United States
Department of
Agriculture

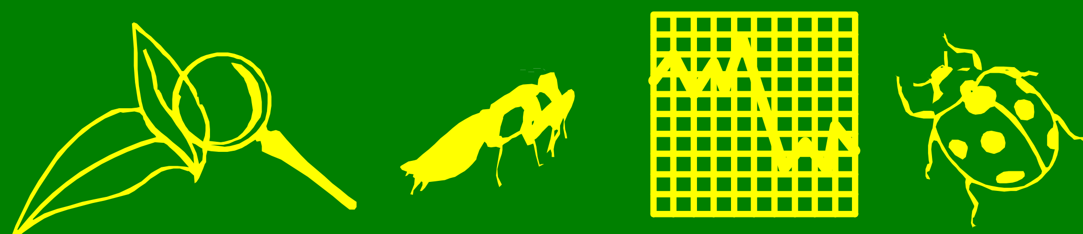
Miscellaneous
Publication
Number 1542

An Economic Research Service Report

Proceedings of the Third National IPM Symposium/Workshop

Broadening Support for 21st Century IPM

Edited by Sarah Lynch, Catherine Greene, and
Carol Kramer-LeBlanc



February 27-March 1, 1996
Washington, DC

Proceedings of the Third National IPM Symposium/Workshop: **Broadening Support for 21st Century IPM.** Sarah Lynch, Cathy Greene, and Carol Kramer-LeBlanc, editors. U.S. Department of Agriculture, Economic Research Service, Natural Resources and Environment Division. Miscellaneous Publication No. 1542.

Abstract

The Third National IPM Symposium/Workshop took place in Washington, D.C., from February 27 through March 1, 1996. More than 600 participants from around the country attended the symposium/workshop reflecting a wide spectrum of professional interests including scientists (social, biological, and environmental), agricultural producers, and representatives of agribusiness and non-profit organizations. Two dominant themes provided a unifying focus. "Putting Customers First" focused on reaching out to the diverse customer base of USDA programs to identify IPM research and implementation needs. "Assessing IPM Program Impacts" addressed how to incorporate economic, environmental, and public health assessment in IPM research and extension activities. Other topics covered included analytical and data needs for pest-management programs, policies for promoting biological and reduced risk alternatives, and overcoming barriers to increased adoption of IPM practices and technologies.

Keywords: Integrated pest management (IPM), economic assessment, environmental impact evaluation, public health assessment, pesticide policy, biological and reduced risk alternatives.

Washington, DC 20005-4788 May 1997

Sponsored By:

ESCOP Pest Management Strategies Subcommittee

ECOP IPM Task Force

USDA Cooperative State Research, Education, and Extension Service

USDA Economic Research Service

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Part I. Preface

The Third National IPM Symposium Workshop: Broadening Support for 21st Century IPM

The Third National Integrated Pest Management Symposium/Workshop was especially timely and important, in light of the Clinton Administration's National IPM Initiative to promote IPM for economic and environmental reasons and to develop the research and extension tools to expand its adoption to 75 percent of U.S. crop acreage by the year 2000. This document provides the proceedings of that workshop, which took place in Washington, D.C. , Feb. 27–Mar. 1, 1996. Attended by more than 600 participants from around the country, the Symposium/Workshop was co-sponsored by two USDA agencies, the Cooperative State Research, Education, and Extension Service (CSREES) and the Economic Research Service (ERS), along with the Extension and Experiment Station Committees on Organization and Policy (ECOP/ ESCOP) and their IPM subcommittees. Each of these sponsors has a long history of supporting IPM programming in accordance with its primary functions: CSREES sponsors research and extension education efforts, working with both ECOP and ESCOP, while the Economic Research Service conducts economic research and provides policy analysis.

The partnership formed for the Third National IPM Symposium/Workshop reflected a commitment on the part of the National IPM Program team to better integrate social, environmental, and health scientists into IPM program design and evaluation. The Symposium Planning Committee worked together in a year-long effort to design an IPM conference focused on two primary themes:

1) "Putting Customers First" in the design and delivery of IPM programs, and

2) "Assessing IPM Program Impacts" by integrating from the start assessment activities that document impacts on farm profitability, the environment, and public health resulting from IPM adoption.

These two dominant themes provided the unifying focus for the numerous presentations and research contributions that followed over the course of the 3-1/2 day workshop. The conference sponsors agreed that for the administration's strategic goal of IPM adoption on 75 percent of the Nation's cropland by the year 2000 to become a reality, the programs developed through cooperative research and extended through educational efforts would have to address the needs of USDA customers. The conference sponsors also agreed that the customer base of the Department of Agriculture, along with its Federal and State partners, is broad and diverse. The IPM customer base includes those who care about the profitability of the agricultural sector and low consumer food prices. This base also includes customers who are committed to environmental stewardship and to minimizing any adverse impacts of agriculture and the use of agricultural chemicals on public health. Thus, the concerns of customers for agricultural profitability are tempered by commitment to environmental quality and public health. IPM programs need to be tailored to incorporate these multiple concerns in the diverse ways they arise in a given location.

All the involved agencies and cosponsors worked closely in the design and execution of this Symposium/Workshop. ERS took the lead in developing the economic-assessment portion of the conference, which included both plenary and panel presentations and selected paper sessions, and in compiling and editing the proceedings. CSREES, ESCOP, and ECOP took major responsibility for fleshing out the sessions directed at putting customers first, organizing a preconference on team building, facilitating commodity workshops, organizing a series of panel discussions on IPM program issues, and managing the IPM poster sessions.

The Symposium/Workshop stressed as one of its two major themes, "Putting Customers First." Here, a broad variety of commodity-producer spokespersons discussed the priorities they saw for IPM research and extension. One strong producer theme was that research and extension programs must be adapted to local conditions to meet producer needs. Thus, producers need to participate with state-university researchers, USDA/ARS, and Extension educators to ensure that customer goals, preferences, values and resources are addressed by the program. To be effective, program implementation must assist customers in overcoming any constraints or barriers to adoption or program success, and through systematic assessment (built into program design) customers must be convinced of program performance.

In addition to producers, customers include a variety of often overlapping interests, including environmentalists, consumer groups, and the public-health community. "Putting Customers First" requires developing or strengthening skills involved in building diverse teams for program design and implementation. As is evident in these Proceedings, the wide diversity of participants provides the strength of new insights and skills. In addition, the commodity-group perspectives as well as the numerous research abstracts reveal the richness of technical agricultural expertise that can be applied to the task of creating ever-more-profitable and environmentally sustainable agriculture.

As numerous Symposium/Workshop speakers expressed, societal concerns about the impacts of agricultural production practices, particularly the use of synthetic chemicals, on the environment (i.e., water quality, wildlife, and habitat), occupational safety, and food safety are real and will continue. IPM programs, when oriented toward the twin objectives of enhanced profitability and better environmental and public-health performance, provide the possibilities for win-win strategies for agriculture, for society, and for rural and urban interests. The IPM community's challenge is to educate an increasingly urban Congress of the potentially broad set of benefits associated with effective IPM program strategies that incorporate environmental and public-health objectives by giving them evidence of what works.

The critical importance of documenting impacts motivated the second theme of the Symposium/Workshop, “Assessing IPM Program Impacts.” Incorporating economic, environmental, and public-health assessment into IPM research and extension activities provides customers with information about what works and documents economic and environmental impacts of concern to both producers and consumers. Responding to recommendations made by a panel of social, biological, and environmental scientists convened by CSREES and ERS at Big Sky, Montana, in July 1995, ERS commissioned a set of white papers from a group of specialists skilled in assessment methods, which focused on specific recom-mendations as to how IPM programs might be evaluated with regard to impacts on economic performance, environmental-impact amelioration, and lower risk to public health. By building economic, environmental, and/or public-health objectives into research and extension programs, IPM practitioners are able to appeal to a broad spectrum of customers, identify strategies that work to meet the objectives identified, and modify or adjust IPM programs to achieve multiple project goals.

The focus on assessment is, in part, motivated by public demand for government accountability. The Government Performance and Results Act (GPRA) of 1993 is one of the most recent legislative attempts to link the expenditures of public funds to actual program results. Integrated pest management programs sponsored by the U.S. Department of Agriculture and all of its Federal and State land-grant partners can best answer these challenges if they are designed from the start to meet broad-based customer needs and if they are structured and operated to learn what does and does not work through systematic economic, environmental, and (where warranted) public-health assessment activities.

The organization of the Proceedings approximates the order of presentations at the Symposium/Workshop. All speakers were provided the opportunity to furnish written materials for inclusion here; however, not all speakers chose to do so. The volume is organized as follows. Part II, “Putting Customers First,” provides statements of priority needs in the realm of IPM research and extension activities, identified by IPM customers at the first plenary session. Representatives of major producer groups were joined by a representative of the environmental community, USDA Deputy Secretary Rominger, and representatives of the land-grant universities as well as crop consultants in stating their priorities for IPM research and extension programs. Part III, "Assessing IPM Program Impacts," includes five papers commissioned by ERS focusing on assessment methods, particularly economic, environmental, and public-health assessment, as well as a review of barriers to adoption of IPM and methods of overcoming barriers through policy incentives. Summaries of the selected paper sessions organized by ERS dealing with assessment-related topics are found in this section. Part IV, "Analytical and Data Needs for Pest-Management Programs," and Part V, Policies for Promoting Biological and Reduced-Risk Alternatives," present summaries of workshops held during the conference. Part VI, "Working with Customers to Identify IPM Research and Implementation Priorities," includes a report of the preconference workshop on team building and a summary of results of commodity workshops charged with identifying IPM program priorities. Part VII, "Focus on the Future," contains the comments made in the last plenary session of the Symposium/Workshop. Abstracts of the posters presented at the Symposium/Workshop are found in the Appendix.

Acknowledgments

The Third National IPM Symposium/Workshop Coordinators were Barry Jacobsen, CSREES; and Carol Kramer-LeBlanc, Sarah Lynch, and Cathy Greene, ERS. We would like to thank Margot Anderson, Andy Anderson, and Margriet Caswell at ERS and Barry Jacobsen, Michael Fitzner, and Gerrit Cuperus at CSREES for their careful review of the proceedings and their useful suggestions on organization and presentation of the material. Authors (and editors, too) benefited from the able technical editing provided by Fred O'Hara and Tom McDonald. Susan DeGeorge designed the cover. At various stages in the process of assembling, editing, and distributing the proceedings, we were fortunate to have the assistance of Kathy Kimble-Day at CSREES and Janet Stevens, Dawn Williams, Pam Weaver, Yvette Curry, Sandy Uhler, and Nora McCann at ERS.

Part II. Putting Customers First

Introduction

One of the two organizing themes of the IPM Symposium/Workshop was "Putting Customers First" in the conception, design, implementation, and assessment of IPM programs. For a program to be successful in each of the above mentioned phases, it must address customer goals; be consistent with customer values, preferences, and resources; assist customers in overcoming constraints or barriers to adoption; and undergo systematic assessment to evaluate program performance.

The IPM customer base is diverse. It includes public and private landscape managers, producers of food and fiber, consumers, agribusinesses, and environmental groups, to name a few. The interests of these groups are complex, at times overlapping, at times in conflict. The challenge of "Putting Customers First" is to identify and, where necessary, reconcile the myriad interests.

Given this broad and diverse customer base, the first afternoon of the IPM Symposium/Workshop was devoted to hearing a variety of views. The objective of these presentations, some more and some less formal, was to paint a picture of the breadth and depth of customer concerns with IPM programs. USDA Deputy Secretary Richard Rominger opened the conference with a brief presentation in which he discussed the USDA IPM Initiative in the broader context of a U.S. agriculture increasingly reliant on world markets and depending critically for its competitive edge on the public's commitment to agricultural research. Rominger spoke of needed investments in research on alternative pest-management options, new crops, soil health, water quality, wildlife, and other areas. He noted that Congress is increasingly urban and suburban. The implications, Rominger argued, are that agriculture and agricultural research must appeal to a broader constituency to receive support. So, while meeting the primary needs of farmers, agricultural research and IPM must also address the broader needs of society.

Following Deputy Secretary Rominger were Ken Evans of the Arizona Farm Bureau, Polly Hoppin from the World Wildlife Fund, Lynn Olsen of the National Potato Council, David Benner of the Research Committee of the State Horticulture Association of Pennsylvania, and Don Jameson of the National Alliance of Independent Crop Consultants. Each of the speakers presented their organization's priorities for IPM research and extension programs. The speakers had significant areas of agreement: the importance of pest-management approaches that enhance both farm-level profitability and environmental stewardship; the need for producers to have access to a broader array of pest-management options; the importance of applied on-farm research; and the imperative of including producers and other stakeholders in setting research and extension priorities.

A wide range of estimates, however, were offered of where U.S. agriculture was in terms of meeting the administration's 75-percent IPM adoption goal. Many factors help explain the divergent assessments, including crop and regional differences, to be sure, but also different visions held of IPM by members of its broad customer base. This divergence underscores the challenge IPM practioners face in working with a diverse client base to forge a consensus on goals and priorities for IPM research and extension. Strategies and tools for dealing with this challenge are discussed throughout the rest of the Symposium/Workshop.

The USDA IPM Initiative

Richard Rominger
Deputy Secretary, USDA

I do not think there is any issue that I deal with in this job that hits closer to home or better represents what I consider to be my life's work than integrated pest management. The soil of our Yolo County, California, family farm does not run through my fingers every day. It does not need to. I am not with my sons as they make regular decisions on bio-pesticides or apply *Bacillus thuringiensis* (B.t.) to certain crops. And I do not need to be. The kinship I have with the effort to farm in a way that protects the environment is a lifelong, deeply ingrained bond, and I appreciate your invitation to join in this very timely, and personal, discussion.

IPM Viewed Through a Microscope

The English writer G.K. Chesterton once said, "The telescope makes the world smaller, it is only the microscope that makes it large." We cannot afford to look at IPM through a telescope. That vision is simply too narrow, too unrealistic, and too out-of-touch with the complex factors that will determine its future. Today I want to put IPM under a microscope. I want to examine it under a lens and view it in terms of the bigger context in which it does, and must, exist.

That context includes the vision this Administration shares for IPM and agricultural research, the problems that all aspects of agricultural research face as we enter the late 1990s, and what we must do to counter those problems.

Administration's Vision for Agricultural Research

Export Picture

Central to any agricultural outlook today is the international trade environment. A description of agricultural exports at this point might seem like an abrupt U-turn; but the exports vehicle is actually traveling the same route as our IPM and research programs. Last week, at the Agricultural Outlook Forum, Secretary Glickman announced that the value of U.S. agricultural exports should hit $60 billion this year, which keeps us on track to achieve our long-term projections of $66 billion for exports by the first year of the 21st century. Those exports mean real economic benefits, incomes, and jobs. That is one part of the story. The other part is how reliant American agriculture is on exports and how much more reliant we will become.

In 1994, exports represented about 23 percent of agricultural producers' gross cash receipts from the marketplace. That figure may hit 31 percent by the turn of the century. Now, contrast that with the economy as a whole. Overall, exports accounted for only 11 percent of the nation's gross domestic product in 1994. That figure is projected to hit 13 percent by the year 2000.

The bottom line is that *American agriculture is right now twice as reliant on international markets as the economy as a whole and will be 2.5 times as reliant by the turn of the century*. The expectation is that long-term domestic demand will grow more slowly than long-term productivity. Add to this the fact that, as the rest of the world becomes more prosperous and as population grows, foreign demand will remain strong, particularly in Asia and Latin America. It is clear that agriculture's future and its prosperity depend on a growing export market.

Investment in Infrastructure

These trends and projections complement what is going on within agriculture itself. As the turmoil over the Farm Bill demonstrates, agriculture continues to move away from restrictive government and toward programs that are increasingly market-oriented. Secretary Glickman said last week at the Outlook Forum that "what government does *outside* the traditional commodity programs will become increasingly important." The Secretary strongly supported, as he has over and over again, investment in infrastructure, research, conservation, and rural development. *Investment* is the key. It is vital if farmers are to have the solid foundation they need to prosper and compete in the world.

U.S. agriculture is the most competitive in the world. But we will remain competitive only if the Federal Government retains its vital roles; ensuring research for new crops and keeping our soil sound, our water safe, and our wildlife protected. The Secretary's strong pro-research stance echoes the President's commitment. It echoes our consistent theme that *everyone* who works to equip farmers with the necessary production tools is working toward meeting global food demand, and research is among the most important of those tools.

Last spring, at the National Rural Conference in Ames, Iowa, President Clinton said, "We need more agricultural research, not less. We should not back up on research, we should intensify research . . . . Even as we give responsibilities back to the states and local government and the private sector, the national government has a responsibility and an obligation to support adequate research."

The result of the President's commitment is that the Senate-passed Farm Bill included the research title proposed by the Administration last year. The Administration's support is also evident in our goal to help producers implement IPM methods on 75 percent of total crop acreage by the year 2000, our additional Farm Bill proposals, and our budget requests.

Problems Facing Agricultural Research

There is something about the budget side of the picture that reminds me of that great story about the scientist, unjustly accused and convicted of a major crime, who found himself incarcerated with a long-term sentence in a jail in the middle of the desert. His cellmate turned out to be another scientist. Determined to escape, the first man tried to convince his coprofessional to make the attempt with him, but the man refused. After much planning and with undetected help of other inmates, our scientist made his escape. But the heat of the desert, the lack of food and water, and his inability to locate another human being anywhere drove him almost mad, and he was forced to turn around and return to the jail. He reported his terrible experience to the other scientist, who surprised him by saying, "Yes, I know; I tried it and failed too, for the same reasons." The first scientist responded bitterly, "For heaven's sake, man, when you knew I was going to make a break for it, why didn't you tell me what it was like out there?" To which his cellmate replied, with a shrug of the shoulders, "Who publishes negative results?"

Like you, we are very disappointed about the negative results from our FY 1996 budget request. Congress fell far short of giving us most of the increase we wanted in the President's budget for the IPM Initiative. The final appropriations bill gave us $20.5 million. That is a slight ($2-million) increase over last year. With that $2 million, we were able to establish a new initiative to meet farmers' critical pest-management needs. But it does not even approach the $36.5 million that we requested to help producers implement IPM.

These funds are in addition to the approximately $110 million for ongoing research in our base program of IPM and biocontrol work. I know that this funding shortfall for the IPM Initiative will affect several goals, such as providing universities more grants for research and giving ARS funds to conduct "area-wide" IPM projects. But I also know that this reflects budget reality today. This is the bigger budget picture that we see when we look through the microscope, whether we like it or not. Our concern is that the Congress must consider the long-term needs of agriculture, and not just the short-term budget battle. We hope, when the House takes up the Farm Bill this week, that it will build on the progress the Senate has made, particularly in the area of research.

Secretary Glickman has often said that the budget must not be balanced on agriculture's back. But the budget is not an abstract affair. Part of the issue is: *who*is doing the balancing? Writing this Farm Bill is a Congress that is increasingly urban and suburban and generally lacking in a rural or farm background.

In 1994, for the first time, the top five positions in the House were held by members from suburban districts. If we take into account the members who have announced retirements in 1996, the next Congress is likely to have the smallest number of senators and representatives from rural districts in the nation's history. The implications here are greater than reduced voting power among those who can channel funds to agriculture and research. It also means that the traditional, solid political base for agricultural research is being replaced by a more diversified group that often benefits from agricultural research indirectly. This constituency includes domestic and foreign producers as well as consumers, people in the marketing system, and others related in some way to the food and agriculture industries.

How Shall We Respond?

All of this is one way of saying that those of us involved in agricultural research must move from the defense and see this, *make this*, a time of opportunity. Public agricultural research was, at one time, the model for all public research and can be again, with some practicality and accountability to back it up.

Others Need to Know

First, we must recognize that we have a tough sell out there. We might get frustrated that our proven, life-enhancing research, education, and extension must run a gauntlet of skepticism and scrutiny. But that is a fact of life in this environment, and we must deal with it. Scientists talk about the environment or "ecology" for public support of public science. They talk about the "social contract" between themselves and the public and how it is changing. I am determined, just as Secretary Glickman and Under Secretary Karl Stauber are, to give what it takes to counteract today's "ecology" of skepticism. That means more of what I call "results-thinking." It also means greater accountability for the funds allocated to us and, perhaps, just a little more PR (public relations). We all know how much our agricultural scientists throughout the land-grant system and USDA achieve. But others need to know.

They need to know about the efficiency of the federal-state-local partnership for agricultural research, extension, and education. They need to look at Federal funds as the glue of the partnership. Every Federal dollar appropriated for agricultural research, extension, and teaching leverages four to five state, local, and private dollars. The annual rate of return on the overall investment in research and extension is between 30 and 50 percent, depending on location and commodity. How many other investments can match that? As a bonus, this is a partnership that assures that critical national issues get local attention and not just a "one size fits all" solution.

Others need to understand the impact of the federal–state science and education partnership on issues that concern society. Consumers, for example, want more than an abundant food supply. They want to reduce real or perceived health risks of chemicals in food, and they want assurance that production is environmentally friendly. IPM is a perfect example of the cutting-edge work being done to meet these demands and to balance production and the environment. I wonder how many understand that IPM is dollar-wise and environmentally friendly and that, because of it, pesticide use is down?

- I wonder how many have heard of IPM's great contributions in Texas, a savings of 20,000 jobs and a $1.5 billion annual savings in pesticide applications.

- How many know what is going on in Utah, where growers saved more than $8 million over the past five years, as more than 70 percent switched to IPM.

- Do they know that USDA and ARS researchers have released three corn lines with super resistance to the European corn borer, the world's most devastating corn pest?

- Or do they know that Midwest farmers are heeding the advice of extension specialists to improve their use of insecticides and as a result are reducing their production costs by some $2.00 to $4.00 an acre?

- I wonder how many are aware of the microprocessor developed by Purdue plant pathologists that saves spraying costs and reduces fungicide applications or the weather monitor developed by Missouri researchers that helps farmers cut pesticide use.

Accountability

But I am a practical fellow. In the current competition for funding, listing all we have done and are doing is important but not enough. The budget these days is not only about numbers. It is also about being accountable for funds allocated; meeting farmers' real needs in the field; and showing concrete, specific results. The Government Performance and Results Act requires all federally operated and funded programs to show measurable outcomes from Federal dollars. I urge all of you in agricultural research and science, especially with the applied nature of your work, to embrace this accountability. This is an opportunity to lead the Federal research community once again.

We must remember, though, that we are accountable to more than just the requirements of law. At a basic level, we are accountable to the farmers of this country. Our efforts are effective if they help *them* to meet the economic and environmental challenges they face in the field every day. It is important that we keep that basic accountability to farmers foremost in our minds and direct our IPM efforts toward meeting their most important needs.

Government's Response

At USDA, we are also looking at the big picture. Since 1946, we have cast USDA's research goals as "plant" science; or "animal" science; or "soil, water, and air" sciences. Now, it is imperative that we improve the linkages between the different disciplines. Researchers cannot operate in a vacuum. And that is where USDA comes in. The Secretary and I may not work in a lab, but we are pretty effective with pen and paper. What we have done in the past three years is to set the stage for a "systems" approach to the biological, physical, and social sciences. We have linked research to extension and education under the Cooperative State Research, Education, and Extension Service. We feel this is the most accurate blueprint for the work to be done: to meet the needs of our customers with world-class research and statistics and to extend that knowledge to end users.

We also requested, and got in the Senate-passed farm bill, what is called a Fund for Rural America. I do not think there is any greater evidence of the weight this Administration puts on rural economic development than the fact that this Fund was one of the major factors in achieving passage of the Senate bill. The purpose of the Fund is to supplement dollars going to agricultural-research and rural-development programs. This money will help diversify the agricultural sector and boost economic opportunity in rural America.

President Clinton is adamant on the point that this Farm Bill *must* provide essential research funding that brings farmers the latest farming techniques and keeps American agriculture ahead of the competition. The Senate bill authorizes the Secretary to transfer $300 million into the Fund over three years, two-thirds earmarked to rural development and one-third to research grants. We feel that these funds represent an important investment and are desperately needed. But they still fall short, and we urge the House to improve on the Fund as it works on the Farm Bill this week.

The Fund for Rural America is just the latest small success in this Administration's ongoing support for agricultural research. I want to thank you again for this chance to put IPM under the microscope. IPM has a great track record. We know its significance to consumers, trade, and society. We are dealing with some big challenges, and IPM must function, practically and effectively, in a bigger context. This is a time of opportunity, not defense. Once we achieve this kind of thinking, then we will have done for IPM what it does for all of us.

What American Farmers Need from USDA and Their Land-Grant Universities to Implement IPM on 75 Percent of U.S. Crop Acres

Ken Evans
Arizona Farm Bureau

The sound of the chopper's blade pierced the predawn fog over the yet to be planted cotton field in the desert Southwest. The unique thing about this helicopter was not that it was flying in zero visibility, nor that it was applying an ultra-low-volume preplant herbicide, nor even that it could stay in flight for more than two hours without refilling or refueling.

The really unique thing was that it was being flown by a computer, from the seat of a Suburban, parked at the edge of the field with DGPS/GIS and remote-control technology that was perfected in the Gulf War.

By spraying only 13 acres out of an 80-acre field that had a weed problem identified and located on a digital map the prior year, chemical usage and costs were reduced dramatically. Imagine being able to identify the location and specifics of a pest problem in a field and then being able to return exactly to that same spot a week, a month, a year, or ten years later. A small peek through the window of the future, perhaps, but to those of us in production agriculture, it provides a glimpse of the promise that tomorrow's technology truly holds for American farmers.

I appreciate the opportunity to appear before you today, representing the 4.5 million member American Farm Bureau. Our national president, Dean Kleckner, is leading a trade fact-finding mission to Vietnam and Indonesia. But I am sure that what I am about to say, and what my friend President Kleckner would say, are very similar.

It is a pleasure to address the many who work so hard on behalf of America's farm and ranch families. No matter how big American agriculture becomes, it is, and always will be, the men and women of rural America who till the soil and produce the products needed by people around the world.

Today, I have been asked to address what American farmers need from the USDA and our land-grant universities to implement integrated pest management on 75 percent of our crop acreage. If that is truly what you want to hear, this would have to be a very short talk. You see, I am here to tell you that American agriculture is well past the IPM concept. Actually, IPM is technically old hat.

Farmers understand that we do not have to eradicate every pest we see. It does not make ecologic or economic sense, and we could not do it even if we wanted to. There are too many examples of resistant pests coming back stronger than ever after fields have been treated.

Take my alfalfa fields. Aphids and weevils used to give me fits. We would spray the field and knock down the pests, but in the process, predators would disappear, too, even when we used pest-specific chemicals. The pesticide did not harm the beneficials directly, but they starved to death. This action resulted in a recurrent need to spray because when the next wave of aphids and weevils hit, no predators were around, and my hay yields would get knocked for a loop.

So, now I rely on cultural practices, such as release of beneficial insects and better timing of cutting, as well as farm planning to ensure compatible crop rotations and adjoining crop synergy. I apply chemicals only as a final resort to return a balance to my fields and to defend my economic future.

This leads me to point out that, when I must use the most effective chemical, it had better be there for me. We are losing too many good, safe, crop-protection chemicals to the Delaney Clause and to increasingly sensitive measuring devices. Many of our necessary minor-use chemicals will be taken from us as manufacturers realize they cannot recapture exorbitant reregistration costs. We need effective, efficient chemicals as a last resort to save our crops and to help mother nature remain balanced. We have learned to place them where and when they will do the most good. I repeat, actually and factually, IPM is technically old hat.

America's farmers and ranchers are well on the way to addressing the next paradigm, which is very much like the boy scout supermarksman who, when asked to explain his astounding shouting prowess, declared "ah shucks, ain't nothing, ya just shoot first and draw the target later." Some government officials learn that trick early and practice it often. When I asked some of my cohorts what it would take to get them to implement IPM on 75 percent of their acreage, they wanted to know why they should ignore good management on the remaining one-fourth of their land.

In that light, the future objective of pest management lies in being able to produce more yield with fewer chemical and energy resources.

Major improvements are dependent on five factors:

1. the ability to define and record the exact locations of pests;
2. the ability to return to exactly that same location at a later time for followup observation or control;
3. the ability to apply precise amounts of designer chemicals to that exact spot, not to that section or quarter section, but to the exact acre that needs to be sprayed;
4. the ability to manage pests, not just kill them;
5. the ability to understand that pest management is only one component of whole-farm management, or holistic farming as it is referred to today.

I want to use my time today to share with you some of the thoughts and goals of working farmers across America. We are stewards; there is no two ways about it. I take care of my land because it takes care of me. That may sound cutesy, but it is true. Financially, physically, and mentally, my farm sustains me and much more.

Modern farmers recognize that our efforts affect more than our immediate acreage. In my management scheme, I look beyond my fence row, beyond the horizon. What I do on my acreage affects my business, touches my neighbors, and ripples throughout the country and the world. My job as a farmer is to work with nature, not against it.

Just a few of the tools we use to accomplish that stewardship include:

- prescription, species-specific chemicals
- variable-rate application equipment
- remote computer-controlled application systems
- satellite remote imagery
- global positioning and geographic information systems
- real-time, site-specific, and regional reporting of pest infestations

The future of U.S. agriculture in a global economy depends on our ability to increase our effective throughput: not to produce more per acre, but to produce more from each unit of resource expended. Farmers use these tools to weave together the many resource elements that affect us to develop a sound and sensible whole-farm management scheme.

What are some of these elements? They include water quality and availability, soil type, microclimate identification, topography, crop adaptability, preservation of wildlife habitat, pest alternate host symbiosis, plant population diversity, and crop synergy.

There is another important element often forgotten by those who do not farm but who wish to control what farmers do. That element is the human need for food and fiber. We must produce food and fiber, flowers and fish, forestry products, and (more and more these days) industrial feedstocks.

America's farms, through the work of America's farmers, must provide enough food, fiber, and industrial feedstock not just for Americans but for a hungry and growing world. After analyzing these and other elements, such as environmental and wildlife impacts, we seek to implement our goal of building an energy-efficient, low-maintenance, high-yielding, multifaceted, interdependent production system that we call a farm.

By using the knowledge, provided in large part by you and your fellow researchers, farmers like myself seek to develop a sustaining, sustainable farming operation. In the West, we have been traditionally on the cutting edge. What surfaces and is ultimately adopted by us usually works its way into mainstream America in a decade or two. Improved agricultural management practices have moved far swifter. As an example, I would submit that our concept of conservation is different than what some here in the East think.

Conservation is not a plan. It is not a project, or a chore list, or a checklist against which someone can measure compliance. Conservation is a philosophy, deeply held and carefully practiced, by today's responsible farmer. As farmers, we must look at the whole, not the parts.

Integrated pest management still addresses the parts. When management, cultural practices, and other farm tools are integrated to manage pest problems, we call it IPM. That is a start in the right direction, but only a start. Modern farmers have moved past that stage.

IPM is one component of holistic farming that farmers who will prosper in the 21st century are adopting and implementing today. The world has witnessed a tremendous growth in agricultural production, in large part by imitating U.S. farmers. Technological advances just keep coming.

- Computerized tractors know precisely where they are, anywhere on Earth, in precise longitude and latitude.

- Tractors know and show not only how much fuel per hour they burn but how much fuel per acre and gallons per bushel of corn produced they consume.

From genetically altered hybrid seed that produces crops that repel pests to designer, species-specific protection chemicals, U.S. farmers are rapidly adopting the latest innovations.

Farmers have learned to incorporate these innovations into a total-farm-management program, or holistic farming, not solely into pest control. Agricultural chemicals, for example, serve a very useful, very definite purpose. However, many farmers agree with me that chemicals should be one of our last lines of defense, not our first.

We have come to realize that there is not, and should not be, a chemical solution to every farm problem. The attitudes of farmers about agricultural chemicals and pest control are maturing and changing along with society's: not every bug or every strange plant is a pest. We have changed our goals. We recognize we do not have to increase our yield per acre year after year after year. We have learned to maximize returns and quality while reducing inputs and costs.

From you, we need real-farm, real-life help and guidance, not "Epcot Center" type science. You know what I mean: not the sterile lab, government grant, sci-fi advances that look good on "the next step" but do not pan out in my neck of Arizona. But no matter how modern, how far-reaching the innovations, it is still the farmer's love for the land that most influences our stewardship. I am not sure that university people understand this fully. I also do not know what people here in the Beltway understand. But farmers do appreciate the need for basic research.

In fact, during the Farm Bill debate, the Farm Bureau steadfastly supported two points: not loan supports, not deficiency payments, but market development and agricultural research. Keep in mind, we need help not only to be productive 100 years from now, but also to survive tomorrow. Help us face the economic pressures. Help us face the social pressures.

We hope you recognize that this 75-percent goal is not what agriculture needs. We want to take care of 100 percent of what we can. We want to enhance the environment. We want to feed and clothe the world. And we want to make a profit so that this can be a continuing process. I want to leave my land in better shape than when I started, and I want to endow my kids with my love for the land. I am not unique. I am not in the vanguard. America's farmers and ranchers are proud to lead the world not only in productivity but also in resource conservation.

I thank you for this opportunity to discuss one American farmer's philosophy for tomorrow and today.

Reducing Pesticide Reliance and Risk Through Adoption of IPM: An Environmental and Agricultural Win-Win

Polly Hoppin
World Wildlife Fund

I appreciate the opportunity to be here and speak with you today. I am here to represent the environmental viewpoint, although I know in this audience there are many others, as we heard from Ken Evans, who agree that environmental and public-health goals are high priorities for IPM. The commitment of the USDA staff working on the Integrated Pest Management Initiative [Barry Jacobsen and Mike Fitzner and (at ERS) Carol Kramer, Sarah Lynch, and Cathy Greene, just to name a few] to environmental concerns (not just rhetorically but as it will translate into program evaluation) is impressive.

I am going to focus my talk today on the importance of debating and then coming to agreement about societal goals and about establishing mechanisms for measuring progress toward them. I, and others from consumer and environmental organizations, think it is time for many in the IPM community to stop trying to be all things to all people. They should clearly describe the relationship between IPM and environmental and public-health objectives (which polls show Joe Q. Public cares very much about) and make ambitious plans to assist large numbers of farmers in moving away from heavy reliance on pesticides by reestablishing healthy ecosystems on their farms.

First, a word about policy goals.

The 1995–1996 Congressional session was dominated by a historic debate and struggle to agree on and adopt a way to balance the Federal budget. The debate has focused on three key decisions:

1. How to set the goal for changes in fiscal policy leading to a balanced budget.
2. The appropriate changes in programs and policies needed to achieve the consensus goal.
3. How to keep score.

By late fall last year, the White House and Republicans in Congress had finally agreed that the goal should be a balanced budget in seven years and that the budget agreement and its detailed components must collectively reach this goal. While disagreements over tax cuts and spending priorities have yet to be resolved, just agreeing on this goal and how progress toward it would be measured and monitored was a major step and was the focus of weeks of intense negotiations between the White House and Republican leaders in Congress.

Anyone trying to manage a budget, whether for a government agency, a local organization, or a family, knows that goals matter, as do accurate and honest numbers, in keeping track of your checkbook, credit card debt and obligations, mortgages, retirement funds, and (lest we forget where we are) Federal income taxes, flat or otherwise.

Clear and measurable goals and an honest, credible way to monitor progress are clearly also vital in the environmental-policy arena. The Clean Air Act set goals for pollution levels and the number of days they could be exceeded. Various international agreements and protocols have set clear-cut goals and established timetables for achieving them, with more on the horizon.

Other encouraging examples can be drawn from industrial pollution prevention. Companies participating in EPA's voluntary “33/50" program have agreed to reduce their emissions of 18 toxic chemicals over specified time periods. Many companies have far exceeded their original commitments.

Like most environmental and consumer groups concerned about pesticides, the World Wildlife Fund (WWF) applauded the Administration for making a commitment in June 1993 to promote pesticide reduction and sustainable agriculture. WWF took USDA's followup pledge to aim for adoption of IPM on 75 percent of crop acreage by the year 2000 as an indication of the seriousness of the commitment. In the past two years we have worked with grower groups, government specialists, and other environmental organizations in an effort to help determine what this goal really means and to help foster agreement on constructive steps the USDA, EPA, and FDA can and should take toward achieving this goal. While we have a long way to go, WWF is encouraged by what we see as growing momentum toward IPM around the country, fueled in no small part by innovative farmers who are, in many respects, far ahead of policymakers and scientists in making IPM happen on their farms.

As WWF assessed USDA's and EPA's plans for working toward this goal, we and agricultural and environmental groups raised questions such as:

- What will be the baseline, and how will we track progress towards the goal of 75 percent of crop acreage in IPM?
- What crops and regions are farthest from and closest to achieving this goal, and what are the implications for R&D resources and for policy?
- Will environmental goals, which are at the heart of the original definition of IPM, be central elements of the IPM that USDA is promoting or will they simply be beneficial side effects that likely, but not necessarily, come with IPM adoption?
- More specifically, how will IPM adoption affect pesticide use and risks?

The case I want to make today is that it is in the best interest of the IPM community to more clearly delineate the environmental contributions of various kinds of IPM systems, to go public and indeed market these contributions, and to help target public and private sector resources toward IPM systems that minimize environmental impacts. Environmental and consumer organizations will be supportive of IPM to the extent that it results in improvement in environmental quality and public health.

How can you convince the public that IPM is addressing their concerns? You can define IPM more clearly, distinguishing between systems that still rely heavily on chemical pesticides and those that maximize the opportunities for adequate pest management existing in a well-balanced biological system. You can make a public commitment to moving as many producers in the direction of biointensive IPM systems as possible. You can propose ways of measuring individual and aggregate progress toward the kinds of IPM that rely less on hazardous pesticide products. And you can publicize data used in measuring progress.

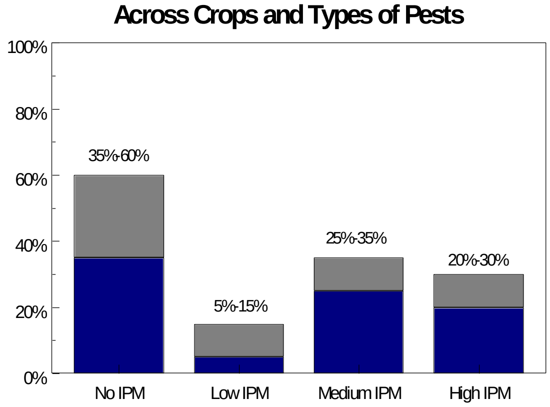
What has been done so far to measure IPM adoption and to distinguish between chemically intensive and biointensive IPM?

In response to the many questions raised about President Clinton's IPM adoption goal, the USDA's Economic Research Service completed an innovative study on a very short timetable. The report used a simple method to estimate the number of acres of several major crops under no IPM and under "low," "medium," and "high" levels of IPM. Figure 1 presents our synthesis of USDA's findings.

In its 1994 study, USDA estimated IPM adoption for field crops, fruits and nuts, and vegetables. Its estimates were constrained by the data it had available from the Cropping Practices Surveys carried out from 1990 to 1993. All these surveys include detailed pesticide-use data, but varying amounts of information (from almost none to considerable) on other pest-management practices. USDA based IPM adoption principally on whether a field was scouted and sprayed in accordance with specified thresholds. Higher levels of adoption required the use of additional practices considered

Figure 1

USDA Estimate of IPM Adoption: A Synthesis Across Crops and Types of Pests



* Shaded areas define ranges in values reported for different crops and classes of pests.

by USDA as "indicative of an IPM approach." Clearly, USDA's analysis was not comprehensive, nor did it claim to be.

What does the USDA study tell us about the starting point toward the 75-percent IPM goal? The Department did not add up its estimates of IPM adoption across categories of pests. But if it had, the numbers would have come out that roughly half of the acreage was under one of the three levels of IPM:

- About 5 to 15 percent was under low-level IPM, just scouting and applications in accordance with thresholds.
- About 25 to 35 percent was under medium-level IPM, which requires scouting and adherence to thresholds plus one or two additional practices from a list of those considered by USDA as "indicative of an IPM approach."
- About 20 to 30 percent was under a high level of IPM, scouting plus thresholds plus three or more practices "indicative of an IPM approach."

There are a number of weaknesses with this method, readily acknowledged by USDA, that stem largely from lack of data.

First, and most important to the environmental and consumer communities, the data do not distinguish between practices that are related to treatment with chemical pesticides, and those that are preventive (that is, based on altering the biological and ecological interactions between crops, pests, and beneficial organisms). Practices that constitute treatment with, or contribute to the efficiency of, pesticides are considered as "indicative of an IPM approach" by USDA's criteria, as are practices that draw upon and are most compatible with biological relationships on the farm.

In the interests of time, I will not go through this in detail, but let me give you an example. Five of seven weed-management practices included on USDA's list of "indicative of an IPM approach" are in fact required if herbicides are to be used. They are:

- post-emergent-only applications
- alternating herbicide active ingredients
- banding
- spot treatments/field mapping
- reduced rates of application when weeds are small

Only two of the seven, crop rotation and mechanical cultivation, could help distinguish systems that remain heavily dependent on pesticides from those that are biointensive. A longer version of my remarks details the practices for the other major classes of pests and other cropping systems considered "indicative of an IPM approach." All include more practices essential to effective pesticide use than those integral to biointensive IPM.

WWF has developed a method for measuring pesticide reduction and adoption of IPM that, we think, substantially improves on USDA's initial study. It is on this method and the conclusions we have drawn about the prevalence of IPM in the United States that I would like to spend the rest of my time today.

WWF's experience with measurable goals used to drive pesticide reduction in other countries made us especially interested in the 1994 USDA report. As we discussed the basis of the Department's estimates with experts in the field and a wide range of stakeholders, we became convinced that more work was needed to come up with a measurement method truer to the ecological foundation of IPM. We were encouraged by the openness of USDA analysts in considering different approaches and started a set of activities and analyses in early 1995, with the help of consultant Chuck Benbrook.

Our method evolved with each interaction we had with pest-management specialists in formal meetings we convened or in casual conversations. For instance, Dr. Charles Mellinger, Technical Director of Glades Crop Care, a major independent crop consulting firm in Jupiter, Florida, explained that their fresh-market-tomato IPM program has at least 60 distinct "practices" or components, not all of which are needed every year, but which are relied upon sequentially as a function of what scouts observe in the field. Dr. Mellinger urged us to develop a method that takes into account the dynamic aspects of IPM, dynamic because of changing weather, pest pressure, markets, the emergence of resistance or secondary pests, or changes in technology.

I know Charlie is here, and feel confident in saying to him in response to his challenge: we are not there yet, but we are moving in the right direction. In designing our measurement method, WWF sought a system that can be adapted to changing conditions and that can be stretched to accommodate the widely different pest-management challenges found across the country.

Like the USDA continuum, WWF's IPM continuum has four zones. The criteria for IPM adoption change as you move along the continuum, getting more complex and more biologically oriented and prevention-focused.

At the core of our method for measuring adoption of IPM is a variable we call the "IPM System Ratio." The IPM ratio is composed of two variables: "dose-adjusted acre-treatments" (DAAT) and "preventive practice points" (PPP). The value for IPM System Ratio is calculated at the field/farm level, and equals PPP divided by DAAT. As farmers move along the IPM continuum toward biointensive IPM and reduce their reliance on pesticides, they typically adopt additional prevention-based practices and IPM System Ratio values rise.

The DAAT variable is a way of taking into account the large differences in application rates between older and newer low-dose products, as well as the typical, rather than the full label or average, application rate of a given product. It is a spatial measure that adds up the number of active-ingredient applications made with a specified rate of application. An example of our empirical findings in the case of use and reliance on atrazine, a major problem pesticide, follows in figure 2.

The IPM preventive-practices variable is the sum of biologically and ecologically based practices that either reduce pest pressure, increase the number and role of beneficial organisms, or enhance a crop's ability to overcome a degree of pest pressure.

The differences in approaches between USDA's study and our method include:

- In our method, the ratio of chemical treatments relative to preventive practices, which categorizes farmers in the different zones, is tailored to particular crop agroecosystems.

Figure 2

Atrazine Dose-Adjusted Acre Treatments

* Atrazine product labels call for 1.6 to 2.0 pounds a.i. per corn acre treated.

* Average rate of application in 1994 was 1.07 pounds a.i. per acre treated.

* Proxy-dose used in calculating dose-adjusted acre-treatments equals 1.23 pounds (1.15 times the average rate of 1.07; or 77% of the minimum recommended rate).

* 42,832,000 corn acres were treated at any rate of application in 1994

* 37,030,000 dose-adjusted acre treatments at 1.23 lbs/acre in 1994.

* Practices that reduce dose-adjusted acre treatments on a given field --

*Banding	*Reduced Rates by Targeting
*Spot-spraying	Weeds When Small

- In contrast, USDA counts the number of practices, irrespective of treatment intensity.
- USDA's method does not consider reliance on and use of pesticides nor levels of pest pressure.

WWF's first detailed empirical application of this method was carried out by our consultant Chuck Benbrook and assessed integrated weed-management systems on corn and soybean farms in 1994. Earlier this month, Chuck presented the method and preliminary results at a workshop at the Weed Science Association (WSA) annual meeting in Norfolk, Virginia. He received positive feedback from many researchers, some of whom offered to work with us in applying the method in their State. To those here today, let me add we would welcome a chance to collaborate with IPM research teams, commodity groups, consultants, regional coops and marketing companies, and others working to develop ways to measure IPM adoption and to quantify the public-health, economic, and environmental-quality benefits of IPM.

According to USDA's criteria, 57 percent of soybean acreage was managed under medium or high IPM (based on the 1993 Cropping Practices Survey database). WWF has studied the 1994 Cropping Practices Survey. According to our criteria, about 36 percent was managed under medium and high levels of IPM, and only 6 percent of that was under biointensive integrated weed management. In both soybeans and corn, our method results in far fewer acres in the high zone than does the USDA method.

What do we do with these data once we have them? That depends on who is using them. Together, soybean growers, crop consultants, and Extension personnel could assess whether it is technically feasible for the growers in the low zone to move to the medium zone (e.g., whether or not differences in levels of IPM adoption stem from a pest outbreak specific to a particular region, weather, or other factors beyond a grower's control). They could set goals for percentages of soybean growers moving into higher zones and develop programs to achieve those goals. Growers of food products could consider developing a label describing practices of growers in the high zone, aiming for a premium price.

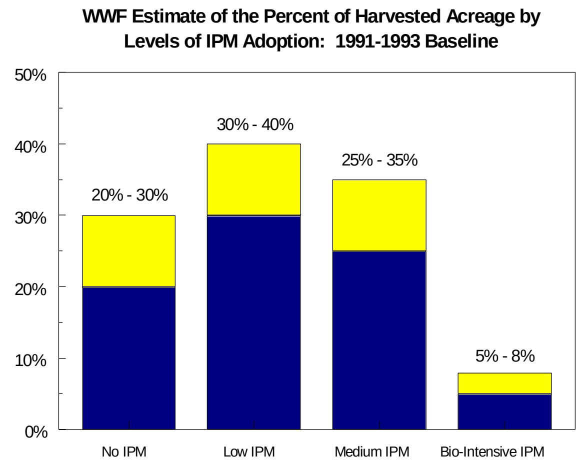
Our next step with these data was to further explore growers' reliance on pesticides in the different zones. As I noted earlier, reducing the use of pesticides is a top priority for environmental and consumer groups, and we think the ability to point to reduced reliance and risk is an important asset for practitioners and policymakers promoting IPM. We propose seven indicators of pesticide reliance, also detailed in the longer version of my presentation.

Based on our preliminary work, we have made a rough estimate of baseline IPM adoption in 1992–1994 (fig. 3). The figure includes ranges reflecting the fact we have not completed our analysis. But based on the differences between our method and USDA's method, we feel confident the calculated values will fall within the ranges presented here.

So what do these data suggest about the President's 75-percent goal?

Based on USDA's de facto decision-rule, that any acre scouted and sprayed in accordance with a threshold counts as at least low level IPM, at least 50 percent of the nation's cultivated acreage is under IPM. In fact, with USDA's definition, many more acres may be in IPM because USDA did not count

Figure 3



acreage under organic or other biologically based production systems that do not involve the spraying of pesticides, nor acreage where there is very little pest pressure (because producers did not necessarily spray in accordance with a threshold), nor acreage for which there are no applicable thresholds. In contrast, with our definition, anywhere from 30 to 43 percent is already in the medium and high zones of IPM. The biggest difference between USDA's and WWF's estimates is in the high zone: WWF estimates 5 to 8 percent and USDA estimates 20 to 30 percent.

The President chose wisely in setting a goal of 75-percent IPM adoption. But to say that we are almost there is to say that we are not moving much beyond the *status quo* of pest management that relies heavily, though efficiently, on pesticides. We suggest that it is ambitious but doable to aim for 75 percent of crop acreage in the high or medium zones of IPM for all major categories of pests requiring routine pesticide use. It will clearly take longer than three more years to achieve this goal, and progress will remain incremental as growers move along the IPM continuum.

Clearly, there is much work to be done to move from our current estimate of IPM adoption (a little more than a third of acreage in the medium and high zones) to reach 75 percent of acreage in these zones, the President's goal as WWF interprets it. We think the nation will require at least 10 years to achieve this goal. We also believe that not only can it be done, it must be done to reverse troubling trends in public-health risks and environmental contamination.

We base our confidence in large part on the rapidly growing enthusiasm for farmer-led participatory research, which gets scientists out into the field to do systems-based research in the best lab of all for solving pest-management problems: the real world. We also are encouraged by the number and effectiveness of reduced-risk biopesticides gaining registration by EPA as well as by the positive results many growers are achieving through the release of beneficial organisms. Over time, as farmers move closer to biointensive IPM and as biodiversity is restored both above and below the ground, new products and approaches will become more useful, helping to keep pest populations under control in those years when biological processes do not fully meet the challenge.

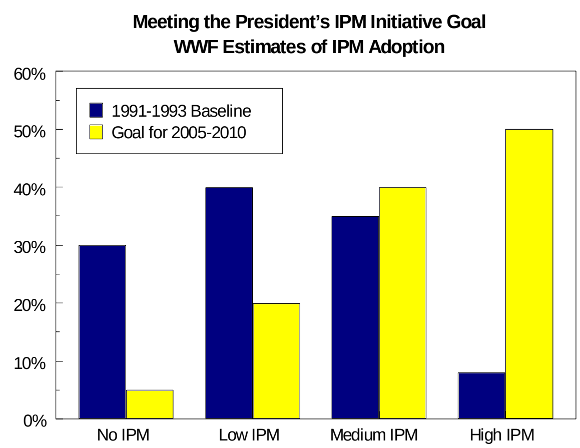
Adding risk to the equation is a final step (both key and difficult) in linking IPM adoption to reduced public-health and environmental risks. Four major categories of pesticide toxicity must be assessed: acute mammalian toxicity, chronic mammalian toxicity, ecotoxicity, and impacts on cropping system sustainability and beneficial organisms. Risk-indicator index values can be used to estimate the environmental and/or health consequences of pesticide use measured by pounds applied and/or dose-adjusted acre treatments, by crop or region, by pest-management system, and over time. Because adoption of biointensive IPM requires enhancing biodiversity and beneficial populations, farmers have to make a special commitment to reducing the use of broadly toxic, ecologically disruptive pesticides. The positive consequences of change in the selection of active ingredients will be captured more fully when measures of pesticide reliance and use are adjusted in accordance with toxicity indexes.

To conclude, across the United States and elsewhere in the world, the train is out of the station in terms of public concern (at least three more major reports and books on risks from synthetic chemicals will be published between now and June) and in terms of growers and processors marketing their produce as “green,” “clean,” and “better.” It is time to agree on ambitious, meas-urable goals and to get on with attaining them, a process that will be far more successful if all communities supporting progress along the IPM continuum can work together to convince an always skeptical Congress that IPM is the way to go. Figure 4 presents both our IPM-adoption base-line estimate in 1991–93, and our goals for 2010.

We are certain American farmers are eager to move in this direction and that the nation’s pest-management professionals are ready to help accelerate progress along the IPM continuum. We hope USDA, EPA, and agribusiness will work cooperatively to find more effective ways to use the current level of public and private resources invested in pest management and pesticide-safety research and regulation. As a nation, we may be better off by spending less time studying and arguing over pesticide risks, and more on overcoming the many, real, technical, informational, and economic barriers to progress toward bio-intensive IPM.

Cooperative approaches will accomplish far more than the past decade's still-unresolved debate over reforms to the Delaney Clause, enlivened periodically by the pesticide-of-the-month syndrome. The increasingly contentious nature of pesticide and pest-management policy issues in the United States has poorly served both farmers and the general public. It has divided those who need to work together to craft and support changes in policy and in research and education funding priorities. Such changes are essential to assure that attainment of the President’s IPM goal is both realistic and worth doing.

Figure 4



IPM Needs of Potato Producers

Lynn Olsen
National Potato Council

The potato is America's favorite vegetable and is grown in all 50 states on a commercial basis. We grow potatoes in all types of geographic areas: sandy soils, clay soils, peat soils, and many others. Cold, hot, wet, dry, and all kinds of weather conditions make potato growing a challenge. What is IPM? At a meeting in Washington State three weeks ago it was suggested that IPM is environmental stewardship. The potato industry is and has been practicing IPM long before it became a buzzword. Why? Because we had to for economic reasons and out of pride in our farms and industry. The definition of IPM keeps changing, and I am not sure that is all bad, but it does make it harder to understand.

Some of the things that we do to decrease pesticide use and risk in our industry are only common sense. We use small grains, sweet and field corn, alfalfa, green manure crops, and others in our potato rotations for nematode, insect, and weed control. We sample soils for fertility needs, soil PH, and nematode counts. We sample petioles and soil during the growing season so we can apply nutrients when and if they are needed.

Scouting by crop consultants, fertilizer and chemical field men, and processor representatives are part of our everyday life these days. We as growers also scout our fields. We spend many hours checking our fields for insects, moisture, and other potato problems by ourselves and, some-times, with other industry people.

The way we irrigate and the amount of water we use and the way it is applied are changing all the time. For the better, I might add. Water quality is becoming better every year.

Moldboard plowing has been reduced dramatically in favor of deep ripping. This leaves most of the previous crop residue on top of the ground, which helps retain moisture and helps stop erosion. Pitting or damming is a practice that has been around many years and is widely used with sprinkler irrigation.

Furrow irrigation has been helped by the use of PAM, which is a polymer that is used to dramatically reduce soil erosion and increase moisture and nutrient retention. The use of straw mulch in furrow irrigation has had a big impact on water quality.

Circle irrigation is changing all the time. We can apply water where and when we want it with new and better technology. We have high-pressure and low-pressure systems; impact, spray, and rotor sprinklers; and drops and drags for better water coverage in different soil types and growing conditions.

"Site specific" is fast becoming part of our farming vocabulary. The use of global satellite positioning (GSP) is increasing. We take soil samples every 1.5 to 4 acres in each field. This is letting us put nutrients and pesticides where we need them. GSP is being used more all the time. Yield monitors and irrigation systems are also being tied into GSP for more information. Aerial applicators are also using GSP for spraying fields.

Computers? You bet! In everything we do. Wisconsin's growers and university people have developed a $400,000 system they call Wisdom. Many of you saw Wisdom displayed two years ago in Las Vegas. They are continually updating it. This type of management program for our potato crops and other crops commonly grown in our rotations helps bring more IPM into practical use faster. This past July, several potato-research people from different states were given hands-on instruction on how to use Wisdom. This instruction was made available by a grant from the EPA to the National Potato Council through their Environmental Stewardship program. Information like this is being used and changed to work in different growing areas.

Potato varieties, whether they are genetically engineered or brought about by Extension breeding programs for specific uses, are being used as they become available. Some of these varieties are resistant to pests. Some need less fertilizer and water, and others do not bruise as easily. Some are for specific processing uses, such as french fries. Some are bred for looks and shelf life because of consumer demands.

Many of these things I have mentioned have happened because of research at the State and Federal levels, but also because they were environmentally sound and economically feasible.

The government does not have to give us incentives to reduce fertilizer and pesticide use. Common sense; improved safety for our families, workers, and consumers; protection of our environment; and economic survival are all the incentives we need. I keep talking about economics, but if it is not economically feasible, we are out of business, and we do not eat, and neither does the rest of the world.

Selective pesticides, as opposed to those with broad-spectrum activity; timing of applications because of harmful pest thresholds instead of spraying by the calendar; and using short residual or nonpersistent pesticides are things we use when possible. The late-blight epidemic has caused us to use more crop-protection fungicides than normal because of the violent nature of the beast. Late blight has become an epidemic. We hope we can at least slow it down until research can find some solutions.

Another consideration is the development of pesticide resistance. Alternating classes of chemicals, site-specific applications, resistant varieties, and the use of B.t. are ways we try to slow down resistance.

The use of ADMIRE that became available in 1995 reduced the use of other active ingredients by 100,000 lbs. in one state alone last year. Also, the use of tank-mixed materials was reduced from five to a maximum of two in this state. Potato growers hope that the good use of fertilizer and chemicals will prevent more regulations.

The National Potato Council now has a research database for use from the Extension Service and land-grant universities. The research database is organized both by State and discipline. Disciplines are: disease, economics, engineering, entomology, irrigation, plant pathology, soils/fertility, storage, varietal development, and weed science. The states covered are Colorado, Delaware, Idaho, Maine, Michigan, Nebraska, North Carolina, Oregon, Pennsylvania, Washington, and Wisconsin. We also cover the Red River Valley. We started with 1990, went through 1994, and are in the process of collecting 1995 information. As I said earlier, potatoes are grown in all 50 states, so we know our database is not complete, but it is a start. We decided to start with 1990 instead of earlier because of the time involved in providing and compiling the research information. The credit for compiling this database goes to Dean Zuleger and Tim Johnson of the Wisconsin Potato and Vegetable Growers Association. Dean and Tim spent at least 160 hours between them planning and implementing the database. The state potato offices spent untold hours collecting and providing the information to Dean and Tim. A diskette was provided to each state that participated in this project. To use the information, you must have the program Quattro Pro for Windows or Microsoft Excel. This past week we received a copy of all federally funded potato research in the U.S. for 1995. We will have to disaggregate these research projects by discipline and State, but a lot of thanks goes to USDA for providing this information to us.

What can the USDA do for the United States potato growers? First, we wondered why a national research database was not already available for use by researchers and the potato industry? You would think it would only take a telephone call to obtain this information. It took a lot more. Thanks to Undersecretary Karl Stauber and Mike Fitzner, we received this information.

Although most researchers will not agree with us, we know there is duplication of research to a certain extent. We feel 20 percent duplication is on the low side, but this much we have found. We know this by conversations with growers from another state. Not only is this a waste of grower money, it is also a waste of Federal and State monies. It is also a waste of research time. Potato researchers need to communicate with each other more than they are. Grower-identified and -driven priorities are the inputs needed to increase our use of IPM.

Let growers set the priorities that affect local areas in each state because these growing areas have different problems and needs. Two years ago at the request of EPA, we identified 23 geographic potato-growing areas in the 11 fall potato growing states. I reemphasize, local areas know what is needed; Extension and land grant universities can facilitate the process of finding out those needs.

Growers are private and independent individuals, and it is sometimes very hard to get their input. But we will help because this is something we, as a grower group, and various people and agencies within the USDA and EPA have been working to change. Three years ago when we were trying to get NTN registered, we had a meeting with EPA and USDA, and our feeling was that these two agencies did not communicate with each other very often. Larry Ellworth at USDA has been working with EPA personnel to address issues that affect the public and growers, and we appreciate this. I am sure there is more interaction than this between the USDA and EPA, but if there is not, we are in real trouble. Communication is the key to success. Growers must get more involved in conferences like this. How many growers of any commodity are here today? That is more than the seven or eight that were in Las Vegas at the Second IPM workshop. Although there is a lot more grower involvement in this workshop, it still is not enough. But, it is headed in the right direction. A lot of good information will be presented by the people involved in this conference, but let us make sure that the information they share with us gets to the growers. It has to be in grower hands to be used.

A grower must see locally the accomplishments of any program. Actually, he must see the results on his own farm.

State, regional, and area IPM teams have been set up. To growers, this looks like typical government overkill. I am sure it is not, but let us take a look at what has happened by this time next year and reevaluate these teams' programs and progress. This is probably already part of the strategic plan but I thought is was worth mentioning from the growers' point of view.

Producers need more information about well designed crop-rotation programs. Good rotation plans for specific crops could slow pest resistance to crop-protection chemicals. Economically viable rotation plans could also improve soil tilth. This, in turn, would reduce wind and water erosion.

The National Agricultural Statistics Service (NASS) needs more funding so that the National Potato Council and USDA researchers and EPA can identify fertilizer and pesticide use and pests. The NASS now surveys the 11 fall growing states. Fertilizer and crop-protection chemicals and 10 target pests are included in this survey.

We need information on spring and summer states and a breakdown by geographic areas. Some geographic areas are very small, like the Skagit Valley in Northwestern Washington. Others are very large like the Red River Valley in Minnesota and North Dakota or the Columbia Basin in Oregon and Washington.

Statistics also need to show why there is an increase in crop-protection chemicals some years and reductions in others. Late blight is a problem that mandates the use of more pesticides in some states one year but not the next. This information needs to be in the statistics, and we need to document why these variations occur. Weather seems to be the number one reason for the increase or decrease from one year to the next. Also, the new strains of late blight need to be identified in the statistics so we know why pesticide use increased or decreased. Growers need to feel more comfortable about why and by whom these statistics are used. So, more information is better, but it is also more time consuming and expensive for everyone.

Under the Federal Crop Insurance Corporation, growers who practice IPM should have lower rates than those who do not. The Extension Service needs more funds to evaluate IPM trials and demonstrations on farms. Research programs need to have long term funding (5 to 10 years) instead of having to develop and submit grant applications yearly. USDA needs to understand grower practices before putting more rules and regulations into place that impact production and use of IPM practices. Growers must be at the center in development of IPM programs, and their advice sought continually. It is not that we are smarter than anyone else, but we need to be part of the IPM program. We need new and better ways to forecast the weather so we know when to apply pesticides. USDA needs to let the public know that IPM is being used.

The USDA could work closer with the EPA on plant-back restrictions on new "safer" chemicals that restrict their use by growers.

I am sure I have sounded very negative about the USDA but I can tell you that the pluses far outnumber the minuses. Without the help from the different groups and personnel within USDA, growers would still be using outdated practices. USDA has brought U.S. potato growers to the point where IPM is used every day. We certainly appreciate all the help we have received.

In the USDA IPM Initiative Strategic Plan, "stakeholders" are identified as growers, consultants, land-grant-university faculty (Extension and research), appropriate State and Federal agencies, nongovernmental environmental, consumer public-interest groups, and others. In the "others" group, there is one that should be listed and not as "other," and that is financial institutions (or as growers say, "our banker"). They have as much influence over growers as anyone else. Potato growers' costs are anywhere from $1,000 to $2,600 per acre, depending on the area and problems encountered. Most growers have to pledge all their assets to obtain a loan. Bankers are going to make sure they get their money, one way or the other. That could mean forcing the grower to apply pesticides that are not needed.

The National Potato Council realized several years ago that we needed to interact with the environmental community. We still are not doing as much as we should be, but we are making growers aware of some concerns environmental groups have. Polly Hoppin, who spoke earlier, was on a panel at our annual meeting last year. Because of people like Polly, attitudes about environmental groups are changing in the grower community.

We also know that Congress sometimes rams things down your throats, and that makes IPM harder to implement, but sometimes growers can help get changes made by Congress if you let us know.

Communications! Farmers are probably the poorest at letting people know what we are doing, but we are getting better at it.

We feel we are practicing IPM very close to the 75-percent level mandated. Some states, and especially those areas that specialize in seed production, are at much higher percentages. IPM is different in every area, which makes it much harder to explain to the growers and public.

Are we satisfied where we are? Absolutely not! We have to keep striving to do better.

As I mentioned before, the National Potato Council is a charter member of EPA's Environmental Stewardship Program. At our next annual meeting, we will be presenting the first annual National Potato Council Pesticide Environmental Stewardship Award to one grower from each of the seven regions we have selected. There are four major components to be considered:

- reduction in pesticide risk
- extensive use of IPM tactics
- use of biological control or alternative pest-control methods
- groundwater, surface water, and habitat protection

There are several areas within each of these four components. These awards will give recognition to growers who are practicing environmental stewardship.

Remember, we believe environmental stewardship is IPM, and IPM is environmental stewardship.

IPM Needs of Apple Producers

David Benner
Pennsylvania Apple Grower

IPM was first introduced to the Pennsylvania apple industry 30 years ago. The possibility of reducing pesticides is what got the growers interested. Positive results from early research led to increased interest by growers. Increased interest led to increased research. Increased research progressed to more positive results. Today, the eastern apple industry routinely acknowledges IPM as the best approach to growing high-quality apple crops. Our industry has been using IPM commercially for the past 15 years, and efforts are continuing to be made in many directions to increase the intensity of applying additional IPM.

I have served on the research committee for the State Horticulture Association of Pennsylvania for 14 years. When I first joined the committee, we had less than $10,000 to direct toward research. The IPM ball was beginning to roll back then and needed to be accelerated. Efforts to increase the budget went into gear, and two weeks ago the committee invested $74,000 in apple research projects for 1996. I am proud to report to you that the increased funds came directly from three specific sources: Pennsylvania growers, apple processors, and packers. And, just to further exemplify how committed we are to advancing our industry, these funds are all voluntary commitments, and I repeat the word voluntary.

Another example of the intensity level of apple growers in the East is “regionalization.” It is no secret that Federal and State budgets have decreased funding in the past six years for tree fruit research. Grower representatives and college of agriculture research and extension people from Pennsylvania, Maryland, West Virginia, and Virginia have been meeting for two years in an effort to maximize their respective research and extension dollars. Within the past 90 days, New Jersey has accepted the invitation to share in these regionalized efforts.

It is most important that you understand how concerned an apple grower is about the environment. An apple tree is planted at a location in a field. It is the grower’s responsibility to manage the environment of that location to assure production and profitability for the expected life and productivity of that tree for up to 30 years. To put this into relative perspective, let me remind you that, excluding sleep time, the human body rarely remains in the same spot for more than an hour and a half. During this 30-year tree life, 25 commercial crops might be produced. Not only does the environment of the tree need to be managed for 30 years, but the environment of each separate crop must be managed according to the factors affecting that crop.

IPM is accepted by apple growers because it is grower friendly. It offers crop-management tools, techniques, and practices that guarantee growers a more stable orchard environment, the ability to maintain or increase the quality of each crop, the ability (when everything works together) to allow for less use of pesticides, and the chance to show a profit after each crop.

I am sad to report that there are some things going on in 1996 that affect IPM that are not grower friendly.

First, the Delaney Clause has become outdated by technology and must be revised or replaced. To imply that the “presence” of a pesticide residue translates directly into “danger” is absolutely false. We must help our legislators understand that we need the Delaney Clause modernized because, in its present draft, it is holding IPM back and restricting it from progressing. Remember, as participants of IPM programs, we can only control the speed of adoption, we cannot determine the final results. We do not know what the final result will be; extended scientific research will be the only ultimate factor to determine the future of IPM.

Second, random removal of products presently available to growers, especially before new products are labeled as replacements is not grower friendly. We need to help EPA understand that any and every tool in our IPM toolbox is valuable. To take an old or worn one away without replacing it with a new and better one retards IPM progress immensely.

- When a product is removed, more stress is put on the remaining products to do the job, en-couraging situations in which a pest may develop resistance. When this happens, we do not have a problem anymore, we have a disaster. I was informed within the past week that EPA plans to announce a proposal to ban the use of two post-bloom miticides by 1997: Kelthane and Omite. This action will reduce the growers' choices from four to two and means that the responsibility of control, instead of being spread over four choices, must then be assumed by the remaining two, Vydate and Carzol. Mites have been documented to develop resistance to pesti-cides in two years; I hope someone has a plan.

- Contrary to what some may believe, the honest fact is simply that more products available to a grower for the control of any pest can ultimately lead to a lesser amount of pesticide being used.

- When a product that controls multiple pests is removed, it must be guaranteed that qualified substitutes and/or replacements be available for all the pests, not just the major one or two.

- Uniformity of label restrictions can be a problem. Captan is the only apple fungicide to which no resistance has ever been recorded. It is very important to our industry. However, growers remain confused as to why a four-day reentry interval must be observed for entering the orchard while only a one-day interval exists from the time of application to harvest and consumption of the fruit. In other words, two days after you eat the apple it is still illegal to walk into the orchard.

Third, assume for a moment that knowledge and IPM tools are presently available that could eliminate a grower's crop disaster. Why does not the grower know it? Whose responsibility is it that he learn it? How are IPM changes and updates communicated to growers? These questions all have the same answer: the Extension Service. You have already heard me report that Pennsylvania increased its research funding nearly ninefold in 14 years. It is only logical to assume that the Extension Service is going to require additional resources to communicate these results. New chemistry involving the use and effects of pesticides, new techniques that eliminate the need for pesticides, and new technologies that require updated use of pesticides are examples of the vast responsibility of communication our present Extension Service bears. We must together develop and maintain resources that enable Extension to serve us adequately. Failure to communicate can only lead to retarding the speed at which IPM can move.

Finally, my last area of concern involves a subject we would all like to forget. However, we must not, because we surely do not ever want such an event to occur again to any crop. I refer to the 1988 crisis the apple industry endured involving Alar. Valid scientific research results must be the sole source of energy by which we move forward with IPM. One-sided research and the failure to communicate and educate ourselves in the arena of IPM are not acceptable factors in IPM development.

The Eastern apple industry is proud of its relationship with IPM. We encourage everyone to act professionally and respond positively to the challenges of taking IPM to the next level. We acknowledge the constant potential volatility of IPM but continue to accept the responsibility of stewardship of its implementation.

Implementing the National IPM Goal: What Crop Consultants Need

Don Jameson
National Alliance of Independent Crop Consultants

Ladies and Gentlemen, on the behalf of the National Alliance of Independent Crop Consultants (NAICC), I want to express our appreciation for the opportunity to address this meeting as well as participate in the poster session.

Our topic is: Implementing the National IPM. Goal: What Crop Consultants Need. First, may I define a consultant as we represent them. We are men and women participating in the practice of applied agricultural production. We use knowledge of agronomy and entomology, among other disciplines. We use knowledge of the crop, along with information out of the field about the crop's status, to help farmer clients make rational "best management decisions." We both walk and scout fields, as well as use advanced and sophisticated equipment for sensing conditions in the field. We give judgment not just on products and rates of chemicals but also on risk reduction. Consultants use memory and experience as well as models and computers to analyze results that aid in decision choices.

Our members are compensated by fees paid by their grower clients rather than indirectly through the sale of crop-production inputs.

A recent Doanes Agricultural Service Company survey indicates a growing profession, with consultants having a direct influence on one in six farm crop acres in the United States. Personally, I have been associated with the broad concepts of integrated pest management for most of my life, having grown up on a diversified Kansas farm where it was common practice for my father to alternate between soybeans and field corn. This was a simple applied strategy to avoid problems with corn rootworm and corn stalk-borer. However, I have recently become considerably more active in my reading and thinking on the current considerations flowing into this gigantic concept that has been labeled IPM. It is a concept as wide as the Mississippi and intricately as curious as the cultural complexities of the Orient.

It is no wonder that those of us deeply involved tend to approach it in the broader sense as integrated crop management.

My goal now for a few minutes is to make a presentation of four main points of need we in the NAICC believe that Department of Agriculture can provide or continue to provide (I use the word "continue" because your support has existed already in many ways).

As an illustration of our needs, allow me to first tell a story of several players in the mint industry. These are the people that flavored your toothpaste this morning. I hope to illustrate the four points I will yet speak to. This is a success story.

Mint is a multidisciplinary challenge. It has unique nutrient and water demands. It is vulnerable to several stem and leaf diseases. One of these stem-fungus diseases (verticillium) can be enhanced by one of the two major nematodes that can infect the roots. The leaf-foliage pests are mites, grasshoppers, aphids, cutworms, and loopers. These show up above ground. Oh, there is one more of the order: *Lepidoptera*, a root borer who can do a mega root canal, rendering the plant dead on arrival come spring. The adult root borers fly and mate in July and August.

Do you see the makings for an integrated pest-management system here?

My newly hired pest-management specialist is learning, but he cannot explain it all. He never had a nematology course. My other staff entomologist understands those pests with wings and six legs. But, the part on diseases and nematodes, well that is another department where he had no course preparation.

Nineteen years ago, Jim Todd on our staff was digging and problem solving: he found an alien. It turns out to be the beginnings for explaining how we had "winter injury" during mild Pasadena winters. He gets credit for the first discovery of mint root borer (MRB) in Washington State. Oregon already was at work.

Recognition of the problem moves to the Mint Research Commission, and cooperative funding goes to Dr. Pike of Washington State University Research and Extension Service.

With the aid of a chemical company, several tactics for control are worked out: tillage, cultural practices, and a postharvest chemical-pesticide treatment.

Some people begin to see another pest. There are reports of failings in natural mite control heretofore not observed. Dare we say one chemical had shifted the equilibrium in the population dynamics of another? Besides a chemical pesticide, what other options could be used?

Then a company developed a biocontrol beneficial parasitic nematode. It is a new idea; the industry is cautious; the control cost is $90/acre (three times the conventional treatment). Meanwhile, the USDA Agricultural Research Service (ARS) scientists at Yakima think of pheromones and of using timed summer sprays on the adults. Dr. Harry Davis camps out many nights in Sonny's mint field. He studies their nocturnal flight and mating habits, and he pretty well nails it down. Colleagues crack the pheromone code and can synthesize it. They license the pheromone to a private manufacturer. Mint-root-borer field-sampling techniques and thresholds are developed by Dr. Pike and other research and Extension scientists at Oregon State University and the University of Idaho. Our firm, Agrimanagement, offers a commercial detection and control management service to farmers. Samplers are hired.

Dr. Davis calls us for lists of fields known to be hot with infestation. We furnish these, and he camps out more nights and tests his pheromone product. Meanwhile, the biocontrol company is gaining creditability and is able to enlarge the market. The price falls to $50 per acre with favorable anecdotal reports coming in. I persuade Larry to try it on two fields, we do a postseason sample, and this bio--control looks exciting.

Then in 1993, ARS furnishes pheromones to the private consultant to try out. Trap catches are counted and charted. Data are correlated to Weather Service data. A summer control spray is applied to several fields. Growers Don, Larry, Mike, and Sonny try it in July on the strength of their consultants' argument and persuasion. It stretches the budget about $25/acre.

The September root-sampling results come in. Some fields show a bull's-eye direct hit. Others show less definitive results. Sonny says it was money down a rat hole. More research is needed. Who needs to do that?

Because of funding constraints, the university project on MRB has been terminated. The private consulting company continues with its own resources and grower-invested trials. Sonny tries it one more time. Some say the technique is flawed. But we believe we see it working and usable. It scores for Sonny this time. Great, a postharvest chemical will not be needed!

Now we have another tool. The strategy of pheromone trapping is adopted by an observing chemical/fertilizer dealer. September samplings for larva expand before treatments are *carte blanche* applied. Also, biocontrol parasitic nematodes have come down to $39 per acre for the officially recommended dose.

Now we have a multifaceted system for mint root borer control in place. Other parts (bio- and chemical control) are under development, but there are still mites, foliage disease, and the nematodes. One chemical-company- and university-tested nematode product would work and has met residue standards. It has been on the long IR-4 waiting list, memory says, for four years. Some are hoping for release during the fall of 1996; check with us next year.

The representatives of various commodity groups speaking here before me furnished a fine prelude to my remarks. Indeed, many of our needs for IPM are the same because these people are our direct employers. As my story illustrated:

First, we need trained and educated people to fill our ranks. These need to be people trained in multi-disciplinary education with skills in diagnosis and problem solving. We need Government acceptance and support for the concept of moving toward a multidisciplinary curriculum at the undergraduate and graduate levels.

At our workshop on Wednesday the panel will expand the vision of how this can work, especially to the promotion of IPM goals. We believe academic, government, and private practitioners can cooperate to develop this concept. Regional programs could lead to a doctor of plant health degree or to what is called a professional degree.

Second, we need publicly funded agricultural science research. This has been the very bedstone used to build today's IPM systems. Government needs to acknowledge this vital role and even to promote to the public the value of allocating dollars to agricultural research.

In developing research goals, researchers and policymakers can benefit from a close relationship between the grower and crop advisors and consultants. We consultants do need to be participants in helping identify the type of research or policies needed. By our involvement, we can be used to deliver information to the producer and to return observations and experience to the researchers and policymakers.

On the topic of research needs, good points have already been made by the commodity representatives and by Chuck Peters. In a phrase, we do need the infrastructure, the policies, and stimulation of private and public entities to bring systems of control and biocontrol products for primary or "rescue" use into the market.

As former primary pests are contained by IPM strategies or via transgenics, new secondaries may emerge. Other issues of resistance management will deserve continual attention and research.

This takes me to a different question that is important to the end users of IPM tactics: The economic gain or advantage for a farmer-user must be planned for, achieved, and promoted. But if there can be gain, there can also be loss incurred by the use of soft, biocontrol systems if nature does not cooperate. This risk has always been shouldered by the producer. Fresh thinking and discussion is needed on the issue of the economic risk and liability that may arise when using an IPM tactic or system that fails in comparison to a conventional approach.

Third, crop consultants need the recognition of our established NAICC certification program. By meeting its stringent education, experience, and continuing-education requirements, advisors and consultants can be distinguished as a Certified Professional Crop Consultant. NAICC has worked with EPA and the USDA in the development of this program to make sure it satisfies expected standards.

Such credentials should assure policymakers, farmers, and the general public that those purveyors of methods and information, who farmers freely choose to advise them, are competent.

Fourth, consultants need supporting policies to promote and stabilize them as private firms delivering IPM services. Funding and policy for IPM programs need to be designed in such a way that they do not strongly subsidize competition from the public sector where private services are in place or can be available to assume the job. Policy should permit funding allocations to be directed or shared by private entities when they are able to codirect and execute research projects.`

Independent or private crop consultants should seek to participate in the initial design and thinking of IPM planning committees. However, it is important that funding be available to support consultant travel and time in such activities. We acknowledge that you do appreciate the difference between a public salaried employee and the private business farmer or crop advisor who leaves his place of business to participate in a conference or committee meeting directed to issues of public policy.

Privatization of agricultural-technology and information transfer and adaptation is evidence of the overall long-term success and validity of Federal and university agricultural research and Extension systems.

Crop consultants have a unique personal relationship with their individual clients that makes them able to transfer information that is accurate as well as specifically adapted to the demands of each farmer. This relationship is important for State and Federal environmental compliance as well. Growers do consistently express confidence and satisfaction with their consultants. This confidence allows us to be highly effective in transferring technical advice and regulatory information.

Simply said, consultants must get good results or they will not be hired back. In other words, our work is under ongoing assessment.

Part III. Assessing IPM Impacts

Introduction

The second theme of the Third National Symposium/Workshop, "Assessing IPM Program Impacts," was motivated by several factors. First, the Clinton Administration's commitment to implementing IPM practices on 75 percent of crop acres by the year 2000 has put a spotlight on defining and measuring the degree and extent of IPM adoption in the United States. Second, the concomitant goal of reducing reliance on high-risk pesticides to garner environmental and public-health benefits demands new methods of measuring pesticide impacts. Third, to meet the demand for greater accountability for public expenditures (as legislated in the Government Performance and Results Act passed by Congress in 1993), the USDA IPM Initiative and National IPM Implementation Plan require integration of assessment activities in future IPM funding proposals.

Careful documentation of IPM program impacts can help demonstrate that recommended IPM technologies and practices are both profitable for producers and reduce reliance on agricultural chemicals that are harmful to the environment and/or public health. While the need for better documentation of IPM program impacts is clear, a consensus has not yet been forged about the appropriate assessment method(s) to use. Past efforts to evaluate IPM-program impacts have generally focused on the cost and efficacy of IPM practices. Environmental impacts were often limited to measuring pesticide-use reduction. Enlarging the assessment domain to include broader concepts of environmental and public-health impacts adds additional complexity that can best be addressed by the adoption of multidisciplinary assessment approaches.

USDA officials and a private consultant presented their views on integrating multidisciplinary assessment into IPM research and extension programs in the plenary session, "Assessing IPM Program Impacts." These opening comments were followed by the presentation of five papers commissioned by the Economic Research Service that provided a starting point for an interdisciplinary discussion of the appropriate methods and approaches for measuring economic, environmental, and public-health impacts of IPM programs. Each of these papers is published in its entirety here. ERS also organized five selected paper sessions during the Symposium/Workshop that provided a venue for the presentation of empirical and methodological research results exploring some aspect of IPM evaluation. A summary of each paper presented is provided at the end of this section of the Proceedings.

Karl Stauber, (former) Under Secretary for Research, Education, and Economics, and Susan Offutt, Administrator of the Economic Research Service (ERS), opened the plenary session devoted to assessment. In their introductory comments, the Under Secretary and the Administrator expressed the Department of Agriculture's commitment to supporting multidisciplinary assessment of IPM impacts. Stauber, in his program overview, "Interdisciplinary Collaboration to Achieve IPM Goals," highlighted the importance of establishing IPM research and extension priorities that reflect both producer needs and public concern about agriculture's effects on environmental quality and human health. He argued that accountability for the use of public funds will require a transparent assessment process that documents progress toward achieving priorities identified by all the stakeholders. In his view, IPM adoption offers producers and society a potential win-win solution by maintaining producer profits and addressing environmental and public-health issues associated with pesticide use.

Terry Nipp, President of AESOP Enterprises, Ltd., in his presentation, "Accountability: The Best Defense is a Good Offense," underscored the importance of establishing an open assessment process that documents progress toward the achievement of societal priorities. In his view, agricultural research and extension programs that can demonstrate benefits to producers and improvements in meeting important societal goals (such as environmental protection, worker safety, safe water and food, and wildlife protection) will have a higher probability of retaining and maybe even increasing their public funding.

Having made the case for integrated interdisciplinary assessment, the authors of the five commissioned papers addressed alternative assessment approaches. Integrating different disciplinary perspectives into a coordinated assessment was the challenge undertaken in the paper by John Antle and Susan Capalbo, "Integrated Assessment of IPM Impacts: An Overview." Because no single technology will be superior in all assessment areas, a unifying framework is needed to assess the tradeoffs among economic, environmental, and public-health impacts of alternative production technologies. The authors described how physical impacts, once identified, can then be converted into monetary values, thereby providing a common unit of measurement. They then explain how to use a benefit-cost framework to assess the tradeoffs between different objectives.

Susan Riha, Lois Levitan, and John Hutson in "Environmental Impact Assessment: The Quest for a Holistic Picture" outlined the issues that must be addressed in assessing pesticides' impacts on the environment. They discussed objectives, strengths, and weaknesses of existing environmental assessment methods and identified conceptual and data challenges that must be overcome to improve these assessment tools. Important issues (such as who is going to use the assessment, time frame, budget, and the tradeoffs between ease-of-use versus complexity and short run versus longrun) were identified as important questions useful in determining the appropriateness of alternative ap-proaches and tools in environmental assessment.

The many challenges encountered in trying to measure and assess acute and chronic health impacts of occupational exposure to pesticides are explored in "Occupational Exposure to Pesticides and Their Effects on Human Health" presented by Aaron Blair, Marcie Francis, and Sarah Lynch. The authors reviewed current public-health research on the relationship between occupational exposure to pesticides and the development of acute and chronic diseases, including cancer and diseases of the nervous, immune, and reproductive systems. Understanding how and to what degree pesticide exposure occurs [source(s), route(s), duration, and dose] is critical to estimating public-health impacts.

A more detailed description of how to conduct economic-impact assessment is provided in "A Primer on Economic Assessment of Integrated Pest Management" by George Norton, Jeffrey Mullen, and Edwin Rajotte. The authors walk readers through the "nuts and bolts" of conducting an integrated economic assessment, including a process for defining IPM systems, identifying appropriate assessment methods, establishing statistically valid baseline data, and integrating and analyzing this information in a benefit-cost framework. While recognizing that the site-specific nature of IPM systems means that a standardized approach to measuring impacts is not possible, the authors identified a core set of methods that can form part of virtually any IPM impact assessment. They also presented an overview of some of the methods that are available to address other dimensions of an integrated assessment.

Farm-level profitability and technical efficiency are two powerful factors influencing producer adoption of new technologies. However, IPM practitioners have been puzzled by the lack of adoption of some IPM practices or technologies that have been both profitable and efficient. In "Practical Considerations in Assessing Barriers to IPM Adoption," Peter Nowak, Steven Padgitt, and Thomas Hoban identified other considerations besides economic and technical efficiency that influence adoption of alternative agricultural practices. The authors argued that IPM is an information-intensive production system. Deepening and expanding the use of IPM will depend on increasing the number of producers who *want to* and *can* incorporate site-specific, multifaceted information in their pest-management decision making. Viewing IPM as a decision-making process rather than as a list of practices makes the task of measuring adoption vastly more complex. The authors presented a typology of barriers to adoption of IPM practices that differentiates between producers who are unable, unwilling, or both unwilling and unable to adopt IPM systems. If gains are to be made in deepening and expanding adoption of IPM, then understanding the important differences between the reasons for not adopting recommended IPM practices will contribute greatly to the identification of appropriate policies and strategies.

While each of the presentations and commissioned papers dealt with different aspects of impact assessment, collectively they identified key elements that must be addressed in conducting integrated assessment. First, because of the diversity in agroecosystems, IPM systems, weather, and pest pressures, appropriate methods may need to be adapted to reflect site-specific conditions. Second, because of this diversity, each locale must develop a consensus on assessment priorities through an open, transparent process that includes all stake-holders. Budget constraints and data availability limit what can be studied, so agreement must be reached by stakeholders on what is to be assessed and how. Third, relevant disciplines must be included at the start of the research project to allow researchers to agree upon a common unit of analysis for data collection, scientifically valid data-collection procedures, spatial and temporal scales, and complementary methods to quantify the impacts of IPM production technologies. Working together from the start will facilitate the integration of the different disciplines' methodological approaches into a comprehensive assessment. Fourth, converting impacts into a common monetary measure facilitates the comparison of different impacts and the assessment of tradeoffs between different objectives. Finally, an assessment must quantify the economic, environmental, and public-health impacts of IPM adoption and show the regional and socioeconomic distribution of these impacts.

Interdisciplinary Collaboration to Achieve IPM Goals

Karl Stauber
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I would like to add to that of the Administrator of the Economic Research Service, Dr. Susan Offutt, my welcome to participants of the Third National IPM Symposium/Workshop. An important theme of this conference is "Meeting the IPM Goal." The conference program reflects the importance of two important elements identified by the USDA IPM Initiative as critical to the success of meeting this administration's IPM goals. The first, "Putting Customers First," means that priorities for IPM research and educational programs must reflect our customer-identified needs. These needs must be identified through a systematic planning process involving all stakeholders. The second, "Incorporating Impact Assessment," implies that the successful implementation of the IPM Initiative will require us to carefully document the environmen- tal, economic, public-health, and social impacts of increased IPM implementation by farmers and other IPM users.

The USDA IPM Initiative is a coordinated Department-wide effort to realize the Clinton administration's goal of implementing IPM practices on 75 percent of the nation's crop acres by the year 2000. This goal, set jointly by the Department of Agriculture, the Environmental Protection Agency, and the Food and Drug Administration in the fall of 1993, reflects the administration's commitment to improving environmental quality while maintaining the agricultural sector's profitability and global competitiveness. The administration has backed this commitment with increased budget proposals to support IPM research and extension education programs in both FY 96 and FY 97 budget requests. The proposed increases are the first significant increases for IPM research and extension activities since the Nixon administration. The USDA Strategic Plan for the IPM Initiative commits the Department to provide research, educational, and programmatic support to address priority needs identified by farmers and other IPM stakeholders.

The 75-percent IPM goal has stimulated a great deal of discussion as to its origin and what it means in terms of a measurable goal. This goal must be viewed in the context of public concern about environmental quality, food safety, and the use of pesticides by both agricultural and urban users. Several European countries have mandated pesticide-use-reduction goals in response to similar concerns about pesticide impacts on the environment and public health. The Administration's 75-percent goal depends on voluntary adoption of IPM practices rather than mandated use-reduction goals. It emphasizes the proven track record of the land-grant-university system as an agent of innovation and change. In addition, the administration's goal focuses on the potential for IPM to reduce farmer reliance on pesticides while enhancing economic and environmental benefits to producers and society as a whole.

The IPM Initiative, carried out by the research, education, and economics mission area of USDA, will provide increased support for basic and implementation research and educational programs needed to encourage voluntary adoption of IPM systems. The IPM Initiative will not only reach out to new adopters of IPM practices but will provide support for present IPM users to incorporate more sophisticated IPM tactics on their farms.

The 1994 Economic Research Service report on IPM adoption indicates that basic IPM tactics are used on approximately 50 percent of U.S. crop acres. This might indicate that we are two-thirds of the way to our goal. I prefer a more ambitious interpretation. While many American farmers have adopted some basic IPM tactics, we need to invest in focused research and education programs to provide the foundation for new farmers to adopt IPM production practices and at the same time provide existing IPM users with a range of more comprehensive IPM tactics to adopt.

A new report from the National Research Council encourages the adoption of "ecologically based IPM." To promote the adoption of ecologically based IPM we must commit ourselves to a significant public investment in both research and extension education. It is clear that achievement of ecologically based IPM or the simpler goal of implementation of IPM on 75 percent of the crop acreage will require integrated program planning that involves both the biological and social sciences if the IPM Initiative is to be responsive to the complex demands placed on agriculture in today's society. This Initiative epitomizes the type of approach that will be increasingly demanded by the public to address a variety of issues in the agricultural sector. Why? Because pest-management issues are elements of a broad array of multidimensional challenges that agriculture confronts: protection of natural resources and the environment, viability of rural communities, sustainability, public investment in agricultural research, education and farm programs, and global competitiveness. The USDA, in cooperation with its land-grant-university partners and a broadly defined user community, must create a coordinated strategy to engage both disciplinary science and interdisciplinary system-oriented approaches to address increasingly complex agricultural problems.

Public concerns over agriculture's effects on environmental quality and human health must be addressed in planning and implementing the IPM Initiative. Also important, however, is the need for producers to achieve sustainable economic returns for their investment. By involving all of IPM's stakeholders in a dialogue, we can address the private-risk, public-benefit paradigm. The adoption of IPM practices can provide a win-win solution to pest problems by maintaining producers' economic viability and global competitiveness and at the same time addressing environmental and public health issues associated with pesticide use.

The key to expanded IPM adoption is to understand that IPM practices and technologies are site-specific and both knowledge- and information-intensive and that producers will not adopt unprofitable practices. The IPM Initiative will succeed if it focuses its resources on research and education priorities identified at the local level by producers and other stakeholders. Critical to the success of the Initiative is the establishment of an assessment process that documents progress toward achieving the priorities identified by the stakeholders. Information derived from the assessment process improves accountability and contributes to a better understanding of the factors that contribute to both success and failure.

I have asked the Economic Research Service, working through the USDA IPM Coordinator and IPM Program Subcommittee and with other USDA agencies and the EPA, to take the lead in formulating an assessment plan for the IPM Initiative. This plan will help with assessment at both the national and local level and will require the unique disciplinary expertise of both the biological and social sciences and the forging of new interdisciplinary alliances.

This conference offers an opportunity to increase our understanding of the components of successful IPM programs and the environmental, economic, public-health, and social impacts of IPM programs. The dialog and planning initiated during this symposium/workshop will contribute both to strengthening disciplinary science and forging the synergistic new interdisciplinary alliances needed to achieve the administration's IPM goal. I will watch with interest how the challenges of "Putting Our Customers First" and "Incorporating Impact Assessment" are addressed in the IPM plans being developed at both the state and production-region levels. I and other members of the administration will work with Congress to bring the needed new resources for research and education to your local programs.

Integrated Assessment of IPM Impacts: An Overview

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Introduction

The purpose of this paper is to provide an overview of how the economic, environmental, and public-health benefits and impacts of IPM can be measured and used in an integrated assessment of IPM. Before addressing how this can be done, it is important to explain why it should be done, particularly because most IPM researchers do not consider impact assessment a part of IPM research, and it has not been included in most IPM research projects.

There are a number of important reasons why we need to do integrated assessment of IPM impacts (see Antle and Wagenet 1995 for a more detailed discussion). First, from the scientific perspective, we need information on the expected benefits and costs of alternative research strategies to set research priorities, to design research, and to evaluate research. In short, to do good science, we need to use resources efficiently; and to do that, we need to be able to assess how productive science is. There is also a need for this information to conduct policy research.

Second, there is a growing demand by the public and by government for publicly funded research, such as IPM research, to be socially and economically accountable. Executive orders under the Reagan, Bush, and Clinton administrations have required accountability for major new regulations and policies, and Congress has required similar accountability under the Government Performance Review Act. The need for this information is particularly acute to justify expenditures on publicly funded research, such as IPM, in an era of declining government spending on research, and it is needed to set priorities among competing research programs. Indeed, USDA's IPM Initiative is built on the premise that development and adoption of IPM will yield economic, environmental, and human-health benefits to producers and to society. Obviously, it is USDA's responsibility to demonstrate that the research sponsored by this program actually achieves those objectives if this line of research is to justify continued funding.

Researchers naturally tend to view impact assessment as a burdensome, costly task that diverts resources from scientific work. But this view of impact assessment is mistaken on several grounds. First and foremost, this view is much like the person who is in such a hurry to get somewhere that he does not bother to look at the map. How can we defend the claims made for the benefits of IPM if we do not document them? Second, if there really are substantial economic, environmental, and public health benefits from IPM, IPM researchers have a strong vested interest in having those benefits quantified and documented. It would be myopic, indeed, for IPM researchers not to view impact assessment as an essential part of the IPM research agenda. Finally, there is a tendency to view economics, environmental science, and health science as not part of IPM and therefore as detracting from the pool of money available for IPM research. This view ignores the fact that in a world where publicly funded science must be justified by the benefits it yields, there may be no pool of money for any kind of IPM research if the benefits cannot be documented and quantified in a scientifically sound manner.

In the remainder of this paper, we address the question of how to do integrated impact assessment for IPM research. There are two essential points that we would like to emphasize in our discussion of impact assessment:

Impact assessment must be an integral part of doing IPM research and extension and must be integrated into research and extension projects from their inception:

- to facilitate interdisciplinary collaboration in the design and implementation of data collection and analysis;

- to ensure that the research is useful and relevant in economic, environmental, and public-health terms;
- to ensure that the impact assessments are timely and cost-effective. It is often argued that impact assessment is too time consuming and costly. This is not true if impact-assessment research is integrated into research projects from their inception.

Impact assessment is an application of the economic tool of benefit-cost analysis, combined with appropriate data and models from production economics, environmental science, and health science.

Because it is difficult to value all of the environmental and health impacts, impact assessment should strive to quantify tradeoffs among economic, environment, and health impacts. These tradeoff relationships can be used to assess the benefits associated with IPM technologies.

The Impact-Assessment Framework

Benefit-cost analysis provides the basis for a multidisciplinary approach to assessing impacts of IPM and other research activities (Antle and Wagenet 1995). Note that the use of "multidisciplinary" is meant to convey the need for collaboration across the full spectrum of biological, physical, and social sciences that are needed to address the impacts of agricultural technology. The first step is for scientists to set research objectives that reflect public priorities. We shall describe these objectives broadly as food supply, human health, and environmental. The public's priorities may be embodied in state or federal legislation or may be communicated to research administrators and scientists by local interest groups, such as commodity, farm, or environmental organizations. Researchers then formulate strategies to meet these objectives. For each strategy, researchers collaborate to estimate the impacts of the prospective technologies on production, human health, and the environment.

Once impacts are estimated by each discipline, economists can translate the impacts into monetary values. The valuation of market goods, like wheat, is straightforward because market prices can be used. The monetary valuation of nonmarket goods, such as environmental amenities, is more difficult but can be done in some cases and is a major component of environmental-economics research (Freeman 1993). The present and future benefits and costs of the prospective technologies are translated into present values with a technique known as discounting. This technique weights monetary benefits and costs by a discount factor that takes into consideration how far into the future the benefit or cost occurs. These discounted benefits and costs are then summed over time. The difference between discounted benefits and costs of each strategy is its net present value (NPV).

Because agricultural research is an uncertain undertaking, the ultimate value of research to society is also uncertain. Researchers must consider the probability of success of each research strategy and uncertainties associated with estimating benefits and costs of research. For example, taking into account the scientific and economic uncertainties, each research strategy may be associated with a pessimistic (low) NPV value and an optimistic (high) NPV value. Weighting these possible NPVs by their probability of occurrence yields the statistical expected value of the NPV. Research strategies are ordered according to their expected NPV, and only projects with a positive expected value are considered acceptable. When some of the impacts, such as changes in human health or the environment, defy quantification or valuation in monetary terms, a qualitative assessment can supplement the quantitative analysis.

A number of issues that cannot be treated here in detail must be considered in implementing impact assessment. One critical issue is identifying the distribution of benefits and costs across the affected groups. For example, the economics literature considers how research conducted in one geographic region affects productivity in other regions. An important part of environmental and health impact assessment is identifying the relevant population. Another issue arises when public research is an input into the private development of technology. In this case, the research contributions from both the public and private sectors must be determined.

Assessing Impacts of Pest-Management Research

To illustrate how impact assessment can be designed and used in IPM research, let us now consider the challenge of designing pest-management research to accomplish the sustainable agriculture goals in the 1990 farm bill. As we noted in the Introduction, one important motivation for impact assessment is the need to set research priorities. We consider two research strategies. One is based on genetic manipulation of the plant to resist a pest, such as the development of late-blight-resistant potato varieties, which if successful would eliminate the need for certain classes of pesticides, such as the fungicides used to control late blight; the other is based on a conventional IPM strategy, such as improving the timing and amount of fungicides applied to potato crops, that may reduce but does not eliminate pesticide use.

A successful pest-management strategy must be profitable to individual farmers and for the indus-try as a whole if it is to be widely adopted. In collaboration with the biological researchers, economists can estimate changes in pesticide use, labor, other inputs, and yields associated with the two research strategies. The extent of adoption of the technology by the industry and its economic impact at the farm and industry level can then be estimated. Many such studies of IPM have been conducted by agricultural economists (e.g., Carlson and Wetzstein 1993).

The human-health and environmental impacts of a change in pest-management technology also can be quantified. Despite the public perception that IPM techniques reduce or eliminate pesticide use, many IPM techniques are based on "economic thresholds" for pesticide application that do not explicitly consider either environmental or human-health impacts. The agricultural-science community tends to assume that environmental and health problems associated with technologies are caused by inefficient use of the technology. Inefficient use may indeed be one source of health and environmental problems, as in pesticide use by farmers in developing countries. But even the correct use of an "economic threshold" could result in overuse of a pesticide when off-farm environmental or health effects are considered. These "external costs" are particularly important in policy design because they are not borne by farmers and the market does not provide an economic incentive for farmers to take corrective actions.

Teams of economists, occupational-health specialists, and environmental scientists can assemble data on human toxicity of the pesticides, their transport, and fate in the environment. These data can be used to estimate changes in human-health risk, water quality, and other key dimensions of health and the environment associated with the IPM technologies and the use of recombinantly derived resistant varieties. If the agricultural products are traded internationally, international standards for pesticide residues and the use of genetically altered materials must be considered in the estimation of benefits and costs. If the data on the economic, health, and environmental benefits are combined, the net present value (NPV) of each technology can be estimated.

Various outcomes are possible in this example, depending on the weights attached to crop production, environmental quality, and health. If both strategies yield a positive expected NPV and if the research budgets are adequate, then both strategies might be funded to account for the uncertainties in research. If the biogenetic research strategy is more costly and the benefits of reduced pesticide use are not large or if its success is highly uncertain, then the less-costly, more-reliable IPM strategy might be preferred. But if the health or environmental costs of using pesticides are sufficiently large, the benefits of the biogenetic strategy that could eliminate the use of pesticides might yield the higher expected NPV. It is also possible that neither line of research could yield sufficiently high benefits to justify its cost.

Designing Integrated Assessments: Units of Measurement and Aggregation

It should be apparent from the preceding discus-sion that researchers involved in an interdisciplin-ary project must coordinate their research designs so that data can be integrated across disciplines and used for impact assessment. We assume that the production impacts of prospective technologies have been quantified by agricultural scientists. Soil and crop science tell us that the environmental benefits of reduced pesticide use vary according to soil and climatic conditions. The pesticide-reducing technologies will be adopted by many farms operating in widely differing climatic conditions and soils. Thus, pesticide impacts vary across the physical and economic units in production. Likewise, public health researchers know that the human health impacts of pesticides vary across individuals in the affected populations. How can we quantify the benefits of technologies whose impacts vary across space or time?

This question raises a fundamental issue in the design of research for impact assessment. Biological and physical science research typically focus on the cellular, plant, animal, or field level. This level is different than the level at which technologies affect the public and at which public policies are directed. Even policies at the local level will be directed at a population of biological, physical, or economic units. In water policy, for example, federal law requires states to assess impacts and to formulate policies at the level of a well-defined environmental entity, such as a watershed or aquifer.

The solution to this problem is for researchers from all concerned disciplines to be involved at the inception of the research, so that they can agree upon a unit of analysis to use in quantifying the impacts of production technologies. In the water-quality example, soil scientists, and economists can define a unit of measurement, such as a farmer's field, at which both the economic and environmental impacts of the technologies can be reliably assessed. The physical impacts in the population of farm fields can be described by probability distributions of solute leaching below the root zone and runoff into surface water. Economists can also estimate in probabilistic terms how farmers change pesticide use as they adopt the new pesticide-reducing technologies. By combining these physical and economic data for the physical and economic populations, it is possible to estimate the mean environmental impacts in the population or to assess the probability that leaching or runoff will exceed a critical level. This environmental-risk information can then be related directly to policy objectives.

Assessing Impacts: The Role of Tradeoffs

Identifying the impacts of production technologies on human health and the environment takes us a significant step closer to making the link from science to impact assessment and policy formation. But in both research planning and impact assessment, it is rare that one research strategy or technology dominates all others in all relevant dimensions. One technology may be more productive but also riskier for human health than another; thus, tradeoffs among economic, health, and environmental goals must be assessed.

One solution to this problem is to obtain a common unit of measurement by converting physical impacts to monetary values. The use of monetary values is appealing because the economic impacts of a technology on producers and consumers--changes in net returns to producers and changes in the real incomes of consumers--can be measured with market prices. Government policies often distort market prices, so analysts must consider these distortions.

Health and environmental impacts of technology create an additional valuation problem. The monetary valuation of changes in human health and environmental quality usually cannot be measured directly because these are nonmarket goods. The valuation of nonmarket goods has been a major research objective in environmental economics for the past 30 years. An established set of techniques now exists to obtain values for nonmarket impacts that are comparable to market prices.

There are, however, several significant limitations to the application of nonmarket valuation techniques. First, the transferability of valuations is an unresolved issue in the economics literature, and it may be prohibitively costly to undertake a valuation study corresponding to every nonmarket effect that needs to be considered in an impact assessment (Larson 1995). Second, the reliability of the valuation techniques has been questioned in the economics profession, and the economic valuation of some nonmarket effects is controversial in the public mind and may not be accepted by the public as a basis for impact assessment (Smith 1992; Portney 1994).

For these reasons, we believe it is important for researchers conducting impact assessments to present tradeoffs among economic, environmental, and public-health impacts whether or not nonmarket valuation techniques are used to translate impacts into monetary terms.

How It Is Done: Assessing the Economic, Environmental, and Health Tradeoffs of Pesticide Use in Potato Production

We now illustrate the impact assessment methods outlined above by describing a study designed to assess the economic, environmental, and health effects of pesticide use in potato production. Detailed descriptions of this study can be found in Antle, Crissman, and Capalbo (1994); Crissman, Cole, and Carpio (1994); and Antle et al. (1996).

This study of the economic, environmental, and human-health effects of pesticides sponsored by the International Potato Center was based in the Carchi Province in northern Ecuador in a highland zone 30 km south of the Colombian border. Production occurs between the altitudes of 2,800 and 3,400 m on steeply sloped, deep volcanic soils. Just half a degree north of the equator, there are virtually no changes in day length, little seasonal variation in temperature, and limited variation in rainfall.

The cropping system is dominated by potatoes and pasture for dairy cattle, with these two crops rotated in a potato-potato-pasture cycle that takes about 2 years. Because of the equatorial Andean climate, there are no distinct planting or harvesting seasons, and potato production occurs continuously. Production data were collected in a farm-level survey on 40 farms during 1990 to 1992 by trained enumerators who lived in the region and made bimonthly visits to the farms. Data were collected for individual parcels, where a parcel is defined as a single crop cycle on a farmer's field.

This physical environment is highly conducive to certain potato pests, notably the soil-dwelling larvae of the Andean weevil (*Premnotrypes vorax*) and the late-blight fungus (*Phytophthora infestans*). With backpack sprayers, farmers make an average of more than seven applications of pesticides to each parcel. Though a wide array of products was used, three types dominated the selection. The dithiocarbamate Mancozeb accounted for more than 80 percent of total active ingredient of fungicides. The carbamate Carbofuran and the organophosphate Methamdiophos accounted for 47 percent and 43 percent of all insecticide active ingredients applied. Carbofuran is used to control the Andean weevil, and the organophosphates are used on foliar insect pests. Most farmers manage several fields, so that potato production and pesticide use are continuous throughout the year. An important consequence of continuous production is a year-round potential for occupational and incidental exposure to pesticides. Pesticides are not used in the pasture cycle and are seldom used in other crops that may be included in the rotation, such as legumes. Thus a farmer’s exposure to pesticides comes almost entirely from potato production.

The project’s research team consisted of agricultural economists, soil scientists, and occupational health researchers. In the planning stage of the project, the study watersheds were identified, and the decision was made to collect production data at the field level. Detailed parcel-level production data were collected on a monthly basis, with emphasis on accurate measurement of pesticide use. An important part of the production work was to account for the fact that a large number of different types of pesticides are used in the production system. The watersheds were classified into four agroecological zones, and soils, and related data were collected by the environmental impact team for simulation modeling of the transport and fate of pesticides in the environment.

To examine the health impacts of this pesticide use, the health research team conducted a survey of the farm population and an age- and education-matched reference group not exposed to pesticides. All participants answered questions on pesticide use and medical problems, received a clinical examination by a field physician, completed a series of tests of nervous system function, and underwent blood tests. These tests were oriented toward those effects most likely to be associated with the insecticide and fungicide exposures that the agricultural team had documented. Crissman, Cole, and Carpio (1994) describe the higher rates of skin problems (dermatitis), reduced vibration sensation, lower cholinesterase levels, and generally poorer neurobehavioral test results among the farm population compared to the reference group.

Following the approach described by Antle, Capalbo, and Crissman (1994), primary production data were used to estimate econometric models that represent the farmers' decisions on the extensive (crop choice) and intensive (input use) margins. These econometric models provided the parameters for construction of a stochastic simulation model of the production system. The outcomes of this economic simulation model were then input into two other simulation models: a physical simulation model to estimate environmental impact, defined here in terms of the leaching of pesticides beyond the crop root zone; and a simulation model based on statistically estimated relationships between pesticide use on the farm and the neurobehavioral status of members of the farm population.

These three integrated simulation models were used to assess the economic, environmental, and farm-population health impacts of various scenarios, including alternative pest-management scenarios. Simulation-model output can be displayed in graphs that illustrate the tradeoffs between agricultural output and changes in environmental quality (e.g., leaching of an insecticide below the root zone) for the current management practices and an IPM practice that involved more effective carbofuran application techniques. Similarly, the tradeoffs between agricultural output and health risk under current management practices, under the IPM technology, and for a combination of IPM and improved farmworker protection practices can be constructed. In this particular study, these tradeoff relationships showed that there are substantial tradeoffs among output, environmental, and health outcomes and that IPM practices improve health as much as or more than better self-protection practices. In other words, this case study showed that IPM could generate substantial benefits by reducing numbers of insecticide applications and thus lowering exposure to hazardous insecticides.

Conclusions

In this paper, we argue that impact assessment must be an integral part of doing IPM or any other publicly funded agricultural research. Impact assessment does not take resources away from IPM research, rather it is an integral part of doing research that addresses society's concerns about the impacts of agriculture on environmental quality and public health. A key goal of impact-assessment research should be to quantify tradeoffs among economic, environmental, and public-health outcomes.

Another important message we would like to convey to the research community is that we must not be overwhelmed by the apparent complexity of these problems. Successful research programs will use experts from each relevant discipline to identify key first-order impacts in each area (economic, environment, and health) and focus on them. Interdisciplinary collaboration at the research design stage will also ensure that units of measurement are compatible across disciplines so that research results can be integrated for impact assessment.

Finally, it must be emphasized that in impact assessment, as in all scientific research, there is no cookbook solution. The general approach described here must be adapted to each production system to account for its most important impacts.

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Environmental-Impact Assessment: The Quest for a Holistic Picture

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Agriculture intentionally disturbs the natural ecosystem and imposes a managed system that has multiple direct and indirect environmental consequences. Given the uncertainty and complexity of these consequences, a number of different approaches for assessing the impacts of agricultural practices on the environment have been proposed and discussed. All these methods can be viewed as attempts to answer the question "What are the environmental consequences of agricultural management decisions?" IPM investigators are currently being challenged to respond to this question as part of their research and as one means of assessing the success of IPM. Previously, IPM has been judged primarily in terms of the cost and efficacy of IPM practices. To the extent that environmental impact was considered, it was assessed primarily by reduction in pesticide use or by indicators important to implementing IPM (for example, the impacts on beneficial arthropods).

The objectives of this paper are twofold: first, to encourage IPM investigators to think more deeply about the potentials, limitations, and complexities of environmental-impact assessment and, second, to acquaint IPM investigators with the range of current approaches they might use to evaluate environmental impacts of their IPM programs. The paper is divided into four sections. The first section discusses the meaning of environmental impact. Our purpose is to inspire researchers to think broadly when considering environmental impacts, and to illustrate some of the consequences of a narrow view of the environment. The second section describes a number of challenges in conducting environmental-impact assessments. The point of this section is to encourage researchers to recognize problems with current environmental assessment methods and to use these as a motivation for improving assessment tools. The third section presents a typology of approaches to environmental assessment. We discuss the objectives, strengths, and limitations of various assessment methods but do not evaluate particular environmental assessment methods. This section is meant to encourage researchers to consider how different types of assessment methods may or may not be suitable for their project. The last section considers some practical issues that researchers face in deciding which assessment method to use. These issues include determining who the assessment is supposed to serve and trade-offs in ease-of-use versus complexity. The aim of this section is to encourage researchers to consider these issues explicitly before choosing an environmental assessment method.

Defining Environmental Impacts

When we refer to environmental impact, what comes to mind will differ depending on one's view of the environment and the components of the environment that one values. Environmental-impact assessments measure or estimate impacts on one or more environmental indicators. Many groups are concerned with assessing the degree to which various components of the environment are changing. However, different groups may have a particular interest in particular components of the environment and little interest in others. We have chosen to review several concepts that we hope will encourage researchers to think more broadly when considering what is meant by the environment and which environmental variables might be assessed for impact. These concepts include (1) how newer ideas differ from the classic ecotoxicological model, (2) how we focus on events that occur in various places in space and time, and (3) the physical resource base. Environmental impacts can be thought of as including all nontarget impacts; but for the purposes of this paper (and following the EPA Science Advisory Board, see Cooper 1993), we are not considering human-health effects as environmental impacts.

Chemical to Biocriteria

When considering if a pesticide application has had an environmental impact, we might first think in terms of how the application of pesticides on the farm affects the pesticide concentration in ground and surface waters, the atmosphere, and soils. Pesticide input on the farm can be related to pesticide concentration in the environment by applying a fate model that predicts how the pesticide will move from where it is applied to the environment of interest. The concentration of the pesticide in the environment is then related to potential impact on specific biota with toxicity ratings and some type of exposure factor. Traditionally, ecotoxicology has focused on single-species toxicity testing in the laboratory to develop repeatable thresholds of response to changes in toxin concentration and exposure (Cairns 1995). These tests have the advantage of linking a biological response to a specified level of toxin and, therefore, in theory, can maintain a link between a farm-management decision (e.g., pesticide application) and a biological response (e.g., death of fish). The impact on biota established through such tests (e.g., an LD_{50}) are referred to as test endpoints (Suter 1995). If chemical concentration exceeds a toxicity threshold for one or more species, then the environment is considered to be impacted. This approach to defining environmental impact is summarized in figure 1a.

One of the reasons that the classic ecotoxicological model has been widely used is that it is easier to set goals and write regulations related to chemical levels (e.g., in terms of the concentration of pesticide in groundwater) than in terms of impacts on ecosystems. Objections have been raised to the individual-species toxicity tests that are integral to this model. These objections include: the limited array of species used may not be most sensitive, the same species is not most sensitive to all chemicals, and species may respond differently when not isolated from other species (Cairns 1995). Micro- and mesoscale testing systems have been developed to overcome some of these objections. The results of these tests have been considered by some too inconsistent to be practicable, although Cairns (1995) believes this approach may have been too easily dismissed. More generally, the classic ecotoxicological model fails when the acceptable level of a chemical in the environment as established from test endpoints does not correlate with the environmental impacts of interest to the public. Another shortcoming of applying the classic ecotoxicology model to assessments of agricultural impact is that people are generally not directly concerned with the level of a chemical in the environment per se, even if this level is lethal to 50 percent of a specific organism in a test. What is of interest to them is the impact of management decisions on such components of the environment as populations of biota and the functioning of ecosystems (Karr 1995), which are sometimes referred to as assessment endpoints (Suter 1995). We will use the term decision endpoints in referring to these environmental components that are of actual interest to various decision-making groups.

In response to some of the limitations of the classic ecotoxicological model, with its focus on chemical criteria, some scientists suggest using field-measured biological criteria that can be more directly related to decision endpoints (Karr 1995) rather than single-species toxicity tests (Fig. 1b). The use of biological criteria as indicators of environmental impact has both a public and a scientific tradition. For centuries, people have been concerned about fish supplies and more recently have expressed concern for the preservation of other wildlife (Policansky 1993). There is increasing public and scientific interest in the more general notion of environmental integrity and a recognition by the scientific community that single-species toxicity is not necessarily indicative of system-level responses (Policansky 1993; Barbour et al. 1995; Cairns 1995). Characterizing environmental integrity generally requires measures of an array of biological attributes. These can include use of habitat indices, conditions of individual organisms (i.e., diseases, anomalies, or metabolic processes), community structure measures (i.e., taxa richness and trophic dynamics), and productivity measures. In environmental assessment, this approach has probably been taken furthest in evaluating the integrity of water resources (Barbour et al. 1995).

Although biocriteria are important indicators of environmental impact, their use raises several problems. There is not currently a widely accepted, multidimensional measure of biological integrity/ecosystem quality (Barbour et al. 1995). An index of biotic integrity (IBI) has been developed with biosurvey data to construct a multimetric index of heterogeneous variables (Karr 1981; Simon and Lyons 1995). Criticisms of this index approach include ambiguity, eclipsing of one metric by another, arbitrary variance, unreality involved in combining unlike metrics, post hoc justification, single linear scale of response, inability to use in diagnostics, and nonsense results. Simon and Lyons (1995) attempt to defend IBI in the face of these criticisms, but many of Suter's concerns are inherent to such indices and therefore should be taken seriously.

A second problem in the use of biocriteria is in defining appropriate reference conditions, particularly in terrestrial ecosystems (Policansky 1993; Hughes 1995). The problems encountered in defining reference conditions can be easily illustrated by issues in restoration ecology. To what condition should derelict or degraded land be restored? Both in restoration ecology and in defining an acceptable biological status of an ecosystem, it has been recognized that human values must be taken into consideration. Diamond (1987), in his studies of restoration ecology, points out that different segments of the population hold different values and therefore different views of appropriate restoration conditions. Hughes (1995) position is that "The [biological] reference condition must be politically palatable and reasonable. In other words, it must be acceptable and understandable by persons most concerned with nature for its own sake and those unconcerned with nature or only concerned with what it can provide humans. If the process for determining the reference condition is acceptable and understandable by only one of these groups, it will not be broadly implemented by the majority of persons who fall between these two extremes."

Another important concern with the use of biocriteria in environmental-impact assessment is that the cause of biological impairment is often difficult to infer from measures of biological integrity. Changes in biological integrity may be caused by one or more environmental stresses produced by any number of management decisions. Recently, multimetric approaches have been proposed to develop thresholds with biocriteria that may be useful in identifying different types of stresses (Barbour et al. 1995). However, it will likely prove difficult to develop fate or process models that can relate the impact of a particular farm-management decision to the biological integrity of nearby streams and lakes. So, while the environmental-impact-assessment model summarized in figure 1b has the advantage of using decision rather than test endpoints, a disadvantage lies in the difficulty of linking specific farm-management practices to perturbations in environmental integrity.

The EPA has been providing guidance to the states on the development and use of biological criteria (Southerland and Stibling 1995). Although at first glance biological criteria may appear complicated to implement in IPM assessment programs, IPM researchers and practitioners are already using biological indicators in their research on beneficial organisms and predator-prey relationships as indicators of community structure and trophic dependencies.

Spatial and Temporal Scales

In defining environmental impacts, it is important to consider a range of temporal and spatial scales, not just what happens on or near the farm in the current year. Usually, research focuses on localized small-scale, short-term impacts or on large-scale, long-term impacts, as illustrated by the diagonal line drawn in figure 2. However, off-diagonal processes are often important; for example, long-term effects of chemicals on the genetics of organisms or the rapid transfer of a chemical over relatively long distances through preferential flow.

Spatial and temporal scales are also important to consider when data are transferred between disciplines, when data are used to infer trends, and when data produced at one scale or in a narrowly defined system are used to interpret studies at a different scale or in a wider system, such as a landscape. Impacts of agriculture are generally experienced at spatial and temporal scales much larger than those at which environmental measurements are made. Processes in the landscape occur over a wide range of scales, but sampling is usually restricted to scales of time and space determined by sampling procedures and the time frame of a research or monitoring project. For example, soil scientists measure and monitor chemical concentrations at scales ranging from soil profile to field during experiments that rarely last more than a few years.

How should we approach measurement and monitoring at larger scales? Applying conventional measurement techniques to more sites for longer time periods can provide useful information, but it requires excessive effort and is costly. We need to rethink the way in which we approach such broad-scale projects, starting with an assessment of pathways and impacts and tailoring monitoring strategies to the whole system rather than to a few arbitrary points in it. Field monitoring and measurement strategies for broad-scale projects should be carefully planned and evaluated, taking into account both temporal and spatial variability. Techniques for parameter estimation, monitoring, and modeling should change as we move from point of application to catchment or to regional scales and should attempt to predict responses and impacts over decades rather than months.

Natural Resource Use and Sustainability

Another consideration in assessing the environmental impacts of agricultural production and distribution is in terms of resource use, both depletion of nonrenewable resources and consumption or transformation of renewable resources. Assessments of resource and energy use often are found under the rubric of energy or resource analysis, life-cycle assessment, systems analysis, or systems ecology (Cottrell 1955; Odum 1971; Cook 1976; Daly 1980; Pimentel 1980; Odum 1983; Helsel 1987; Hall, Cleveland, Kaufmann 1986; Fava et al. 1991, 1993; Guinee and Heijungs 1993, 1995; Daly and Cobb 1994; Schroll, H. 1994; Hall 1995). These assessments generally depend upon measures of the quantity and rate of consumption of resources and also upon abiotic indicators of physical changes in the environment.

Choices of agricultural pest-management practices may have long-term impacts on atmospheric and soil quality. For example, United Nations scientists estimate that methyl bromide, which is used primarily as a soil fumigant in agriculture, is responsible for 5 to 10 percent of the thinning of the stratospheric ozone layer. Thinning of the ozone shield is an indicator of physical change in the environment that has been related to human-health problems, to effects on nonhuman biota, and to marine and agricultural productivity (Allen et al. 1995; UNEP 1992, 1994, 1995).

On a global scale, fossil-energy resources are finite and nonrenewable, although their use has quite different economic and social ramifications as a cost of production in different political jurisdictions. Fossil energy is used in agriculture directly as a fuel and indirectly as embodied in farm machinery, transportation, pumped irrigation, synthetic pesticides, and chemical fertilizers. When quantities of fossil inputs are converted to energy units (such as calories, joules, and BTUs), it can be seen that the ratio of energy input to output in agriculture has changed significantly over time and with changing priorities and options in production and distribution. Fossil energy and electricity use on U.S. farms had increased more than sixfold between the turn of the century and the late 1970s when oil-price shocks spurred energy conservation throughout the economy. At peak usage in 1978, direct and indirect energy use on farms was equivalent to 5 percent of total U.S. energy consumption, while energy inputs to the entire food system (including distribution and processing) have been estimated at three to four times that amount. By 1990, however, energy productivity in agriculture had doubled from the minimum levels of the mid-1970s because of conservation, reduced acreage tilled, and greater use of diesel fuel, which delivers more mechanical energy per unit than gasoline (Cleveland 1995).

The significance of energy as an economic cost of production is, of course, recognized by growers, but we stress it here because energy analysis is a means of making a link between socioeconomic factors and environmental consequences. It is estimated that domestic sources of high-quality fossil energy will be depleted within the lifetimes of people who are now middle aged (Hall, Cleveland, and Kaufmann 1986). This will likely have serious, widespread ramifications on our environment and way of life, affecting the scale and location of agricultural production, the delineation of marketscapes and food systems, the demand for agricultural land and labor, the use of synthetic (fossil-based) pesticides and nutrients, and interest in promoting nonfossil-based alternatives in pest control and fertilization. Despite the relatively short time scale of these projected changes, we have seen stops and starts in developing policies and pricing systems that inspire more efficient use of these resources. Therefore, we suggest that evaluating the environmental consequences of the use of nonrenewable resources and slowing the use of renewable resources may provide additional insights and leverage in policy formation.

Summary: What is Environmental-Impact Assessment?

We consider the environmental impacts of agriculture to encompass all nontarget impacts, although in the context of the parameters mandated for this paper, we do not focus in great detail on direct impacts on human beings through occupational or other exposure. Nevertheless, it is important to realize that impacts on terrestrial, aquatic, and atmospheric systems clearly can have indirect impacts on human health; also that many of the nuanced, sublethal impacts that are being recognized on human health may have parallel impacts on nonhuman biota. We have attempted to show that many facets of the environment can be affected, directly or indirectly, by agricultural practices.

Environmental-impact assessments are measures or estimates of consequences of management decisions on one or more environmental indicators. They may be simply methods for identifying changes in the environment, or they may be tools for decision making that also assess the magnitude and significance of these changes.

Challenges in Assessing Environmental Impacts

In this section we shift from describing possible environmental impacts of agriculture to discussing some of the challenges and potential difficulties researchers face in developing systems to assess these impacts. These are conceptual challenges that are not, for the most part, likely to have quick technical solutions. The issues we discuss are organized into three sections: the identification and integration of environmental indicators; the bias against future impacts or, alternatively, our greater ease and ability in measuring and assessing current and tangible impacts; and the reality of data limitations that constrain the development of assessment models in covering the breadth of environmental parameters we mention in the first section.

Choosing Environmental Indicators and Deciding How to Integrate Them

As we have noted, many environmental indicators are needed to fully describe the environmental impacts of a pest-management product or method. To use the example of pesticide toxicity, there is no single species or group of biota that is most sensitive to all pesticides and thus useful as a surrogate for all others in toxicity testing. This truism applies to other environmental perturbations as well. We cannot rely on a single indicator species or abiotic effect to tell all we need to know about the impacts of any management decision. Scientists are therefore faced with the need to test and evaluate impacts on various groups of biota and then to integrate the results to create a composite assessment of environmental impacts of a pest-control method or other management strategy. One can grasp the conceptual challenge this poses by thinking about how one would go about weighting and summing an evaluation of impacts on human beings in relation to impacts on other biota, especially if the impacts were dissimilar in magnitude and type.

Another challenge to creating a composite assessment of environmental impacts of agricultural strategies is finding a meaningful common currency to describe different types of impacts. In answering many questions about environmental impacts, monetary values do not adequately describe non-market costs, such as the loss of an individual life, loss of biodiversity, impacts on nongame species, disruption of an ecosystem, future costs of current soil erosion, or loss of irreplaceable resources. Ongoing research in several disciplines is aimed at devising means of valuing environmental and other nonmarket goods; much of this work falls under the rubric of ecological economics (Daly 1991; Daly and Town-send 1993; Daly and Cobb 1994; Guinee and Hei-jungs 1995; Krishnan, Harris, and Goodwin 1995).

In some agricultural impact-assessment systems, both environmental parameters and on-farm economic costs are rated on a unitless scale; in others, on-farm costs are quantified in monetary terms, and environmental costs are indexed separately and 'flagged' to indicate a hazard or high risk. In a number of other systems, monetary values are imputed to a range of environmental impacts with one of several methods, such as replacement or remediation costs, lost productivity, or willingness to pay (contingent valuation) as the basis for assigning value to impacts. The drawback to remediation or replacement-cost accounting is that money is only a useful measure of impact if the environmental parameters or organisms in question are of intrinsic economic interest to people or if the costs of previous remediation efforts are known (see Pimentel et al. 1992). Contingent valuation is a useful measure only if the group surveyed for their willingness to pay are realistically able to assign monetary values to the nonmarket goods in question and are not swayed by thinking there will be possible economic or regulatory ramifications from answers that are biased high or low. Surveys to find out how much money individuals would be willing to pay for a nonmarket good are valid only when the sample represents the population that will bear most of the associated costs or reaps most of the associated benefits. To give an example illustrating this last point: a farmer's willingness to pay to avoid polluting water with a toxic pesticide or fertilizer runoff is not a reasonable or accurate way to value this environmental damage because all of society suffers from the results of such pollution and pays the costs of remediation. On the other hand, a survey assessing farmers' willingness to pay to avoid toxic risk to pesticide applicators may indeed be a reasonable method of valuation because this environmental cost affects farmers disproportion-ately. In designing assessment systems, it is important to remember that willingness to pay does not measure the existence or extent of an environmental problem; rather it measures attitude toward a problem and whether the problem bothers a particular stakeholder enough to pay for an alternative (Levitan et al. 1995).

Another challenge of creating composite assessments of environmental impacts is that no one set of social or environmental indicators is most appropriate to use in assessing impacts of agriculture. Different circumstances and objectives prioritize different indicators and interpretations. One may answer the question of how to integrate, weight, and value impacts in the context of one assessment scenario, but these issues will reemerge when the question of environmental impacts is asked on a different scale or with different objectives. For example, the types of data required to create a decision model for a farmer to use in the field in choosing a least-impact but efficacious pest-control method may not be the same as the data required for a national policy model assessing agricultural practices. To illustrate: while IPM farmers want to avoid using pesticides that harm parasites and predators specific to the crop pests in their fields, these producers might be misled by a decision model based on the more generic information about impacts of pesticides on beneficials that might be used in a national model of environmental impacts of IPM. Were the national model to consider impacts on beneficials at all, it would most likely rely on EPA data on acute toxic impacts of pesticides to honey bees, which are the only beneficials included in EPA's Ecological Effects data set (U.S. EPA 1996). Even if the toxic dose responses were comparable for honey bees and other beneficials, the significance of these effects might be quite different. When honey bees are repelled from a field by pyrethroid pesticides, for example, they survive and move on to another nectar source; however, if beneficial parasites and predators are repelled from a location, they are not then available to work as biological control agents. The design of an assessment system must, therefore, be appropriate to the objectives of the audience served.

Bias Against Future as Compared to Present Impacts

There are several ways in which we can be biased against considering future, as compared to present, impacts. Returning to our space-time diagram (fig.

2), the issues that tend to concern us most are those that occur in our immediate space and time frame. This implies that current activities that lead to environmental impacts at more distance places and times tend to receive less attention. For example, most ecotoxicity testing of pesticides emphasizes their short-term lethality rather than their chronic and cumulative impacts. Or we may be more interested in the short-term reduction in pesticide use that occurs when pest-resistant varieties are introduced than in the long-term impact on pest populations caused by the use of pest-resistant varieties. Long-term and cumulative impacts are more difficult to comprehend and quantify than short-term impacts, and less data are generally available. As a result, less weight tends to be given to these impacts in environmental assessments.

A second manner in which we can be biased against the future as compared to the present is by not considering impacts associated with future events (Garetz 1993), such as leaking of improperly stored pesticides in the future. Assessing future impacts of future events can be more uncertain than assessing impacts of current events, but this does not mean that such impacts are less important. For example, the Superfund Program and Hazardous Waste Program were established primarily on the basis of future rather than current risks.

Another problem for current assessments is that, as environmental systems change or become better understood in the future, the impact of IPM and other farm-management systems may be assessed differently. This assertion implies that assessors must be aware of new information and problems and be prepared to modify or change their assessment methods to account for changes in our knowledge base.

Data Limitations

Data are required at all stages of environmental assessment of agriculture. Data can be divided into different classes. Recognizing the variety of types of data enables us to place the availability of data into perspective. Data that describe intrinsic properties of a system are unlikely to change with time. Examples of these are soil data, rainfall, and climate records. Other data are valid for short time periods, such as farm-management information, and therefore have to be collected frequently. Yet other data may vary according to the type of assessment or as new knowledge becomes available. For these reasons, it is difficult to define a minimum data set for IPM planning and evaluation that will be widely applicable or remain constant for a long time. Because many environmental impacts are produced on different temporal and spatial scales than they are experienced, data for assessing these impacts cannot be collected on-farm, an important factor that differentiates environmental assessments from farm-scale economic assessments of IPM and other agricultural systems.

Toxicological- and ecological-effects data sets of pesticides are incomplete. In addition, some of the existing toxicity data are inappropriate to use as the basis for assessing relative impacts of different agricultural management strategies because they were not collected with standardized protocols and, therefore, are not comparable (Levitan et al. 1995). Moreover, there are very limited data and no standardized data sets on new biocides, such as microbial and fungal pesticides. The scientific community is only beginning to develop tools and to collect data for assessing positive and negative environmental impacts of biointensive IPM practices. The reasons for this are twofold. First, there are many interlinked physical, chemical, and biological processes that play a role in IPM, and it would be unusual for all of these processes to be fully understood and quantified for specific evaluations. Second, natural systems are inherently variable, both in space and time, and, to characterize both their average behavior as well as their variability, high-intensity sampling is required. Because it is often the occasional extreme occurrences that may lead to environmental damage, it is important to be able to predict the likelihood of these events (Wagenet and Hutson 1994; Jury and Gruber 1989).

As we note in an earlier section, most available data on pesticide environmental impacts originate from toxicity tests on single species of biota. In addition to limitations associated with testing single species of organisms, these data are also of limited value because the pesticides tested are generally applied in single doses of individual active ingredients.

Impacts to the environment, however, are from mixtures of active ingredients, whether tank mixes or mixes of residues in the environment, that can be greater or less than the sum of impacts from individual toxins. Cumulative impacts from repeated or extended exposures can also be different than impacts of single, larger exposures. Little is known about cumulative impacts and interactive effects, particularly in terrestrial systems, even though both human and nonhuman biota are virtually always exposed to chemical mixes and amounts that change spatially and over time (Yang 1994). Yang concludes that the toxicology of long-term, low-level exposures to chemical mixtures produces subtle effects, unlike acute toxic responses to higher doses; that such toxic interactions are possible at environmentally realistic levels; that the toxic responses may be from unconventional endpoints that are not usually tested; that there is a possibility that residual effects may become interactive with later exposures; and that these exposures may pose a safety risk to the public. While these comments are intended to apply to human subjects, we can extrapolate these principles and concerns to nonhuman biota, some populations of which may be more vulnerable to such risks because of limited mobility and physiological factors.

Summary: Challenges in Assessing Environmental Impacts

Although most of us support environmental-impact assessment in theory, many may express considerable skepticism about environmental-impact assessment in practice. There are numerous practical and theoretical problems in designing and conducting environmental-impact assessments. In this section, we have identified several challenges or concerns that can be raised in relation to most efforts at environmental assessment. We take the view that these are legitimate concerns that in many cases cannot currently be adequately addressed. However, we would argue that delaying environmental-impact assessment until these concerns can be dealt with effectively is not likely to be a productive strategy. Rather, environmental-impact methods are likely to be gradually improved as more researchers attempt to implement environmental assessments.

Methods for Impact Assessment

In this section, we review several categories of environmental-impact-assessment methods, including surveys and monitoring, fate models, and categorical indices of impacts. In each case, we discuss the objectives, strengths, and limitations of the methodology. All of these approaches have been used in environmental assessments of agriculture. The aim of this section of the paper is to encourage IPM researchers to actively consider the objectives and assumptions of the methods they are using and to refine methods, where feasible, rather than mechanically adopting methods without appropriate adaptations. In this way, researchers will not only increase the usefulness of their assessment, but may also contribute to the development of environmental-assessment methods.

Sampling and Monitoring

Of all the methodologies we will be discussing, sampling and monitoring are the most familiar to IPM researchers. Sample surveys are used in many fields to characterize populations (used broadly here to include biotic and abiotic phenomena) that are too large to census. Monitoring of various components of the environment usually involves repeating sample surveys over time. However, there are cases when monitoring involves measuring changes in the entire population of interest rather than in a sample of that population, for example when monitoring changes in a population of some endangered species. In any case, the major objective of monitoring is to address questions concerning the present status, changes, and future trends in the population that is being monitored (Larsen 1995).

On the national level, the U.S. Geological Survey, the USDA Soil Surveys, and the national network of weather stations have long been engaged in surveying the physical resource base of the nation and in providing this information to the public. More recently, there has been a growth in the use of surveys to characterize the natural and agricultural resource base. Examples include the National Agricultural Statistical Survey, the Forest Inventory Assessment, the National Wetlands Inventory, and the National Acidic Precipitation Program's survey of lakes and streams. Surveys conducted over time add a temporal dimension to survey data, thus moving beyond a snapshot approach to resource inventory and essentially becoming a monitoring exercise. The EPA's Environmental Monitoring and Assessment Program (EMAP) is an example of a program designed to track changes in important environmental indicators that have been selected to characterize the condition of the nation's ecosystems. Another example of an environmental monitoring program is the Swiss National Soil Monitoring Network (Desaules 1993).

IPM researchers are familiar with sampling and monitoring of the environment at the local level because these activities are a major part of IPM research and practice. The strengths and weaknesses of surveying and monitoring are similar at local and regional levels. Surveys based on population samples make it feasible to characterize environmental resources, such as soil, lakes, and streams, as well as biotic populations that are too large to census. Otherwise, the status of a population would have to be inferred from an indicator or other species or simulation modeling. Monitoring can also be used to provide data for evaluating whether a system is changing and to predict future trends.

Obvious problems with sampling and monitoring are those of cost, convenience, and extrapolation. Often, so many samples must be taken to validly describe a population that the cost of sampling may become prohibitive. At other times, it can be impractical to choose a valid sample population. For example, farmers who are interested in working with extension agents and researchers to implement new pest-management strategies are not necessarily representative of the entire population of farmers who are using more conventional techniques. Given the voluntary nature of such arrangements, it may not be practical to select an unbiased sample of farmers. Lastly, without using other tools, the results of the sampling and monitoring work cannot be used to draw inferences about other populations (i.e., other farms, other practices, other components of the environment).

There are several other problems associated with monitoring beyond those of cost, convenience, and inability to extrapolate to populations not represented by the sample. Much of the rationale for monitoring lies in trend detection. However, in some environments, trend detection has been likened to looking for a needle in a haystack, with the needle being very small changes representing a trend lost in the haystack of measurement error and natural random fluctuations in time and space (Oliver 1993). Clearly, knowledge of natural fluctuations in time (e.g., seasonal effects) and space (e.g., soil types or soil depth) need to be considered in designing a monitoring system (Oliver 1993).

Dynamic simulation models can be used to predict temporal and spatial fluctuations and potentially to improve the design of a monitoring system. When the trend is very small compared to natural fluctuations in time and space, then other approaches need to be considered. An interesting improvement over standard monitoring is the combination of regional mass balances with monitoring data by the soil monitoring network in Switzerland mentioned above (Bader and Baccini 1993; von Streiger and Obrist 1993). The approach used in the Swiss study is to identify various categories of farms and then apply a model that distributes system inputs and outputs by farm category with regional average data. This method was used to identify agricultural land at high risk for copper contamination (in this case it was 11.9 percent of the total cultivated land) and then to focus monitoring activity on this smaller area of cultivated land at high risk. Such an approach can guide those responsible for monitoring and can influence how often and where samples should be collected.

Fate Models

Integrating and extrapolating physical, chemical, and biological processes in the environment is an essential part of assessing impacts of agriculture. Natural systems are dynamic. Models identify the relative importance of various dissipation pathways, and allow estimation of flux densities, concentrations, residence times, and exposure. Because most data collection is performed at detailed scales, simulation models are an attractive option for extending these data to broader space and time scales. Models may be viewed as repositories for dynamic processes, analogous to databases, which are often repositories for static data only.

Dynamic simulation models vary in their scope and complexity (Addiscott and Wagenet 1985), falling into broad use categories of education, screening, regulation, and research. The simplest of these models require few data and sometimes contain overly simplistic assumptions, but are easy to run and are useful for demonstrating the principles of environmental interaction. Screening models are usually used to rank chemicals in terms of potential environmental impact, and generally compare the relative impact of different chemicals against a constant environmental background. Models currently used for pesticide registration include environmental dynamics (rainfall, temperature, etc.) but exclude processes that may be important but are currently difficult to quantify, such as sorption kinetics. In regulatory models, processes are often represented as simply as possible, consistent with current knowledge and available data. Regulatory models make extensive use of libraries of existing databases and are structured to perform multiple executions easily. Research models are the most detailed in terms of their representation of processes. Their data demands are usually high, and considerable knowledge and experience are required to use them effectively.

The complexity and dynamic nature of environmental processes make simulation particularly attractive. The use of computer simulation models is increasing despite controversy over their validity and applicability. The controversy arises from opposing views of how models should be used. At one extreme are those who feel that models should contain only processes that have been proved valid and that they should not be applied outside a range of situations for which they are applicable. At the other extreme are those who would apply models even though the processes or data are known to be inapplicable to the situation under study. Useful applications probably lie between these two extremes, especially when combined with a critical and insightful evaluation of the output. Hauhs (1990) suggests that models should be applied until they are shown to be invalid, because they represent the current level of knowledge. However, if evidence from measurement, monitoring, or experience suggests that the model is deficient or inappropriate, then the scientific foundation of the model should be reexamined and improved.

When a model is used outside the situation in which it has proven applicable, it is important to remember that the model is a hypothesis and that subsequent measurement may prove it invalid or incomplete. Other approaches and available data should be reviewed before embarking on a modeling exercise. Such a review will highlight areas where there are insufficient data, thus highlighting the role of model output as a possible substitute. During this evaluation process, major mass-balance components may be estimated and deemed sufficiently accurate to satisfy demands of other disciplines.

Environmental evaluation often consists of the application of established scientific principles or models from several disciplines to larger-scale systems. The models employed at this larger scale are based on processes determined at the research scale. Processes that control responses at the larger (e.g., catchment) scale should be included but are not necessarily present in smaller-scale models. At larger, more complex levels, direct cause-and-effect relationships are more difficult to establish, and existing process-based models may become inadequate. Long-term experience and monitoring may become the sole measures of behavior at larger scales. But if models are viewed as providing hypotheses about system response at the larger scale, then it may be possible to design experiments or measurement exercises that can help assess the models. In this way we may develop a science at the larger environmental scale that does not depend completely on scaling-up of local-scale research.

Index or Ranking of Impacts of Pest-Control Products and Methods

Whereas monitoring systems tell you what is found at a particular time and place and fate models estimate what is likely to be found at other times and places, indexing or ranking systems for environmental-impact assessment estimate relative impacts of agricultural practices, such as the use of different pesticides. To explain this method, we describe a generic indexing system in which biologically or ecologically significant threshold levels for an environmental variable are used to define categories of impact, hazard, or risk. For example, if a certain pesticide kills half of a sample of honey bees at an exposure level less than one microgram per bee, that pesticide is categorized as posing a high risk to honey bees.

Some indexing systems use categories, such as high, moderate, low or no risk; in others these categories are analogous to the colors at a stop light: red for high hazard, impact, or risk; yellow, where there are moderate impacts and the practice should be used with caution; and green to indicate there is little or no impact from the practice. In some systems, these categories are scored, and the scores serve as the common currency to be weighted and summed in creating a composite assessment of impact from the practice. In other systems, continuous numerical ratings are used rather than discrete categorical interpretations of the data about impact. These numbers may be derived directly from toxicity tests (such as an LD_{50} value), may be a numerical test result modified by an exposure factor or other situation-specific property, or may be a ratio of environmental concentration to an effective concentration that causes a measurable impact (such as an LD_{50} or EC_{50}). In other systems, such as the World Wildlife Fund's assessment of adoption of IPM practices described by Hoppin (this volume Part II), the categories are behavioral. They are expressed as types of IPM practices (low-level, medium, and biointensive IPM) rather than as categories of magnitude of impact. In such behavioral systems, a relationship is assumed between certain behaviors or practices and the impacts of the practices.

Indexing and ranking systems are well-suited for comparing relative impacts of similar pest-management options, such as comparing toxicity of different pesticides, each of which has been assessed for the same endpoints at similar levels of exposure. Because of the conceptual difficulties in integrating different measures and indicators of impact, there is a greater margin of creative interpretation when indexing is used to compare impacts of quite different options. Some examples are comparing impacts of herbicides to control weeds versus tillage or comparing regional food-production systems where pesticides may be used to the environmental impacts of transporting organically produced food from a different agricultural region. Such systems are well suited for evaluation with hybrid assessment tools that draw on the strengths of both indexing and simulation methods.

Indexing systems are useful for evaluating many types of environmental variables, not only those that can be sampled, monitored, or mathematically modeled. It enables the leap from assessments based on test endpoints to the development of systems for assessing decision endpoints. We return to the example of the impact of different pesticides on honey bees to illustrate the difference: The measurement of toxicity to an organism is a test endpoint that provides data on the rate of pesticide application lethal to bees or the rate at which certain behaviors (such as nectar-collecting activity) will change. However, what a beekeeper is more likely to want to know is the combination of factors affecting hive survival or crop pollination. Management decisions of farmers and beekeepers could be affected by knowing how the impact on honey bees might be reduced by using a different pesticide, a lower dosage, or a different time of application.

In this example, acute toxicity to adult honey bees may not be the crucial variable for the beekeeper's decision because the most toxic pesticides may rapidly kill worker bees in the field or repel them from the field (as pyrethroid insecticides do), whereas somewhat less-acutely toxic pesticides may mix with the nectar or pollen and be brought back to the hive and fed to the brood, which is the next generation of workers. Or the less acutely toxic pesticide may have a sublethal impact on the adults, reducing their activity level and decreasing long-term chances of hive survival. Indexing systems have the potential of integrating test endpoints and ranking decision endpoints. A decision-making aid for determining whether a situation is hazardous to hive survival or pollination success might require the integration of a number of tests. Decision models for efficient and safe management practices for farmers, growers, livestock managers, and beekeepers might differ from each other and also be different from assessment models intended to summarize long-term and off-farm impacts to the environment and society. Without modifications (such as those described in this example) to incorporate site- and situation-specific factors, ranking systems reflect a generalized condition. In pesticide-ranking systems, site- and situation-specific factors include dose, time of day and season of application, and qualities of the formulated product.

A challenge in developing indexing systems is that the integration of impacts on specific endpoints into a composite assessment of impacts on the environment involves value judgment. The challenge is in justifying these judgments and in creating assessment tools that are sufficiently transparent and flexible to enable situation-specific modifications in the integrating algorithm. As methods are developed to incorporate situation-specific sensitivity to impacts, the value of indexing systems will improve.

Directions and Trends in Impact-Assessment Systems

We identify three areas in which we expect to see important changes in the development of impact assessment systems for agriculture:

1. More data must be produced on environmental impacts, broadly understood to include a range of environmental indicators. Perhaps it is even more crucial to stress that improved datasets of high-quality, comparable data (i.e., collected under standardized and recommended protocols) must be organized and made accessible to the assessment research community.

2. With better data and with a broader conceptualization of environmental impacts (going beyond single-species toxicity testing and measures of pollutant concentration in water), assessment systems will evolve to consider additional environmental variables and endpoints.

3. Developers of assessment systems will collaborate to overcome limitations of each individual methodological approach and will synthesize and build on the advantages of monitoring, modeling, indexing, and other methodologies. Systems will be developed that are more transparent and flexible in setting impact criteria, in determining which variables to include in the model, and in weighting relative importance of these variables in the system. With improved input data, and these other modifications, assessment models will be able to portray a more holistic picture of environmental impacts.

Choosing an Assessment Method

In this section, we consider some practical issues that face many researchers and that can ultimately have an important, if not decisive, role in determining the outcome of an assessment method. These issues include identifying the decisions, societal values, and assessment endpoints involved in the environmental assessment and factors to consider when selecting an appropriate model. The aim of this section is to encourage researchers to consider these issues explicitly before choosing an environmental-assessment method.

Identifying Decisions, Values, and Assessment Endpoints

Throughout this paper, we have emphasized that environmental-impact assessment has no single, well-defined method. In the first section, we emphasized that there are numerous environmental assessment endpoints of interest to various groups. In the next section, we raised questions suggesting that it is still not possible to conduct a complete (i.e., holistic) environmental assessment. In the third section we discussed the objectives, strengths, and limitations of some existing methods for environmental assessment of agriculture, pointing out limitations to each of these methods. How, then, should IPM researchers determine an appropriate approach to use in assessing the environmental impact(s) of the management systems they are promoting? Suter (1995) states that the selection of an appropriate environmental-assessment method that will lead to an informed decision must involve not only the assessors but also must be guided by an understanding of the public values involved in the decision. He suggests that selecting the appropriate method requires addressing four questions: (1) What is the nature of the decision? (2) What societal values are involved in the hazard to be assessed? (3) How can those values be operationally defined as assessment endpoints? (4) What combination of models, test endpoints, and other data will most efficiently provide an assessment of the assessment endpoints in a form suitable for the decision? In the next few paragraphs, we discuss these and other questions related to choosing a particular environmental-assessment method.

Before selecting an environmental-assessment method, it is critical to determine who is expected to use the assessment method and the information it produces. Is the information to be used by government agencies to assess policy impacts, or by growers to inform them of the potential environmental consequences of management decisions? Because many pest-management systems involve multiple decisions, IPM assessments potentially involve contrasting the impact of a range of decisions (the impact of the application of different pesticides, at different rates, at different times, and at different places) rather than just contrasting the standard use of a pesticide with no use of a pesticide.

There can be multiple societal values involved in estimating hazards of pesticide use. Excluding human-health concerns, farmers are concerned about the impacts of pesticides on beneficials and the inducement of pesticide resistance in target populations. Regulatory agencies are concerned with how farm-management decisions may impact benchmark values for pesticide levels in water and air. Other government agencies may be interested in endpoints that are important on a global scale and thus subject to international negotiations (Cairns 1995). Many in the general public are concerned with the impacts of pesticides on nontarget organisms, while environmentalists are also concerned with long-term, ecosystem-level impacts that may not be safeguarded by current standards. Scientists are concerned with potentially significant, unstudied impacts. Depending on the environmental values of the assessment developers and target audience, assessments of environmental impact of alternative decisions could be primarily focused on the short-term versus the long-term consequences and on site-specific versus regional or national impacts. Some groups may be interested in potential negative environmental consequences of proposed practices and want these to be compared to the environmental impact of standard production practices. Thus, the assessment or decision endpoints of most interest are likely to differ among different groups (Suter 1995). A quotation earlier in the paper (Hughes 1995) suggests that an environmental assessment of IPM should include assessment endpoints of interest to a broad spectrum of interested parties. Cairns (1995), in an article dealing with future trends in ecotoxicology, argues that ecotoxicological information will need to be more site-specific and produced more rapidly.

The implications of Suter's questions referred to at the beginning of this section are that only once the nature of the decision(s), societal values involved, and assessment endpoints are identified can the models, test endpoints, and data necessary to assess the endpoint be determined. As Suter points out, despite this ideal, most assessments have to rely on standard test endpoints available from existing toxicity data. These values generally are not the assessment endpoints. In this case, the role of the assessor must include tailoring the assessment to the decision. When considering use of an existing environmental-assessment tool, it is important to determine whether the assumptions and data used in developing the tool are appropriate to conditions or systems under which it will now be applied. For example, a pesticide hazard rating developed for apple orchards may not be appropriate for vegetable- or grain-crop systems. There may be a need for further measurements, and it may also be necessary to refine or further develop the assessment tool.

Choice of a Model

Choice of a model will depend on the reason for modeling (i.e., the questions we expect to answer). For example, a screening model may provide all the information required if the objective is merely to rank chemicals in terms of their potential for reaching groundwater. However, if a site-specific assessment is required, then data pertaining to that site and its weather have to be included, which necessitates a more complex model. In a scientific study of isolated and controlled processes, a simple model is likely to be successful, whereas more complex models that include many processes are required for large-scale simulations. Regardless of the application, an intelligent selection of a model requires the user to have a clear understanding of how well the processes included in the candidate models describe the processes likely to be important in the field.

At the outset, we need to recognize that the processes included in models are usually elucidated under highly controlled conditions. Interactions between processes and their behavior under changing environmental conditions are rarely studied, except in field experiments limited both in space and time. Thus, models are constructed to predict behavior under field conditions and to extrapolate processes to other soils and over longer times. Because it is impossible to measure everything, it is inevitable that models will be used to provide an extension of empirical knowledge.

Toward a Holistic Approach to Environmental-Impact Assessment of Agriculture

We will close by referring to the objectives reflected in the title of this paper: "Environmental-Impact Assessment: The Quest for a Holistic Picture," but with this quest modified somewhat by the conceptual challenges and technical limitations we have described. We have stressed the point that no single assessment system could include all of the environmental parameters we have mentioned and do so accurately at all scales of operation (from decisions made on a farmer's fields, to evaluating regional or watershed impacts, to national policy models, to planetary assessments). Nevertheless, in designing and implementing assessment systems, we believe it is preferable to *think about* the implications and ramifications of an agricultural practice on all of a system rather than to think only about a limited portion of the system while believing or implying that it is an assessment of impact on the entire system. We need to remember that environmental processes continue to occur even if they are not being monitored, sampled, or included in the assessment model.

In creating decision tools from assessment systems, we must think broadly about environmental impacts and develop methods for integrating environmental costs, public-health costs, social costs, and on-farm costs without losing valuable information about each set of issues. What this suggests is that both environmental impacts (nontarget costs) and farm-cost data (target impacts) need to be collected but analyzed independently. Conclusions from an analysis of the monetary costs of pest control should not influence or mitigate assessments of nontarget (environmental or social) costs. After all, environmental degradation and resource depletion resulting from a given practice do not decline because the economic costs of doing without a pesticide are high. Environmental impacts do not go away just because there are few alternative practices or products available. However, while the environmental assessment should not be mitigated by production-cost data, the *decision* about which production strategy to follow must, of course, weigh the information gleaned about on-farm costs as well as environmental impacts. These decisions should not be made in a black box. When the economic costs of environmental protection are high, society perhaps needs to consider whether and how to shift that economic burden from the farmer or the consumer to a larger group. In order to have this discussion, the methods and results of impact-assessment systems must remain visible (fig. 3).

So what can be expected from environmental-impact assessment systems? As we have implied, there are many ways to evaluate the environment and many ways to integrate a summary of impacts from specific agricultural strategies. We suggest that one of the greatest values of developing environmental-impact assessment systems is that they will facilitate rational social discourse about the effects, implications, and sustainability of agricultural production and marketing systems. It is our hope and prediction that good assessment systems will draw a broader group of better-informed parties into that discussion.

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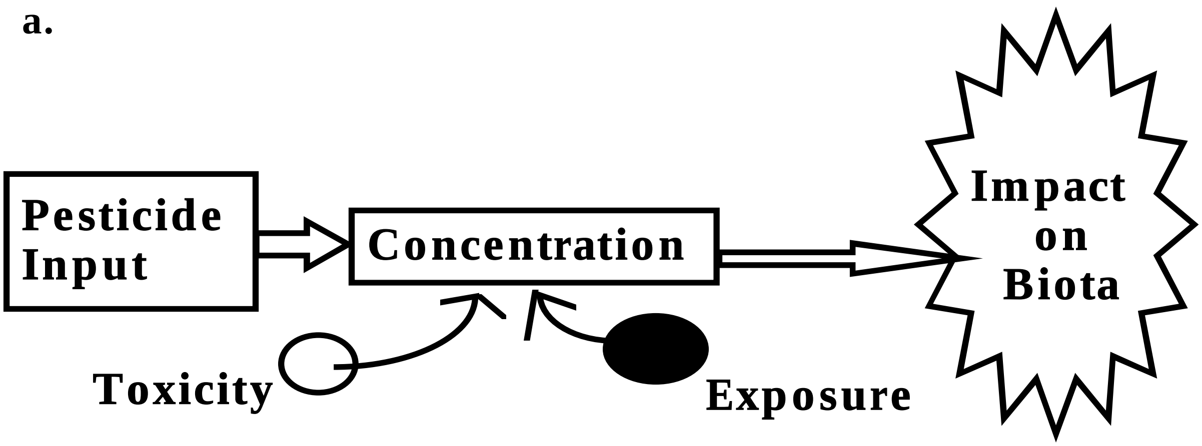
Figure 1a and 1b. Space and time scales of environmental studies.



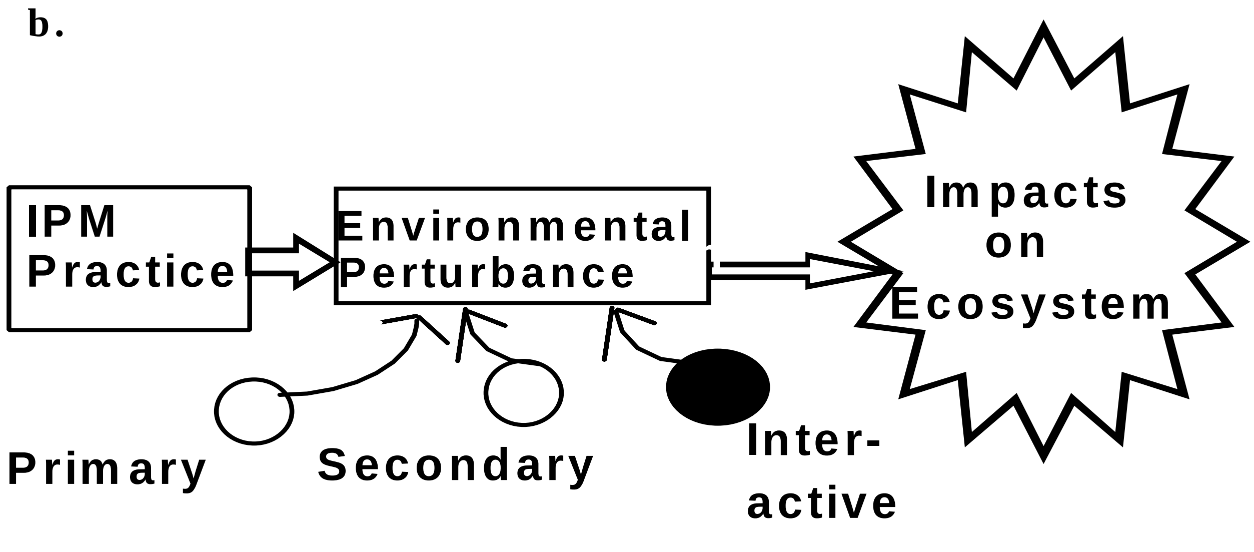


Figure 2. **Environmental impact models**.

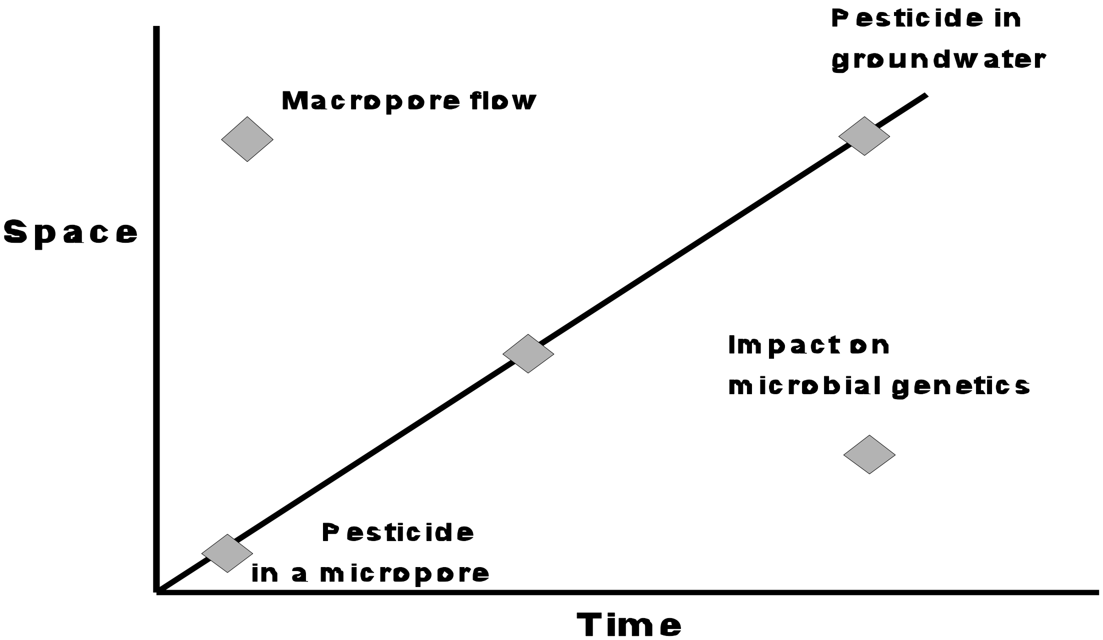
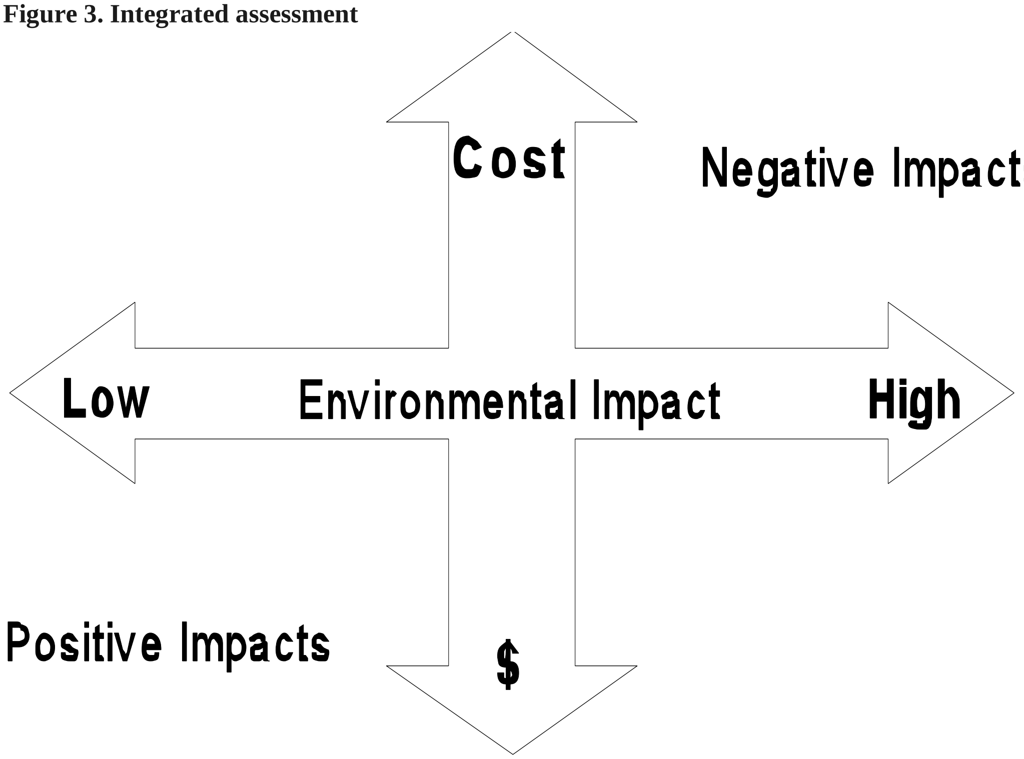


Figure 3. Integrated assessment



Occupational Exposures to Pesticides and Their Effects on Human Health

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Since the 1940s, use of synthetic pesticides has assumed an increasingly important role in control of pests in both agricultural and nonagricultural settings. Total use of pesticides in the United States has risen from an estimated 540 million pounds of active ingredient in the mid-1960s to 1,081 million pounds in 1993. Roughly three-fourths of this quantity is used in the agricultural sector, with the remainder divided somewhat evenly between home and garden and commercial and government use (USEPA 1994). The benefits of pesticides are many (Wilkinson 1990). On the agricultural side, they increase yields and diminish storage losses, thereby contributing to an abundant and inexpensive food supply. They have a direct role in public health through control of insects and other disease vectors.

While the benefits are substantial, there are costs associated with using pesticides. In fact, concern about potential human-health effects from these chemicals has paralleled their use and is usually credited with providing the stimulus for the environmental movement (Carson 1962). Modern industrial societies use many chemicals, but pesticides are unique in that they are designed to have adverse biologic effects. This property has accentuated the scrutiny they receive.

The adverse effects associated with pesticide use include impacts directly borne by the user, as well as those borne by society as a whole. Examples of the former include the development of pest resistance, secondary pest outbreaks, and damage to agricultural ecosystems. Examples of the latter include adverse impacts on worker safety, surface- and groundwater quality, biodiversity, ecosystem health, and consumer safety. These adverse effects can occur from direct contact with pesticides during mixing and application, from contact with contaminated equipment, from working the fields where pesticide residues occur, or from contamination of food or water. This paper will focus on the public-health impacts resulting from occupational exposures, but the other routes of exposure mentioned are also important, and discussions of these can be found in Nigg et al. (1990), NAS (1993), and Pease et al. (1995).

The challenge, then, is to strike a balance between the benefits and costs of pesticide use in agriculture. This is a difficult task given the complexities involved in detecting and monetizing many of the adverse impacts. But, as evidenced by the presentations at this workshop, there are emerging methods and approaches that can be used.

Integrated pest management (IPM) methods and techniques that diminish the frequency and amount of chemicals used, identify lower risk alternatives, and/or promote safe use and disposal of pesticides potentially could have measurable beneficial effects on human health. Identifying and measuring these impacts will require an understanding of the approaches and methods that public-health experts use to detect and measure the effects of pesticides on human health.

In this paper, previous research on pesticides and human health is summarized to highlight areas of concern about potential pesticide exposure and disease outcomes and to provide guidance for future research directions on pesticides. Results from epidemiologic studies are reviewed with a focus on chronic disease, particularly cancer. Possible mechanisms of action are discussed to provide a framework for research and evaluation of results. Techniques for monitoring pesticide exposure are reviewed to outline possible approaches for assessing changes in exposure associated with IPM techniques. Finally, approaches used in assessing public-health impacts are briefly described.

Assessing Human-Health Hazards

Three research approaches are currently used to obtain information on human-health hazards associated with pesticide exposure: (1) assessing links between exposure and disease, (2) relating exposure to biologic effects other than disease, and (3) evaluating exposure alone. These three approaches provide a hierarchical approach to research that focuses on different aspects of the exposure-disease process and that offers special opportunities in different situations.

The first category evaluates the relationship between pesticide exposure and disease. Pesticide exposure may cause acute and chronic effects. Chronic effects are much more difficult to evaluate than acute effects because years may pass between the initiating exposure and the development of disease symptoms. For cancer, the time period may be twenty or more years. This lengthy lag period creates many practical research problems, particularly the difficulty in assessing exposures that occurred many years in the past. Despite the practical difficulties, the approach focusing on the exposure-disease linkage is critical because it is essential to establishing a causal link and dose-response relationship.

The significant time lag between exposure and full-blown disease has been one motivation for the incorporation of laboratory techniques into human epidemiologic studies, particularly in cancer research. These new procedures are designed to evaluate the relationship between exposure to potentially hazardous chemicals and biologic effects that occur prior to full development of cancer or other diseases. Such a technique offers several advantages in our effort to understand environmentally caused disease. It greatly shortens the time between exposure and outcome because the period between exposure and many types of biologic damage is usually days or weeks instead of years, as with disease. This shortened response time occurs because the outcome of interest is not full-blown disease, but biologic damage or conditions that may eventually lead to disease. Examples of such biologic outcomes include chromosome aberrations, gene mutations, immune-system abnormalities, and hormone disruptions. Epidemiologic studies with laboratory components can also be very instrumental in expanding our general understanding of how diseases are caused. Such information can be helpful in developing new therapeutic procedures and interventions.

Direct monitoring of exposures is the third approach for assessing potential hazards posed by pesticides. It is the method of choice if there is already clear evidence that the chemical poses a hazard. In such situations, eliminating or minimizing the exposure is crucial. Exposure studies serve a range-finding function. If no exposure occurs, then obviously no hazard exists. Exposure studies also provide an indication of the appropriate level of concern because the toxicologic effect is usually proportional to the dose. Exposure studies also have a practical advantage over study of disease or biologic damage. For disease and biologic damage, some time must pass before assessment of hazardous effects is possible. With exposure monitoring, assessment is all that is required. This quick feedback has important preventive implications because corrective actions can be put into place promptly.

Human-Health Effects from Pesticide Exposure

Research on human-health effects serves as the basis for determining the need for preventive actions. Early research focused primarily on acute effects, such as poisoning; but more recently, interest in chronic diseases has increased.

Acute Effects

Although poisonings and death from acute pesticide exposures are well documented (Hayes 1975), statistics for most countries (including the United States) are incomplete. Given this caveat, there is some evidence that fatalities from pesticide exposure in the United States fell between the 1950s and 1970s (Hayes and Vaughan 1977). Information on pesticide-poisoning symptoms is even more limited than that for fatalities, and many symptoms undoubtedly go unreported or misdiagnosed. In California, where physicians are required by law to report pesticide poisonings, approximately 2,000 pesticide-related illnesses occur annually (Edmiston and Maddy 1987). A survey in Iowa in the 1990s found that approximately one-third of the farmers reported they had experienced some symptoms associated with pesticide use, such as headaches and vision difficulties (Blair et al. 1995).

Chronic Diseases

Chronic diseases are more difficult to evaluate than acute effects because they do not occur immediately after exposure. Some of the chronic diseases of concern include cancer (Blair et al. 1990) and diseases of the nervous system (Ecobichon et al. 1990), immune system (Thomas et al. 1990), and reproductive system (Mattison et al. 1990). The quantity and quality of the data available on these different diseases vary considerably. Cancer has received more attention than the others, and efforts are needed to correct this imbalance.

Neurologic Diseases. Diseases of the nervous system resulting from pesticide exposure are of special concern. Many insecticides target the nervous system of insects, thus it is not surprising that human exposures cause tremors, anorexia, muscular weakness, insomnia, convulsions, and depression (Echobichon et al. 1990). These symptoms have occurred with pesticides from a number of different chemical classes, including organochlorines, organophosphates, and carbamates. In a now classic study, many of the symptoms listed above occurred among workers with prolonged exposure to Kepone (chlordecone) in the Hopwell incident (Taylor 1985). In this incident, symptoms for many workers gradually disappeared after exposure ceased, but they persisted for several years in some of the most heavily exposed workers. Similarly, a study of individuals seeking health care for pesticide poisoning in California found they experienced neurobehavioral deficits (sustained visual attention and mood scales) and slower finger-tapping responses than individuals never experiencing a poisoning episode (Steenland et al. 1994). Recent studies of Parkinson's disease have suggested that pesticides may increase the risk of this chronic, debilitating, neurologic condition (Semchuk and Love 1995).

Cancer. The need to study human cancer and pesticide exposures is driven by several observations. First, pesticides were among the earliest chemicals evaluated for carcinogenicity in animal bioassays. To date, the National Toxicology Program has evaluated about 50 pesticides, and for about one-half of those tested there was some evidence of carcinogenicity (Huff et al. 1991). Carcinogenic activity occurred among pesticides in several chemical classes, including organochlorine, organophosphates, carbamates, herbicides, and fungicides. Although evidence of carcinogenicity in animals is not proof that the pesticide causes cancer in humans, positive bioassays do identify chemicals that need more intensive evaluation.

Epidemiologic studies of agricultural populations also indicate possible cancer hazards from pesticide exposure. In the 1970s the National Cancer Institute mapped cancer mortality rates at the county level (Mason et al. 1975). These maps provided clues for causes of cancer. The maps showed that many cancers clustered strongly in urban areas. For example, high lung-cancer rates were primarily located in the major metropolitan areas. On the other hand, for some of the lymphatic and hematopoietic cancers, high-rate areas were in nonurban, agricultural areas. Leukemia, for example, had a band of high-rate counties occurring in the central United States running from the Dakotas to Texas (Blair et al. 1980; Mason et al. 1975). These high-rate areas did not generally include cities and suggested that factors associated with the rural lifestyle may be involved.

Broad occupational surveys conducted in a number of developed countries provide information that can be used to evaluate mortality patterns among farmers. Overall, farmers are a very healthy group (table 1). Compared to the general population, they have a low overall mortality. Some of the diseases with strikingly low mortality rates among farmers include cardiovascular disease and cancers of the lung, esophagus, bladder, colon, and liver (Blair et al. 1992). In nearly every study, rates for total mortality; all cancer; and cancers of the lung, bladder, and colon were lower among farmers than among the general population. In terms of a healthy lifestyle, farmers are doing a lot of things right. Mortality rates for several of the cancers are low because farmers have a lower prevalence of smoking than the general population. Other factors that may contribute to lower risks include farmers' high level of physical activity and residence in areas with little air pollution.

In contrast to the generally lower mortality rates discussed above, farmers from many countries tend to experience elevated mortality from leukemia; non-Hodgkin's lymphoma; multiple myeloma (these are cancers of the blood and lymph system); skin cancer; and cancers of the lip, prostate, stomach, and brain (Blair et al. 1992) (table 1). Special death-certificate studies also found farmers experience excesses for these tumors (Blair et al. 1993). The tumors excessive among farmers do not fall into any obvious grouping other than they are not strongly associated with smoking. They vary in frequency, histology, and prognosis. The excesses for these cancers, against a background of low mortality from all causes, suggest a role for work-related exposures, and farmers have many potentially hazardous exposures, including pesticides. Several high-rate tumors among farmers are increasing in the general population, including multiple myeloma, non-Hodgkin's lymphoma, melanoma, and cancers of the brain and prostate (Devesa et al. 1987). Thus, understanding the factors contributing to these cancers in farmers may have broad public-health implications.

Mapping projects and mortality surveys suggest that farmers experience high rates for a few cancers. More sophisticated, analytic investigations are necessary to identify which, if any, factors in the agricultural environment contribute to these cancer excesses. Analytic studies at the National Cancer Institute have focused on lymphatic and hematopoietic cancers [i.e., multiple myeloma, non-Hodgkin's lymphoma, and leukemia (Blair and Zahm 1995)]. The strongest association identified to date has been between the herbicide 2,4-D and non-Hodgkin's lymphoma.

The studies mentioned above will be used to illustrate one investigatory method used to evaluate chronic disease risks from pesticide exposure. Investigations on non-Hodgkin's lymphoma in Kansas (Hoar et al. 1986) and Nebraska (Zahm et al. 1990) obtained information on the use of specific pesticides from interviews with farmers. Non-Hodgkin's lymphoma was associated with 2,4-D in both states, and relative risks (RR) rose with reported frequency of use. Farmers reporting use of 2,4-D 21 or more days per year had a relative risk of 7.6 in Kansas (table 2). Farmers who rarely used protective equipment, such as rubber gloves or masks, were at higher risk (RR 2.1) than those who used protective equipment (RR 1.6). Risk of non-Hodgkin's lymphoma also rose with frequency of reported use of 2,4-D in Nebraska to more than threefold among those reporting more than 20 days of use (Zahm et al. 1990) (table 3). In Nebraska, delay in changing clothing after applying 2,4-D increased risk of non-Hodgkin's lymphoma. Those who changed clothing right away had a relative risk of 1.1, those who waited until the end of the day had 1.5, and those who wore the same clothing the next day had 4.7. These findings indicate that simple protective practices, such as wearing rubber gloves and prompt changes of clothing, may be quite efficient in minimizing occupational exposure to pesticides during mixing and application. The associations between non-Hodgkin's lymphoma and reported use of the herbicide 2,4-D among farmers in Kansas and Nebraska could not be explained by established risk factors for this tumor or from use of other pesticides.

Not all studies evaluating non-Hodgkin's lymphoma and 2,4-D found an association. A study in Iowa and Minnesota found only a very small and statistically nonsignificant relative risk of 1.2 (Cantor et al. 1992). In this study, as in the investigations in Kansas and Nebraska, however, failure to use protective equipment tended to yield larger relative risks of non-Hodgkin's lymphoma from exposure to a number of pesticides, providing a further indication of the benefit of the safe handling of these chemicals.

Farmers appear to be taking more care while using pesticides. Preliminary results from the ongoing Agricultural Health Study of farm families being conducted by the National Cancer Institute, the National Institute of Environmental Health Sciences, and the Environmental Protection Agency show that, compared with 10 years ago, more farmers are taking protective actions during pesticide use (table 4). There is still room for improvement, but the trends are clearly in a desirable direction.

Immune System. The immune system acts to protect the body against foreign invaders. It is composed of a number of cellular and chemical components. Factors that affect the proper functioning of the immune system can have far-reaching effects and impact many diseases. Immunologic testing is relatively rare in humans, but a tiered scheme has been proposed for experiments in rodents (Luster et al. 1988). Few immunotoxicologic studies in humans have been conducted, but investigations in laboratory animals have noted decreased resistance to bacterial infection from methylparathion and carbofuran, decreased cytotoxic lymphocyte response from malathion, thymus atrophy from DDT, increased susceptibility to viral infection from dieldrin, suppression of T-cell activity from chlordane, and enhanced T- and B-cell immune response from 2,4-D (Thomas et al. 1990).

Reproductive System. Testing of pesticides for reproductive effects is far from complete. Chemicals appear to affect reproduction by direct germ-cell destruction or hormonal actions (Mattison et al. 1990). Some effects are known in humans. In men, the pesticide dibromochloropropane (DBCP) causes a decrease in sperm production and/or production of abnormal sperm (Milby and Whorton 1980; Lipschultz et al. 1980), while chlordecone reduced sperm motility (Taylor et al. 1978). DDT, methoxychlor, chlordecone, and Lindane have reproductive effects in animals, but effects in humans have not been carefully evaluated (Mattison et al. 1990). There is a need to develop and apply standardized techniques to evaluate potential reproductive effects of pesticides in humans.

Current Research

Several large-scale research efforts are under way to evaluate risk of cancer and other diseases among farmers and farm families from various agricultural exposures, including pesticides. In the United States, the Agricultural Health Study, a collaborative effort involving the National Cancer Institute, the National Institute of Environmental Health Sciences, and the Environmental Protection Agency, is designed to evaluate cancer, neurologic disease, and reproductive outcomes among 75,000 farmers, farmers' spouses, and children in Iowa and North Carolina (Alavanja et al. 1995). In this prospective investigation, information on pesticides obtained includes specific chemicals used, timing and frequency of use, and protective practices employed. The cohort will be followed for 10 or more years to identify diseases that occur. Participants will be recontacted periodically to obtain information on any changes in pesticide practices, including use of IPM practices.

In Canada, persons identified as engaged in farming from the 1970 Census were identified and linked to the Agricultural Census to obtain more information on their agricultural practices. This large cohort, which includes essentially all the farmers in Canada, will be followed to determine cancer incidence and mortality (Wigle et al. 1990). Analyses to date have observed associations between the use of herbicides and development of non-Hodgkin's lymphoma (Wigle et al. 1990) and prostate cancer (Morrison et al. 1992). Continued followup of the cohort for mortality and cancer incidence will allow the evaluation of risks of many diseases in relation to pesticide use and the production of various agricultural commodities.

In 1990, Congress provided the National Institute for Occupational Safety and Health (NIOSH) with special funding to initiate a program in agricultural safety and health. The program consisted of several components, including: (1) a survey of farm-family health and hazards to develop more complete information on disease and injuries among farmers, (2) research into etiology of diseases and injuries, (3) efforts to develop and improve intervention strategies, (4) surveillance to monitor results, and (5) cancer control demonstration projects (CDC/NIOSH 1992).

The National Cancer Institute is conducting a series of methodologic projects to obtain information necessary to plan epidemiologic studies of migrant and seasonal farm workers (Zahm and Blair 1993). This population of agricultural workers, despite opportunities for considerable exposure to pesticides, has rarely been included in epidemiologic investigations. Pesticide exposure at an early age and lack of facilities for cleanup may put migrant and seasonal workers at high risk of disease.

Biologic Effects of Pesticide Exposure

Incorporation of laboratory (i.e., biochemical) techniques into epidemiologic studies offers opportunities not available with more traditional methods. These new techniques can be instrumental in the investigation of many acute and chronic diseases (Schulte and Perera 1993), but they have been especially beneficial for cancer (Perera and Santella 1993). These biochemical measures can sometimes, but not always, be used to evaluate exposure from pesticides, mechanisms of cancer causation, and the relationship between exposure and biologic damage. Evaluations can be made more quickly than with the more traditional disease-related epidemiology and with small numbers of subjects. Disadvantages include a lack of a reliable and accurate laboratory procedure to measure dose or outcome and cost. Each test can be quite expensive.

It is possible to measure levels of a number of pesticides, or their metabolites, in blood or urine (Saleh et al. 1994). Biologic measures of exposure will be discussed in greater detail in the section on exposure assessment.

Research on cancer can be used to illustrate the benefit of biologic markers in the investigation of pesticide exposure and mechanisms of carcinogenicity. Pesticides may cause cancer or other diseases through several mechanisms, including direct damage to genetic material (e.g., gene mutations), damage to other important biologic molecules, or hormonal effects.

A number of pesticides are genotoxic (i.e., they cause genetic damage). In one study, genetic damage from 65 pesticides was evaluated through 14 different tests. About 50 percent of the pesticides showed some genetic activity. Nine pesticides were active in most tests, 26 were active in several tests, and 30 were inactive in all tests (Garrett et al. 1986). Chromosome damage (Garry et al. 1989) and genomic instability (Kirsch and Lipkowitz 1992) have been noted among insecticide and fungicide applicators in the grain industry. These findings indicate that pesticides may cause disease by directly damaging the genetic material, and this offers an opportunity for short-term evaluation of persons exposed to pesticides.

As we have noted earlier, pesticides may affect the proper functioning of the immune system, and this may have repercussions on a number of diseases. Pesticidal action through this mechanism also offers an opportunity to evaluate short-term effects of exposure. Newcombe et al. (1992) have proposed that organophosphate pesticides may play a role in carcinogenesis through their inhibition of certain enzymes (i.e., serine esterases). These enzymes perform a critical role in the proper functioning of T lymphocytes and natural killer cells in the blood. These cells, if functioning properly, destroy virus-infected and transformed cells that may be precursors for malignant lymphomas. Anything that affects serine esterases could, therefore, increase the risk of lymphoma, and some organophosphate insecticides appear to have this capability (Newcombe et al. 1994). A possible effect of organophosphate insecticides on lymphomas is especially interesting given the excess of this cancer often observed among farmers (Blair et al. 1992).

Recently concern has arisen that some pesticides and other chemicals may cause disease because they mimic important hormones (McLachlan 1993). Chemicals that have been shown to exhibit weak estrogenic properties include polychlorinated biphenyls, DDT, and Kepone. The theoretical basis for the action of such chemicals is that they mimic a hormone by binding to the hormone receptor molecule. Through this binding, they can elicit normal hormone actions, including reproductive, developmental, and carcinogenic effects.

The concern over chemicals with potential hormonal effects has been reinforced by recent studies of breast cancer. Several investigations have found higher levels of DDT, or its major metabolite DDE, among women with breast cancer than among women without cancer (Falck et al. 1992; Wolff et al. 1993). DDT is fat soluble and persists for years, even decades, in body tissues. Because of this persistence, measurements of DDT/DDE in blood provide an excellent indication of dose. This methodological approach of comparing levels in persons with and without a disease can be used for other chemicals that have long biologic half lives, such as other organochlorine pesticides.

Human-Exposure Assessment

One of the goals of IPM is to reduce the use of chemicals that are toxic to humans and the environment. It may be necessary to balance the use of greater quantities of less toxic products with smaller quantities of more toxic chemicals and to strike a balance between potential human-health risks and risks to the environment.

Human exposures to agricultural chemicals may occur through several routes. Pesticides may be inhaled during mixing, loading, and application or through volatilization or spray drift. Dermal exposures occur from direct contact with pesticides (concentrated or dilute) or with surfaces (e.g., equipment, leaves, and soil) that have been treated. Pesticide-contaminated soil or plant material may be blown through the air or tracked into the house. General environmental exposures may occur from consumption of pesticide-treated foods and drinking water that contains agricultural chemicals.

With varied routes of exposure, there are also many potentially exposed populations. One obvious group is agricultural workers who mix, load, and apply pesticides or who enter pesticide-treated fields. The families of agricultural workers may incur exposures from activities in treated fields, drift from application, pesticides tracked into the home, or by contact with contaminated trucks or other equipment (Simcox et al. 1995).

Exposures to the general public may occur from home pesticide use, whether it is applied by the homeowner or by a professional applicator, or from treated public areas, such as roadways and recreational areas. The EPA has sponsored a large nonoccupational pesticide exposure study (USEPA 1990; R.W. Whitmore et al. 1994). In addition, the general public may be exposed to pesticides from consumption of food containing pesticide residues or from contaminated drinking water. Of particular concern, following the National Academy of Sciences report *Pesticides in the Diets of Infants and Children* (NAS 1993), are exposures to sensitive populations, including the young, elderly, and immunocompromised.

To assess exposures in any of the above populations, accurate and reliable monitoring procedures are essential. There are many methods for measuring or estimating exposure to pesticides and agricultural chemicals. The types of exposure-assessment methods chosen depend upon the time and resources available.

Quantitative Exposure-Assessment Methods

Quantitative exposure-assessment methods have been used for decades for estimating both dermal and inhalation exposures to various occupational groups and are now being applied to other potentially exposed groups (residents, children, etc.). Measurement of exposures that occur via the dermal and inhalation routes will be the primary focus of this discussion. The EPA provides exposure-assessment guidelines for measurement of applicator and reentry exposures and for exposure assessment in general (USEPA 1987; USEPA 1984). These documents and the new Occupational and Residential Postapplication Exposure Monitoring Test Guidelines (USEPA 1996) provide a good background on various quantitative exposure-assessment techniques.

The measurement of pesticide residues in food, combined with a knowledge of the type and amount of foods we consume, is the most common method for estimating dietary exposure and will not be discussed here. There is software available for the calculation of dietary exposure (for example, TAS EXPOSURE I® and IV®). A more detailed discussion of the assessment of risk from food or water consumption is beyond the scope of this paper. The interested reader may find the following publications helpful, Chaisson et al. (1991), USEPA (1992), and NAS (1993).

Dermal Exposure. Dermal-exposure-assessment techniques estimate the amount of product that ends up on the skin during and following various tasks and activities. Generally, these methods require the collection of a sample that then undergoes laboratory analysis. Sample collection requires the availability of accurate and precise analytical methods for the chemicals of interest.

One of the simplest methods for determining dermal exposure uses patches on various body parts. A patch is generally a 2.5- to 4-in. square of cellulose, gauze, or some chromatographic material that is secured to the outside of clothing or hats. After exposure, these patches are carefully removed, packaged, and sent to a laboratory for analysis. Patches are generally placed on the head, tops of the shoulders, on the back of the neck, on the upper chest, in the back of the forearms, and in front of the thighs and lower legs. It may be necessary to place additional pads depending upon the work task and the clothing worn. Patches may also be placed under the work clothing to estimate the amount of product that penetrates through the material.

A more accurate estimate of total-body exposure can be made if entire garments worn during the task are removed and analyzed for the chemical of interest. These commercially available garments must be removed carefully to prevent cross-contamination. It is possible to extract chemicals from the entire garment; however, generally, the garment is cut up, and individual segments are analyzed. This allows the estimates of exposure to arms, trunk, and legs to determine which body parts receive the highest exposures.

Unprotected hands have the greatest potential for dermal exposure. Even when protective gloves are worn, products may penetrate the gloves, or pesticides may be transferred to the hands when the gloves are adjusted or removed. Historically, the method for measuring hand exposure is the hand rinse. After exposure, hands are rinsed in a solvent to remove the pesticide. Isopropanol is commonly used; however, other solvents, including water with a surfactant, may be more appropriate, depending on the chemical of interest. The person exposed may wash his hands in a measured quantity of solvent in a basin, and the washing solution is collected and analyzed. Alternatively, a person places his hands in a plastic bag containing a measured amount of solvent and shakes his hands for at least 2 minutes. The bag is then closed and sent for analysis. This method is simple but highly variable (Fenske et al. 1994) because it is difficult to remove all pesticide from the hands, particularly around the fingernails and cuticles.

Sampling gloves may be used for estimating the total hand exposure. These gloves may be worn alone or inside of work gloves. Generally, these gloves are made of cotton (pall bearers' gloves) or of nylon knit (pickers' gloves). The nylon knit is stronger and less likely to rip or be punctured during normal work tasks. The gloves are peeled off so that they are turned inside out to prevent cross-contamination. As with the whole-body dosimeters, they are then sent to the laboratory for extraction and analysis.

A technique that may be applicable to certain liquid pesticide products uses a fluorescent tracer dye added to the tank mix for products that are sprayed. The tracer dye glows when viewed under ultraviolet light. Richard Fenske at the University of Washington has developed a quantitative method for estimating the amount of fluorescent material on the skin with video-imaging techniques (Fenske et al. 1986). This technique will not work for all potential exposures because of degradation of the fluorescent dye over time and with exposure to the sun. Also it is difficult to add the dye to some formulations. Fluorescent tracers, even without the video-imaging, show which body parts have been exposed to pesticides. This technique is an excellent teaching tool for showing workers how their activities and habits affect dermal exposure (Fenske 1988; Fenske 1990).

Inhalation Exposure. Vacuum pumps are used for measuring the quantity of a product in the air, either as a vapor or as an aerosol. The pump draws air through a collection medium. Small pumps can be worn by the person to measure personal exposure or it may be placed in the area to provide a stationary measure of exposure. Collection media for gases and vapors are usually some type of adsorbent, such as charcoal or chromatographic materials, or it could be a liquid solution that traps or reacts with the chemical of interest. Aerosols (particles or droplets) are generally collected on some type of filter medium or are trapped in a liquid. Filters are generally made of cellulose, glass fiber, or some type of plastic, such as PVC or polyurethane foam, and trapping solutions may be organic solvents or water-based weak acids or bases. The collection media are sent to a laboratory for analysis. It may also be possible to use direct-reading instruments in which a pump draws contaminated air past a sensor or into a portable chromatograph. This type of measurement technique provides for instantaneous assessment of exposure and is useful for education of the exposed person.

Respirators with an absorbent material in front of the filters represents an older technique to measure inhalation exposure. Quarter-, half-, or full-face filtering respirators may be used. The person wearing the respirator, in the process of inhalation, acts as the vacuum pump to draw air through the filter. This method provides a direct measure of inhalation exposure and does not require an estimate to be made about the breathing rate of the exposed individual.

Biologic Monitoring. Air and dermal sampling measure exposure at the person–environment boundary. To estimate absorbed dose from the measurement techniques above, assumptions must be made about the breathing rate and the amount of chemical absorbed through the lungs and skin. Measurement of chemicals or their metabolites in biologic media, however, can directly determine the amount of chemical that actually enters the body and integrates the exposures from all routes that occur over time. Care must be taken to collect the sample at a biologically relevant time period. Many pesticides are eliminated from the body in a few days; thus, the sampling must occur in close time proximity to exposure. See *Biological Monitoring for Pesticide Exposure* (Wang et al. 1989) for reports of various pesticide studies that used biological monitoring.

Urine is the most common, noninvasive, biologic medium that may be analyzed for pesticides or their metabolites. It is collected in a sterile container over a certain time period (usually 2 to 24 hours). The use of urine as a measure of exposure is based upon good toxicologic and chemical knowledge of the substance under study. Urine may not be the most appropriate medium if the metabolites are not specific, the substance is fat-soluble, or an analytical method is not available. One difficulty that may arise is that workers or other study subjects may refuse to provide urine samples because of concern about drug testing. Care must be taken to provide adequate information to the subjects concerning the purpose of the study.

Blood, plasma, and serum measurements are commonly used for the assessment of certain chemicals. For example, cholinesterase levels in the blood are an indication of exposure to organophosphate and carbamate pesticides (Hayes et al. 1980). However, this technique is invasive, requires trained personnel to draw blood, and is frequently opposed by the exposed person because of concern about possible infection.

Exhaled air may be collected to measure exposure to certain volatile and nonpolar pesticides. This technique has been used primarily for fumigants and provides a measure of recent exposure. Because it is noninvasive, it may be more acceptable to the subjects. Unfortunately, it is not always simple to get reproducible results. This technique is more useful simply as an indicator of exposure and not as a quantitative technique.

Surface Contamination. In addition to measuring dermal exposure directly, techniques for measuring the amount of pesticide on various surfaces are often valuable. An estimate of exposure may be made if the amount of chemical on the surfaces is known along with an estimate of the amount of surface contacted, the amount of material transferred from those surfaces, and a measure of dermal absorption. One method for determining the amount of dislodgeable foliar residue is to punch out circles from leaves or, for plants with small leaves, blades, or needles, by cutting representative samples. Pesticide residues are dislodged into an aqueous solution, usually a wetting agent in water. A second method for the collection of surface residues works well on turf or on surfaces like floors or carpets. This method involves dragging or rolling a sample-collection medium across the surface. The amount of residue on the collection medium and the area of surface contacted allows the calculation of the dislodgeable residue on that surface. The dislodgeable residues on hard surfaces may be measured by wipe sampling. An area of specific size is wiped across the area with an even pressure.

Two less commonly used techniques of surface sampling may be appropriate for certain conditions. A vacuum cleaner may be used to collect pesticide-containing dusts from hard surfaces, carpet, and upholstery (Lewis et al. 1994). Alternatively, in an experimental study, representative pieces of various household materials may be placed in the area before pesticide application. These coupons would then be removed and extracted or wiped.

Soil may also be sampled by removing soil samples from the surface and separating the soil into particle-size fractions. Generally, only particles less than 147 μm in diameter are extracted and analyzed for pesticide residues.

Exposure Models and Databases

As an alternative to the collection of air, dermal, and surface concentration data, a variety of models and databases are available for estimating pesticide exposure. Probably the most well-known database is the Pesticide Handlers Exposure Database (PHED). This database was developed by EPA, Health Canada, and the American Crop Protection Association. It consists of thousands of replicates of exposure data on mixers, loaders, applicators, and flaggers. Each replicate contains the measured dermal and/or inhalation exposures and the exposure factors that describe that particular situation including the type of formulation, amount handled, concentration, weather conditions, mixing/loading or application equipment, and crops or areas treated.

PHED is not chemical specific. The theory behind this database assumes that the formulation is the best indicator of exposure and physical and chemical characteristics of the pesticide are less important. Based upon this hypothesis, a database was developed along with various statistical and exposure-calculation software to allow an exposure calculation based simply upon the product use. For example, if one wanted to estimate the exposure of an applicator to a pesticide with an emulsifiable concentrate formulation that was applied in a specific amount via closed-cab air blast to peaches but had no actual measurements, PHED would provide both a dermal and inhalation exposure estimate. This model is a stand-alone program. Persons may also add their own exposure data or compare their data to that already in the database.

In addition to PHED, two European models exist for estimation of mixer, loader, and applicator exposure. The U.K. Predictive Operator Exposure Model (POEM) and the German BBA model use exposure factors for various formulation and application scenarios. Both models are available as EXCEL© spreadsheets. Comparison of the results of these two models indicates that POEM is generally more conservative than the BBA model.

Two additional databases are in the development stage. As a result of EPA data call-ins, industry groups have formed three task forces. There is a spray-drift task force that is developing data and models for spray-drift exposures. In the initial stages, the Agricultural Re-entry Task Force (ARTF) and the Outdoor Residential Task Force are collecting data and commissioning studies that will result in a database/model similar to PHED.

Advantages and Disadvantages of Exposure Estimation Methods

Quantitative exposure-assessment methods that involve the actual collection of air, dermal, or surface concentration data provide the most detailed and appropriate exposure estimates. They are chemical specific and exposure-scenario specific. Unfortunately, they are always expensive and involve time for planning, execution, and analysis. A worker-exposure study involving 15 replicate measurements may cost $100,000 to $500,000. Although the exposure measurements may be collected over a week, the preparation, analysis, and report writing may take a year or more. These studies depend upon the cooperation of the persons being monitored, which, if the exposures require the collection of biological samples, may be difficult to obtain.

Models and databases provide a good alternative. Unfortunately, these data are available only for pesticide mixers, loaders, and applicators. Other databases are being developed but are not yet ready for public use. The advantages to using models such as PHED, POEM, and BBA are that they are ready now and can provide answers quickly at little cost. The major disadvantage is that not all formulation/application scenarios are covered by these models. There are very little data for newer formulation types, such as the microencapsulated products.

Semiquantitative methods are useful for answering the present/absent exposure question but may not be appropriate when it is necessary to choose between two products. The detail of a quantitative exposure assessment is missing. Also, there may not be data available for the exposure conditions of interest (e.g., tracking a pesticide into a home).

Exposure Issues for IPM

The exposure-assessment methods described in this paper will allow the estimation of exposure, and with knowledge of the epidemiology and toxicology of the chemicals, human-health risks may be determined. Factors that play a critical role in the exposure calculation are the potential routes of exposure, the populations potentially exposed, and the amount of chemicals used. Exposure estimation may be simple or detailed, depending on the level of specificity of the answer that is needed. One of the most difficult aspects of exposure assessment is the determination of all potentially exposed groups. Frequently, only worker exposure is considered. Other populations that should be considered include farm families, bystanders, and persons who contact pesticides outside of the agricultural environment. Quantitative measurement of exposure is time consuming and costly. It is, however, precise and represents the situation of interest better than any other method. The use of exposure models and databases may provide quick, relatively inexpensive answers to exposure questions if the databases have information on a specific product and use scenario. If detailed information is not necessary, information from use records, pesticide registrants, and the literature may be sufficient for a gross exposure assessment.

There are a number of excellent researchers capable of providing information and guidance on quantitative and qualitative exposure-assessment techniques including the well-known academic scientists Richard Fenske at the University of Washington in Seattle, William Poppendorf at Utah State University in Logan, and Herbert Nigg at the University of Florida in Lake Alfred.

In addition, most of the large pesticide-manufacturing companies have industrial hygienists and regulatory toxicologists on staff who regularly perform exposure studies on their products. Pesticide manufacturers provide a starting point for the determination of what types of studies have already been conducted to assess exposure to their products. In addition, many private consulting firms specialize in exposure assessment to pesticides and agrochemicals.

Public-Health-Impact Assessment

Assessing the impact of changes in pesticide exposure levels and risk resulting from the use of IPM practices requires an understanding of the potential tradeoffs between risks to human health, environmental quality, and agricultural-production possibilities. How particular sets of IPM practices and technologies change pesticide-exposure levels and risk to the applicator, applicator's family, and other farm workers is a critical piece of data needed to assess these tradeoffs. However, exposure levels alone do not provide a comprehensive picture of the changes in risk to those in agriculture or society as a whole because pesticides can have multiple impact dimensions that include not only occupational health and safety, but water quality, wildlife habitat, bio-diversity, and agricultural production, to name a few.

Public-health impacts must be incorporated into an integrated-assessment framework that facilitates the comparison of impacts of IPM practices on risk in other vectors of concern. Failure to assess changes in relative risk in a comprehensive fashion might result in a small reduction of risk in one vector and a large increase in another, resulting in a net increase in risk to society (Levitan et al. 1995; Mullen 1995). Methods used by economists and other environmental scientists to conduct assessments that include these multiple impacts are described in detail in this volume by Norton, Riha et al., and Antle and Capalbo (see also Mullen 1995; Levitan et al. 1995).

Estimating the monetary costs of real or potential public-health impacts is an important component of an integrated assessment. Several different approaches have been used to assess the public-health impacts of changes in production practices that reduce pesticide exposure. In cases where the dose-response relationship of a pesticide and a particular health outcome is established, a "cost-of-illness" approach can be used. By estimating the medical costs of treating the health outcome and the value of lost wages resulting from the illness, an estimate can be made of the health costs of using a particular chemical (Crissman 1994; Antle and Pingali 1994). The cost-of-illness approach represents the lower bound of estimated health costs. A more accurate measure of health costs would include an estimate of what people would pay to avoid becoming ill and the value of the suffering and inconvenience of being ill. Estimates of this "psychic" value can be obtained through surveys that ask people how much they would pay to avoid this adverse health outcome (Cropper 1994).

An example of the cost-of-illness approach is found in Antle and Pingali (1994). The authors found that for certain rice producers in the Philippines, when treatment costs and lost wages were incorporated into an overall economic assessment, the positive production benefits to the farmer from using the pesticide did not exceed the costs. In cases where, after incorporating direct health costs resulting from pesticide use, the cost of using that pesticide do not exceed the production benefits to the producer, then it is not necessary to estimate the psychic costs. This represents a "win-win" situation because productivity does not decline and risk is reduced. In cases where the production benefits exceed the costs, even with health costs incorporated, the value of avoiding illness must be incorporated (Cropper 1994).

In many cases, however, the dose relationship between a pesticide and particular health outcome is not clearly understood or quantified. Thus, it is not possible to estimate the actual medical-treatment costs and lost wages resulting from the use of a particular pesticide. Norton et al. (this volume Part III) identify and describe the four steps involved in estimating the impact of a change in pesticide exposure resulting from the adoption of an IPM practice. The first step is to identify the pesticide's risks to the environment and public health. Levitan et al. (1995), Kovach et al. (1992), Higley and Wintersteen (1992), and Mullen (1995) describe approaches used to rank pesticides by their degree of risk (e.g., low, medium, and high) in one or more vectors of concern. The second step is to quantify the effects of IPM adoption on the use and exposure to pesticides by their risk category. Developing an estimate of society's "willingness to pay" for reduced pesticide risk is the third step. Usually, the value to society of reducing that risk is not available. Contingent valuation (CV), a controversial but often employed technique, is an approach used to establish through opinion surveys monetary values for things not valued in the marketplace. When a CV approach is used, respondents are asked to make and value tradeoffs among environmental, public-health, and other reference goods (Mullen 1995, Higley and Winterstein 1992). This method derives estimates of society's "willingness to pay" for reductions in real or potential risk. The fourth and final step involves using these estimates to value the change in risk levels resulting from IPM practices. This monetary estimate of the public-health costs can then be incorporated into a comprehensive assessment of impacts.

Conclusions

IPM methods and technologies can have an impact on the entire ecosystem. Good IPM practices (such as inventory control, reduction of spill hazards, personnel training, pesticide formulation considerations, and product substitution) will reduce both worker and environmental exposures. The ability to demonstrate a reduced risk to humans from an IPM program should be a major selling point of such a plan. To accomplish this, one must know the health risks of the current practices and the potential risks from the new practices. Ongoing research efforts to evaluate the risk of cancer and other diseases among farmers, farm families, and farm workers from various agricultural chemical exposures will expand our knowledge about these critical relationships.

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Table 1. Causes of death showing deficits and excesses among farmers

Cause of Death	Number of Studies	Number with R/R* less than 1.0
Total mortality	10	9
Ischemic heart disease	12	12
All cancer	20	18
Lung	24	23
Bladder	21	19
Colon	15	13
Esophagus	18	12
Pancreas	20	11
Rectum	13	6
Kidney	15	9
Skin, nonmelanotic	8	4
Non-Hodgkin's lymphoma	14	5
Brain	18	5
Connective tissue	7	2
Prostate	22	6
Leukemia	23	9
Stomach	24	9
Multiple myeloma	12	2
Melanoma	11	2
Hodgkin's disease	12	2
Lip	8	0

*R/R = Relative risk

Table 2. Relative risk of non-Hodgkin's lymphoma and reported frequency of herbicide use among Kansas farmers using 2,4-D

	Number of Exposed Cases	Number of Exposed Controls	Relative Risk
Never farmed	37	286	1.0
Days per year of use			
1–2	6	17	2.7
3–5	4	16	1.6
6–0	4	16	1.9
11–20	4	9	3.0
21 or more	5	6	7.6

Table 3. Relative risk of non-Hodgkin's lymphoma and reported frequency of 2,4-D use among Nebraska farmers

	Number Exposed Cases	Number Exposed Controls	Relative Risk
Never farmed	54	184	1.0
Days per year of use			
1–5	16	44	1.2
6–20	12	25	1.6
21 or more	3	4	3.3

Table 4. Current and past use of protective practices among Iowa and North Carolina farmers

	10 Years Ago (%)	Currently (%)
Use rubber gloves		
Iowa	43	80
North Carolina	26	48
Use rubber boots		
Iowa	6	14
North Carolina	4	12
Change clothes immediately		
Iowa	5	9
North Carolina	20	30
Wash application clothes separately		
Iowa	63	81
North Carolina	50	68

A Primer on Economic Assessment of Integrated Pest Management

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Introduction

Scientists engaged in integrated-pest-management projects and programs are frequently asked about the benefits and costs of their IPM activities. They are asked to respond to such questions as:

- What is the impact of your IPM program?
- We spent $xx on your IPM program; what did we get for those funds?
- What are the environmental benefits of your IPM program?
- How profitable will IPM (or a particular IPM strategy) be for my farm?

Answering these questions requires practical assessment methods that are rigorous enough to provide credible responses yet cost-effective enough not to absorb too much of a total IPM budget. Using relatively standard evaluation methods can help ensure rigor and facilitate assessment of aggregate benefits across programs, but use of innovative assessment methods may also be required to evaluate difficult-to-measure impacts.

The questions posed above imply that the audience for impact assessments includes both (1) IPM users (e.g., farmers) interested in the benefits and costs of specific IPM tactics and strategies and (2) those responsible for funding and administering IPM projects and programs who are interested in more-aggregate impacts. Benefits can be measured at the level of the firm or for society as a whole. Goals for IPM include both economic profitability as well as environmental and health improvement. A range of methods are available to address these multiple dimensions of IPM impact assessment. Some of the methods require specialized training in economics while others do not. They all require adherence to certain standards for gathering and analyzing data if they are to provide believable results.

The purpose of this paper is to identify a core set of methods that can form part of virtually any IPM impact assessment and to highlight some of the possibilities for more complete analysis of IPM programs. Because defining IPM and measuring its adoption is a critical first step in any impact assessment, that topic is addressed first. Then, methods for basic economic assessment are presented, and finally, methods for environmental and health assessment are elaborated.

Defining IPM

A commonly understood, commodity- and location-specific definition of IPM is needed to define IPM and to measure its level of adoption. A process involving local stakeholders is recommended for establishing the definition, while recognizing that measures of IPM adoption will be used for impact assessment at various levels (local, state, regional, and national), and hence, some standardization in approach is needed to facilitate the more aggregate level assessments as well. The two aspects of standardization that can help in developing a definition that is workable across these levels are (1) agreeing on a common set of goals for IPM and (2) agreeing on a minimum set of levels into which the IPM continuum will be divided.

Goals

IPM can contribute to goals of (1) increasing income to IPM users and society as a whole through increased productivity and lower cost products and (2) enhancing environmental quality and health through reduced use of hazardous chemicals. These two primary goals can have several components as well. The process for establishing weights on these goals or their components should involve a broad spectrum of stakeholders.

Levels

IPM adoption is seldom a with-or-without situation because of the many potential practices involved and the fact that these practices are often adopted to varying degrees. Progress can be measured along vectors that express the extent to which progress has been achieved in meeting particular IPM goals through adopting individual or sets of IPM practices. In some studies, practices have been grouped to identify levels of adoption, such as none, low, medium, and high. In other studies, a continuous scale has been developed that gives points to different IPM practices. If scientists evaluating IPM programs could agree on using a scale with at least four levels, aggregation across programs would be facilitated. If a more detailed point scale were used, it could always be categorized down into these coarser levels if desired.

Process

The process of defining IPM can be flexible within each program, but should begin by defining the boundaries in time and space where the program is fairly homogeneous. Stakeholders for the IPM program must be identified, such as producers, scientists, extension agents, consumers, and others. Representatives of these stakeholder groups can be assembled and, with the help of a coordinator or facilitator, a participatory process can be used to identify existing IPM tactics or strategies that are available to control the pest problem(s) within the program boundaries. Once these tactics and strategies are identified, they can be grouped to delineate at least four levels of IPM adoption. The more data that can be supplied by scientists with respect to the effects of these IPM practices on production or pesticide use, the easier it will be to group them. Even with accurate data, the grouping will vary with the implicit weights attached by stakeholders to the income versus environmental goals.

This grouping of practices into levels of adoption on the IPM continuum is the most common method used for defining IPM adoption. It was used in the national IPM evaluation study in the mid-1980s (Rajotte et al. 1985), by the Economic Research Service, U.S. Department of Agriculture (Vandeman et al. 1994), and in a recent study by the World Wildlife Fund (Benbrook 1996) among others. An alternative to grouping practices is to attach points to the individual IPM tactics and strategies to derive a continuous scale. Stakeholders will vary the points they attach depending on their weights on economic versus environmental goals. An example of applying this point system procedure is provided by Hollingsworth et al. (1992) for the Massachusetts apple IPM program.

It makes little difference whether a set of levels or a continuous scale is used because either procedure can yield results amenable for project- or aggregate-level analysis. However, the makeup of the stakeholder group can influence the results because of the effect on weights applied to the two primary goals of IPM.

Basic Economic Assessment

A wide range of methods is available for assessing farm-level or more aggregate-level impacts of IPM on income, income risk, and the environment and health. These methods are seldom direct substitutes for each other, although often a particular method can be applied at different levels of detail. Also, the results of applying one method are frequently an input into a second method. For many difficult-to-measure impacts, particularly those related to the environment, additional research is needed to refine the methods, and many detailed IPM impact assessments are research projects in their own right. As a result, they can absorb significant time and resources. The intent in this section is first to highlight the various methods available for impact assessment and the resources required to implement them and then to discuss, in more detail, a core set of methods that can be used in virtually any basic economic evaluation of IPM.

Farm-Level Profitability

The primary method used for farm-level profitability analysis is to budget out the effects of changes in input and output quantities and prices as a result of adopting IPM practices. Budgets can be constructed as *enterprise* budgets, *partial* budgets, or *whole-farm* budgets. Examples of enterprise and partial budgets are provided below; but basically, enterprise budgets list all income and expenses (variable and fixed) associated with a particular enterprise, while partial budgets may include several enterprises but only include benefit and cost items expected to change significantly as a result of changes in production practices. A whole-farm budget includes all enterprises on a farm, and therefore can consider second-order changes in any activity as a result of introducing IPM practices. The most common types of budgets used for assessing IPM impacts are enterprise and partial budgets.

When budgeting is used to compare yields, costs, and profitability of IPM practices, statistical significance of differences should be tested. For example, if there are two groups of farmers, adopters and nonadopters, a t-test can be run to test for significant differences between mean yields, or analysis of variance can be used to test for significant differences among yields of a crop grown under three or four levels of IPM. However, it is generally preferable to test for significant differences in yields or profits with regression analysis with samples derived from populations of IPM adopters of different levels. For example, a yield-response equation can be estimated in which dummy variables are included to account for differences in IPM adoption. The t-statistics are then calculated for the coefficients on the dummy variables to account for significant differences, while other variables are included in the model to hold constant many of the non-IPM factors affecting yields. Masud et al. (1984) provide an example for delayed planting dates to control cotton bollweevils in the Texas Rolling Plains.

Results of budgeting analysis can be used by scientists and extension workers to judge the profitability of practices they are developing or will be recommending to farmers or of practices already adopted. A second major use of budget information is as an input into a more aggregate assessment of the economic benefits and costs of an IPM program as discussed below. The key audience in this case may be those responsible for funding the IPM program.

Farmers considering adopting particular IPM tactics or strategies are interested in their projected *profitability* as well as their economic *risk*. Risk may arise from biological, technical, or economic factors. A *payoff matrix* can be developed that lists projected net returns for different pest-management practices and severities of pests. (See table 1.)

Table 1. **A hypothetical monetary payoff matrix for insect control per hectare**

Pest Severity	Conventional	IPM
Light	\$200	\$350
Severe	\$50	-\$50

The decision to adopt a particular practice must be made before information is available on pest severity. Therefore, the decision will depend on the producer's ability to absorb risk and on an assessment of the probabilities of light or severe pest attacks. If historical information is available to help in calculating the probabilities, expected monetary outcomes could be calculated for each pest-management practice. In addition, the cells in the matrix could be subdivided to account for risks associated with crop prices and other factors. Pest forecasting can be used to provide information on the probability of a severe or light pest attack.

Additional discussion of payoff matrices is found in Reichelderfer, Carlson, and Norton (1984). An example of the use of economic analysis in a decision theory approach to crop-disease forecasting and control is provided by Carlson (1970).

The attractiveness of alternative pest-management practices to farmers in the presence of risk can also be assessed with a technique called *stochastic dominance* (SD). Stochastic dominance allows for comparisons of probability distributions to determine the most preferred choice for different classes of decision makers. There are three basic types of SD. First-degree SD ranks all distributions for all decision makers. Second-degree SD ranks distributions for risk averters. Unfortunately many distributions are left unranked with first- and second-degree SD. The third type of SD, called generalized SD, can be used to determine whether or not all producers in more narrow sets of risk preferences will prefer one cumulative distribution of net income associated with a management strategy or another or have no preference. Pairs of alternative pest-management strategies may be examined for various sets of producers. These sets of producers can be defined by their levels of risk aversion.

An example of the use of generalized SD in the economic evaluation and comparison of IPM strategies with conventional strategies for soybeans is found in Greene et al. (1985). Studies that use first- and second-degree SD include Musser et al. (1981), Moffit et al. (1983), and McGucklin (1983).

Farm-level economic evaluations of IPM programs are often concerned not only with the choice of practices but also with the optimal level of pest control with those practices. If profit maximization is assumed as the goal, optimal use of an IPM practice occurs when the marginal increase in net returns from applying another unit of the practice equals the marginal cost of its application. Entomologists in particular have applied this concept when identifying *economic thresholds* for pest densities. An economic threshold is the pest population that produces incremental damage equal to the cost of preventing that damage (Headley 1972). If the pest density is below this threshold, no treatment is justified. If it is above this level, treatment should occur to reduce pests to this level. IPM programs often involve monitoring or scouting to provide information to producers on pest densities in relation to the threshold.

The determination of what the economic threshold level should be is difficult because it is influenced by many factors. *Damage functions* are needed that relate pest levels to crop losses. Pesticide costs, output prices, effects of pesticide use on the development of pest resistance, and the effects on predators are other important factors that influence the threshold. And, if risk aversion on the part of producers and off-site costs of pesticide pollution are considered, economic thresholds might differ substantially from ones that only consider direct effects on net returns.

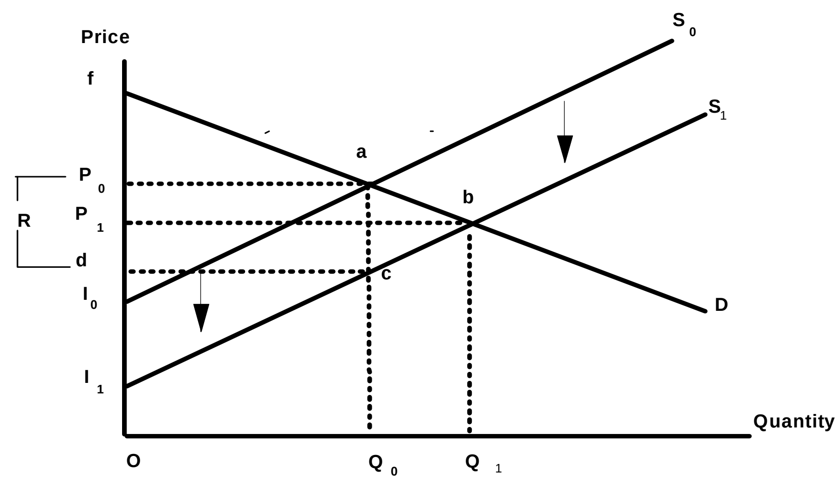
Several economists have studied optimal use of pest-management practices with *mathematical programming* techniques, such as *linear programming, nonlinear programming, and dynamic programming*. Linear programming maximizes an objective function (such as net returns from a set of cropping activities) subject to resource constraints (such as land, labor, capital, and water). Cropping activities can be included that incorporate various types of IPM practices. Enterprise budgets are incorporated in the model, and the sensitivity of the solution to changes in price and resource availability is easily examined. Linear programming assumes all activities and constraints can be cast in linear form. Martin et al. (1991) provides an example of an analysis of alternative tillage systems, crop rotations, and herbicide use on East-Central cornbelt farms. Nonlinear programming is an extension of linear programming that allows for nonlinear relationships. An application of nonlinear programming to a pest-management problem that includes pesticide resistance is found in Gutierrez et al. (1979). Dynamic programming allows for examination of optimal pest-control strategies when time is an independent argument in the models and the variables (such as plant product, pest population density, and the stock of pest susceptibility to pesticides) are all functions of time. Zacharias and Grube (1983) provide an example of applying such a model to examine optimal control of corn rootworm and soybean cyst nematode in Illinois.

Aggregate Economic Impacts

Methods for measuring the aggregate economic impacts of IPM programs on society as a whole can involve several techniques, but at the heart of these techniques is basic benefit-cost analysis. This analysis takes into account changes produced by IPM in production, costs, prices to producers and consumers, and the timing of these changes, giving greater weight to costs and benefits that occur sooner rather than later. Environmental and health effects can also be included if data are available. Methods for assessing environmental and health impacts are discussed in more detail below.

When widespread adoption of IPM occurs across large areas, changes in crop prices, cropping patterns, producer profits, and social welfare can occur. These differences arise because of changes in costs and because greater supplies affect prices to producers and consumers. These changes are illustrated in figure 1. In this model, S_0 represents

Figure 1. Research induces a shift down in the supply curve from S_0 to S_1 resulting in a cost saving per unit of output of R.



the supply curve before adoption of a set of IPM practices, and D represents the demand curve. The initial price and quantity are P_0 and Q_0. Suppose adoption of IPM leads to a savings of R per unit in the average and marginal cost of production, reflected as a shift down in the supply curve to S_1. This supply shift leads to an increase in production and consumption to Q_1 (by $\Delta Q = Q_1 - Q_0$) and the market price falls to P_1 (by $\Delta P = P_1 - P_0$). Consumers are better off because they can consume more of the commodity at a lower price. Consumers benefit from the lower price by an amount equal to their cost-saving on the original quantity ($Q_0 \times \Delta P$) plus their net benefits from the increment to consumption. Although they may receive a lower price per unit, producers are better off, too, because their costs have fallen by R per unit, an amount greater than the fall in price. Producers gain the increase in profits on the original quantity (i.e., $Q_0 \times R - \Delta P$) plus the profits earned on the additional output. Total benefits are obtained as the sum of producer and consumer benefits. The distribution of benefits between pro-ducers and consumers depends on the size of the fall in price (ΔP) relative to the fall in costs (R) and on the nature of the supply shift. Examples of IPM evaluation that have assessed these income benefits to producers and consumers are found in Taylor and Lacewell (1977) and in Napit et al. (1988). Formulas for calculating consumer and producer gains and losses for a variety of market situations are found in Alston, Norton, and Pardey (1995).

Economists call this method of calculating economic gains and losses *economic-surplus* analysis. The most difficult component of an economic-surplus analysis is the calculation or prediction of the proportionate shift in supply following IPM adoption. Cost differences as well as adoption rates must be calculated or projected. Adoption rates are particularly difficult to estimate because they include changes in acreage as well as the proportion of producers adopting. Producer surveys can help in estimating adoption as discussed below. Several studies have estimated econometric relationships that assess factors influencing past adoption. These models can then be used to help predict future adoption. Napit et al. (1988), Harper et al. (1990), and Fernandez-Cornejo et al. (1992) provide examples in which *logit models* were used to estimate the relative importance of several socio-economic and other variables in influencing IPM adoption.

Once changes in economic surplus are calculated or projected over time, benefit/cost analysis can be completed in which *net present values***,** *internal rates of return***,** or *benefit/cost ratios* are calculated.

The benefit side is the total economic surplus calculated year by year, and the costs are the public expenditures on IPM programs. Benefit-cost analysis takes into account the fact that the sooner the benefits occur the more they are worth.

Changes in economic surplus can also be imbedded in mathematical programming models to predict interregional changes in production following the introduction of a widespread IPM program or to predict the impacts of IPM following policy changes that encourage and discourage IPM use. The interregional analysis can use *quadratic programming,* while policy models are likely to use dynamic programming (see, for example, Archibald 1984) or *dynamic simulation* (see, for example, Kazmierczak 1991). These dynamic models do not have standard algorithms and hence are more difficult to solve than the static (linear or quadratic) programming models. However, because the impact of IPM programs is inherently dynamic because of factors like pest resistance to pesticides, the results of dynamic models can be more realistic than static models if sufficient complexity is incorporated in themodels. The advantage of dynamic simulations over dynamic programming is the ability to add more complexity to an empirically tractable model.

Resources Required

The time, people, and financial resources required to implement the impact assessment methods highlighted above differ significantly. Enterprise or partial- enterprise budgeting, which are described in greater detail below, can be accomplished in a relatively short time (weeks) with little input needed from economists and with the primary costs involving surveys to identify cost differences by adoption levels. Likewise, simple payoff matrices can be constructed with little input from economists, although more complex risk analyses quickly become research projects in their own right, are greatly facilitated by input from economists, and can require several months to complete.

Most of the whole-farm-planning and mathematical-programming methods require the assistance of economists and several months time to complete. Likewise, the aggregate analyses involving economic surplus and benefit-cost analyses require collaboration between biological scientists and economists and can take several months. It is not the analysis itself that takes time, but the data collection.

Suggested Core Set of Methods

The suggested core set of methods for basic economic assessment of IPM include (1) a combination of enterprise and partial-enterprise budgeting and (2) benefit-cost analysis. The budgets can provide the field- and farm-level impact assessments required by producers, extension workers, and consultants for profitability assessments. They also generate information that is an input into the benefit-cost analysis required to demonstrate program impacts at a more aggregate level to those responsible for funding IPM programs.

Four basic steps in the economic assessment include:

1. Define IPM practices.
2. Define levels of IPM.
3. Identify production and input changes, and budget them out by adoption level.
4. Benefit-cost analysis to assess aggregate impacts.

Define IPM Practices. A participatory process as mentioned above with stakeholder groups including scientists, producers, consultants, and others can be used to identify the key pests and the tactics and strategies available to manage those pests within the program boundaries.

Define Levels of IPM. As discussed earlier, once the tactics and strategies are identified, the stakeholder groups should delineate at least four levels of IPM adoption: none, low, medium, and high. These levels will be based on subjective assessment of the contributions of the practices to

Table 2. Example of Baseline Survey Variables for Economic Analysis of IPM

1. *Inputs and Outputs (need quantity per acre, price per unit, percent acreage treated, number of times treated, method of treatment, who treated, etc).*
Herbicides, insecticides, nematicides, fungicides, labor for pest management, pheromone traps, scouting (self or hired), custom spraying, predators, outputs

2. *Extent of IPM adoption*
Practices used and percent of acres on which particular practices are used

3. *Pest problems and densities (in appropriate units)*
Arthropods, diseases, nematodes, rodents, birds, elephants, and weeds

4. *Producer and farm characteristics*
Farm size, acreage of crop, age and education of farmer, gender, years farming, ethnic identification, approximate value of farm, approximate value of farm products sold, and percent of income from farming

5. *Others*
Quality effects

economic and environmental goals. Each tactic or strategy can be listed on the board and then subjectively grouped based on these assessments. The assessments are inevitably subjective because unless one has already completed an economic and environmental assessment of the impacts of tactics and strategies, the stakeholder group can only provide very rough judgments on the contribution of the practices to each of the two goals. In other words, there is a bit of a chicken-and-egg problem in defining IPM. However, once some basic IPM impact assessment has been completed, future assessments are facilitated by the existing database.

Identify Production and Input Changes and Budget Them Out. Two primary options are available for gathering the necessary data to budget out the economic impacts of IPM. The first option is to conduct a baseline survey of producers in the area targeted by the IPM program with an interview. Questions should focus on (1) input and output quantities and prices that may change as a result of IPM, (2) pest problems and densities, (3) producer and farm characteristics, and (4) extent of IPM adoption. Basic-enterprise budgets available for the commodity and region are then modified based on the results of the baseline survey. Agricultural economists in the states involved and at the U.S. Department of Agriculture can help in locating the basic-enterprise budgets to be modified. A sample list of data needed is provided in table 2.

The second option is to construct complete-enterprise budgets from scratch by collecting information on all inputs by operation, preferably by having the farmers collect them in a standard tabular format as they do each operation, such as land preparation, planting, fertilization, pest management, cultivation, and harvesting. Data (quantities and prices) are collected on inputs like seeds, fertilizer, pesticides, labor, machinery use, and water and on all outputs. Pest population or pressure is measured as well. Data are also needed on output quantities and prices, quality (if relevant), and producer and farm characteristics.

Regardless of which of the two approaches is employed, a sample size of at least 30 per sample stratification group is required. For example, if pest management varies by farm size group (small, medium, and large), then the sample size should be at least 3 x 30 = 90. The costs of these two approaches can differ substantially, and the detailed collection of enterprise data by farm operation does not necessarily yield more accurate results if outputs and inputs vary substantially from year to year. A baseline interview survey can ask for estimated levels of the most important variables, say, for the past three years to help average out weather, pest, or price-induced differences across years.

Let us assume that the partial-enterprise budget data are collected through a baseline survey, rather than data for a complete-enterprise budget. Input and output quantities and prices are then entered into a budget form like the one shown in table 3. Total returns, costs, and net returns to management

Table 3. Enterprise Budget Form

	Unit	Price/ Unit	Low IPM Quantity	Value	Price/ Unit	Medium IPM Quantity	Value	Price/ Unit	High IPM Quantity	Value
Gross receipts	___	___	___	___	___	___	___	___	___	___
Variable costs										
Preharvest (nonpest management)	___	___	___	___	___	___	___	___	___	___
Preharvest (pest management)										
Insecticide	___	___	___	___	___	___	___	___	___	___
Herbicide	___	___	___	___	___	___	___	___	___	___
Nematicide	___	___	___	___	___	___	___	___	___	___
Fungicide	___	___	___	___	___	___	___	___	___	___
Scouting	___	___	___	___	___	___	___	___	___	___
Labor and machinery	___	___	___	___	___	___	___	___	___	___
Pheromone traps	___	___	___	___	___	___	___	___	___	___
Predators	___	___	___	___	___	___	___	___	___	___
Total preharvest costs	___	___	___	___	___	___	___	___	___	___
Total harvest costs	___	___	___	___	___	___	___	___	___	___
Interest on pest management variable costs	___	___	___	___	___	___	___	___	___	___
Total variable costs	___	___	___	___	___	___	___	___	___	___
Total fixed costs	___	___	___	___	___	___	___	___	___	___
Total costs	___	___	___	___	___	___	___	___	___	___
Return to Management	___	___	___	___	___	___	___	___	___	___

are then calculated for IPM adopters at different levels of adoption. These results can be presented to producers by IPM extension workers and private consultants to demonstrate the profitability of IPM adoption. The results can also be incorporated in an aggregate benefit-cost assessment of IPM programs and shown to those who administer or fund the programs.

Benefit-Cost Analysis to Assess Aggregate Impacts. Aggregate-impact analysis takes the differences in costs per unit of production for different levels of IPM adoption; combines them with information on the geographical spread and timing of adoption; and (1) projects the economic benefits year by year produced by previous and/or potential IPM adoption, (2) discounts the annual benefits to account for the fact that benefits received sooner are worth more than benefits received later, and (3) compares the discounted benefits to discounted costs of the IPM program to produce a net present value or benefit-cost ratio. A rate of return on the IPM investment can also be calculated.

Benefit estimates can be generated by comparing cost differences across IPM levels with information from the baseline survey, estimating the length of time that these practices have been used, and projecting continued IPM adoption in the future. Alternatively, the baseline results can be compared with the results of a followup survey administered in a future year. A third alternative is to gather the information on the baseline survey and then to project the extent and timing of adoption with estimates by stakeholder groups.

Let us assume that the benefit of $20 per acre is estimated for use of high as compared to a medium level of IPM based on a baseline survey and partial-enterprise budgeting. Let us assume that it is estimated that 20,000 acres will be under the high level of IPM and that the acreage will be maintained for the next 10 years. Furthermore, let us assume that the program that produced the IPM practices took 5 years, cost $100,000 per year, and was completed last year. If we assume a discount rate of 5 percent and no price effect caused by the additional production that might result from the lower cost of production, an economist would then calculate the net economic benefits as the discounted benefits less the compounded costs:

$$=\sum_{t=0}^{4} \frac{400{,}000}{(1.05)^t} - \sum_{t=1}^{5} (100{,}000)(1.05)^t$$

$$= 1{,}818{,}380 - 580{,}191$$

$$= 1{,}238{,}189 \, .$$

If the influence of the IPM program was such that the lower cost and resulting production increase were large enough to influence the price of the commodity, economists would model the market as well, use a formula to estimate the economic benefits from a graph such as figure 1, and estimate or project the benefits for each year. For example, the benefits are equal to the area I_0abI_1 for a market situation with no trade, such as the one illustrated in figure 1. The formula to calculate these benefits is $KP_0Q_0(1 + 0.5Zn)$, where:

K = proportionate cost change
P_0 = initial price
Q_0 = initial quantity
Z = Ke/(e+n)
e = supply elasticity
n = demand elasticity

Other formulas would be appropriate for other market situations. Although the formulas presented in this section are not complex, biological scientists would be well advised to involve economists in this type of aggregate-impact assessment.

Methods for Environmental and Health Assessment

Increased attention has focused in recent years on the actual or potential environmental benefits of IPM. Measurement of these benefits is difficult for two primary reasons. First, assessing the physical or biological effects of alternative levels of pesticide use under different IPM practices is challenging. Second, the economic value associated with environmental effects is generally not priced in the market. The first problem has been addressed in studies by Kovach et al. (1992), Higley and Wintersteen (1992), and Mullen (1995). Kovach et al. divided the environmental effects into farmer, worker, consumer, and ecological components and used a variety of databases on the toxicity of pesticides in different settings to classify and weight the environmental impacts of pesticides, based on dermal toxicity, chronic toxicity, systemicity, fish toxicity, leaching potential, surface-loss potential, bird half-life, soil half-life, bee toxicity, beneficial arthropod toxicity, and plant-surface half-life. This weighting allowed them to arrive at an *environmental-impact quotient* by pesticide. They then multiplied this quotient by the percent active ingredient and application rates to obtain an environmental rating for the pesticide in field use. They compared the environmental impacts of traditional and IPM strategies; but they did not attempt to place an economic value on the differences in environmental impacts.

Higley and Wintersteen assessed the environmental risks of pesticides on three broad areas of environmental risk (water quality, nontarget organisms, and human health) that were then subdivided into eight specific categories [surface water, groundwater, aquatic organisms, birds, mammals, beneficial insects, humans (acute toxicity), and humans (chronic toxicity)]. They then classified each pesticide into high risk, medium risk, low risk, or no risk for each environmental category based on a set of criteria from several different studies. Mullen used a similar set of environmental categories.

Unlike Kovach et al., however, Higley and Wintersteen as well as Mullen tackled the issue of placing a value on benefits not priced in the market. They each used *contingent valuation* (CV) to assess the relative importance that individuals place on the environmental-risk categories and the amount they would be willing to pay to avoid high, moderate, and low levels of risk from a pesticide application. Higley and Wintersteen surveyed 8,000 midwestern producers. They used the results to estimate the environmental costs per pesticide. Mullen surveyed 3,000 households throughout the United States. He went a step further and estimated the effects of IPM adoption in apples and peanuts in Virginia on pesticide use. He then used the results of the CV analysis to calculate the economic value of the environmental benefits of IPM.

Contingent valuation is one of the few procedures available for estimating environmental costs associated with pesticide use (or environmental benefits of IPM if pesticide use declines). The procedure has been used for roughly 20 years (and particularly in the past 10 years) in other settings to estimate nonmarket costs or benefits. Typically, CV studies provide respondents with information about a hypothetical action that would reduce the likelihood of a future environmental problem, such as pesticide exposure to fish. Respondents are given some specific information about the nature of the damages. They are then confronted with a question or questions about the maximum amount they would be willing to pay to reduce the problem.

The CV technique has been controversial. Some have argued that respondents give answers that are irrational, that they do not understand what they are being asked to value, and that they do not take the questions seriously because they are hypothetical (Arrow et al. 1993). Others have argued that these problems can be minimized with carefully designed and administered surveys. Arrow et al. provide a detailed discussion of these issues.

The CV technique is one of the few procedures currently available for estimating the aggregate environmental benefits of IPM programs. However, other methods could be used for specific types of environmental effects. For example, hospital records on the costs associated with acute pesticide poisonings, insurance costs for farmworkers exposed to pesticides, costs of restoring polluted wildlife habitats, and other partial market-based techniques can be used in some situations. Antle and Pingali (1994) and Rola and Pingali (1993) have assessed the economic value of acute human-health effects associated with pesticide use in the Philippines. They considered both the medical costs and the effects of health problems on farmworker productivity. A related study was completed by Chrissman and Antle in Ecuador.

The whole area of valuing environmental benefits of IPM is flush with possibilities for close collaborations between biological scientists and economists. Biological scientists can continue to refine our knowledge of the physical or biological effects of pesticide use on various aspects of the environment and health. Economists can continue to refine methods for valuing these effects.

At the moment, it appears that CV analysis may be the one method available that can be used to place a value on the range of environmental and health effects of IPM in a cost-effective manner. Therefore, the section that follows describes the steps in implementing such an analysis.

Steps in a Basic Environmental Assessment of an IPM Program

Assuming that the level of IPM adoption has already been defined for a particular crop and region as discussed above, four basic steps are required for environmental and health assessment of an IPM program:

1. identifying pesticide risks to the environment,
2. assessing the effects of IPM adoption on pesticide use,
3. estimating society's willingness to pay for reduced pesticide risks, and
4. calculating reduction in risk levels and ap-plying willingness-to-pay estimates to them.

These steps were applied in an analysis of the environmental benefits of the apple and peanut IPM programs in Virginia by Mullen (1995) and are summarized in a paper by Mullen et al. (1996). The following is a brief summary of the steps with results presented for the Virginia peanut IPM program.

Identifying Pesticide Risks to the Environment

Pesticide risk to the environment is related to the amount of active ingredients (a.i.) applied. However, total pounds of a.i. applied per year is not the best measure of risk because pesticides differ with respect to their toxicity, mobility, and persistence. A given pesticide also may pose different levels of risk to different components of the environment. Substitution of one pesticide for another may reduce the risk to one component but raise it to others. To address this issue, the environment can be divided into eight broad categories (groundwater, surface water, acute human health, chronic human health, aquatic species, birds, mammals, and arthropods) and three levels of pesticide risk can be identified (high, moderate, and low).

Active ingredients can be assigned one risk level (j = 1 to 3) for each environmental category (i = 1 to 8), resulting in 24 risk/environmental classes for pesticides. Rather than measuring the change in total pounds of all a.i., it is preferable to measure the change in pounds of a.i. in each ij pesticide class attributable to IPM adoption. Separate criteria can be used for each environmental category to classify the risk posed by each a.i. The following is a brief summary of how risk levels were assigned to each a.i. for each environmental category in Mullen et al.

The assignment of groundwater risk to an active ingredient was based on the Pesticide Leaching Matrix developed by the U.S. Department of Agriculture Soil Conservation Service (USDA/SCS) (Becker et al.). The matrix accounts for both soil and pesticide leaching properties. If a pesticide-leaching rating was not available, Gustafson's Ubiquity Score was used to assign groundwater risk to the pesticide. Likewise, the assignment of surface water risk to an a.i. was based on the Surface Runoff Matrix developed by USDA/SCS. If a surface loss rating was not assigned to a pesticide, Red Flag values for water solubility, soil K_{OC}, and soil half-life developed by the EPA were used.

The assignment of acute human-health risks was based on signal words assigned by EPA to the formulated product. EPA requires all pesticides to be labeled with Danger, Warning, or Caution, depending on toxicity LD_{50}s for oral, dermal, and inhalation exposure; and eye and skin effects. (LD_{50} is the dose that kills 50 percent of the test population.) Criteria for assigning chronic-health-risk levels were based on the results of tests evaluating teratogenicity, mutagenicity, and carcinogenicity of each pesticide.

Aquatic species' risk levels were based on LD_{50}s and a weight for surface-water risk (because a pesticide cannot pose a risk to aquatic species if it does not reach surface waters). Assignment of risk of a pesticide to avian and mammalian categories was based on LC_{50}s and the highest level of risk to any species within the category. To assess risk to nontarget arthropods, several references were consulted, including EXTOXNET; Smith, Higley and Wintersteen; Kovach et al.; Worthington, Hartley, and Kidd; and EPA reregistration reports.

Assessing Effects of IPM on Pesticide Use

To estimate the reductions in external costs attributable to an IPM program, an estimate is needed of the proportional change in pesticide use induced by adoption of IPM on the study crop. Estimating this change entails comparing the current level of use under IPM to an estimate of what use would be in the absence of the IPM program.

Total pounds of an a.i. class applied per year to a study area can be denoted Use_{ij}, where i = environmental category and j = risk level as defined above. Use_{ij} is composed of two elements, use on the study crop (Use_{ijs}) and use on other crops in the study area (Use_{ija}) so that

$$Use_{ij} = \sum_{a=1}^{n-1} (Use_{ija}) + Use_{ijs},$$

where n is the number of crops grown in the study area.

Regression analysis can be used to examine the relationship between Use_{ijs} and various levels of adoption of IPM. A general form of this relationship can be represented by:

$$Use_{ijs} = F(IPM\ adoption,\ acreage\ of\ the\ study\ crop,\ pest\ severity,\ farmer\ characteristics)$$

For example, the four levels of IPM adoption defined above can be included as dummy variables and variables such as farm size, age, farmer education, and an index of pest infestation severity can be included. Realized and potential proportional reductions in Use_{ij} can then be calculated by comparing Use_{ij} with and without IPM.

Willingness to Pay to Reduce Pesticide Risks

Estimates are needed of society's willingness to pay to avoid pesticide risks to the eight environmental categories. There are few market proxies for the value of avoiding risk to any of these categories and none that would serve for all of them. Therefore, Mullen administered a contingent valuation survey (CVS) to a random sample of 3,000 U.S. residents.

The survey contained an introduction with a brief overview of the value of pesticides as an agricultural input and of the potential for pesticides to damage the environment and human health. The questionnaire began by asking the respondent's average monthly grocery bill. This question was relatively easy to answer and served to get the respondent involved in the survey. It also provided a baseline for a subsequent question on willingness to pay.

The willingness-to-pay (WTP) questions began with a brief definition of "high risks to the environment and human health from pesticide use." Respondents were asked their willingness to pay to avoid high risks via an increase in their monthly grocery bill. This payment vehicle was chosen because grocery prices might increase if the use of an entire class of pesticides was restricted. After answering the WTP questions, the respondents were asked to rate (from 0 to 6) how important it is to avoid high risks to each of the eight environmental and human-health categories considered in the study. The same format (risk definition, willingness-to-pay questions, and assignment of importance levels) was repeated for moderate and low risks.

The survey was mailed to individuals drawn randomly from motor vehicle registration records and telephone directories throughout the United States. A second mailing was sent 25 days later to 833 addresses, selected at random from those that had not returned the survey. Several surveys (384) were returned as undeliverable, and 454 responses were received.

To minimize the length of the questionnaire, the CVS respondents were asked to reveal their willingness to pay to avoid a given level of risk to the environment as a whole (WTP_j), rather than their willingness to pay for each category (WTP_{ij}). The importance rankings by category from the survey were then used to infer the respondent's WTP_{ij} from their WTP_j.

$$WTP_{ij} = \frac{importance_i}{\sum_{i=1}^{8} importance_i} \ x \ WTP_j$$

The results of the CVS, with 46 outliers deleted, are presented in table 4. Following previous studies (Desvousges et al. 1993), responses were considered outliers if the WTP_j exceeded 5 percent of the respondent's annual income.

Calculating Risk Reductions and Applying Willingness-to-Pay Estimates

Risk reductions produced by reduced pesticide use resulting from IPM adoption can be combined with the willingness-to-pay estimates to assess the economic value of environmental benefit of IPM. The following is an example of such an analysis for peanuts in Virginia.

Table 4. Willingness to Pay to Reduce Environmental Risk ($/month)

Environmental Category	High Risk Mean	High Risk Std Dev	High Risk N	Moderate Risk Mean	Moderate Risk Std Dev	Moderate Risk N	Low Risk Mean	Low Risk Std Dev	Low Risk N
Acute Human	4.28	4.68	397	2.89	3.44	392	1.74	2.75	388
Chronic Human	4.59	4.85	397	3.14	3.68	392	1.89	2.87	388
Groundwater	4.56	4.75	397	3.08	3.62	392	1.86	2.91	388
Surface Water	4.40	4.62	397	2.93	3.43	392	1.76	2.79	388
Aquatic Species	4.37	4.64	397	2.88	3.42	392	1.75	2.84	388
Avian Species	4.15	4.48	397	2.72	3.23	392	1.63	2.67	388
Mammalian Species	4.13	4.46	397	2.71	3.25	392	1.65	2.69	388
Arthropods	3.76	4.33	397	2.49	3.11	392	1.50	2.54	388

The Virginia IPM program in peanuts focused on developing a disease-forecasting system to reduce fungicide use. In 1979, an early leaf spot advisory system (ELSA) was developed in Virginia to identify environmental conditions favorable to early leaf spot infection. Prior to ELSA, the conventional method for combating early leaf spot in Virginia peanuts was to apply chlorothalonil to peanut fields at 14-day intervals. By accurately predicting periods of early leaf spot infection, the ELSA forecasts and fungicide recommendations have allowed farmers to apply chlorothalonil in a more judicious manner.

In a four-year evaluation study from 1987 to 1990, it was found that farmers following ELSA recommendations made, on average, 33 percent fewer applications of chlorothalonil than farmers using the 14-day spray regime. Yields from the ELSA farms were not significantly different than yields from the 14-day spray farms; nor was there a significant difference in the value of those yields. By 1990, 94 percent of Virginia's peanut producers were applying chlorothalonil based on ELSA recommendations (Phipps 1993).

Recall that Use_{ij} is comprised of two components, the total amount of a.i. class *ij* applied to all crops in the study area other than the study crop ($\Sigma\ Use_{ija}$), and the total amount of a.i. class *ij* applied to the study crop (Use_{ijs}). The calculation of Use_{ija} is represented by

$$Use_{ija} = \sum_{p=1}^{m} (Acres_a \ x \ Treat_{ap} \ x \ Rate_{ap})$$

where m = number of active ingredients of class *ij* applied to crop *a*, $Acres_a$ = number of acres of crop *a* harvested in the study area, $Treat_{ap}$ = proportion of study area acres of crop *a* treated with active ingredient *p*, and $Rate_{ap}$ = pounds of active ingredient *p* applied per acre per year to crop *a*.

Similarly, $Use_{ijs,w/ELSA}$, the amount of active ingredient of class *ij* applied to peanuts in the study area in 1992, is calculated by

$$Use_{ijs,w/ELSA} = \sum_{p=1}^{m} (Acres_s \ x \ Treat_{sp} \ x \ Rate_{sp})$$

where m = number of active ingredients of class *ij* applied to peanuts, $Acres_s$ = number of harvested acres of peanuts in the study area, $Treat_{sp}$ = proportion of study area peanut acres treated with active ingredient *p*, and $Rate_{sp}$ = pounds of active ingredient *p* applied per acre per year to peanuts.

The total amount of a.i. class *ij* applied to all crops in the study area in 1992 is given by

$$Use_{ij,w/ELSA} = \sum_{a=1}^{n-1} (Use_{ija}) + Use_{ijs,w/ELSA}$$

where n is the number of crops grown in the study area.

Assuming that producers following ELSA recommendations applied 33 percent less chlorothalonil in 1992 than producers using a calendar spray schedule *and* that 94 percent of Virginia's peanut producers used ELSA while 6 percent used calendar sprays, one can solve for the amount of chlorothalonil that would have been applied in the absence of ELSA with the equations

$X = 1.5 \times Y$ and

$Z = \text{Acres}_s \times (0.94 \times Y + .06 \times X)$,

where X is the pounds of chlorothalonil applied per acre per year to farms with a 14-day spray schedule, Y is the pounds of chlorothalonil applied per acre per year to farms following ELSA recommendations, Acres_s is the number of peanut acres harvested in the study area in 1992, and Z is the total pounds of chlorothalonil applied to peanuts in the study area in 1992.

The amount of a.i. class *ij* that would have been applied to the study area without ELSA, $\text{Use}_{ij,w/o\ ELSA}$ is calculated as

$$Use_{ij,w/oELSA} = \sum_{a=1}^{n-1} (Use_{ija}) + \sum_{p=1}^{m-1} (Use_{ijsp}) + X * Acres_s$$

where n is the number of crops grown in the study area, p is the number of active ingredients of class *ij* other than chlorothalonil applied to peanuts in the study area, and $X \times \text{Acres}_s$ is the total pounds of chlorothalonil that would have been applied to the study area in the absence of ELSA. The estimates of $\text{Use}_{ij,w/ELSA}$ and $\text{Use}_{ij,w/o\ ELSA}$ for the relevant a.i. classes are presented in table 5.

The savings in the external costs inflicted on each of the environmental-risk categories are represented by: $Savings_{ij} = WTP_{ij} \times POP \times Realized_{ij}$, where POP is the population in the study area and Realized_{ij} is the realized proportionate reduction in Use_{ij}. The total savings in external costs (environmental benefits) attributable to the ELSA program is simply the sum of the savings for each of the eight relevant *ij* categories (table 5). The total savings in external costs are approximately $844,000 per year (in 1992 dollars).

The willingness-to-pay estimates developed in the Mullen study can be applied in other studies without the need to repeat the CVS. Procedures developed for assessing risk levels to eight environmental categories can also be used elsewhere. Risk levels were assigned to more than 130 pesticidal active ingredients in Virginia, and some of these results should be useful in other studies as well. Tables with these risk levels are available from the authors, and their availability can reduce the time and effort required in future studies. These risk assignments may also be used by farmers to guide their selection of pesticides.

Conclusions

A variety of approaches are available to assess economic and environmental impacts of IPM programs. Most of the approaches require collaboration between biological scientists and economists. It is possible to complete partial-enterprise budgets with relatively little assistance from economists. However, most aggregate-impact assessments aimed at audiences like administrators or funding agencies require a multidisciplinary approach in which, at a minimum, economic-surplus and benefit-cost analyses are completed. Some progress has been made in assessing the economic value of environmental benefits, but this topic is ripe for additional research. If pesticide reductions from IPM are estimated as well as hazard levels of those pesticides, the willingness-to-pay estimates provided in table 4 can be used to assess the economic value of the environmental benefits of an IPM program.

Table 5. Estimates of Chlorothalonil Use With and Without ELSA and Savings in External Costs (Environmental Benefits)

Active Ingredient Class	$Use_{ij,w/ELSA}$ (1000 lbs)	$Use_{ij,w/o\ ELSA}$ (1000 lbs)	Percent Reduction in Use_{ij} Produced by ELSA	Savings in External Costs (1000 $)
Low risk to groundwater	747	844	11.56	142
High risk to surface water	1937	2035	4.80	139
High risk to aquatic species	1857	1954	4.99	144
High risk to acute human health	1745	1842	5.30	149
Moderate risk to chronic human health	2268	2366	4.13	85
Low risk to avian species	2241	2338	4.17	45
Low risk to mammalian species	965	1063	9.18	100
Low risk to nontarget arthropods	2325	2423	4.03	40
Total				844

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Practical Considerations in Assessing Barriers to IPM Adoption

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The charge to the rural sociologists participating in this session was simple and direct: "no theory, no research findings, just practical explanations of what your discipline has to offer to those promoting the adoption of integrated-pest-management (IPM) practices." Asking scientists to make presentations without theory or data was difficult, yet achievable, when considering the objectives of this session. The challenge facing the rural sociologists in this session was to find a balance between providing a one-size-fits-all "cookbook" of IPM adoption on the one hand, and losing the audience with myopic research detail on the other. Instead, the presenters were asked to provide practical recommendations on how social processes could be applied to increasing IPM adoption.

In the first section of our paper, we raise a number of important issues regarding the foundation upon which higher levels of IPM adoption are expected to occur. A critical question is associated with the value placed on information, the very substructure upon which IPM recommendations are developed. That is, producers engaged in integrated pest management collect, analyze, and use information as the basis for pest-management decisions. This requirement for the analytical use of quality information occurs in a context where the producer is often overwhelmed by diverse data sets (e.g., markets, weather, new technologies, input prices, farm programs, and community activities). As we point out, it is into this context that IPM programs are trying to get producers to recognize and use quality information. We develop the argument that current adoption levels may represent the "easy" cases, and either enhancing the level of adoption or persuading remaining nonadopters to attempt IPM practices may require qualitatively different initiatives. It cannot be "more of the same" if we are to achieve the 75-percent adoption objectives.

In the second section, we discus IPM adoption and barriers to this process. As is the case with most complex phenomena, measurement is a critical issue. Adoption of IPM practices can be measured on different levels. We describe four levels of measurement associated with IPM practices. These levels more or less represent a continuum from simple measures that characterized past program-accountability efforts (accounting level of measurement), current efforts (proportional level of measurement), future efforts based on site-specific accuracy in using IPM practices, to the distribution of those practices across an ecological landscape. We identify and discuss a set of barriers producers encounter when faced with IPM-adoption decisions. This analysis is based on understanding IPM adoption from the perspective of the producer. This contribution concludes by noting that producers are making correct and rational decisions in rejecting IPM recommendations because of the presence of one or more of these barriers. Those interested in increasing IPM adoption rates are encouraged to address these barriers rather than blaming the farmer for current nonadoption decisions.

In the third section of this paper, we examine some of the social processes that often impact IPM program efforts. Successful IPM programs are usually based around the cooperative efforts of multiple agencies, organizations, firms, and producer groups. These partnerships do not "just happen," but require careful planning and support. We discuss some of the factors associated with conflict management, building consensus, and improving communication critical to the success of these partnerships. Finally, we address the difficult issue of social-impact assessment associated with IPM adoption. The diffusion of IPM across a production region or commodity will produce "winners and losers" as a consequence of that process. IPM program managers and professionals need to be aware that their efforts will have these impacts. How to assess and manage these impacts are a final theme in our presentation.

Overcoming the Plateau in Adoption of Integrated Pest Management

The benchmark of 75 percent of the nation's managed acres under IPM by the year 2000 is a challenging but justifiable goal. After all, IPM has been promoted and publicly funded for more than a generation. On the optimistic side, the goal might just be achievable. If a less rigorous definition of IPM is invoked and self-report data are used, then current levels of IPM adoption would be regarded as relatively high and within reach of the benchmark (Vandeman et al. 1994). For insect control in corn, we might already be at the benchmark. For weed control in corn, adoption may be about two-thirds of the benchmark, and perhaps adoption is as high as 80 percent for weed control in soybeans (Vandeman et al. 1994). However, if more stringent definitions are used, such as those proposed by some interest groups, the level of adoption may be regarded as half or less of these levels (Cate and Hinkle 1994).

The Foundation for IPM

A key question is, "Has the foundation been laid with producers for doing the right things for the right reasons?" Fundamentally, IPM is a "whole-system," intensive, and information-based management approach. As such, IPM cannot be reduced to a cafeteria of independent or substitutable practices. Unfortunately, much adoption literature is based on single-practice innovations, and too frequently analysis has been approached from a simple-technology perspective. Understandably, this is a consequence of subject-matter specialization and the setting of parameters for scientific inquiry. Unfortunately, solutions based on substituting one technology for another have limitations when extrapolating to an integrated-systems approach, where there may be many acceptable (desirable) solutions to the puzzle. This could include some solutions that, when taken at face value or in a single time frame, may appear contradictory to the overall intent of the system being advocated (i.e., unique incidents where high levels of pesticide use is warranted). Or, conversely, a set of practices might appear to be consistent with IPM but are not rooted in the systems approach underlying most concepts of IPM.

IPM as a Process

Without question, defining IPM is an ongoing process, both in the abstract and in practice. Debate continues regarding the importance of certain goals and priorities for IPM, such as use of and dependence on chemical pest-control practices (Gray 1995). Nonetheless, there is general agreement that IPM is an information-based approach providing multiple options for pest control based on sound data inputs. Underlying all of this, then, is an essential ingredient, namely an information base generated from on-farm or site-specific observations. Meaningful pest scouting and subsequent documentation from the scouting activity must be central to decisions if a management system is to qualify as IPM. What is less clear is the extent to which crop producers value and appreciate the importance of such site-specific information in pest control and overall crop production and whether producers have identified with the systems approach it represents. The extent that this foundation is not a motivational factor represents a major barrier to full IPM adoption. IPM is a managment and information-intensive pest-management system and should be acknowledged as a version of "precision farming," even though it has neither the glamour of nor dependence upon Geographical Information Systems (GIS) or Global Positioning Systems (GPS) technologies. Broadening the definition to include IPM would allow producers to garner some of the benefits of precision farming without adopting these new and developing technologies.

IPM in the Information Age

Only when the value of on-site data is well understood and incorporated in the decision-making process has the foundation for IPM been established. Therefore, when attempting to "sell" IPM, it needs to be done from an integrated-systems and information-age perspective and not as a list of individual practices. Further, its advocacy must be undergirded with the values, norms, and technologies (i.e., the culture) of the information age. This involves at least a few important departures from the mass production, mass society, and economy-of-scale agriculture framework that has been and remains pervasive among producers.

The information age should not be mistaken as merely more information or intrigue associated with information-age technologies, such as the computer chip, the Internet, home pages, GIS, GPS, or variable-rate technology (VRT). The promise of the information age is that information would be different from mass society/mass media information. The notion that one size (with a little alteration) will fit most, if not all, situations, is replaced with the expectation that information must be custom-designed for each site-specific situation.

As producers perceive the beneftis from site-specific information, it begins to have a market value. That makes information a commodity or product akin to other inputs into the production process. In the case of IPM, pest scouting is an example of a type of information input. In the case of integrated crop management (ICM), additional kinds of site-specific information (nutrient levels, yields, soil types, crop rotation histories, etc.) are part of a more complex mix. And the value of this onsite-generated data is realized when it is interpreted and juxtaposed against more generalized research-based findings and principles. In short, production information and pest-control information must be more than dealer sales counter calculations that use a general formula and a few rough data estimates.

Producing, recording, analyzing, and applying site-specific data in conjunction with more general research-based knowledge does not come without a cost, either in the form of a purchased service or a direct investment in time and effort by the producer. Failure to recognize the importance to invest in quality information may well put a ceiling on full adoption of IPM and thereby limit the production and environmental benefits that potentially can accrue from more universal adoption of IPM. While the data are somewhat ambiguous, a recent study of corn and soybean producers in Iowa point to a reticence to identify with and commit to the importance of quality onsite and farm-produced data in decision making.

IPM and On-Farm Data

Findings from several surveys of corn and soybean producers in the Midwest provide insights into current production practices and suggest the need to more strongly reinforce the value of onfarm-produced data as the basis for promoting increased adoption of IPM. Sample surveys conducted in Iowa suggest that farmers in that state do not universally identify with IPM. Indeed, less than 10 percent of farmers say they make “heavy use” of IPM, with perhaps as many as one-quarter who identify with “moderate” or “heavy” use. Fully two in five say they do not use IPM. This percentage has been fairly stable for the past five years (Lasley 1989; 1994). When asked about individual cultural practices to limit dependence upon pesticides, certain practices are adopted much more widely than IPM itself (mechanical cultivation), while others (banding herbicides and using degree days) are quite similar to IPM in extent of use (Lasley 1994). In the past several years, information providers in the state [Extension, National Resources Conservation Service (NRCS), and several in the private sector] have been promoting the broader concept of ICM, which also makes strong application of onfarm and site-specific information. At least for now, identification with ICM among Iowa’s corn and soybean producers is less than for IPM (Lasley 1994).

On the critical issue of scouting, the findings look quite promising on the surface, but in-depth questioning elicits concern about whether a number of farmers have deceived themselves on what constitutes acceptable and rigorous scouting for high-management IPM needs. Again, the Iowa Farm and Rural Life Poll has quizzed Iowa farmers on scouting, and this has been augmented in other surveys as well. Most (90 percent) Iowa farmers indicated they make at least limited use of scouting and one in five indicate “heavy” use (Lasley 1994). However, when Iowa farmers were asked the question in a slightly different way, namely how many times do they walk their fields to specifically check for the presence of insects, weeds, diseases, or other problems, half of the farmer respondents indicated three times or less per growing season, and less than one-fifth indicated a half dozen times or more (Padgett 1990). Although Czapar et al. (1995)

found higher levels of farmer scouting among central Illinois farmers, their sample may have included more large-scale grain farmers than the Iowa surveys.

Particularly the Iowa studies, but to some extent also the Czapar et al. Illinois study, raise questions about whether farmers see the importance of rigor in recording, using, and incorporating scouting information for management purposes. Currently, most scouting is done by the farmers themselves, and professional crop scouting is relatively infrequent. Both Lasley and Czapar et al. report use of professional crop scouting by approximately 7 percent of their study respondents. General crop consulting may be at a higher level, however. An extrapolated estimate by Doane Agricultural Services (1993) places professional crop consulting nationally at 21 percent for corn and at 12 percent for soybeans. Padgett (1990) found that cost was a major factor inhibiting Iowa farmers from purchasing the servies of professional scouts or crop consultants. At the time his study was conducted, approximately 5 percent of the farmer respondents indicated an interest in professional scouting when priced at the market rate, but as many as one-third expressed an interest if the scouting was offered at about one-half the existing market rate.

When a pilot effort, the Model Farms Project, was launched in Iowa, it provided incentives for integrated crop-management services, including systematic scouting. Interest was high in the initial identification of project cooperators. But, by the time user fees were incrementally increased over a three-year period to a competitive market level, approximately one-half of the original cooperators left the program (Petrzelka, Padgitt, and Wintersteen 1995). The most frequent reason cited among those leaving the program was that they did not see sufficient economic benefit from the crop consulting services. Nearly two-thirds of those leaving the program (64 percent) gave this as a reason, with just slightly fewer noting they could not financially afford to continue the service (58 percent). These reasons are in sharp contrast and surpass the frequency with which they noted yield loss (4 percent), incompatibility with their current production system (8 percent), and inability to control weeds and insects (11 percent). Also, the lack of economic benefit contrasts sharply with project records, which document the return on investment to be more in the range of four to one at full market value. The value is reasonably close to estimates made by continuing clients of Iowa's private crop consultant, who in a 1993 survey reported by a margin of four to one that their benefit exceeded the investment, and nearly half of whom said the rate of return was at least quadruple the investment (Petrzelka et al. 1995).

Finally, among the profile of Model Farms cooperators in Iowa (farmers selected because they were more forward looking than the average producer), many did not keep and use field-based records, the kinds of records that facilitate information-intensive management decisions. However, over the course of the project, most of those who remained in the project did change and adopted to a much greater extent the notion of site-specific record keeping. Their changes were substantial and document progress because record keeping is not a highly enjoyed activity by Iowa farmers, especially when compared to crop and field work (Lasley 1992). Consequently, Iowa farmers reported spending very little time at it. Sixty-two percent of respondents to the 1992 Iowa Farm and Rural Life Poll reported investing 5 hours or less per month keeping and analyzing records. This is not the profile needed in a management-intensive, information-age production system and lends credence to the notion that, while adoption of individual IPM practices may be increasing, the decisions are likely based on less than ideal information and full analysis of individual resources and conditions.

Farmer Behavior and the Potential for IPM

If the above premise is correct, then part (and perhaps much) of the challenge to move IPM adoption beyond the current plateau is prompting producers to understand the value of quality data and apply it in more systematic and rigorous ways than they currently are doing when choosing pest-control strategies. The simple answer, but not necessarily a simple task, is to increase producers' awareness and change their attitudes. The Iowa studies suggest that at least on the surface attitudes are already in place. For example, when asked if savings and benefits from detailed record keeping justify the added time, cost, and effort incurred, there is strong agreement and very little disagreement (Petrzelka, Padgitt, and Wintersteen 1995). This finding is not altogether surprising nor different from most adults who accept the notion of healthier diets and regular exercise to better wellness but continue with behaviors that are quite counter to that end. Habit, the path of least resistance, enjoying existing behaviors, avoiding less-desirable activities, and the ability to rationalize and justify a given behavior are strong impulses. This occurs among farmers as well as the general public. Theories of cognitive dissonance, which postulate a tendency to resolve such discrepancies if they are pointed out, have some support in laboratory experiments, but certainly they leave a lot of variance unexplained.

For many producers, much of the rationalization limiting adoption of high management appears rooted in an economy of scale framework and the belief that time can be more profitably invested in expanded acreage production rather than refinements in current production practices. Such an outlook is consistent with personal work preferences and is deeply ingrained in a fairly pervasive "agri-culture" that values "bigger is better," "big iron," and "macho" approaches to production, including pest control. Moderating such values to give greater priority to information as a commodity is a slow process, and one that needs to be approached actively and persistently.

Learning how to do this needs to be taken seriously. Much can be learned by listening to farmers, and much can be learned from those whose livelihoods are dependent upon "closing the deal."

First, some observations from listening to farmers. In a series of open-ended conversations with farmers across Iowa about high-management systems for soil conservation and water quality protection (Imerman et al. 1996), six criteria for making decisions reoccur in the transcripts. With some caution, these topics can be inferred to be relevant to other high-management and environmental-protection systems. In rank order, the criteria were: profitability, yield stability, production compatibility, input cost containment, risk reduction, and environmental quality. A case can be made that IPM systems have advantages for each of these farmer-defined priorities. However, the advantages are not always apparent and must be reinforced on a regular basis. One factor apparent to the reader of the transcripts of these conversations is the well-established psychological principle that individuals interpret events in the context of their own worlds of experience and modify interpretations significantly from "objective" information that is presented (Schkade 1994). Also, casual observation or an anecdote often takes on equal status (reliability, accuracy, and generalizability) of more rigorous scientific data unless the fallacy is confronted, something that is unlikely to happen with mass-media and passive-education strategies. Staff of the Iowa Model Farms Project have been perplexed by the discrepancy between profitability (as shown from project records) and perception of some of the project coordinators. This is both the frustrating and challenging aspect of being in the business of promotion and advocacy. Clearly, opportunities must be seized. As with other kinds of changed behavior, when appropriate, reinforcement should be offered, and discrepancies should be made obvious. Most public servants have been reluctant to be so bold as to do the latter, however.

This observation leads to a related final point, the necessity to overcome fear, reticence, and anxiety in asking for a commitment to action. Often, agency employees fear asking for a commitment from clients. This feeling is not altogether different from an adolescent asking for that first date or dance. Agency staff rationalize that "our role is to educate," "to provide technical assistance," or "to point out alternatives," and not to promote or recommend. To not bring to closure a decision and instead follow the path of least resistance is not worthy of a "change agent." And, it is not consistent with the expectations increasingly being placed on staff roles in public agencies. The need to call for action and ask for a commitment became very real for NRCS in implementing conservation compliance. And it is very real if IPM is to be on 75 percent of managed acres in just five planting seasons.

Assessing Barriers to IPM Adoption

There is a wide and diverse research literature on the adoption of IPM. The purpose of this section of the paper is not to review or synthesize this literature, rather it is to draw out the practical lessons to be learned from this body of research. The intent is to provide practical guidelines to plant pathologists, entomologists, agronomists, and the many other professionals for whom IPM is an integral part of their career objectives.

The dominant perspective used in this paper is that of the grower, producer, or farmer. It is based on the assumption that one does not increase the use of IPM practices among this group unless one first understands how and why new practices are adopted, rejected, or modified.

First and foremost, it is critical to understand that adoption is a process. It is not a discrete, dichotomous event where one moves from nonadopter to adopter status as the result of a single decision. While colloquial language may characterize the adoption process as a binary event, in actuality it can encompass a series of identifiable stages or steps.

The initial stage is where the grower needs to become aware of a specific IPM practice or set of practices. This awarenes occurs in one of two ways. The individual may have a problem (e.g., pest losses or a feeling that excess funds are being spent on agrichemicals) and is seeking a solution, or some external party calls attention to a hitherto unrecognized problem (e.g., health or environmental problems derived from a reliance on agrichemicals) for which this party also holds a solution (IPM). While the distinction between these two situations is important for designing intervention or marketing programs, for now the important fact is that the grower becomes aware of something called IPM.

The grower will then seek knowledge about this practice to evaluate both the production and economic dimensions. This knowledge will take a variety of forms; from formal scientific research results to hearsay at local producer gathering places. Obtaining sufficient knowledge about the practice may be easy and straightforward, or it may be complex and difficult. The knowledge about the practice, positive, negative, and ambiguous, is constantly updated in an effort to transform it into information that is locally salient and decision focused. A producer may decide on the basis of this information that the practice will not work, is not cost-effective, or may be worth a try.

If the practice (or practices) being evaluated is conducive to division, then a producer may decide to try using it on a small-scale basis first. This trial stage allows growers to assess whether they can manage the practice, if needed forms of inputs and assistance are readily available, and if the practice will be profitable across a production cycle. Because of the dynamic interaction of pest cycles, weather, and actions of neighboring producers, the trial process may be extended through several production cycles. If the outcome of this small-scale trial is positive, a producer may decide to move to full-scale adoption. That is, apply the practice to all applicable acres. Of course, the converse is also true. The producer may decide at any time in this decision process to reject the practice and maintain traditional practices while looking for other feasible solutions.

Factors Influencing This Process

Adoption or rejection does not occur as an individual act isolated from the context in which it occurs. Instead, a number of factors influence both the outcome and speed of this decision process. These include the nature of the IPM practice, characteristics of the operation, infrastructure support, and managerial capabilities. There are a number of research generalizations that tell us that the complexity, divisibility, cost, and compatibility of the practice influence the speed and outcome of the adoption process. Characteristics of the operation also influence the adoption process. For example, larger, specialized operations are more likely to adopt at a faster rate than smaller, diversified operations. A critical element is the amount and quality of what can be called infrastructure support, including factors like the amount and nature of research being conducted in the public sector, the viability of private-sector information markets, cost-effective access to supporting materials and supplies, availability of quality labor or managerial expertise, and the lack of active opposition from local agrichemical suppliers.

Measuring Adoption

Measuring the adoption of IPM practices can be more complex than it sounds. At first glance, it appears to be nothing more than a question of whether a grower is or is not using a specific practice. Yet this simplistic view quickly changes as one begins to assess how it is being used, where it is being used, and the appropriateness of that use relative to actual pest conditions. Complexity aside, measuring adoption of IPM practices is the foundation of any viable IPM program. These IPM programs, in either the public or private sector, often have goals or objectives associated with them. Being able to measure adoption informs the public or shareholders to the extent the program is achieving these goals or objectives. Measuring adoption can also provide information on the efficiency of the IPM program. Just how many resources are being used to achieve certain levels of adoption is a question that any organization or firm needs to address sooner or later. For public sector organizations who must also address equity issues, the question of who is adopting these practices is important. For example, has the program focused on those with the greatest economic need, those with the greatest human-health risks, or those where there is the greatest potential for environmental damage? All these questions are important, and all are based on the idea of measuring adoption of IPM practices in a valid and reliable fashion.

The foundation of any science is describing, explaining, predicting, and possibly controlling variation. For behavioral or social scientists, the focus is on explaining variation in human behavior. Producers, growers, and farmers, contrary to common perception, are not a homogeneous mass. There is as much richness and diversity in farmer behavior as there is in the pests and pathogens associated with IPM practices. Because of this diversity, it is difficult to discuss adoption as if it were a singular concept. The bottom line is that the methodological sophistication found in the sciences underlying IPM programs needs to be matched by efforts to measure the adoption process. Discussing the methodological sophistication needed to measure IPM adoption, however, is not the focus of this paper. Nonetheless, it would be an omission not to at least mention these issues while describing practical considerations in addressing barriers to IPM adoption. It would be difficult to know if a barrier exists or has been overcome unless one also measures the adoption process.

Measuring adoption of IPM practices can occur at four different levels of measurement, each of which has its own advantages and disadvantages. These measures are not mutually exclusive, but are sequential and cumulative. That is, one has to move through the lower levels of measurement to obtain higher levels of measurement.

Measuring Adoption with Accounting Measures implies the use of many of the traditional methods used to count audience response to programming efforts. Counting the number of individuals who participate in a program, who receive a newsletter or other educational material, or who show up at field days or demonstrations are all examples of the accounting method of measuring adoption. This is the simplest measure of adoption but is also the lowest in terms of validity and reliability. The only weaker measure known is the “wild guess” relative to adoption rates.

Measuring Adoption with Proportional Measures is perhaps the most common method used in formal studies. Individuals are asked if they are using certain practices or engaging in specified behaviors. These dichotomous responses (e.g., yes or no) are then statistically manipulated in one of three ways: (1) Individuals are classified as adopters or nonadopters of IPM based on the proportion of yes to no answers; (2) Individuals are classified as to the level of IPM use according to some ordinal scale of measurement (e.g., low, medium, or high), again based on the proportion of practices used that are judged to be critical to IPM; or (3) the extent of IPM adoption is calculated by determining the proportion of applicable acres on which the salient behaviors are applied (e.g., individual is using IPM on 68 percent of all corn acres).

Measuring Adoption with Accuracy-in-Use Measures attempts to account for the appropriateness of the salient behaviors. This level involves some measure of the ecological setting of the adoption behavior as well as the timing of the behavior. For example, spot spraying a postemergent herbicide at reduced rates may be an appropriate IPM behavior depending on weed composition and pressure. This level of measurement involves measuring features about the pest population within site-specific settings and then comparing actual pest control behaviors relative to recommended behaviors before making a judgment on IPM adoption. The phrase "accuracy-in-use" can be used to describe this method. It implies that adoption is more than simply engaging in a certain behavior, that the precision or accuracy of that behavior relative to pest conditions should dictate how IPM is being used. This method differs from the proportional measure of adoption in that it also accounts for the nature and level of pest pressure or for the risk of significant crop damage if inappropriate actions are taken. This latter factor is especially important in high-value horticultural crops.

Measuring Adoption with Distributional Measures is the most complex in that it incorporates both the spatial and temporal dimensions of the behaviors. It is an ecologically based measure of adoption in that determining which behaviors can be classified as IPM is dependent on pest dynamics across space and time (not limited to a field/grove or a particular period during the production process). Spatial patterns of pest dynamics (e.g., life cycles and mobility patterns) are examined to determine appropriate behaviors at particular points in time. IPM is based on landscape assessments of habitat conducive to pests, the distribution of agricultural practices, and efforts to model pest dynamics within this setting. Intervention strategies are designed on the basis of this system or holistic analysis. While no studies could be found that used this level of adoption measurement, the advent of spatial position and digitizing technologies should facilitate the development of this method.

The advantages and disadvantages of these four levels of measurement are summarized in table 1. Other comparative dimensions could have been selected, but the objective was to provide a broad overview of each of these methods within the context of an IPM program. The intent is to illustrate the resulting differences as one moves across the levels of IPM measurement.

Barriers to IPM Adoption

There is a need to abandon the stereotype that adoption of IPM occurs among "progressive" producers while nonadopters are "laggards" or "traditional" farmers. Basing the rationale for the nonadoption decision on psychological characterizations of the target audience is inaccurate, nonproductive, and not supported by the research literature. The dominant theme of the following material is that producers often have very good reasons for why they are either unwilling or unable to adopt IPM recommendations. Rather than "blaming" these individuals for their nonadoption decision, more effort needs to be spent on assessing why this outcome occurs. Those promoting IPM practices need to recognize that growers frequently have very good and rational reasons for rejecting IPM recommendations. These reasons, in light of the title of this paper, can be called barriers to IPM adoption. Understanding the distribution and strength of these barriers among target audiences is the basis for accelerating the adoption of IPM practices.

Farmers do not adopt IPM practices for two basic reasons; they are unable or unwilling. These reasons are not mutually exclusive. Farmers can be able yet unwilling, willing but unable, and of course both unwilling and unable. These may sound like minor semantic distinctions, but the difference between a farmer being unwilling or unable is crucial when designing the appropriate remedial strategy. Accelerating the adoption of an IPM practice must be based on understanding why farmers are rejecting these technologies and recommendations. Are they unable, unwilling, or both?

Barriers: Being Unable to Adopt an IPM technique implies presence of an obstacle or situation where the decision not to adopt is rational and correct. The farmer is making a sound decision in rejecting an IPM practice because of this obstacle. The important point is that the farmer may be willing to adopt the practices, but for one

Table 1. Comparative Analysis of Different Measures of IPM Adoption

	Accounting	Proportional	Accuracy-in-Use	Distributional
Measurement issue	Any indicator of program participation	Dichotomous measure of IPM use or extent of use across applicable areas	When and how specific practices are used while accounting for appropriateness of action	Where specific practices are being used as defined by geographical or biological parameters
Unit of measurement	Individual	Number of practices used or percent of crop acres	Difference between actual use and recommended use	Spatial pattern (polygon) of use in a landscape
Cost	Low	Moderate	Moderate to high	Moderate to high
Ease of use	Easy	Moderate	Complex	Complex
Utility	Low for program justification and evaluation of effectiveness	Adequate to estimate level or extent of adoption of specific practices	Good for targeting to increase efficiency of an IPM program	Good for targeting to increase effectiveness of IPM programs
Validity	Low	Moderate	High	High
Sample frame	None: count program participants	Usually random sample	Random; population of targeted area; stratified or proportionate by IPM user	Spatial sampling based on geographical or ecological features
Required disciplinary mix	None, any discipline can manage	Typical leadership by one discipline with cooperation of other sciences	Multidisciplinary with complementary responsibilities among social and biological sciences	Interdisciplinary with issues and methods being developed concur-rently

or more of the following nine reasons is unable to make this decision. Each reason for inability to adopt is followed by a brief summary of the appropriate remedial strategy.

Information Lacking or Scarce. A farmer may be unable to adopt a practice because some of the basic information needed for a sound economic and agronomic analysis is missing. *Remedial Strategy: develop and distribute the necessary information to those needing it.*

High Cost of Obtaining Information. Even in our highly touted information age, the time, expense, and difficulty of obtaining site-specific information may be too high. Contrary to common belief, obtaining relevant information is not free to the farmer. *Remedial Strategy: increase accessibility and ease of obtaining the basic information for those needing it.*

Production System Too Complex with IPM. A defining characteristic of any production technique is its simplicity or ease of use. There is an extensive research literature that shows the complexity of a technology is inversely related to the rate and degree of adoption. *Remedial Strategy: redesign and simplify the IPM recom-mendations or encourage incremental adoption*.

IPM Practice Too Expensive. Investment, costs, and influence on net returns are major concerns of today's commercial farmer. Systems must be agro-nomically sound and have an affordable price tag. *Remedial Strategy: subsidize the adoption decision or redesign a less expensive system*.

Excessive Quantity or Quality of Labor Requirements. Land, labor, and capital still determine the nature of the farm firm. The labor requirements associated with an IPM technique must be perceived as commensurate with the capabilities of the farm firm. *Remedial Strategy: redesign the IPM technique to reduce labor requirements or subsidize the hiring of adequate labor*.

Too Short a Planning Horizon to Begin the Adoption Process. An IPM practice may be rejected by a farm firm because of the current planning horizon relative to the time associated with recouping initial investments, learning costs, or depreciation of capital investments. Many of today's farmers will not be farming in two or three years because of retirement and other transitional forces. Their making a long-term investment within the context of a short planning horizon is not logical. *Remedial Strategy: redesign the system for incremental adoption or subsidize a short-term unprofitable decision.*

Limited Availability and Accessibility of Supporting Resources. Few farmers adopt a new production or IPM practice without significant support. This support can take the form of local crop consultants or agrichemical dealers willing to take the risk of supporting practices not currently being used in their trade area, other farmers using these practices who are willing to share both successes and failures, and a USDA research and assistance network capable of answering farmer questions. *Remedial Strategy: build the capacity of local assistance networks to meet local demands. Target the development of local assistance networks in the areas needing them the most. Develop methods to promote IPM practices on the basis of need, not the ability to pay or past cooperator status.*

Inadequate Managerial Skills. As in the case of the physical resource base they manage, there is tremendous diversity among farmers. One dimension of this diversity is managerial skill. Too often IPM practices are designed for the average or above-average manager. Local assistance networks are also oriented to this group of farmers because of the performance and evaluation systems used in USDA. All this can create a situation where farmers with less-than-average management capabilities receive little or no assistance to build these skills. *Remedial Strategy: focus assistance and skill-building opportunities on those farmers needing them the most, not just the most receptive.*

Little or No Control over the Adoption Decision. It is common to view the farmer as some independent decision maker who "calls all the shots." The farmer, therefore, becomes the focal point of most efforts to transfer new practices. In many situations, however, a decision cannot be made without the approval of a partner, source of financial credit, landlord, or some other third party. These other interests must be convinced of the merits of an IPM technique. *Remedial Strategy: Determine who can make or has significant influence on adoption decisions and focus efforts on those persons or organizations. Also, recognize that an adoption decision is often a family decision, and therefore persuasion efforts need to address relevant family members.*

Barriers: Being Unwilling to Adopt an IPM practice implies that the farmer has not been persuaded that the practice will work or is appropriate for the farm operation. There are a number of reasons why this persuasion does not occur. Again, as in the case of the inability to adopt, many of these situations are beyond the farmer's control. Therefore, the farmer is making a correct decision in rejecting the practice. Until the correct form of persuasion is offered to the farmer, this land manager will remain unwilling to adopt. Six reasons for being unwilling to adopt with a synopsis of appropriate remedial strategies follow.

Information Conflicts or Inconsistency. A farmer may be unwilling to adopt an IPM practice because of inconsistency or even outright conflicts in the information about the practice. A farmer may hear that a IPM practice will increase labor requirements, increase risk, or narrow windows of opportunity to accomplish certain tasks. The farmer may also hear about the experiences of another local farmer who claims it requires less labor, does not influence risk, and has no influence on timing of activities. These types of divergent messages must be resolved in the farmer's mind. *Remedial Strategy: work to develop a consistent information base. Where legitimate differences exist, offer explanations of these differences*.

Poor Applicability and Relevance of Information. To make a sound decision, farmers need information that is applicable and relevant to their farms. Data from a neighboring state or even across the county may be judged as not meeting local conditions. To be convincing, these data must be adapted and made available relative to local situations. *Remedial Strategy: develop and distribute relevant information on a local basis.*

Inconsistencies Between Current Production Practices and the IPM Procedures. IPM practices do not always easily fit into existing production systems. In these cases, the general expectation has been that the farmer will adapt operations to meet the adoption requirements of the IPM practice. This case can be contrasted with a situation where a flexible technology is designed so that it can be adapted to fit into a farmer's operation. *Remedial Strategy: develop flexible IPM practices capable of being altered to meet unique farm conditions*.

Ignorance on the Part of the Farmer or Promoter of the IPM Practices. Ignorance is not a pejorative term. Instead, it implies a situation where an individual has not had the opportunity to learn. This ignorance could be surrounding the basic economic and agronomic facts of the IPM practice, or for change agents it could be a lack of sensitivity to the basic needs of a potential adopter. *Remedial Strategy: determine the actual (and not the assumed) assistance needs of the target audience; then design education and assistance programs based on farmers' needs, not agency or business expertise*.

Increased Risk (Real or Perceived) of Negative Outcomes. An IPM practice can increase the probability of a negative outcome in many ways. The complexity of a practice or system into which it is incorporated, importance of the timeliness of operations, and the interdependence of inputs can all increase perceived or real uncertainty and risk. Some farmers are simply unwilling to make a major decision under conditions of uncertainty, or where there is significant risk. *Remedial Strategy: redesign the IPM practice or address risk in two basic ways; either increase information so probabilistic outcomes can be calculated, or subsidize the farmer to take a risk.*

Belief in Traditional Practices. Although we often scorn traditional beliefs and practices in agriculture, let us not forget that those "traditional" farmers continue to survive in today's competitive environment while thousands of their "innovative" or "progressive" neighbors have gone out of business. Some farmers are unwilling to change because those traditional practices represent the least risk in dynamic agricultural markets. *Remedial Strategy: demonstrate not only that the new way (use of IPM practices) is better than the old way but also that the new way does not increase risk for the farm operation*.

Putting It All Together: Assessment and Targeting to Accelerate the Adoption of IPM

One can make at least three general observations from the foregoing lists of why farmers are either unable or unwilling to adopt IPM practices. First, increasing the adoption of IPM practices is dependent on first addressing reasons why farmers are unable to adopt. Once these impediments are removed, then it is a question of persuading the farmer from being unwilling to adopt.

Second, many of the factors causing farmers to be unable or unwilling to adopt are beyond their control. Blaming the farmer for not adopting IPM practices is not only erroneous in many cases, it is also hypocritical. Instead of always focusing on the farmer, more attention needs to be given to our efforts in understanding and addressing the many reasons why farmers are unwilling or unable to adopt. In many cases it is not so much a "farmer failure" as it is a "system failure."

Third, broad-scale use of any one or even several of the remedial strategies suggested is doomed to failure. A “shotgun” approach to using technical, financial, or educational assistance is not the answer. Instead, considerably more effort needs to be spent trying to understand the reasons why a farmer may be unable or unwilling to adopt. Based on spatial distributions of those reasons, one should be able to target specific types of assistance in a format compatible with the capabilities of the target groups. The promotional strategies that worked for the early adopters will not be as effective with later adopters. If we want accelerated rates of adoption for IPM practices, then we must be as willing to accept new ideas and methods as we expect potential adopters to be.

One final observation is relevant to this topic. During the past 50 years, we have seen tremendous shifts in the structure of our agricultural system, significant gains in the science of detecting and explaining natural-resource problems, and extensive advances in both resource-management policy and the IPM practices supported by these programs. But despite all these advances, we are still in the “horse and buggy” days of understanding and meeting farmers’ needs as defined by the farmer. Instead of using the sophisticated communication campaigns and marketing strategies commonplace in agriculture's private sector, we continue to rely on crude “educate, regulate, or bribe” tactics. Unless we begin to spend a little more time and effort trying to understand all the complex reasons why farmers are unable or unwilling to adopt, our aspirations for wide-scale adoption of IPM practices are destined to fail.

Social Influences on and Impacts of IPM

Building public support for integrated pest management (IPM) is essential. On the one hand, farmers need information and motivation to adopt IPM practices. On the other hand, public officials and citizens need to better understand and support farmers’ efforts to produce food with reduced chemical inputs. It is also important to anticipate and manage the social impacts of new farming practices, such as those associated with IPM.

In this section of the paper, we provide IPM professionals and others with three kinds of information and strategies that will make it easier to work effectively with a wide range of groups and individuals. First, we discuss how to build productive IPM partnerships. Second, we present proven techniques for managing conflicts, building consensus, and improving communication. Finally, guidelines are provided for assessing and managing the social impacts of IPM.

IPM professionals work within a larger community that includes colleagues from other disciplines, as well as a range of stakeholder groups. You need to understand the people, politics, and institutions in your community. Formal organizations, such as government agencies, bring individuals together to pursue goals they cannot achieve alone. Less formal groups also permeate a community. These include political leaders, community organizations, the media, and other stakeholders. Stakeholders include any individuals or groups who have an interest in or will in some way be affected by your IPM efforts. Farmers, environmental groups, government agencies, farm businesses, and recreational users are examples of stakeholders. Social customs and cultural values also influence IPM acceptance.

Several broader societal trends may influence IPM efforts. One important social trend involves shifting demographics, including urbanization (Hoban 1994). Most people today have little understanding of or appreciation for agricultural issues and problems. Political power and influence continue to shift away from the agricultural community toward nonfarm interests. The farm sector is expected to produce a cheap and abundant supply of food while reducing the use of chem-icals, water, and land. On a related point, as people move from urban to rural areas, conflicts can arise over issues like pesticide use, livestock waste, and other perceived risks. How the agricultural sector responds to these and other social issues will influence future policies and programs.

Another important trend is the development of broad-based and strong public support for environmental quality (Dunlap and Catton 1979). A profound societal shift has occurred in people's views about the environment (Buttel 1987). Most people now hold an environmental world view and have values that will support IPM. The public has grown more concerned about environmental and food-safety risks (Hoban 1991). People are demanding a greater voice in decisions about risk management. The public wants a risk-free world. Most people rely on intuitive risk judgments (typically called risk perceptions) rather than on scientific data. Their information comes largely from the media. People are also very concerned about indirect risks, such as impacts on quality of life, property values, and future generations. Because many influential political leaders have the same perceptions as other citizens, political decisions are often made on subjective grounds, as well.

Building IPM Partnerships

The human or "people" aspects of IPM have an important influence on the success of your efforts. Successful IPM requires partnerships among a number of different individuals, groups, and organizations. Through partnerships, people and organizations work together cooperatively toward a common goal. Partnerships allow for local development and ownership of solutions, which can heighten community support for IPM.

Farmers and landowners are vitally important because that is where the action takes place. Local businesses (including input dealers, banks, and consultants) influence adoption of IPM. Various government agencies provide information, as well as technical and financial assistance. They also have expertise in farm planning and management. Local elected officials are also vitally important because they provide political support. Other partners, including the media and teachers, can help with education and information efforts.

Partnerships are the backbone of effective natural-resource management (Hoban 1992). Partnerships can result in more efficient use of staff and financial resources. Partnerships foster a spirit of collaboration and cooperation. They can promote fairness and minimize the potential for negative social and economic impacts. Most importantly, partnerships lead to more creative and acceptable ways to protect natural resources. This is particularly true when a broad range of disciplines are involved with IPM efforts.

Partnerships do have some disadvantages. It takes time and skill to create successful partnerships. Maintaining motivation and enthusiasm is another challenge, especially if results do not happen quickly. You need to identify all the relevant stakeholders, then persuade these partners that their efforts are needed. As you build local partnerships, you will encounter these and other challenges. Keep in mind, however, that the benefits of partnerships will usually far outweigh the disadvantages.

Approaching Partnerships Positively. Success depends on involving the right mix of people and organizations in your partnership (Buckholz and Roth 1987). You will need to find people to play a number of roles. Some partners will need to have technical expertise. Some will need coordination and communication skills. It also will help if some partners have political connections or public-policy expertise. As you look around your community, you will find a number of different private and public groups who have a stake in the farming community and/or the environment. Each situation is unique. It is possible to outline several approaches that have been identified for building team performance (Katzenbach and Smith 1993).

- Select partners based on skills, not personalities. Your partnership will need technical, problem-solving, and interpersonal skills. Find the right people, and the partnership will be a success. It will also be important that partners have a spirit of cooperation.

- Establish a sense of urgency and direction. All partners need to believe in a worthwhile purpose. They also want to know what is expected of them. This will build commitment to the partnership and promote success.
- Set ground rules. You will need to set expectations related to meeting attendance, constructive feedback, and other expected contributions. Such rules encourage commitment, cooperation, and trust.

- Start with short-term tasks that have a good chance for success. First impressions mean a lot.

Be sure early projects are realistic and will be "winners." This will build confidence and positive momentum for your partnership.

- Challenge the group regularly with fresh information. New information that you will be gathering as a partnership will help to better understand your situation and improve your effectiveness. New facts often motivate people to action.

- Spend enough time together. It will take time to get your partnership working effectively. Spend time (outside of meetings if possible) to get to know each other and become more comfortable working as a partnership.

Building Consensus Among Partners. Partnerships work best with consensus decision making. The consensus approach offers a number of advantages (Carpenter 1990). First, it helps individuals learn about each other and gain new insights about important issues. Second, consensus decisions are generally better because they reflect the concerns of all parties involved. Third, when people have worked together to understand issues and develop solutions, the outcome is much more acceptable. Fourth, consensus usually leads to faster implementation of decisions (once they are reached) because resistance will be lower. Finally, the consensus process has the longer term benefit of building trust among the partners. The consensus process is most appropriate when issues are complex and negotiable (Susskind and Cruikshank 1987). Effective consensus decisions share the following characteristics:

- Participation is inclusive. All major interests are identified and brought together.

- Participants educate each other. They spend time discussing the history of the issue, their perceptions and concerns, and ideas for solutions. They help plan activities and offer suggestions to make them more effective.

- A common definition of the problem is used. Participants discuss and agree on a constructive definition of the problem.

- Multiple options are identified. Participants seek a range of options to satisfy their respective concerns and avoid pushing single positions.

- Decisions are made by mutual agreement. Participants do not vote; but modify options until everyone agrees that the best decision has been reached.

- Participants are responsible for action. They identify methods for implementing solutions and then work together to promote and monitor implementation.

Obstacles to Partnerships. Despite the best intentions, partnerships are often difficult to establish and maintain (Scholtes and Associates 1988). It is important to recognize and overcome obstacles to partnerships (Hoban 1992a).

- They lack time or other resources. The people in the partnership will also have other commitments. They may view group activities as an unimportant use of their time. Related to this may be other real or perceived costs of partnerships.

- Levels of commitment or interest are low. This can happen if the effort gets bogged down or members are not given enough interesting tasks to do along the way. It also reflects the fact that some members give joint efforts low priority.

- Individualism and elitism is evident. In many respects the idea of working together is contrary to our cultural beliefs in self-sufficiency and competition. People tend to feel it is a sign of strength to be able to solve their own problems. Some people or organizations seem to have one way of doing things and are unable to adapt to change.

- Concern is expressed about loss of autonomy or recognition. People (especially those who represent organizations) worry that partnerships mean a loss of freedom or control over their own activities. Some also worry they may not get enough credit for the work they do within a partnership.

- Goals or missions conflict. Partnerships generally involve diversity in members, including private businesses, public agencies, and citizen groups. These different organizations can have different goals and expectations for the partnership. In fact, some see partnerships mainly as a way to pursue their own agenda.

- Some participants dominate or feuds break out. Some members (often those with authority or expertise) have too much influence over a partnership. Such "experts" can discourage discussion or criticize others' ideas. Partnerships can become battlefields for individuals who have their own feuds or past problems.

Leadership and Coordination

Effective partnerships do not just happen. They depend on coordinators or leaders that emerge from the group (Morrison 1994). As an IPM professional, you may need or want to serve in such a role. Coordinators play some of the same roles as a traditional leader. They do not, however, assume the same control or responsibility as a formal leader. Effective coordinators have a number of important responsibilities. They generally catalyze activities and keep the partnership moving. The coordinator handles, or asks someone to handle, administrative responsibilities (such as preparing reports). This includes calling and conducting meetings.

Effective coordinators have certain characteristics (Scholtes and Associates 1988). They are interested in the group's issues or concerns. Coordinators understand and are sensitive to the social and political situation. Good communication and group interaction skills are also important. Effective coordinators are respected as knowledgeable and fair. They are also able to share responsibility and credit with others in the partnership. Coordinators can help promote compromise and make trade-offs. Good coordinators should be patient, creative, and flexible.

Effective Coordination. Partnerships rely on a skilled coordinator to get the partnership started and to keep it moving. Coordinators should serve as catalysts for the group's decisions and actions. They should not, however, make decisions for the group. This neutral role implies six leadership qualities that are helpful for effective coordination (Katzenbach and Smith 1993):

- Keep the purpose, goals, and approach relevant and meaningful. Coordinators should use their own skills and perspectives to help members of the partnership determine, clarify, and commit to the group's goals. They can inspire appropriate actions, but should not try to move the partnership in any particular direction.

- Build commitment and confidence. The coordinator must understand and try to balance the needs and interests of both individuals and the overall partnership. Positive and constructive feedback helps make the partnership more successful.

- Strengthen the mix and level of skill. Effective coordinators recognize and build on the strengths and skills of individual members of the partnership. Effective partnerships depend on having an appropriate balance of technical, interpersonal, and other skills. The coordinator ensures that all the necessary skills are available for the partnership.

- Manage relationships with outsiders, including removing obstacles. To be effective, partnerships often interact with other groups in the local area. Coordinators often have the responsibility of ensuring that the important external relationships are developed and maintained. Such responsibility may be shared with other members of the partnership.

- Create opportunities for others. Coordinators should not try to do everything themselves. They must provide opportunities for individuals if the partnership is to grow and work effectively. This involves attention to empowerment and delegation.

Understanding Communication. Partnerships are built upon open and ongoing communication (Hoban 1992b). To truly communicate, people must come to a shared understanding. Communication is a two-way process; listening is just as important as speaking. Communication is a skill that can be improved. The following are some general strategies for improving communication with others in your partnership (Williams 1983):

- Look for common ground. Find shared values. Consider shared personal experiences. Be willing to accept differences in perceptions and opinions.

- Find out about others. Learn about others' interests and needs. Consider their perspectives. Let others express themselves freely.

- Attack problems, not people. Do not waste time on personal hostility. Make other people feel good. Avoid criticism and put-downs.

- Give and get respect. Show respect for others' opinions. Put yourself in the other person's shoes. Be responsive to emotions. Speak with confidence, but remain tactful.

- Be explicit and clear. Share your ideas and feelings. Pay attention to nonverbal communication. Select words that have meaning for your listener.

- Proceed slowly. Present one idea at a time. Check for understanding and acceptance of each idea before moving on to the next. Speak in an organized and logical sequence.

- Use the five "Cs" of communication: clarity, completeness, conciseness, concreteness, and correctness.

Understanding Conflict

Most of us experience conflict. Conflicts result from diversity within our society (Susskind and Cruikshank 1987). Individuals and groups differ in their attitudes, beliefs, values, and needs. Conflicts can arise because people perceive shortages of important natural or social resources. Conflicts also arise out of past rivalries and personality differences. Conflict is a natural process that is not always negative (Carpenter and Kennedy 1988). In fact, conflict can even be healthy if it is effectively managed. Conflict provides opportunities for growth and innovation. Also, conflicts may indicate that timing is not yet right for a decision or that additional information is needed.

Conflict management is successful when parties come to a resolution that meets both individual and group needs (Fisher et al. 1991). Successful conflict management and negotiation aim toward achieving consensus. The goal is for all parties to "win" by having at least some of their needs met. Most of us have experience with conflict management and negotiation in private disputes (for example with a salesman over the price of a product, among family members, or with our employer). Public conflicts that may arise from issues (such as environmental quality) are like private disputes, but are also different in several important respects (Carpenter and Kennedy 1988). They generally involve a complicated network of interests and a complex set of issues. Also, procedures for resolving public conflicts are not as standardized.

Ingredients of Conflicts. Conflicts often result because people are different. In dealing effectively with conflict, the best approach is to understand and build on the differences to come up with new ideas. Differences may lead to conflict in several areas (Weeks 1992):

- Needs: Needs are essential to our well-being. Conflicts arise when we ignore others' needs, our own needs, or group needs. Conflicts may also arise when our ability to meet needs is blocked by another person or outside situation.

- Perceptions: People interpret reality differently. They have different perceptions of the severity, causes, and consequences of problems. Conflicts arise from misperceptions or different perceptions.
- Power: How people define and use power has an important influence on the number and types of conflicts they have, as well as what methods they use to manage conflict. Serious conflicts arise when people use power to gain an unfair advantage.

- Values: Values are beliefs or principles we consider to be very important. Serious conflicts arise when people hold incompatible values.

Conflicts also arise when one party refuses to accept that the other party holds something as a value rather than a preference.

- Feelings and emotions: Many people let their feelings and emotions become a major influence over how they deal with conflict. Conflicts also arise because people ignore others' feelings and emotions.

Analyzing Conflicts. Before you attempt to manage conflict, it is important to analyze the nature and type of conflict you are dealing with (Carpenter and Kennedy 1988). The following sets of questions focus on the parties involved, the substance of the conflict, and possible ways to manage conflict:

- The parties involved: Who are the parties involved with the conflict? How are the parties organized, and what is their power base? Are the parties capable of working together? What are the historical relationships among the parties?

- The substance of the issue(s): How did the conflict arise? How are the main and secondary issues described? Are the issues negotiable? Have positions been taken, and if so, are there common interests? What information is available, and what other information is needed? What values or interests are challenged?

- Possible procedures for conflict management: Would consensus serve all parties? Are there external constraints or other influences that must be accommodated? What are the past experiences (if any) of the parties in working together? What is the time line for a decision? Will an outside negotiator be needed?

Conflict Management. Once you have a general understanding of the conflict, you can consider several alternatives for dealing with the conflict. There are five basic strategies for managing conflict (Dotson, et al. 1989). Each has its own appropriate uses and inherent problems.

- Competition involves high concern for one's own interests with less concern for the other parties. The outcome is "win/lose." This is a common approach that includes most attempts at bargaining. Competition is generally used when basic rights are at stake. Unfortunately, the conflict can often escalate, and losers may try to retaliate.

- Collaboration involves a high concern for one's own interests, matched with a high concern for the interests of the other parties. The outcome is "win/win." Collaboration is generally used when concerns for others are important. It is also generally the best strategy when the public interest is at stake. This approach also helps build commitment and reduce bad feelings. The drawbacks are that it takes time and energy. Also, parties may take advantage of the others' trust and openness.

- Compromise involves a high concern for one's own interests along with a moderate concern for the interests of other parties. The outcome is "win some/lose some." Compromise is generally used to achieve temporary solutions, to avoid destructive power struggles, or when time pressures exist. The drawbacks are that parties can lose sight of important values and long-term objectives. This approach can distract the parties from the merits of an issue and also create a cynical climate.

- Accommodation involves a low concern for one's own interests combined with a high concern for the interests of other parties. The outcome is "lose/win." Accommodation is generally used when the issue is more important to others than to you. It represents a "good will gesture." It is also appropriate when you recognize that you are wrong or outmatched by the other parties. The drawbacks are that your own ideas and concerns do not get attention. You may also lose credibility and future influence.

- Avoidance involves a low concern for one's own interests coupled with a low concern for the interests of other parties. The outcome is "lose/lose." Avoidance is generally used when the issue is trivial. It is also helpful when confrontation has the high potential for damage or more information is needed. The drawbacks are that important decisions may be made by default or not at all.

Social-Impact Assessment

Social-impact assessment (SIA) is an important tool for identifying and balancing different interests in a political climate. Freudenburg (1986) points out that SIA is a hybrid offspring of science and the political process. It emerged in response to society's increased concern over environmental degradation and the social consequences of change. Dietz (1986) defines SIA as the identification, analysis, and evaluation of social impacts resulting from a particular action. A social impact is a significant improvement or deterioration in people's well-being or a significant change in an aspect of community concern.

SIA can be particularly appropriate for dealing with conflicts where different groups hold competing values and incompatible interests related to the use of natural resources. Conflicts can arise in any situation where some groups or individuals benefit at the expense of other groups. Since those who benefit from a proposed action are often different from those who pay the associated costs, problems of equity arise (Wolf 1983). As Hester and Cortner (1983) explain, there is nothing new about conflict in natural-resource management. What is new is that resource conflicts are moving more into the local arena, conflicts are more intense and frequent, and most resource managers have not dealt with such conflicts.

SIA can promote conflict resolution by illuminating how benefits and costs will be distributed among various groups. SIA can help ensure that benefits and costs are more fairly distributed. To understand where resource-related conflicts may occur information is needed about: the interests most likely to be involved, the strategies these interests may use to push forward their positions; and the impacts of such conflicts on public agencies and other stakeholders (Hester and Cortner 1983).

Social-Impact-Assessment Processes. Identification of impacts requires imagination, creative thinking, and an understanding of the people being impacted (Dietz 1986). During the analysis, probabilities are assigned to possible impacts, with the use of quantitative and qualitative data, as appropriate. Finally, evaluation integrates the information from the identification and analysis stages into an overall image of the impacts resulting from the proposed action. By nature, SIA should be future-oriented by anticipating consequences before they occur. Future-oriented research allows some chance to mitigate negative impacts and to reduce conflicts among groups. Explicit comparisons are made between conditions as they are likely to be with and without a proposed action (e.g., a new policy, program, technology, or project).

Bryan and Hendee (1983) explain that SIA estimates how proposed policies, programs, or practices will affect people's lives. The goal is to help managers make better decisions. They provide some general principles as a useful framework for SIA:

- Focus on major concerns and issues identified through public participation, talking with local leaders, expert opinion, and experience in similar situations. Collect information on variables that accurately represent the identified issues and concerns. Recognize that social impacts can be positive or negative depending on the context in which they are viewed.

- Note that social effects can be direct or indirect. Investigation of social consequences should include immediate impacts, as well as indirect effects that may be subtle, but important. The appropriate methods and approaches for SIA will vary with the kinds and level of impacts anticipated. Flexibility is needed in the variables used, populations sampled, and geographic areas covered. Methods used to project, compare, display, and disseminate results should reflect the anticipated impacts. The area analyzed may vary with the proposed action and the social effects being evaluated. Before collecting original data, use all existing databases from various governmental agencies, media accounts, research reports, and direct observation. Given limited time, money, and staff, the general idea is often to gather as little new data as necessary.

- The format for reporting SIA depends on what is found. An interdisciplinary team should interpret the significance of identified social impacts.

Decisions can then be made as to the type and level of public participation in decision making.

- Social impacts may be subtle. The cumulative effects of individual management policies and practices may be very large. Communities adjust to change and adapt to social impacts, thus providing a continuing change in baseline conditions.

Types of Social Impacts. The first task of SIA is to define the key variables of interest. It is important to have a rationale as to why each is included in the analysis. The kinds of impacts that should be considered in a given SIA depend on the policy, program, or practice being considered (Dietz 1986). Strategies for measuring the major concepts and collecting the data are also important considerations. This section will summarize those that are most relevant for SIA of integrated pest management.

Not all groups or individuals are equally affected by a particular action. Schnaiberg (1980) stresses the importance of focusing on distributional impacts. Differential impacts occur because different people are affected in different ways at different times. Some groups lose, others gain, and most others fall somewhere in between (i.e., gaining in some ways, but losing in others). In fact, many people may be relatively unaffected by a particular action or non-action. Impacts must be broken out by location, income, occupation, ethnicity, and other features of groups who are disproportionately affected. Researchers need to focus on how actions redistribute resources, wealth, and/or negative impacts among communities, groups, and individuals (Freudenburg 1986).

Impacts can also be grouped according to the social unit or area affected by the action. Many proposed actions have limited impacts on the nation as a whole, but tend to have significant impacts on local communities (Dietz 1986). Different groups of individuals within a limited area will also be affected differently. Impacts can also be distinguished based on how direct or immediate their consequences are for the affected groups. Direct impacts are easier to identify and measure than indirect impacts, which often result from the direct impacts. Likewise, impacts can be seen as relatively short-term or long-term in their effects.

Social impacts vary in terms of objective visibility to the affected populations (Dietz 1986). Subjective impacts are those that are perceived by and of concern to those who are affected. It does not matter whether an outside "objective" analyst finds these impacts of major concern. Objective impacts, on the other hand, are considered significant by the outside analyst, whether or not such impacts are of concern to those groups or individuals directly affected. An effective SIA must identify, analyze, and evaluate both objective and subjective impacts.

A variety of impacts need to be considered in relationship to any changes in policies, programs, or practices. Conditions or impacts that are considered in a given SIA vary with the nature of the proposed action(s). In most cases, the main dependent variable for SIA should be changes in the overall quality of life as experienced by the impacted groups. Social variables, however, have generally been given less attention than economic factors. Social variables are not always recognized as important by decisionmakers (Freudenburg 1986).

Social-Impact-Assessment Methodology. The goal of SIA is to predict and evaluate the full range of social impacts before they occur. According to Wolf (1983) the "bottom line" question is "Who benefits, and who loses if a proposed action were to be implemented?" SIA is, in fact, a multimethod approach that requires researchers to draw selectively from the full range of social-science methods and techniques. Each situation has unique features that require careful selection of appropriate SIA methodologies. Most forms of social-science research can and have been applied to SIA. The relevance of two commonly used techniques will be described: expert-opinion panels and opinion surveys.

To determine the scope and significance of impacts, it is often helpful to tap the knowledge and interest of those most qualified and willing to lend their insight. Structured group processes (such as focus groups) can be used to identify, analyze, and evaluate both subjective and objective impacts (Dietz 1986). Such panels tend to be relatively inexpensive, flexible, and productive. Panels should include technical experts, social scientists, and individuals familiar with the concerns of the various impacted groups. Panels can set priorities for focusing scarce resources (time and money) on the most important types of impacts.

Survey research is a common element of most SIAs. Surveys provide insights into the beliefs, attitudes, and values of various groups regarding a policy, program, or practice under consideration. Values and attitudes represent important data for understanding and evaluating social impacts. How people perceive impacts can be at least as important as the actual impacts. Finsterbusch (1983) explains that surveys provide not only self-reported facts about respondents but also their inner feelings, attitudes, and opinions that cannot be systematically determined in any other way. Decisionmakers need to understand what people like and dislike, as well as how they will respond to alternative actions. Surveys can help establish priorities and assess attitudes toward alternatives. Information can be obtained about community needs and concerns, as well.

Conclusion

It is critical to remember that SIA takes place within political, social, and economic contexts. Interest groups will try to influence the course of SIA efforts and shape the action under investigation. Timing will, therefore, be of critical importance in effective SIA. There are several considerations in ensuring that SIA is included at the right point in the planning process so it can actually influence decisions (Dietz 1986). SIA should be used to identify key impacts at the beginning of the process. Next, SIA should be used to formulate alternative plans. Informal procedures can be very useful in improving plans. Once a set of policies and plans emerges, SIA can help evaluate and judge the proposals.

Integrated pest management efforts will sometimes encounter existing conflicts or even create conflicts among various stakeholders. Such conflicts have a number of important characteristics. They often involve issues about the distribution of costs and benefits. The individuals or groups who benefit from IPM may not be the same as those who pay the costs of changing practices. Natural-resource conflicts are often portrayed in terms of environmental protection versus economic benefits. Keep in mind, however, that IPM can result in both economic and environmental benefits.

Through partnerships and communication, conflicts can be managed so that all sides have at least some of their interests met. IPM professionals need to work with social scientists to better understand the perceptions, needs, and practices of producers. Such interdisciplinary partnerships can also foster more creative, effective, and equitable approaches to IPM planning, implementation, and evaluation.

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Assessing IPM Impacts: Summaries of Selected Papers

Session 1: IPM Adoption: Obstacles, Incentives, and Measurement

Introduction

The Clinton Administration's goal of achieving adoption of IPM practices on 75 percent of crop acreage by the year 2000 has focused new attention on measuring and evaluating the extent and impact of IPM adoption in the United States. Lack of consensus on what constitutes a core set of IPM practices along with data-availability problems have been major obstacles in measuring IPM adoption. The significant crop and regional variation in recommended IPM practices has frequently not been captured in past adoption studies, which often used a standardized list of practices to measure adoption. In addition, the introduction of new production technologies and practices, especially biointensive ones, will require changes in recommended IPM systems that may limit the usefulness of measuring the adoption of specific practices. Moving beyond simple measures of IPM adoption and impact is the focus of this selected-paper session.

Papers Presented

Carlson, Gerald A., and Michelle C. Marra, *The Role of Transgenic Crops in Future IPM Programs: An Economic Perspective,* Department of Agricultural and Resource Economics, North Carolina State University, Raleigh, N.C.

The authors of this paper examined the potential impact the adoption of transgenic crops may have on the adoption of IPM practices and techniques. The recent introduction of two transgenic crops [herbicide-tolerant crop varieties (HTCV) and crop seeds containing the natural insect toxin, *Bacillus thuringiensis* (B.t.)] could have a major impact on current soybean, corn, and cotton production practices. Because these new biotechnologies have the potential to significantly alter existing pesticide use (both quantity and product), increase yields, increase crop tolerance of certain herbicides (they will likely increase pest tolerance to B.t.), and change the use of other farm inputs (tillage practices, rotations, and insect and weed monitoring) their adoption could require significant changes in IPM systems and recommendations. The authors identified critical factors influencing adoption and diffusion of these new biotechnologies and related them to IPM-implementation projects dealing with the affected crops or regions. In their view, failure to account for the potential changes in production will result in IPM research and extension projects that are outmoded.

Coli, William M., and Margaret Christie, *Status Report on a Regional Project to Identify Barriers to and Opportunities for Greater Adoption of IPM,* Department of Entomology, University of Massachusetts, Amherst, Mass.

Coli and Christie provided details of an approach they used to develop site-specific definitions of IPM systems. This approach was used in the northeastern region of the United States to measure adoption of a suite of IPM systems for several important crops (apples, potatoes, strawberries, sweet corn, and spring bedding plants). The purpose of this multistate effort was to develop a scientifically valid approach for establishing a baseline; accurately capturing different degrees of adoption of IPM; and measuring environmental, public-health, and economic impacts. The process consisted of four steps: (1) describe IPM systems that are currently ready for adoption; (2) determine the extent of current IPM adoption with statistically valid techniques; (3) track important environmental, economic, or public-health variables and compare to the established baseline to estimate changes produced by the adoption of IPM practices and techniques; and (4) on the basis of knowledge gained from the preceding steps, prioritize the most critical research, extension, and training needs limiting greater IPM adoption.

According to the authors, stakeholder involvement in the process of establishing IPM definitions, goals, and evaluation criteria was critical to this approach. The diversity of issues (production possibilities, availability of IPM and other alternative production practices, environmental and public-health concerns, weather, pest pressures, etc.,) varied considerably within and among states. Developing program goals and evaluation criteria that are credible with a range of stakeholders and are scientifically valid required multistate, multiorganizational, and multidisciplinary teams.

Gianessi, Leonard P., and James Earl Anderson, *The Influence of Integrated Pest Management Programs on Pesticide Use*, National Center for Food and Agricultural Policy, Washington, D.C.

Methodological deficiencies of past IPM evaluation efforts are reviewed by the authors, and the claim that IPM has resulted in pesticide use reduction is challenged. The authors argue that many factors influence pesticide use, including changes in pest density and type, weather, changes in crop acreage planted, regulatory actions, and development of pest resistance. In a series of case studies of pesticide use changes attributed to IPM, the authors found that in some cases pesticide use was reduced; however, in others pesticide use either increased or the change was not attributable to the adoption of IPM but to other factors, such as the increased use of lower-rate chemicals. They argue for a more comprehensive approach to documenting the impact of IPM adoption on pesticide use. Specifically, they call for detailed documentation of pesticide use (e.g., number of sprays, pounds of individual active ingredients used, and cost of each spray) and the establishment of a baseline for more scientifically valid before-and-after (adoption of IPM) comparisons.

Szmedra, Philip, *The Adoption of IPM in Cotton: Some Issues Concerning Measurement and Evaluation*, USDA, Economic Research Service, Production, Management, and Technology Branch, Washington, D.C.

Efforts to evaluate adoption and impacts of cotton IPM were reviewed by Philip Szmedra. Cotton is an interesting case study because of the "maturity" of the IPM program. IPM research and extension programs encouraging cotton producers to adopt IPM have been in existence for several decades, and many practices associated with IPM programs have been adopted by a majority of cotton producers. However, as IPM systems become more sophisticated and biointensive, sharper delineations of adoption along a continuum will be needed. Szmedra argued that the level of IPM adoption inferred from survey results for a specific crop can vary considerably according to the definition of IPM chosen. This variation is particularly true when trying to differentiate low, medium, and high adopters. To arrive at a more accurate assessment of IPM adoption, Szmedra recommended:

1. a multidisciplinary approach to defining biointensive IPM by crop accompanied by a weighting scheme to better define the IPM-adoption continuum; regional variation necessitates that definitions reflect site-specific differences in recommended IPM practices; and
2. the development of survey instruments that capture sufficient information to identify where respondents are on the IPM continuum and the resulting impact on pesticide use.

Session 2: Health and Environmental Impacts of IPM: Measurement and Valuation

Introduction

Measuring the physical or biological impacts of IPM adoption is a major step in the process of impact assessment. However, the multiple vectors of concern and the probable tradeoffs between economic, environmental, and public-health objectives foster the need for an integrating framework for evaluating these tradeoffs. For example, the substitution of one type of pesticide product for another may reduce pesticide expenditures, improve farm profitability, and reduce potential surface-water pollution but increase worker, wildlife, and beneficial-pest exposure to toxic materials. One problem often encountered in assessing multiple impacts is that the economic value of changes in the environment and/or public health resulting from the adoption of IPM are not priced in the marketplace (e.g., the value of clean water, reduced exposure to toxic materials, rural landscapes, and reduction in pesticide use). Several approaches to integrated assessment are discussed in this session.

Papers Presented

Antle, John, Susan Capalbo, Donald Cole, Charles Crissman, and Richard Wagenet, *Integrated-Simulation-Model Analysis of Economic-*

Environment-Health Tradeoffs, Department of Agricultural Economics and Economics, Montana State University, Bozeman, Mont.

The authors presented a general approach to assessing quantitatively the economic, environmental, and human-health tradeoffs associated with the use of agricultural technologies and how conditions may be improved through the adoption of more sustainable practices (such as IPM). This approach was designed to account for key measurement issues that arise in agricultural-impact assessment. These issues included: the temporal and spatial variability of agricultural impacts; the need to integrate disciplinary models and data at a small scale or level of aggregation, such as the field scale, at which impacts can be reliably modeled; and the need to assess impacts at a large scale or level of aggregation, such as the regional or population level, for purposes of risk assessment and policy analysis.

Antle et al. discussed an application of this approach in a case study of the tradeoffs associated with pesticide use in the potato-pasture production system in the Andean highlands of Ecuador. The interdisciplinary research team collected data on field-level production, pesticide use, watershed pesticide leaching, socioeconomic characteristics, and health status (which included a clinical examination to test for pesticide exposure). These data were then used in three integrated simulation models to assess the economic, environmental, and health impacts of various alternative pest-management scenarios. The Antle et al. analysis indicated that there are large tradeoffs between production and environmental and human health risks and that improved pest-management technologies to reduce pesticide use can help mitigate these tradeoffs.

Blair, Aaron, *The Agricultural Health Study: A Prospective Study of Cancer and Other Diseases among Men and Women in Agriculture*, Occupational Studies Section, National Cancer Institute, Bethesda, Md.

Blair presented a summary of the Agricultural Health Study currently being conducted by the National Cancer Institute (NCI) in collaboration with the National Institute of Environmental Health Sciences (NIEHS) and the U.S. Environmental Protection Agency. To evaluate the linkage between agricultural chemical exposure in the development of cancer, neurological, and other chronic disease outcomes, the Agricultural Health Study has established a large prospective cohort that can be followed for 10 years or more. This study is being conducted in the states of Iowa and North Carolina.

The objectives of the Agricultural Health Survey include: (1) identifying and quantifying cancer risks among men, women, whites, and minorities associated with direct exposure to pesticides and other agricultural agents; (2) evaluating noncancer health risks including neurotoxicity, reproductive effects, immunologic effects, nonmalignant respiratory disease, kidney disease, and growth and development among children; (3) evaluating disease risks among spouses and children of farmers that may arise from direct contact with pesticides and agricultural chemicals used in the home, lawns, and gardens and from indirect contact, such as spray drift, laundering work clothes, or contaminated food or water; and (4) assessing current and past occupational and nonoccupational agricultural exposures through periodic interviews and environmental and biologic monitoring.

During the first year of a 3-year enrollment period, 26,235 people were enrolled, 19,776 registered pesticide applicators and 6,459 spouses of registered farmer applicators. Study organizers estimate that the total cohort in 1997 will include approximately 75,000 adult study subjects. Based on first-year enrollment, the composition of the survey should break down to 49,000 farmer applicators (62 percent of the cohort), 20,000 spouses of farmer applicators (24 percent of the cohort) and 7,000 commercial pesticide applicators (14 percent of the cohort).

Mullen, Jeffrey, and George Norton, *Economic Value of Environmental Benefits of Integrated Pest Management*, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute, Blacksburg, Va.

The authors presented the results of their case study estimating the economic value of the environmental benefits of apple and peanut IPM programs in Virginia. The first step in their approach was to identify the risks posed by individual active ingredients to eight environmental and public-health categories: (1) groundwater; (2) surface water; (3) acute human health; (4) chronic human health; (5) aquatic species; (6) birds; (7) mammals; and (8) arthropods. They then assigned each pesticide to a risk category (high, medium, low, and no risk) for each of the environmental and public-health categories. Second, they defined the degree of IPM adoption and assessed the effects of IPM adoption on pesticide use by degree of adoption. Third, they estimated "willingness to pay" to reduce pesticide risks. These estimates are derived with contingent valuation (CV), a widely used (though controversial) approach to value nonmarketed goods. The authors used opinion surveys to ask respondents to assess the value of hypothetical goods or actions and to estimate the amount they would be "willing to pay" for those changes in real or potential risk.

The value of the environmental benefits obtained from the CV analysis were used to calculate the economic value of environmental benefits resulting from the adoption of IPM practices. The results of this study show that, in Virginia, the peanut IPM program reduced pesticide use but nonsignificant reductions in pesticide use resulted from the apple IPM program. The authors concluded that the peanut IPM program produced substantial environmental benefits but the apple IPM program produced no significant environmental benefits.

Owens, Nicole, Scott Swinton, and Eileen van Ravenswaay, *A New Way to Measure Farmer Willingness to Pay for Safer Herbicides*, Department of Agricultural Economics, Michigan State University, East Lansing, Mich.

Understanding the factors influencing a farmer's decision to use safer pesticides is the subject of the paper presented by Owens, Swinton, and van Ravenswaay. In this study, the authors proposed a method to develop estimates of herbicide demand and farmer "willingness to pay" for safer corn herbicides. The authors also examined the importance of prior knowledge of the health and environmental effects of herbicides, sociodemographic characteristics, and sources of information about production alternatives in influencing farmers' willingness to pay for safer herbicides. The method used in this study capitalizes on the fact that a well-defined market exists for atrazine. In a survey of Michigan farmers, respondents were asked to value "new" herbicides, similar to atrazine, but safer in terms of groundwater leaching potential, human risk of cancer, or toxicity to fish. Fifteen price combinations were derived from three different base prices of atrazine and five different price differentials for the safer formulations of the herbicide.

Preliminary survey results suggested that Michigan farmer's willingness to purchase safer formulations of atrazine appeared to be significantly related to the price difference over ordinary atrazine. For example, when the price differential between atrazine and a nonleaching substitute was zero, more than half the respondents indicated they would purchase the new formulation. However, when the price differential was $3.00 per pound, the percentage willing to purchase the nonleaching product fell to roughly a third. The fact that most respondents were not familiar with many of the health and environmental effects of atrazine may explain some of the observed lack of interest in safer herbicide formulations. While 60 percent of respondents reported hearing about the potential for atrazine to leach, less than half knew it is a possible human carcinogen; can irritate the skin and eye; and is slightly toxic to fish, mammals, and birds. When presented with potential health and environmental effects, respondents often doubted their validity. Survey results indicated that respondents mainly relied on product labels and herbicide dealers for health and environmental information about atrazine.

Session 3: Pesticide Use, Productivity, and Alternatives

Introduction

The role of IPM in contributing to reduced pesticide use has been debated for two decades. Case studies presented at the Third National IPM Symposium/Workshop and in other fora have reported mixed impacts of pesticide use resulting from IPM adoption. This is not surprising given that the scouting methods, economic thresholds, and other IPM tools that have been developed and implemented over the past several decades, primarily for managing major insect pests, have been aimed at improving the efficiency of insecticide use but not necessarily reducing use. In this session, methodological issues involved in measuring changes in pesticide use and factors influencing pest-management choices are discussed. In addition, some empirical results of IPM adoption on pesticide use are reported.

Papers Presented

Ferguson, Walter, Jet Yee, and Mike Fitzner, *Nonchemical Pest- and Nutrient-Management Practices: Limitations to Adoption and Policy Options*, Economic Research Service, Washington, D.C.

During the past decade, the role and importance of crop consultants in influencing farmers' pest- and nutrient-management decisions has expanded. Farmers faced with complex and information-intensive pest-management decisions have turned in increasing numbers to paid consultants for their site- and time-specific recommendations. Ferguson, Yee, and Fitzner presented the results of a 1994 survey of independent crop consultants. The survey explored consultants' perceptions of the level of adoption by farmers of nonchemical pest- and nutrient-management practices and major factors aiding and limiting adoption. Independent crop consultants surveyed indicated that the major limitations to adoption of IPM practices are lack of viable nonchemical tactics, potential lower yields, higher production costs, higher management skills required, lack of information, and lower crop quality.

Hubbell, Bryan, and Gerald Carlson, *Insecticide Selection, Application Rates, and Application Frequencies: Is IPM More Than Total Use Reduction?* Department of Agriculture and Applied Economics, Georgia Station, Griffin, Ga.

Hubbell and Carlson examined the often-claimed proposition that IPM adoption results in pesticide use reduction. In their review of the literature the authors found limited empirical support for IPM's claim of pesticide-use reduction. Further, they discussed why total pounds or expenditures for pesticides may not be the appropriate measure given, the importance of toxicity, persistence, and application rates per acre in determining economic and environmental outcomes. The analysis examined the impacts of four IPM practices: scouting, beneficial insect management, pheromones, and pruning. Using data on U.S. apple growers, the authors estimate three insecticide "component" models and examine the impacts of IPM use on selection of low-rate, low-toxicity insecticides and per-acre application intensity of selected insecticides.

The authors found that the IPM practices studied had a significant impact on selection of insecticide active ingredients and that certain practices significantly affect application rates. However, the selection effect appeared to be toward more specific, highly effective products rather than toward low-rate, low-toxicity insecticides. Adoption of IPM practices did not significantly affect application frequencies, suggesting that IPM adoption may not lead to significant reduction in insecticide quantities used in apple production. The authors argued that if reduction in pesticide toxicity or quantities is the desired outcome, other mechanisms, such as input taxes, may be needed to encourage growers to use safer, low-rate insecticides.

Lichtenberg, Erik, and Rae Zimmerman, *Adoption of Alternative Pest-Management Practices and Pesticide Use* in *the Mid-Atlantic*, Department of Agricultural Economics, University of Maryland, College Park, Md.

The authors examined the complex set of factors influencing farmers' willingness to adopt nonchemical pest-management practices. The study is based on a recent survey of corn and soybean farmers in New York, Pennsylvania, and Maryland. The in-depth survey elicited information on individual farmers' pest-management practices, including several measures of pesticide use (i.e., type of pesticide, number of acres treated, number of applications), use of nonchemical means of control, characteristics of farm operation, farm-level economic indicators, demographic and human-capital indicators, health problems related to pesticides, and attitudes toward health and environmental problems from pesticides. The authors developed a model to assess the adoption of nonchemical controls as a discrete-choice problem where adoption is a function of characteristics of the farm operation, human capital and demographic factors, experiences with health problems from pesticides, and attitudes toward health problems and wildlife injury from pesticides.

Session 4: Interdisciplinary Modeling: Issues and Examples

Introduction

A critical component of efforts to increase the adoption of IPM is the availability of valid and timely information on the cost-effectiveness of IPM compared to conventional agricultural practices. For adoption to occur, producers must be convinced of the cost-effectiveness, profitability, and/or environmental benefits of proposed pest-management alternatives. In addition, from a larger perspective, society must be able to weigh the potential tradeoffs among production, environmental, and public-health objectives. Methodological and data limitations resulting in part from the complexity and diversity of U.S. agroecosystems have contributed to the difficulties encountered in previous attempts to measure the cost-effectiveness of IPM methods. In this session, different methodological issues involved in estimating pesticide productivity and cost-effectiveness are discussed, and alternative approaches proposed.

Papers Presented

Chambers, Robert, and Erik Lichtenberg, *Econometric Evaluation of IPM in Maryland Field Crops*, Department of Agricultural and Resource Economics, University of Maryland, College Park, Md.

Information about the cost-effectiveness of IPM methods is critical for increased adoption. However, shortcomings encountered in past attempts to estimate economic impacts have included how in-season production adjustments and substitutions were modeled, and the reliance on experimental plot conditions that frequently failed to reflect in-field conditions. Chambers and Lichtenberg outlined an econometric approach to estimating pesticide productivity. They illustrated the elements of their method with data from a detailed, farm-level survey on pest management practices, pest conditions, and crop yields of Maryland field-crop producers. They discussed how this approach could contribute to a better understanding of issues related to IPM promotion efforts, such as the impacts of IPM programs on pesticide productivity, the relative cost-effectiveness of IPM and conventional pest-management approaches, and whether IPM results in reduction in pesticide demand by profit-maximizing farmers.

Du, Fang, *Production Function Estimation with Pest-Tolerant Response*, Department of Agricultural Economics and Marketing, Rutgers University, Cook College, New Brunswick, N.J.

The author explored methodological issues involved in developing a production model of pesticide use with pest-tolerant response to examine pesticide efficacy and profitability. Incorporating pest-tolerant responses in modeling pesticide productivity represents an improvement over previous modeling efforts because it addresses the fact that plants will tolerate some quantity of injury from pests without reducing marketable yield. Thus, it is important to distinguish between an input's direct contribution to output (productive) and one that contributes indirectly to output (protective). This study improves upon previous attempts at specifying pesticide production functions by differentiating between productive and protective inputs. The author does this by incorporating into the production function an "abatement function" that includes pesticide level, initial pest population, and pest-tolerant response. Field data are used to test the production model.

Lamp, William, Erik Lichtenberg, David Liewehr, and Lester Vough, *Joint Use of Intercropping and Pesticides to Control Leafhopper on Alfalfa*, Department of Agricultural Economics, University of Maryland, College Park, Md.

William Lamp, Erik Lichtenberg, David Liewehr, and Lester Vough examined five different levels of insecticide application rates to alfalfa plots grown with and without oat intercropping. Oat intercropping is a promising nonchemical means of leafhopper control. Data from a set of experiments were used to evaluate the impact of oat-alfalfa intercropping on the profit-maximizing level of pesticide treatment of leafhopper and on the resulting quantity and quality of forage. These data were used to estimate the parameters of (1) a model linking quantity and quality of output with leafhopper densities in the presence and absence of the oat intercrop and (2) a model representing leafhopper densities as a function of the insecticide application rate. These models were combined with output and insecticide prices to calculate the profit-maximizing insecticide application rate and associated threshold leafhopper density to evaluate the cost-effectiveness of the oat intercrop relative to reliance on chemical means of control.

Swanton, Clarence, and Stephen Murphy, *Weed Science Beyond the Weeds: The Role of Integrated Weed Management (IWM) in Agroecosystem Health*, Department of Crop Science, University of Guelph, Guelph, Ontario, Canada.

Swanton and Murphy made the case for moving beyond descriptive approaches to integrated weed management (IWM) (i.e., the impact on yields and weed interference of different management strategies, such as tillage, cover crop, planting patterns, etc.,) to predictive approaches that estimate future weed problems and the economic risks and benefits of interventions. The authors argued for using predictive IWM approaches that focus on agroecosystem health and integrate biophysical, social, and economic concerns. Two benefits of linking IWM to agroecosystem health were identified by the authors: (1) predictive models within IWM can be incorporated into larger agroecosystem models and (2) the relevance and benefits of IWM should become clearer to the public and government.

Session 5: Economic Impacts of IPM Adoption: Case Studies

Introduction

Methodological and empirical issues encountered in estimating economic impacts of IPM adoption, both *ex ante* and *ex post*, are tackled in this session. The diversity of IPM systems, research questions, and data
availability engender a variety of methodological approaches to measuring impacts of IPM adoption.

Papers Presented

Fernandez-Cornejo, Jorge, *The Microeconomic Consequences of IPM Adoption with an Application to the Case of Tomato Growers*, Economic Research Service, USDA, Washington, D.C.

The author presented a method for calculating the impact of IPM on pesticide use, yields, and farm profits and then applied this method to the case of IPM adoption among fresh-market-tomato producers in eight states. Results of this study indicated that, among fresh-market-tomato growers, adopters of IPM for insects and IPM for diseases applied significantly less insecticides and fungicides respectively than did nonadopters. In this study, IPM adoption for insects and diseases did not have a significant effect on yields and only a small impact on profits. Other factors found important in determining pesticide demand were pesticide prices, farm location, contractual arrangements for the crop, and farm size.

Hamming, Michael, Annu Rauf, Gerald Carner, and Haiyue Nie, *Impact of Widespread Adoption of Integrated Pest Management by Shallot Growers in Indonesia*, Department of Agricultural Economics, Clemson University, Clemson, S.C.

Hamming, Rauf, Carner, and Nie estimated the economic impact in Indonesia of mechanical versus chemical spray applications to control *Spodoptera exigua*, a major insect pest of shallots. Field studies conducted on shallot production in West Java in 1993/1994 collected basic economic information on costs and returns from shallot production, detailed information on pest control methods, and attitudes of farmers regarding some of the key issues of IPM. The economic information was used to construct a statistical model of the shallot production function. Results of the econometric production function analysis showed that all inputs made statistically significant and positive contributions except chemical fertilizers, foliar fertilizer, and pesticides. Data indicated that hand picking alone provided control as effective as insecticide use and hand picking combined. The estimated economic impact of adopting mechanical pest control was calculated as savings from eliminating all insecticide use and reducing sprays to occasional fungicide applications, a potential annual saving countrywide of $46.9 million. If health impacts of pesticide use by shallot growers were included, savings in lost productivity would be even greater.

Jans, Sharon, and Jorge Fernandez-Cornejo, *A Case Study on the Impact of IPM for Oranges in Florida and California*, Economic Research Service, USDA, Washington, D.C.

The authors analyzed the impact of IPM adoption on pesticide use, yields, and producer profits for Florida and California orange growers. In this study, no significant differences were found to exist between IPM adopters and nonadopters when measuring yields, profits, and the number of insecticide applications. The analysis also indicated that nonadopters were more likely to be engaged in off-farm work compared to IPM adopters. The authors argued that the intensive management requirements of IPM for orange production may be an important barrier to IPM adoption.

Scorsone, Eric, *Economic Evaluation of a Proposed Price-Flexible Action Threshold for Tart Cherries*, Department of Agricultural Economics, Michigan State University, East Lansing, Mich.

In this paper, the author examined the performance of a new action-threshold strategy for tart cherries in Michigan. Prices of tart cherries fluctuate widely from season to season, and this uncertainty is not captured in the currently available price-static decision rule underlying action thresholds. Scorsone compares price-static and price-flexible action thresholds for tart cherries with a bioeconomic simulation model. Results of his assessment indicate that the proposed price-flexible action threshold could potentially improve economic performance over the price-static action thresholds and non-IPM strategies.

Swinton, Scott, Leah Cuyno, and Frank Lupi, *Factors Influencing the Adoption of IPM for Corn Rootworm in Michigan*, Department of Agricultural Economics, Michigan State University, 202 Agriculture Hall, East Lansing, MI.

The authors of this study examined factors influencing adoption of three alternative pest management practices (scouting, crop rotation, and reduced insecticide rates) to reduce corn rootworm insecticide use among Michigan corn producers. In addition to explanatory variables often found in adoption studies (farm management practices, personal characteristics of adopters, physical environment and institutional environment), the authors included variables capturing producers' perceptions of financial and environmental risk, yield loss expectations, and sources of pesticide information. The statistical analysis used by the authors included probit and tobit estimation procedures.

Results of the analysis indicated that general management practices, personal characteristics, physical environment, and institutional environment all play a role in determining adoption of the three alternative pest management practices. The analysis also showed that farmer expectations about yield loss in a normal year and source of pesticide information are key variables in explaining adoption of reduced insecticide practices. In contrast the financial and environmental risk variables were not significant in affecting adoption of reduced insecticide practices. The authors concluded that educational programs to inform farmers about the likelihood of economically damaging rootworm infestations might be warranted given the importance of yield loss expectations in influencing reduced insecticide use. In addition, farmer reliance on industry sources for pesticide information suggested that agribusiness should be included in these educational efforts.

Part IV. Analytical and Data Needs for Pest-Management Programs: Panel-Discussion Summaries

Introduction

Good data on pests and pest-management technologies are the prerequisites for building reliable models, performing accurate analyses, developing effective policies, and making good management decisions. The workshop and panel sessions grouped in this chapter discuss ways to improve the data that are collected in survey programs and other USDA programs that address pesticides and pest management.

USDA programs for data collection and analysis are designed to gather information on farming practices, farm and operator characteristics, and economic conditions to address broad issues in U.S. agriculture. The data are needed to determine the full benefits and costs associated with the use of chemical-based pest-management strategies and with the use of alternative strategies such as IPM. The benefits and costs include impacts to farm profits, environmental quality, human health, and the food supply. The data also are needed to assess the extent of adoption of alternative pest-management practices and to ascertain the factors that influence adoption.

The scope and breadth of the public data that are currently available at the national level and the innovations that are being experimented with in USDA and elsewhere are discussed in the opening session in this chapter on data needs for IPM assessment. Prior to the early 1990s, USDA's National Agricultural Statistics Service (NASS) and Economic Research Service (ERS) collected some pesticide-use data for major field crops in major producing States, but little data were collected for fruits and vegetables or for other pest-management practices. Beginning in the early 1990s, USDA began conducting a chemical use and practices survey for fruit and vegetable crops and expanded pest-management data collection for major field crops. In addition, a limited set of data was gathered from 1991 to 1993 on a location-specific basis, rather than by crop, to assess agricultural management practices and chemical use within 10 selected U.S. watersheds. In 1996, ERS and NASS combined several survey programs to collect data on farming practices, input use, yields, and economic characteristics with a single survey instrument. Questions were included on the adoption of several IPM practices. Although survey costs and respondent burdens preclude the use of this design for all commodities on an annual basis at this point, the basic design is scheduled for use with other field crops in subsequent years.

Analytical needs for further data improvement to perform more rigorous assessments of IPM are also discussed in the opening session. One panelist offered suggestions for improving IPM assessment through targeting a major data collection effort toward comparative research. Comparative research would help analysts understand why IPM is used intensively in one setting but not in others through examination of the pest management influences (e.g., State pesticide policies, cultural attributes in different farm settings, the availability of independent crop consultants, better communication technologies by Extension, and physical production-system attributes) that play a major role in IPM adoption. The improvements in national-level data collection that have just been implemented may also help catalyze a better understanding of how and why IPM practices and philosophy are adopted by farmers.

Changes in pesticide use have been used as a measure of environmental and human-heath impacts in the majority of IPM assessment studies conducted previously. More thorough evaluations of the environmental and health impacts of IPM would require systematic collection of water-quality monitoring data and the development of human-health-impact models. California was reported to have a pesticide-illness-surveillance program to track illnesses caused by acute occupational exposure to pesticides. Comparable data are unavailable at the national level, and few other States have similar programs. Comprehensive assessments of the effects of occupational pesticide exposure on the risks of contracting cancer, neurodegenerative disease, and other chronic health problems are rare. The Federal Agricultural Health Study, which was described in the previous chapter, is tracking pesticide use and other factors linked to chronic disease in approximately 75,000 operator/applicators and spouses in two States and will help fill the occupational-health-data gap.

Despite data limitations, environmental-assessment models are being developed and tested by university researchers and consultants for a variety of uses. Some of these models are described in the "Assessing Environmental Impacts" panel session summary. While most of these models make environmental-risk comparisons between pesticides, several also include at least a partial set of cultural and biological pest-management methods.

The benefits of agricultural pesticide use were addressed by three panel and workshop sessions. These sessions covered the data collection and modeling efforts in two USDA pesticide programs, the IR-4 program and the National Agricultural Pesticide Impact Assessment Program (NAPIAP). The IR-4 program collects pesticide-residue data for minor crop uses to help register pesticides for small markets that pesticide manufacturers find unprofitable. This program expects to make increasingly more biopesticides and other "ecosystem friendly" products available though its registration-streamlining program. The NAPIAP program provides information to EPA on the benefits of pesticide use in agriculture for regulatory decision making.

Data-availability issues were central issues in these panels. Data are nonexistent for some important variables (such as the frequency and distribution of many major crop pests) and are of poor quality for others. Better data would allow economists to estimate impacts associated with proposed regulatory actions on pesticides that currently are not calculated, such as costs by changes in pesticide resistance. And biologists could produce better estimates of the yield and quality effects of alternative pest-management technologies with better data.

A "one-stop-shopping" database for pest-management information is currently being built by USDA and Argonne National Laboratory and is described in the last session summary in this chapter. The purpose of the Pest Management Information Decision Support System (PMIDSS) is to facilitate the use of consistent standards for pest-management data collection, to integrate existing pesticide and pest-management databases (including databases on EPA pesticide registrations, resistant varieties, pesticide resistance, and the efficacy of alternative pest-management materials and techniques) and to develop a format that is easy to use and accessible on the Internet.

An early prototype of this system is being used by USDA's Cooperative State Research, Education, and Extension Service (CSREES) to help target the research areas covered by a recent competitive grants program examining pest-management alternatives for farmers. The developers of the PMIDSS hope to produce the most complete information system available and to provide a common resource for the wide range of communities interested in pest management, farmers, food processors and handlers, scientists, regulators, crop consultants, Extension educators, environmentalists, public-health specialists, and others.

Meeting Data Needs for IPM Assessment

Cathy Greene
Economic Research Service, USDA
Moderator

Continued public support for environmental protection along with recent industry interest in performance-based standards and government performance legislation has increased interest in the use of environmental databases for IPM assessment. The objectives for the “data needs” panel presentation were to describe: (1) the structure of current agricultural pesticide, pest-management alternatives, and other environmental databases; (2) current uses and limitations of these databases for IPM research and assessment; and (3) changes that are being made in these databases to improve their quality and usefulness. An additional objective was to solicit suggestions from the audience for additional ways to improve environmental-data-collection efforts.

Panel speakers described various pesticide-related databases and data-collection efforts, including those by USDA, EPA, National Center for Food and Agricultural Policy and the California Environmental Protection Agency. Panelists also discussed methods for measuring IPM adoption and tools for farmers to use for assessing pesticide risks.

In the opening session, panelists updated the audience on improvements that USDA is currently making in its data-collection program on pesticides. USDA has collected pesticide-use data in the past mostly for field crops (e.g., corn, soybeans, wheat, potatoes, and cotton) in major producing States and has sporadically collected pest-management-practices data on these crops since the early 1990s. Also during the early 1990s, USDA added a data-collection program for fruits and vegetables that has a link to socioeconomic farm characteristics for several of these crops. This year, NASS and ERS are implementing a new survey design that will tie input and practice data for one of the major field crops, corn, to the broader set of farm characteristics that includes production costs and returns and demographic data. Additionally, ERS and NASS are experimenting with an agroecosystem-specific design for the IPM practices section of the field corn survey. While these links are only being made for corn this year, additional major field crops will be examined in future years.

National Databases for IPM Assessment, Mary Ahearn, Economic Research Service, USDA, and Sam Rives, National Agricultural Statistics Service, USDA

Why do we care about IPM? What do we want to know about IPM? These questions lead us to the social goal of reducing chemical risks, which is a part of the larger question regarding reducing human health and environmental risks. To understand IPM, we must understand the whole farm setting, including the resource setting. This is also a necessity for addressing the primary social goals of reducing human health and environmental risks.

To collect data on IPM, we need a definition of IPM. This definition is likely to change over time, and any precise definition must be crop and region specific. Are there indicators of IPM that can be used across commodities? Although the policy goals of IPM adoption are to reduce risks from chemicals, science cannot currently tell us clearly what pest-management practices reduce chemical risks. In fact, cutting-edge science may never be clear on this issue because it is an ever-evolving process. In addition, the ability of a defined IPM technology to reduce risk to human health and the environment will vary over many variables, such as pest pressure level, weather, and soil properties. An important empirical question is to explore how IPM adoption affects chemical risk, and other human health and environmental risks, over these variables. That is, we care about the distribution of IPM adoption and IPM’s relation to chemical use over several variables.

No matter what the answers are to the questions regarding a conceptual definition of IPM, any empirical definition will require knowledge of farm-level input use and production practices.

The number-one motivating force behind the decision of farmers to adopt pest-management practices is profitability. We need to be able to evaluate the economic implications of alternative farm technologies (inputs and practices) to provide useful information about the likelihood of adoption and to evaluate the social costs and benefits of adoption for purposes of considering policy options, including education, regulation, and incentive payments. Finally, we can only ask farmers for information that makes sense to them, is unambiguous across farmers, and will have the same meaning to them as the researchers intended. All of these goals must be accomplished with a clear recognition that respondent burden is our constraining variable.

The commodities included in most current farm-level data-collection programs related to pest-management practices are corn, flue-cured tobacco, burley tobacco, peanuts, sorghum, peaches, apples, oranges, grapes, strawberries, tomatoes, and sweet corn. Limited information exists for other fruits and vegetables; past information exists only on inputs and practices for soybeans, wheat, potatoes, and cotton. The pest-management-related data collected include:

- Outputs
- Input use, including characteristics of chemical applications, such as timing
- Who applies chemicals
- Practices
- Sources of information about pest management (e.g., crop consultants)
- Limited information on organic practices
- Costs and returns (paid): incomplete whole farm and commodity-specific
- Georeferencing (for linking to other spatial characteristics, such as resource base)
- Demographics of farmer and household
- Farm-structure characteristics

The additional farm-level data that are currently needed include: target pests associated with practices; costs and returns of IPM (or alternative) practices, paid and unpaid; attitudes about risk; external requirements for pest management (e.g., by lenders or contractors). The ancillary data/information sets that are needed include: pesticide prices; pesticide attributes: toxicities, persistence, mobility; resource characteristics, e.g., soil leachability; objective measure of pest pressure at spatially disaggregated level; expert assessment on recommended practices, including economic thresholds; and environmental values (i.e., for measuring social benefits and costs of alternatives). And to go beyond chemical-use changes as a measure of environmental and human health impacts, we would need objective monitoring [e.g., USGS water quality monitoring, environmental process (fate and transport) models, and human-health-impact models].

National Pesticide Database, James Earl Anderson, National Center for Food and Agricultural Policy

The National Center for Food and Agricultural Policy has developed a national pesticide-use database. This database builds on the NASS pesticide-use database and presents a more complete picture of total U.S. agricultural pesticide use by adding data from various State surveys and other sources. The Center is currently enhancing its pesticide-use reporting by constructing several new databases on pesticide prices, pesticide efficacy, and weed infestation, and it expects to release these products this year.

Databases Used in Pest-Management Evaluations by the California Department of Pesticide Regulation, David Supkoff, California Environmental Protection Agency

California maintains a complete database on agricultural pesticide use, as well as databases on pesticide illnesses and on residues in wells, and has recently developed a database on the availability of nonchemical alternatives.

With the implementation of full use reporting in California in 1990, all agricultural pesticide use must now be reported monthly to the county agricultural commissioner who reports the data to the California Department of Pesticide Regulation (DPR). The reports must include the date and location where the application was made and the kind and amount of pesticide used. Additional information may include acres treated, whether the material was ground or air applied, commodity or site information, and the field to which the pesticide was applied. There are more than 2 million records reported each year, including agricultural, structural, and other nonagricultural applications.

The infrastructure needed to carry out full-use reporting is considerable, with a cost of more than $2,000,000 at the county level alone. Efficiencies have been realized in the past several years through electronic reporting from the counties to DPR. A new program, starting in 1996, has been developed for full electronic reporting from applicators, through the counties, to DPR.

Pesticide-use report (PUR) information is critically important in pest-management evaluations at DPR. Data may be analyzed as pounds of active ingredient applied, acres treated, or number of applications. By linking the PUR to other databases, such as the label database, data can be summarized and evaluated in new ways.

The Label Database contains information on all products currently registered in California. In addition, historical information on past registrations are included. Information includes registration number, registrant information, crops and sites on which the product is registered, active ingredients, pesticide type (insecticide, herbicide, etc.), and formulation type.

Regulatory changes often restrict the availability of pesticides to California farmers. DPR, in cooperation with the University of California Cooperative Extension, developed the Pest Management Survey Database (PMSDB) to determine the availability of alternative products when pesticides become unavailable. This database is presently being expanded in cooperation with the University of California Statewide IPM Project to include both chemical and nonchemical alternatives. The PMSDB assists DPR in predicting the impact of regulatory decisions on the management of economic pests. It is made accessible to researchers and other interested parties through the University Impact system.

In the current, expanded version, which was recently mailed to more than 180 University of California Extension scientists and farm advisors, information is being collected for each of seven California growing regions, for specific pest-control methods and individual target pests, including whether a pest-control method is the only feasible alternative, limitations, resistance, primary and secondary methods of application, and information on quality and yield.

The Pesticide Sales Database contains information collected on all pesticide sales in California. Because home-use pesticide products are not captured in the PUR, the sales database provides an important overview of pesticides used in California. Information in the database is confidential, although general summaries may be available. The Pesticide Illness Surveillance Program (PISP) is the repository for reports on illnesses caused by pesticides, which must be reported in California. The Well Inventory Database contains information on wells sampled for the presence of pesticides. This database identifies positive detections, active ingredients found, and well locations, and it contains information from the DPR as well as outside agencies. The County Agricultural Statistics Database contains county-level statistics on crop acreage along with economic information, such as price and yield. This information is collected by the California Department of Food and Agriculture and is available in electronic form.

Tracking the Extent and Intensity of IPM Adoption, Steven Wolf, Institute for Environmental Studies, University of Wisconsin

Wolf challenged the IPM community to better estimate and track the extent and intensity of IPM in practice at specific points in time and to use these data to better understand and stimulate IPM adoption through policy, education, and research. He criticized much of the previous IPM-adoption research as largely ad hoc and politically motivated and suggested that measuring changes in IPM adoption within agricultural production systems requires rigorous assessment of both the context in which behaviors are examined and the behaviors themselves. One of his suggestions for improvement is to orient IPM assessment activities toward comparative research that looks at why IPM is used intensively in one setting and not another:

- Do State-level policies matter?
- Does priority watershed designation matter?
- Do cultural attributes matter?
- Are there economies of scale inherent in IPM?
- Are there barriers associated with large size?
- Do we see more intense IPM related to the services provided by agrichemical dealers or independent crop consultants?
- Does Extension matter?
- How does IPM practice differ from potatoes to corn?
- What is the role of commodity organizations?
- Does pesticide resistance drive IPM practice?
- Does soil quality affect IPM practice?

While the IPM surveys concentrate on field practices and, to a lesser degree, socioeconomic characteristics of farm firms and are not necessarily oriented toward these research questions, systematic sampling procedures and other tools can be used to collect data that support comparative research. Wolf also argues for more integration of primary and secondary data sets through development and application of spatially explicit sampling and inventorying techniques, and advocates the use of GIS technology to link agroecological and socioeconomic data. This integration allows the behavioral change of individuals as well as the adaptations in farming systems to be examined within the context of hypothesized IPM "drivers," such as modified pest-management regimes, resource-management conflicts, consumer preferences, technological and economic change, public investment, and development of a competitive crop-consulting industry.

An Environmental Yardstick for Pesticides, Joost Reus, Center for Agriculture and Environment, The Netherlands

The purposes for developing a "pesticide yardstick" for farmers are:

- to make the environmental impact of pesticide use visible to farmers and operators,
- to stimulate them to make a more sound selection of pesticides, and
- to evaluate the progress they make towards a more environmentally sound crop protection.

The risk of pesticide use for the environment is assessed by comparing the predicted environmental concentration (PEC) in a certain environmental compartment (soil, water, or groundwater) with the environmental quality standard (e.g., 0.1 x LC_{50} for aquatic organisms); this quotient of PEC and LC_{50} indicates the acute risk for organisms in the environment.

For each active ingredient, environmental impact points (EIP) are calculated, based on this risk quotient, in the following way: EIP = 100(PEC)/environmental quality standard. In other words, if the number of EIP equals 100, the PEC equals the environmental quality standard set by the Dutch government. EIPs are calculated for an application of 1 kg of active ingredient per hectare. The farmer should multiply the standard number of EIP with the actual dose rate if another dose rate is used. To calculate the PEC, differences in environmental characteristics are included, like organic matter content in the soil and distance to surface water. Furthermore, farmers can take into account the dose rate they actually use and the method of application (which determines the percentage of emission).

There are large differences in insecticides' impacts on the environment. Most insecticides are not mobile in soils, so they do not pose a risk to groundwater. An exception is propoxur, which is highly mobile. Cypermethrin is quite persistent in soil and therefore poses a risk to soil organisms. Most insecticides are very toxic to aquatic organisms and have many EIPs for the risk for water organisms.

The environmental yardstick was introduced in practice in 1994. Since then, it has been used by individual farmers, in study groups of farmers, by the extension service, in training courses for farmers and in agricultural schools. In most cases, farmers using the yardstick could reduce their score on the yardstick dramatically. Reductions of more than 90 percent are no exception. Most reductions in the short term were reached by changing from an environmentally harmful pesticide to a pesticide with less risk to the environment.

In the long term, we are trying to motivate farmers to change their crop-protection strategy more fundamentally: first, to use measures to prevent weeds, pests, and diseases; Second, to choose nonchemical crop-protection techniques (although these techniques may have an environmental impact as well); third, if a pesticide application is necessary, to choose the pesticide with the least environmental impact; finally, to choose the application method that causes the least emission of pesticides into the environment.

he Center for Agriculture and Environment (CLM) is a nonprofit, nongovernmental organization that aims to stimulate a more sustainable agriculture. Research in close cooperation with farmers is the core activity of CLM. This research is geared towards: (1) analyzing and quantifying environmental problems at the farm level; (2) developing solutions or measures that are suitable for individual farmers; (3) translating government objectives to specific objectives for individual farmers; and (4) developing proposals for a stimulating and motivating policy.

The philosophy of CLM is that environmental policy should focus on the objectives. Farmers have a personal responsibility, and should have the right, to choose the most cost-effective way of reaching these environmental objectives. Therefore, they should have suitable tools to measure the environmental impact related with their way of farming. CLM therefore developed farm-level indicators or "yardsticks" for nutrients (nutrient bookkeeping) and pesticides. Yardsticks for energy (greenhouse gases), biodiversity, and water (irrigation) are still in development. These yardsticks are used as an information and management tool, but are also used as basis for financial incentives (levies and premiums) and for green labeling of agricultural produce.

Tools for Assessing Environmental Impacts: Emerging Approaches for Different Objectives

Lois Levitan
Cornell University
Moderator

The goal of this session was for participants to become: (1) more knowledgeable about some environmental impacts of pest-control systems that are being developed, (2) a bit better versed about the issues at hand and the research challenges that remain, and (3) more familiar with some of the players in the field.

Presentations

Five panelists, each of whom has played a lead role in developing a model or conceptual tool for assessing impacts of plant-protection methods gave presentations that touched on the following points:

1. The purpose of the system: What or whose perceived need led to the development of the system?
2. Who is intended to use and make decisions based on the system: farmers, farming-system advisors, researchers, regulators, or the public?
3. Which environmental effects and variables have been taken into account? Are only inherent pesticide (and other pest-management products and methods) properties considered, or are site- and situation-specific conditions and farm management decisions also considered?
4. What are the principles behind the calculation(s).
5. What is the format of the output (i.e., computer screen, short handout, or scientific paper).
6. At what stage of development is the system? Is it still evolving? What would be involved in adapting the system for other user groups?

Most of the systems presented are "works in progress." Some focus on pest management, whereas others also assess other components of agricultural systems. Most are structured to enable comparisons of pest-control options. Some evaluate impacts of pesticides exclusively, whereas others also assess nonchemical pest-control methods. Each evaluates impacts on one or more environmental parameters or indicators; some of the systems focus on agroecosystem impacts and indicators, whereas others prioritize consumer and/or occupational risks (which are considered public-health impacts in the framework of these IPM meetings). The systems described here are methods for interpreting empirical field or laboratory (e.g., toxicity) data and data predicted by environmental fate models.

Participants

Joseph Bagdon, Natural Resources Conservation Service, Amherst, Mass., is the project leader for the National Agricultural Pesticide Risk Analysis (NAPRA), which is a water-quality model. Its output is in the form of a climate-based probability that pesticide loss from the field will exceed human health advisory levels. This risk can be compared for different pesticide options. Additional information can be obtained at jbagdon@fnr.umass.edu.

Charles Benbrook, Benbrook Consulting Services, consultant to the Policy Program of the World Wildlife Fund, Washington, D.C., developed a method for measuring progress toward the national adoption of IPM. This system places pest-control practices along a continuum to demonstrate a shifting reliance from treatment to prevention of pest problems. The continuum is divided into four zones on the basis of these farmer behaviors in pest management: no IPM, low and medium transitional IPM systems, and biointensive IPM. Additional information can be obtained at benbrook@hillnet.com.

Lynn Coody, Organic Agsystems Consulting, Eugene, Ore., designed a prototype computer expert system to assist the Technical Advisory Panel of the National Organic Standards Board in developing a list of materials appropriate to use on organic farms. Data about the characteristics of materials are compared with evaluation criteria with weighted values to produce a product rating (allowed, regulated, or prohibited). Results can be reported at three levels of detail. The system is intended to provide a structure for the evaluation process and to simplify the presentation of information needed to satisfy the requirements of the Organic Foods Production Act. Additional information can be obtained at 76305.3545@compuserve. com.

Kevin Klair, Center for Farm Financial Management, University of Minnesota, St. Paul, Minn., is a member of a team that has recently released an updated version of PLANETOR 2.0, which is a comprehensive environmental and economic farm-planning software program. The system combines site-specific environmental models with individual farm financial planning data to evaluate impacts of reducing or changing pesticide, nitrogen, phosphorus, and manure applications; tillage systems; and crop rotations. PLANETOR evaluates alternative management plans for individual farms and compares impacts on soil erosion, nitrate leaching, phosphorus runoff, pesticide movement, and whole-farm profitability. Additional information can be obtained at cffm@cffm.agecon.umn.edu.

Joost Reus, Center for Agriculture and the Environment, Utrecht, The Netherlands, developed the Pesticide Yardstick as a method for farmers to use in selecting pesticides and evaluating progress they make towards more environmentally sound crop protection. In this system, pesticide risk is assessed by comparing predicted environmental concentration (PEC) in a certain environmental compartment with the Dutch environmental quality standard for several indicators. Reus is currently working on a proposal for a joint European project in scoring or ranking pesticides. Additional information can be obtained at clm@gn.apc.org.

Discussion

Group discussion focused on the objectives, potentials, limitations, and research needs regarding environmental impact assessment tools. Discussion themes included:

- Knowledge and database gaps in general and particularly concerning nonsynthetic chemical pest-control methods; also difficulties in assessing impacts and efficacy of biological and cultural control methods.

- Extrapolating or adopting existing and prototype assessment tools to additional crop scenarios and site conditions.

- Methods and challenges in incorporating a broader range of environmental indicators into assessment systems, including indicators of community- and ecosystem-level environmental quality and indicators with longer time horizons (e.g., genetic and reproductive effects).

- Targeting audiences for different assessment tools; structuring assessment systems to meet the objectives and needs of user groups. How to make explicit the limited objectives of an assessment system so results are not misinterpreted or extrapolated beyond the intended purposes and audiences of the assessment tool. How to encourage target group adoption of an assessment procedure and results? What are the barriers to adoption of environmental assessment tools?

- Difficulties in collecting data from farmers and growers who are fearful that identification of an environmental impact will lead to greater regulation in the use of a pest-control method.

- Whether efficacy data belong in environmental-impact assessments.

- Facilitating communication and cooperation among people working to develop and implement environmental impact assessment methods for agriculture. A new, unmoderated e-mail discussion group (Ag-Impact) was announced; it will be administered by the Institute for Agriculture and Trade Policy (IATP) in Minneapolis, Minn., and hosted by Dr. Lois Levitan, Department of Fruit and Vegetable Science at Cornell University. Subscribe by sending e-mail to listproc@mtn.org with the message: subscribe Ag-Impact [your name].

Estimating Biological Benefits of Pesticides for Regulatory Decision Making

Ron Stinner
North Carolina State University
Moderator

Introduction

The National Agricultural Pesticide Impact Assessment Program (NAPIAP), a USDA/State program, was established in 1976 to promote informed regulatory decisions on agricultural pesticides. NAPIAP develops and distributes science-based information evaluating the benefits of pesticides in U.S. agricultural production. The information in NAPIAP assessment documents is provided to the U.S. Environmental Protection Agency (EPA) for use in its regulatory decision-making process. These documents also provide useful information to the USDA, agricultural scientists, and commodity groups. In February 1995, a panel reviewing NAPIAP criticized the program for using excessive "expert opinion" (scientific estimates) in lieu of documented biological data in these assessments. At the same time, the benefit-assessment process has suffered from a lack of protocols that could be used to guide the acquisition of such data. In an effort to better refine the benefit-assessment process, a Benefits Assessment Protocols Working Group was formed in 1995 to address these issues. The Working Group consists of representatives from USDA, EPA, and the American Crop Protection Association (ACPA). This workshop is the first result of the ongoing discussions on the development of assessment protocols.

The panel participants have all had experience with NAPIAP and the benefit-assessment process. Drs. Jenkins and Pike are the NAPIAP State liaison representatives for their respective States and have also participated in the assessment process. Dr. Bridges was a member of the panel that reviewed NAPIAP; he also has done an assessment, using an innovative approach, of the benefits of pesticide use in peanut production.

Panel Presentation

Dr. Jenkins discussed the Pesticide Benefits Assessment Model, developed at Ohio State University. This model attempts to assess the true economic impact of alternative control strategies and to provide information useful to regulatory decision making. The advantages of such an approach are: improved credibility and reliability, less expert opinion, consistent framework, and the development and use of formalized models. He also discussed the data needs and sources presently available.

Dr. Bridges pointed to the major problems with the present benefit-assessment process: imbalance in risk and benefits (with large sums spent on risks and little on benefits), credibility (risk well-defined with systematic approach to assessment; benefits more diffuse and difficult to define), little investment in benefits methodology, and an underestimation of the importance of biological components and their variability. This is true for agribusiness as well as government regulators and university cooperators. Dr. Bridges recommended that NAPIAP develop a common ground for assessments that includes: (1) multiuser databases of pest occurrence (and damage) and demographics of pest-management practices and (2) common, consensual, and systematic processes for assessments.

Dr. Pike addressed the history of assessments, noting that there has always been a balance of both expert opinion and empirical evidence, with the pendulum now moving away from expert opinion. He noted that in spite of regional variations and requirements, NAPIAP should be able to develop a set of protocols that include subjectivity; that is, both models and individuals to interpret the information (model, expert opinion, and empirical data).

Discussion and Conclusions

Numerous questions were raised, such as: How do you estimate the costs of practices (e.g., resistance management, new-product costs, and value of product alternatives)? This question led to a discussion of individual costs versus averaging and the value of prior knowledge (e.g., we know that curative methods always produce a higher return than prophylactic treatments when we average, but not necessarily when looking at individual years and fields).

Where are the data? Can we realistically estimate yield as related to damage indices? Are such models well known, and more important, are they transparent (is it obvious what they do)? This discussion led to a major conclusion that the concept of transparency was critical to the benefit-assessment process. A main concern with expert opinion is how interpretations are made from point A (data or estimates) to point B (recommendations). If the entire logical process from A to B is made clear (hence the term, transparent), then it stops being expert opinion and becomes empirical information. Because yield-quality effects are the most difficult to estimate, models become necessary tools. However, the inherent complexity and variability of our agricultural system demand that any model results be interpreted and analyzed in light of this variability.

The workshop concluded with the consensus that NAPIAP should develop protocol criteria that include the use of transparent models and careful analysis while not forgoing expert opinion. All affected parties should be a part of the development of these protocols. Benefit assessment should be an integral part of product development.

NAPIAP: Issues in Estimating Benefits of Pesticides

Craig Osteen
National Agricultural Pesticide Impact Assessment Program, USDA
Rob Esworthy
U.S. Environmental Protection Agency
Moderators

This session focused on issues of estimating economic impacts of pesticide regulations. These issues are important to IPM because pesticides are important tools in many IPM programs. Pesticide regulations can reduce the options available for some IPM programs with undesirable pest control, environmental, and resistance-management consequences. These concepts can also be applied to analyzing the economic impacts of IPM adoption.

EPA and USDA/NAPIAP have created a working group to review currently used economic methods of USDA and EPA pesticide benefit assessments because of questions raised about their quality. The ultimate purpose is to develop an improved set of guidelines for estimating the economic effects of pesticide regulatory actions. The primary questions of concern are:

1. Are we trying to measure the right things?
2. What methods to estimate economic effects are feasible, given restrictions on time, manpower, etc.?
3. Assuming that acceptable methods are being applied by USDA and EPA, are they being properly applied?
4. Are there new methods that should be employed?

Economic Analysis in the Pesticide Regulatory Process

Rob Esworthy discussed the role of economic analyses in risk-benefit comparisons under FIFRA Special Reviews and other registration decisions and in regulatory-impact analyses. In EPA, as well as NAPIAP, biologists and economists cooperate in the benefit-assessment process. The key elements in assessing the benefits of a pesticide used on a crop include: major pests controlled, chemical and/or nonchemical alternatives to the pesticide, and comparative performance of the alternatives in terms of pest control and crop yield or quality. Ultimately, the economic analyses require estimates of the use of the pesticide in question and changes in yield, quality, and/or production cost associated with changing to alternative control measures.

The Current Approach

Conceptually, the assessment of benefits by USDA and EPA is the same as estimating the annual net efficiency loss of removing the pesticide from the market and switching to the best alternative control option. Monetary values generally are not estimated for health and environmental effects of proposed regulatory actions, which are considered in EPA risk assessments. However, the economic-impact estimates can be used to estimate cost-effectiveness of risk-reducing options.

The standard framework for estimating the net economic effect is based on traditional Marshallian demand-and-supply curves. The supply curve is modified to reflect changes in yield and cost; price and quantity changes are estimated; and changes in consumer and producer surpluses are summed to estimate net effect.

Partial budgeting (change in value of production plus cost change) is used to estimate net effect when price changes are expected to be negligible or data to estimate price changes are not available. A variation on partial budgeting is often used when yield or quality losses are difficult to value: pest control experts are asked to develop equally effective control options, and the net effect is estimated as the cost of the new option minus the cost of the current approach.

Pesticide regulations can affect various groups differently. These so-called distributional effects are not obvious from the "net effect." Distributional effects estimated in assessments often include economic effects on purchasers of affected commodities, growers of affected commodities, users and nonusers of the regulated pesticide, regions where economic losses are particularly severe, and growers of other crops. Changes in commodity-program payments are also estimated, where appropriate, because they can shift the distribution of impacts.

Several methods are used to address price effects and associated welfare effects: demand-and-supply elasticities in simple static-equilibrium models; mathematical (quadratic) programming models; and econometric simulation models, such as AGSIM, that account for simultaneous price, acreage, consumer, and producer effects for several crops.

Comments by Panel

Fred Kuchler argued that the economic effects of pesticide regulations would ultimately affect rents and values of land, a primary fixed factor of production. This link may be an important distributional effect because approximately 40 percent of land in U.S. farms is rented. At one time, most farmers owned all the land they farmed, so separating this effect was not important. But a significant portion of farmland is now owned by people who do not farm. Share rents would be affected in the same years as effects of pesticide regulations on costs and yields occur. Potential renters would ultimately change their cash rent bids as changes in prices, yields, and costs became apparent.

Jerry Carlson focused on some important costs typically neglected in the benefit assessment process: phytotoxic effects of replacement pesticides, changes in drift damage to adjacent fields, changes in resistance development for remaining pesticides, and changes in the variability or risk of crop yield. In addition, there can be effects on the value of human capital: regulations could force growers to use new, unfamiliar techniques and receive lower financial returns until they gain experience with them. Carlson felt that there were difficult tasks where improvement was needed: (1) correctly estimating market shares of replacement controls and (2) estimating crop yield changes for different technologies in different regions by using experimental data. Two other important issues that need to be addressed are estimating changes in commodity-program payments and changes in unit prices of remaining pesticide products.

Erik Lichtenberg argued for a different approach to estimating the effects of regulations and focused on issues of data and data quality. He argued that crop science data fit poorly into the traditional economic framework, and better results could be obtained by collecting data capable of supporting estimation of economic relationships directly. Such data could be collected through USDA Farm Costs and Returns Surveys or pesticide-use surveys. The data currently collected are not sufficient by themselves, however, and would need to be augmented to include such items as: (1) output (yield) information; (2) quantities of individual pesticides used; (3) quantities of other inputs used, such as fertilizers, labor, cultivation methods, other nonchemical control methods, etc.; and (4) prices of all of the above. Panel data that included both cross-sectional and time-series information would support the use of dual methods and estimation of supply and input demand curves. Cross-section data alone would support estimation of production functions directly. The damage-control approach of Lichtenberg and Zilberman could be used to estimate damage; such estimates would be useful to cross-check damage estimates of crop scientists.

Erik Lichtenberg identified some other issues. First, assumptions of perfect competition (no individual buyer or seller can affect market price) may be invalid in some markets. Large buyers of agricultural commodities, such as grain marketers or food processors, could influence the prices that growers receive. In addition, national governments play an important role in marketing commodities in international markets. Second, it is not clear how effects on first-level purchasers of agricultural commodities transmit to effects on retail-level consumers, so that the "consumer effects" currently identified may relate to wholesalers but not retail-level consumers.

IR-4 Minor-Use Registrations

Dick Guest
Rutgers University
Moderator

Overview of the IR-4 Project, Christina L. Hartman, Rutgers University

Interregional Research Project No. 4 (IR-4) was established in 1963 by the Federal Government. The project helps producers obtain registered pesticides for "minor uses" on food crops. Minor uses include minor crops and limited uses on major crops. IR-4 also helps obtain labels for ornamentals. Most of IR-4's resources are directed toward the collection of field-residue data and the chemical analysis of those data. IR-4 receives the majority of its funding from USDA-CSREES, but also receives funding from USDA-ARS, commodity organizations, and pesticide registrants. Cooperating personnel on the project include Extension, ARS, private contractors, and IR-4 university employees. The IR-4 project is administrated from the Headquarters Office located at Rutgers, New Brunswick, New Jersey. Staff at Headquarters include the national director, associate director, national coordinator for research and registration, project planning coordinator, biopesticide coordinator, six study directors, quality-assurance coordinator, and database manager. Regional Offices at the University of California, Davis; Michigan State University; University of Florida; New York Agricultural Extension Service – Geneva; and USDA-ARS, Beltsville, handle the field trials and chemical analysis for the residue projects.

The majority of IR-4 research continues to support chemical registration; however, IR-4 also has an active biopesticide program. This program consists of two parts. The first part is the IR-4 Biopesticide Grants Program. In 1995, IR-4 funded the following projects: pepper-extract trials on minor crops in Washington State, bioherbicide for dodder control in cranberries, citrus root weevil larvae control with *Beauvaria bassiana*, disease-suppressive potting mix, fungi for the control of horticultural pests during shipping, soilborne disease control with *Pseudomonas fluorescens* and *Burkholderia cepacia*, recombinant viruses as a biological insecticide, *Entomophaga maimaiga* for gypsy moth control, and biocontrol of alfalfa disease with *Bacillus cereus*. The second part is petition preparation and submission to EPA. This past year, EPA granted tolerance exemptions for methyl anthranilate on blueberries, cherries, and grapes; for codling moth granulosis virus on apple, pear, walnut, and plum; and for cinnamaldehyde for mushrooms based on IR-4 petitions. In addition, an experimental-use permit was granted for the two organisms used in the microbial potting mix, and an experimental use permit is pending for use of a nonaflatoxin-producing isolate of *Aspergillus flavus* as a niche competitor in Arizona cotton.

The IR-4 program continues to bring pesticide tools of all types to the growers of minor crops. IPM is important to minor-crop production; and by providing more options (or in many cases the only option) for pest control, IPM is more easily implemented in these crops. As we move forward to the year 2000, IR-4 will continue to support IPM through pesticide registrations that will bring more ecologically compatible products to the market.

Pesticides for IPM Programs on Minor Crops: Insect Control, Kenneth S. Samoil, Rutgers University

IR-4 projects are initiated when a pesticide clearance request form detailing the needed pesticide use is received from a grower, an extension agent, or any other interested person besides the registrant. All projects are prioritized by extension agents, IR-4 State liaisons, and/or commodity representatives. In the fall, IR-4 coordinators schedule field trials and laboratory analyses for the following year, with high-priority projects scheduled first.

The IR-4 program is currently working with two new insecticides that fit particularly well into IPM programs: Imidacloprid and Tebufenozide. These compounds both have new modes of action and very low use rates as well as other favorable characteristics.

Imidacloprid is a Bayer product with a broad spectrum of activity against insects, although it is inactive against spider mites and nematodes. Although it affects the insect nervous system, its mode of action differs from organophosphates and carbamates in a way that is unlikely to result in cross-resistance. Typical use rates are 1 to 9 oz active ingredient (ai) per 100 lb seed, or 0.01 to 0.13 lb ai per acre for foliar applications. Imidacloprid is highly systemic, has good residual activity, and may control many insect pests with a single application. When applied as a soil or seed treatment, beneficials that would be harmed by a foliar application are spared. At a sublethal dose, it is still effective at preventing crop damage. IR-4 projects initiated prior to 1996 include uses on spinach, lima beans, succulent beans, greenhouse tomatoes, and cucurbits. In 1996, IR-4 will conduct trials on carrots, turnips, and dandelions. Already, IR-4 data have been used to obtain tolerances on hops and fruiting vegetables (except cucurbits).

Tebufenozide is a Rohm & Haas product that is active only against caterpillars (*Lepidoptera*). It imitates the molting hormone, causing the insect to stop feeding and to produce a new, malformed cuticle beneath the old cuticle. The caterpillar eventually dies of starvation and dehydration. Because it does not affect bees, tebufenozide may be applied during bloom at rates typically in the range of 0.03 to 0.3 lb ai per acre. Predators and parasites of nonlepidopterous pests are not harmed by Tebufenozide; thus, they are able to provide biological control, which in some cases will eliminate the need for other insecticide applications. Studies with this compound have been initiated at IR-4 for the first time in 1996, including work on turnips, blueberries, cranberries, raspberries, and mint.

Magnitude-of-Residue Data for the Establishment of Raw Agricultural Commodity 408 Tolerances for Fungicides, David C. Thompson, Rutgers University

I would like to describe three fungicide programs in which IR-4 has been involved that provide different examples of integrated disease-management strategies. The three examples include: eastern filbert blight, *Alternaria* blotch of apple, and metalaxyl insensitivity management.

IR-4 has been involved in the development of magnitude-of-residue data to support FIFRA Section 18 Specific Emergency Exemptions and ultimately Raw Agricultural Commodity 408 tolerances for Section 3 registrations of the use of chlorothalonil (Bravo®) and fenarimol (Rubigan®) on filberts for the control of eastern filbert blight (EFB) caused by *Anisogramma anomala*. EPA was initially somewhat reluctant to authorize two Section 18s for one disease/crop situation; however, after careful consideration of the situation, they realized that this was a good use of emergency exemptions in a developing IPM program, thereby reducing human exposure.

These two fungicides are used only in the early part of the growing season, which is the time of wet spring weather and maximum EFB infection. The preferred application time is from leaf-bud break through shoot elongation. That period is from late March until late May. Harvesting takes place in late September and October, and residues of both fungicides would be at nondetectable levels at harvest time.

Chlorothalonil is used early in the season, prior to or just as the leaf buds are opening. The excellent sticking activity of Bravo® allows adequate fungicide to be applied to leaf-bud tissue to provide excellent protection against infection.

Fenarimol is used later in the infection period as leaf buds open and new leaf tissue becomes exposed to EFB spores. This fungicide is locally systemic, and needs leaf tissue to be absorbed and translocated at levels necessary for good control of infection. This systemic activity is beneficial in that, once it is applied and absorbed by plant tissue, fenarimol is not washed off or diluted by the frequent rain showers that occur in spring weather, which is the time of maximum EFB infection. Fenarimol has shown “kickback activity” in that it controls fungal spore growth up to 48 hours after the spores have germinated and begun to infect plant tissue. This feature again proves to be valuable in Oregon during wet springtime conditions when growers cannot get into their orchards to spray immediately after a rain because of muddy or slippery conditions.

The percent control of EFB in the five years prior to 1991 has been estimated at 0 to 10 percent. The use of chlorothalonil through emergency exemptions in 1991 and beyond has increased the level of control to 50 percent. The addition of fenarimol is estimated by knowledgeable experts to increase control to greater than 80 percent.

IR-4 has been involved in the development of magnitude-of-residue data to support a Section 18 Specific Emergency Exemption and ultimately a Raw Agricultural Commodity 408 tolerance for Section 3 registrations of the use of iprodione (Rovral®) on apples for the control of *Alternaria* blotch. Iprodione application timing will be based on models. Two models are presently under evaluation. One model is based on a threshold of 65 percent of leaves with symptoms during the period of rapid disease increase (mid-June). The other model is based on accumulation of degree days and hours of leaf wetness. The models will be used to make a decision about the timing of the first fungicide application; subsequent applications will be made at 2- or 3-week intervals. Research has shown that where the first spray of iprodione (Rovral® 4F) was applied when recommended by the models, disease severity and defoliation were not significantly greater than in the preventive treatment where iprodione was applied on a 2-week schedule. The use of either model provided a savings of five fungicide sprays in each of the two orchards evaluated, thereby reducing the chemical load in the environment.

The fungicide metalaxyl has a very specific mode of action. Downy mildew fungi, of which there are many species and genera, have the ability to produce large numbers of spores that can be disseminated and cause new infections through many cycles within a single growing season. These two factors make it highly likely that insensitive strains of downy mildew fungi will develop. Ciba Crop Protection has employed fungicide mixtures to reduce this potential. They have packaged metalaxyl with Mancozeb, Chlorothalonil, or copper fungicides to prevent the development of metalaxyl-insensitive strains of downy mildew. IR-4 has been involved in the development of magnitude-of-residue data to support Raw Agricultural Commodity 408 tolerances for Section 3 registrations of the use of metalaxyl plus copper on many crops for the control of downy mildew. These crops include: arrugula, bok choy chinese cabbage, collards, kale, mustard greens, turnip, swiss chard, raspberry, grape, and papaya.

These three examples are only a few of the many ways that fungicides can be used in IPM/crop protection programs that enhance both food and environmental safety. IR-4 will continue to work cooperatively with growers, grower groups, state scientists, federal scientists, and registrants in obtaining clearances for fungicide uses that provide more optimal pest-management strategies.

Displacement of Aflatoxin-Producing Fungi from Cottonseed, Peter J. Cotty, *Agricultural Research Service, USDA*

There are no reliable and economic methods for preventing aflatoxin contamination of cottonseed, and no products are currently marketed to prevent preharvest contamination. Insect management, irrigation practices, harvest timing, planting date, and crop-handling procedures can be optimized to limit contamination. However, even after optimization, under severe environmental conditions, crops will frequently contain unacceptable levels of contamination. Controls must be effective during crop development and after crop maturation both in the field and in storage. Furthermore, most contamination occurs in damaged bolls; thus, controls must prevent contamination of plant parts compromised by either physiological stress or predation. Meeting these requirements is difficult for procedures that must prevent formation of the relatively rare, highly contaminated seeds that often contain the most contamination. A biopesticide that meets these requirements is being developed. This biopesticide uses naturally occurring atoxigenic strains (do not produce aflatoxins) of *Aspergillus flavus* to competitively exclude aflatoxin-producing fungi and, in so doing, to prevent aflatoxin contamination. The product is expected to provide economic benefit to cotton producers in severely affected portions of Arizona.

The IR-4 Project Biopesticide Program is facilitating the development of this product by assisting in the registration process.

Aflatoxins are toxic, carcinogenic chemicals that frequently occur in foods and feeds. Health concerns have led to regulatory limitations on the aflatoxin content of foods throughout most of the world (Stoloff, van Egmond, and Park 1991). The most toxic and highly regulated aflatoxin is B_1 (Park and Stoloff 1989; Stoloff, van Egmond, and Park 1991). The fungus *Aspergillus flavus* causes aflatoxin contamination of cottonseed. Contamination results in losses for producers, processors, and animal industries that depend on cottonseed for feed (Park and Stoloff 1989). Whole cottonseed and/or cottonseed products are an important dairy and cattle feed. Aflatoxins in cottonseed are transferred to milk in slightly modified form (Park and Stoloff 1989; Park and Stoloff 1989). U.S. regulations prohibit aflatoxin concentrations over 0.5 µg/kg in milk. Milk may be destroyed and entire operations temporarily shut down and quarantined in dairies producing milk tainted with unacceptable aflatoxin levels (Emnett 1989). To prevent unacceptable aflatoxin levels in milk, the regulatory threshold for aflatoxin B_1 in cottonseed fed to dairy cows is 20 µg/kg (Park, Lee, Price, and Pohland 1988; Park and Stoloff 1989). Aflatoxin contamination of cottonseed can be minimized by early harvest, prevention of insect damage, and proper storage (Cotty 1991a; Cotty 1991b). However, even under careful management, unacceptable aflatoxin levels may occur via either unpreventable insect damage to the developing crop (Cotty and Lee 1989) or exposure of the mature crop to moisture prior to harvest (Cotty 1992) or during storage (Russell and Lee 1985), handling, transportation, or even use (Cotty 1991a).

Aspergillus flavus populations are highly complex and are composed of strains that differ morphologically, physiologically, and genetically (Bayman and Cotty 1991; Bayman and Cotty 1993; Cotty 1989). Differences among strains in ability to produce aflatoxins is well known (Davis and Diener 1983), and aflatoxin-producing ability is not correlated with strain ability to colonize and infect developing cotton bolls (Cotty 1989). These observations led to the suggestion that atoxigenic strains of *A. flavus* might be used to exclude toxigenic strains through competition during infection of developing crops, thereby preventing aflatoxin contamination (Cotty 1989; Cotty 1994). In both greenhouse and field experiments, wound inoculation of developing cotton bolls and corn ears simultaneously with toxigenic and atoxigenic strains led to reductions in aflatoxin contamination of the developing crop parts as compared with controls inoculated with only the toxigenic strains (Brown, Cotty, and Cleveland 1991; Cotty 1990). Atoxigenic strains are effective at preventing post-harvest aflatoxin contamination both when the crop is infected naturally in the field and when it is inoculated after harvest (Brown, Cotty, and Cleveland 1991). Thus, competitive exclusion of aflatoxin-producing strains of *A. flavus* with atoxigenic strains of the same fungal species may provide a single method for preventing aflatoxin accumulation throughout crop production and utilization (Cole and Cotty 1990; Cotty 1989; Cotty 1990; Cotty 1994).

In the United States, aflatoxin contamination of cottonseed is most consistent and severe in the irrigated western desert valleys, where contamination is often associated with pink bollworm damage (Cotty 1991a; Cotty and Lee 1989). Cottonseed produced in these valleys has a relatively high value per acre because of high cotton yields and high demand for cottonseed within the area. Contamination levels are highly variable within fields, plants, and even bolls (Cotty 1991a; Cotty and Lee 1989; Lee, Wall, Cotty, and Bayman 1990). Contamination is often associated with seed exhibiting bright green-yellow florescence (BGYF) on the linters under ultraviolet light (1). BGYF cottonseed are typically those infected by *A. flavus* through insect wounds. Results of greenhouse studies suggest atoxigenic strains reduce aflatoxin contamination by competitively excluding aflatoxin-producing strains from the crop (Brown, Cotty, and Cleveland 1991; Cotty 1990; Cotty and Bayman 1993). During seasons when aflatoxin contamination is severe, *A. flavus* populations increase as the cotton crop is produced (Lee, Lee, and Russell 1986). For atoxigenic strains of *A. flavus* to be useful during crop production, they must be applied at a time and in a manner that allows them to compete successfully with aflatoxin-producing strains. In theory, application of an atoxigenic *A. flavus* strain early in the season should give the atoxigenic strain preferential exposure to the developing crop and thus the advantage in competing for crop resources during infection and during *A. flavus* population increases associated with cultivation (Robens and Richard 1992).

An aflatoxin-prevention technology based on atoxigenic strains of *Aspergillus flavus* is being developed for use in the region of Arizona with the most frequent and severe aflatoxin contamination of cottonseed. Strains are seeded into cotton fields at lay by (immediately prior to first bloom). The strains are applied to the soil surface under the crop canopy in the form of colonized sterile wheat seed. When the crop is subsequently irrigated, the atoxigenic strain uses the resources in the colonized wheat seed, sporulates, and disperses to the crop. Wheat seed colonized by atoxigenic strain *Aspergillus flavus* AF36 has been evaluated in small-scale test plots since 1989. Strain seeding caused large and significant changes in the *Aspergillus flavus* population on the crop and in the soil. Applications resulted in the applied atoxigenic strain becoming dominant in the field and aflatoxin-producing strains becoming less frequent. These changes in the *A. flavus* populations were associated with great reductions (75 percent to 99 percent) in aflatoxin contamination (Cotty 1991b). Further tests showed that atoxigenic strain applications have a long-term influence on *A. flavus* populations resident in agricultural fields, suggesting atoxigenic strain applications may have benefits over multiple seasons and that long-term, area-wide changes in the aflatoxin-producing potential of *A. flavus* populations may be achieved. Results of field plot tests indicate that atoxigenic-strain applications do not increase the amount of *A. flavus* on the crop at maturity and do not increase the percent of the cottonseed crop infected by *A. flavus*.

Aspergillus flavus typically becomes associated with crops in the field during crop development and remains associated with the crop during harvest, storage, and processing. Thus, crop vulnerability to aflatoxin contamination remains until the crop is ultimately used. Similarly, atoxigenic strains seeded into agricultural fields prior to crop development will remain associated with the crop until use and may provide long-term postharvest protection from contamination. Atoxigenic strains applied both prior to harvest and after harvest have been shown to provide protection from aflatoxin contamination of corn (Brown, Cotty, and Cleveland 1991), even when toxigenic strains are associated with the crop prior to application.

Economics of aflatoxin contamination will probably dictate the regions in which atoxigenic strains are used. We hope to produce materials for atoxigenic strain applications for $5.00 per acre or less. If treatments are 70-percent effective and an average of 40 percent to 70 percent of seed is above 20 ppb and the benefit of having aflatoxin-free seed is $20 to $40/ton, then growers will gain an average return above an initial $5/acre investment of $0.60/acre to $14.60/acre. Economics may be improved by both long-term and cumulative benefits resulting from strain ability to remain in fields until the next crops are planted. Benefits may also arise from the applied atoxigenic strains remaining with the crop until use and thus preventing increased contamination during transit and in storage at dairies.

Just as dust does not stay in the field in which it is raised, fungi do not stay in the field to which they are applied. Thus, over time, applications may reduce contamination in an area as a whole, facilitating the development of either gin-wide or community-wide management programs. In areas where multiple crops are affected by contamination (i.e., corn, cotton, and peanuts), treatments to one crop may benefit all crops. The economics of applications in such areas may be complex.

Development of a product based on atoxigenic strains and sold as an agrochemical would probably be the simplest course to producing an aflatoxin-control product. However, there are currently no products available for preventing aflatoxin contamination during crop development. Thus, the potential market for such products is unclear. Failure to demonstrate a reliable and ready market for atoxigenic-strain-based products has limited industrial involvement in their development. Alternatives to company development may include development of pest control districts. Advantages of such programs include tailoring the atoxigenic strains and formulations to specific regions, increased cost effectiveness, and development of mechanisms for funding the monitoring of fungal populations.

The next step in development and commercialization of atoxigenic strains is the performance of large-scale commercial tests. These tests will determine how to fit the technology into commercial practice and how to assess benefits of large-scale applications. Because atoxigenic strains are considered biopesticides, such evaluations require entry into the pesticide registration process and granting by the U.S. Environmental Protection Agency of an Experimental Use Permit and an Exemption from Tolerance. Interregional Research Project No. 4 is facilitating the further development of atoxigenic strains by assisting with the registration process. An application to treat a portion of the 1996 commercial cottonseed crop has been submitted.

Dead, weakened, and partially decayed plant tissues are readily available in agricultural environments, and it is not feasible to prevent the use of these resources by fungi. Thus, fungi grow as our crops are grown, and these fungi become associated with the edible portions of the crop. A level of control over which fungi become associated with crops may be provided by seeding select fungal strains into agricultural fields. This selection and seeding of fungal strains may reduce the vulnerability to aflatoxin contamination of all crops grown in a treated area.

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Pest Management Information Decision Support System

Dennis D. Kopp
Cooperative State Research, Education, and Extension Service, USDA
Moderator

What I have been hearing communicated from previous speakers at this symposium are two distinctly different philosophies and goals in regard to IPM. These two differing philosophies represent disparate concepts of, approaches to, and expectations from IPM.

One group views IPM as a program and a way to focus efforts on managing pesticides and their use. Those expressing this view have strong interests in environmental issues, public health, basic research, and pesticide regulation. Representatives expressing these goals and this philosophy see a need for rapid implementation of biologically based pest-management systems as the direction in which IPM should be moving.

Another group at this meeting views IPM as a way to better manage pests. Participants that expressed this philosophy were farmers, industry representatives, commodity-group representatives, and applied agricultural research and Extension scientists. People in this group view pests as the problem issue and that enhanced management tools are needed to address this problem. Those with this philosophy view the use of synthetic chemistries as one of the options in the pragmatic management solutions to pest problems, rather than the pesticide itself being the problem.

The exciting thing about this workshop is that both groups are using this format as a common meeting place to present their concepts and approaches and are seeking shared grounds to communicate their beliefs and differences. The Pest Management Information Decision Support System (PMIDSS) will be useful to all parties interested in pest-management issues, regardless of one's position, goals, issues, or philosophies.

Because the database is still in a formative phase, my concepts remain in the dream category. My dream is that PMIDSS can provide a totally new and more complete package of information re-garding pest-management topics than ever possible before. This information system will put these pieces of data at the fingertips of scientist, regu-lators, and policymakers, allowing users to make more-informed decisions. It must be kept in mind that a dream is a combination of one's reality, one's past, one's present, and one's imagination. Let me share with you now some of the parts of my dream of PMIDSS:

- I see this database as being an information-rich system accessible to government, State, and private organizations. Users will be able to rapidly search, download and identify sources of pest-management information in convenient, usable formats for use in rapid, concise, and documentable decision making.

- I see the database becoming a reality in FY96 through IPM and NAPIAP working as partners by sharing costs, information, personnel, and commitment to this effort.

- I see this as an information system with multiple owners, supporters, users, and contributors. Besides IPM and NAPIAP, other partners in the area of data contribution, development, maintenance, and use would be the State Land Grant Partners, EPA, IR-4, NASS, NCFAP, and AIS, to mention just the obvious.

- In the electronic environment of tomorrow, this database will have to be easy to access, contribute to, update, and use. It will be an information system that allows users to easily search for information, focus on topics or issues, retrieve information, and manage and format output to fit users' needs.

- My dream sees this database as a common decision-making information system on pest-management issues sharing common use by the agricultural, environmental, regulatory, scien-tific, industrial, crop-consultant, Extension, and public-health communities.

- A key link in the data gathering will be the land-grant scientists. Therefore, this information system will be of equivalent or greater use and value to the state scientist as it will be to the Federal partners. State scientists will have the ability to instantaneously bring together pest-management information that was previously either unavailable or difficult to find or handle. This database will be a one-stop shopping spot for pest-management information.

- It will be an information system with many layers of pest-management information, such as pesticide usage, regulatory history of active ingredients, pesticide labels, pesticide-resistance information, host plant resistance, cultural control, comparative performance of different management options, and much more.

Often a person can trace the source of a dream to a real time, place, or incident. My dream can be traced to my experiences with the three people who have collaborated with me on the Pest Management Information Decision Support System Project, Dr. Barry Jacobsen, Dr. Bob Riley, and Mr. Terry Janssen.

Part V. Policies for Promoting Biological and Reduced-Risk Alternatives: Panel-Discussion Summaries

Introduction

A myriad of policy tools (regulations and market incentives) could be used to reduce the negative environmental and health effects of pesticides. The sessions summarized in Part V focused on nonregulatory methods used by USDA to reduce pesticide risks, especially funding for research on alternatives, as well as policy tools used by EPA.

In the first session, eight policy approaches that could be used to reduce pesticide risks were outlined and discussed: (1) regulations on pesticide use, (2) regulations on the conditions of use, (3) taxing pesticides, (4) public funding for alternatives, (5) subsidizing the use of alternatives, (6) quota-based market incentives, (7) providing market information, and (8) moral suasion. One panelist cited successful European programs that use a variety of these approaches (the taxation program in Denmark, Norway, and Sweden; demonstration programs in Germany and the UK; Australia's voluntary agreements between farmer and consumer; and "green labeling" throughout Europe). California's multiple approaches, from mandatory training on biological control for pesticide applicators to an "IPM innovator" public recognition program, were also highlighted.

Does IPM certification help make farming more profitable to growers or does it make mandatory standards more likely? This issue is discussed in a session focusing on consumer concerns about pesticides. IPM certification is the policy approach of providing information to consumers about the environmentally friendly pest-management practices used under IPM production systems so that they can make more informed choices. In a recent survey, customers at farmers' markets and farmstands in Massachusetts, the only State with IPM certification, were generally unaware of IPM, but most said they would prefer it after hearing a definition that stressed environmental benefits. Numerous surveys indicate that consumer concern about pesticides is broader than food residues and includes environmental and farm worker concerns.

Research to develop pesticide alternatives is gaining ground as a major focus of USDA's nonregulatory approach for reducing the risks associated with pesticides, and several sessions in Part V were devoted to biological pest control. These sessions revealed some current successes with the use of biological control in some pest-management areas as well as the need for further research in others. The session on areawide IPM describes five, ongoing, biologically based Agricultural Research Service projects that are gaining support through partnerships with other Federal agencies, universities, commodity associations, and other stakeholder groups. The funding and acreage devoted to most of these projects, which are targeting major insect pests like the codling moth in the Pacific Northwest, have been increasing since their development in the early 1990's.

While the areawide IPM projects all target insect pests, the traditional biocontrol target, the two other sessions, "Limitations to Implementation" and "Exotic Pest Plants" describe some early successes with biocontrol of weeds. Most of the early successes with biocontrol have been for weeds in pastures and on ranges, where herbicides have been too expensive to apply. The need for research on biological management of weeds in cropping systems was underscored in both of these sessions. Robert Luck made a strong argument that the payoff for carefully designed, long-term, fundamental research on a specific ecological interaction, such as the interaction between a specific host plant and its biocontrol agent would be a better understanding of the fundamental mechanisms of similar interactions. He noted that the lack of this type of research has impeded biological and ecological pest management and will require teams and long-term commitment of funding to be successful.

EPA's Pesticide Environmental Stewardship Program is a new program through which pesticide users form a partnership with EPA, and make a voluntary commitment to reduce pesticide risk. This program and California's similar IPM Inno-vator Program use a "moral suasion" policy approach for encouraging the farmers and other pesticide users to reduce their use of risky products. Dozens of organizations have become partners with EPA since the program was launched in December 1994: the American Corn Growers Association, the California Tomato Board, other commodity groups, the Professional Lawn Care Association of America, the Tennessee Valley Authority, and other land managers. Some of EPA's partners have set numerical goals and tar-gets for reducing pesticide risks. The U.S. Depart-ment of Defense, for example, is aiming for a 50-percent reduction in pesticide use by the year 2000.

Finally, several new computer-based technologies [e.g., geographic information systems (GIS) and precision farming] are discussed in terms of their potential influence on IPM. The potential for GIS to "vastly improve" pest-sampling efficiency is described, and examples of its usefulness in characterizing habitat susceptibility (locating, for example, the egg beds of the Australian plague locust through satellite data) were cited. Panelists noted that precision farming will greatly enhance site-specific management capabilities but that mechanical capabilities may not be matched with economic thresholds. Precision farming can increase the efficency of pesticide applications but may not perform as well with other cultural and biological methods. Finally, the recent rapid growth in the U.S. organic industry is described along with the benefits that are anticipated from implementation of national organic certification, such as enhanced consumer confidence in products labeled organic.

Reducing Environmental and Health Risks from Agricultural Chemicals: Policy Considerations

Katherine (Kitty) Smith
Henry A. Wallace Institute
Moderator

When many hear the phrase "pesticide policy," they automatically assume that it applies to pesticides' regulation either in general or with specific reference to the U.S. pesticide registration process through which some pesticide uses are prohibited and others can be (and have been) canceled or restricted. Surely, restrictive regulation is one pesticide-reduction alternative. But there is an array of other policy approaches that have been or could be taken to reduce the use of and/or risk associated with pesticides. This overview of generic policy options identifies the alternatives.

Conceptually, the regulated restriction of some pesticides or pesticide uses has some policy advantages. The approach is direct and transparent. And restriction has been demonstrated to induce and stimulate technological change that can lead to development of new, less risky alternatives to the regulated class of materials. However, depending upon the manner in which restrictive regulation is implemented (particularly in the way that regulatory decisions are made), the approach can also have some distinct disadvantages. The U.S. experience points to the high administrative burden (and associated public costs) of pesticide regulation. Furthermore, the uncertainty associated with measures (of pesticide benefits and risks) used to make regulatory decisions can lead to poor decision rules and inappropriate incentives. For instance, registration costs may provide incentives for manufacturers to withdraw safe materials from the market.

The regulatory approach can also be (and has been) employed to restrict the conditions under which pesticides may be used, rather than restricting the materials themselves. Examples include worker-protection programs and water quality regulations that specify pesticide use conditions to minimize health or environmental risk. This approach, too, is direct and transparent. While less costly, to both policy administrators and pesticide users, than pesticide restriction, risk-reduction regulation can, in general, be harder to monitor and enforce.

Rates of tax sufficient to modify pesticide-use behavior are shown to be very high (more than 50 percent), so there is little room to calibrate tax rates with pesticide risk. Despite technical problems with taxation as a way to reduce pesticide use, it is an effective approach for generating revenues that may then be applied to remediation or prevention of adverse effects of pesticides.

USDA's expanded in-house research and competitive grants programs for IPM and biological pest control are examples of R&D investment. It needs to be noted, however, that the mere *availability* of new technologies and techniques does not guarantee their adoption. There are already a lot of alternative techniques "on the shelf." Appropriate economic conditions and/or incentives must exist before their adoption will displace pesticides.

Short-term subsidies can be used to introduce farmers or other pesticide users to alternatives that are likely to be profitable to the user. Longer-term subsidies are required for sustained adoption of alternatives that are not profitable relative to pesticide use under existing economic conditions without the addition of a subsidy.

A market-based system can be created to allocate reasonable levels of pesticide use. For example, quotas for a maximum level of pesticide risk could be allocated to users who could choose to employ or sell their rights to pesticide use. Quota-based markets have been created for the purpose of limiting air pollution within airsheds and point-source pollution within watersheds. However, the large number of pesticide users and the variance of nonpoint effects of pesticide use across numerous sites complicate the application of this approach to pesticide risk reduction. These large and practical problems probably explain why no simulated market has been tried for pesticide risk.

The preferences expressed by consumers in the marketplace can have a profound impact on the effective demand for pesticides at the producer level, but only if consumers have the information base on which to express preferences through purchasing behavior. Government provision of information, such as through certification of organic production or "green labeling" programs, can fill existing gaps. This approach allows the market to work more effectively through the availability of a fuller information set.

Successful Cooperative Extension System IPM programs demonstrate the potential for farmer education to reduce pesticide use and/or risk. Public-education programs might additionally improve the information base on which both economic and political markets operate.

Government could appeal, through advertisement and public relations campaigns, to individual pesticide manufacturers', distributors', or users' sense of responsibility in minimizing risk to people and the environment. This approach worked for antilittering. But then, there are no proponents for littering.

This set is basically the universe of different policy approaches that *could* be employed to reduce pesticide use or pesticide risk, arrayed according to the degree of intervention each applies to existing systems.

Our panel speakers reviewed what policy avenues have been pursued and what policies are actually being practiced in several venues. From there, we explore what experience has shown to be the problems and successes associated with different policy approaches to pesticide risk reduction.

Survey of OECD Countries' Activities to Reduce Pesticide Risks, Jeanne Richards, Organization for Economic Cooperation and Development

As a part of its pesticide-risk-reduction project, the Organization for Economic Cooperation and Development (OECD) surveyed 19 OECD (developed) countries, 9 Food and Agriculture Organization (less developed) countries, and the European Community to determine what policies and programs are in place to reduce pesticide risk. The surveyed countries' policies varied in three important respects: (1) whether policy goals focused on reducing pesticide use, reducing pesticide risk, or increasing IPM usage; (2) whether programs were implemented at a national scale or addressed by subnational political units; and (3) whether participation was mandatory or voluntary. Despite these differences in approach, many common elements of countries' policies were also identified. For example, all OECD respondents have policies or programs to enhance IPM, including IPM research and development programs and programs to increase the use of biological controls.

The survey and its analysis identified the following as among the more successful programs (in OECD countries other than the U.S. and Canada): pesticide-use-reduction programs in Nordic countries; Australia's voluntary agreements among farmers and consumer associations to reduce pesticide use; European subsidies for environmentally friendly farming; the European Union's "Fifth Environmental Action Plan"; green labeling programs throughout Europe; model-farm demonstrations in Germany and the United Kingdom; and pesticide taxation in Denmark, Norway, and Sweden. Survey respondents' views on what works best and what is needed for effective pesticide-risk-reduction policy identified sound data on pesticide use and systematic methods for measuring programs' progress toward reduction goals as critical needs. Identified ingredients for program success were: farmer participation in programs; farmers' commitment to reducing agriculture's impact on the environment; involvement of both agricultural and pesticide authorities; use of traditional agricultural networks; a whole-systems approach; consideration of economic impacts on and risks borne by farmers who use alternatives to pesticides; and public awareness and support.

California's Multipronged Approach to Pesticide-Risk Reduction, David Supkoff, Department of Pesticide Regulation, California Environmental Protection Agency

The State of California has long been a bellwether for the nation when it comes to pesticide policy. At present, more than half a dozen different State-level programs directly affect pesticide use or associated risks. First, California has its own Worker Protection Program that prescribes the conditions under which farmworkers may legally use pesticides. Enforcement has proved to be a critical function of that program. Second, like all States, California has a program for pesticide-applicator certification. A unique aspect of this program is that, to be certified, pesticide applicators must have training in biological control. Third, California's Groundwater Protection Program directly addresses the use of pesticide materials found to be groundwater contaminants. Water-quality protection with respect to pesticides in California is greatly aided by interagency agreements with the State Water Quality Board to coordinate regulations. Fourth, California has initiated an IPM Innovator Program that gives public recognition to individuals and groups that have implemented strong IPM programs or practices. Basically a form of rewarded moral persuasion, this program has been successful not only in getting pesticide users to experiment with alternatives, but also in gaining broader acceptance of the IPM approach. Fifth, a granting program, Innovations in Pest Management, supplements the State's Extension IPM initiatives. In addition, State pesticide restrictions apply under a variety of other programs, including California's activities toward compliance with the Clean Air Act.

The Role of Risk Analysis in IPM, Nell Ahl, USDA Office of Risk Assessment and Cost-Benefit Analysis

Risk analysis involves risk assessment, risk management, and risk communication to identify potential hazards, determine the likelihood (probability) of their manifestation, and gauge the magnitude of the consequences should the hazards manifest themselves. As an interesting case of pest-management program strategies illustrates, risk analysis can bring added value to IPM-policy decision making.

The eurasian pine shoot beetle (PSB) emerged as a new and potentially serious pest of timber in the upper midwestern United States in 1992. Prior to risk assessment, the State of Michigan proposed 25 mitigation measures, including several required pesticide sprays for trees and logs and met resistance from the timber industry. Risk assessment performed by the USDA's Animal and Plant Health Inspection Service showed, however, that 99.8 percent of the risk from PSB originated in a 2-week period in slab wood at the sawmill site. Treatment of slab wood by burning or grinding it up prior to the end of the 2-week period in the PSB life cycle effectively managed the risk, required no pesticide use, and was a strategy the industry complied with, without the need for regulation. Lessons learned from this experience included: (1) risk assessment should precede risk-management policy decisions; (2) risk communication can work when all parties come together early in the process; and (3) good risk assessment can be an analytical tool to support IPM decisions.

Risk assessment is required for major USDA regulations. In conjunction with cost-benefit analysis, it can give power and context to pesticide-reduction-policy decision making.

Imperatives for Pesticide Reduction Policy, Carolyn Brickey, National Campaign for Pesticide Policy Reform

Clarification or reform in four critical areas of U.S. IPM and pesticide policy are needed to assure pesticide risk reduction. First, a clear, science-based definition of "biologically intensive IPM" is needed to guide policy directions. The definition should provide measurable goals so that policy progress and success can be gauged. Second, USDA should implement an IPM policy goal based on the logical paradigm that IPM lessens reliance on pesticides, less reliance translates into less use, and less use means less risk.

Third, there is a myriad of problems involved in using the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as the basis for managing pesticide risk. For instance, the practice of pesticide product-by-product review rather than review by class of pesticide slows the process and can result in restricted products being replaced by riskier alternatives. Further, the FIFRA process is not providing adequate incentives for technological change, and it perpetuates the promotion and defense of pesticides as the principal tool for pest management.

Fourth, a range of new institutional roles are needed. USDA should make itself a leader in the development of nonchemical pest-management technologies. In particular, public research funds need to be better targeted toward this goal. EPA, in the meantime, needs to change the basis for its risk-benefit determinations, particularly as they address the hormone-mimicking and immuno-logical effects of pesticides. Finally, the food-processing industry needs to adopt and promote new standards for the protection of its customers.

Audience Discussion

Ensuing discussion was brief but clearly underscored the complexity of pesticide-risk reduction policy-making. A number of comments and questions concerned the issues of what ought to constitute risk and where public policy should "draw the line" on unacceptable levels of risk. While such areas of questioning are informed by science, the answers themselves are squarely in the realms of policy and politics.

Responding to Consumer Concerns About Agricultural Chemicals

Carol Kramer
Economic Research Service, USDA
Moderator

The panel was asked to address the subject of consumer concerns about chemicals; to identify policy and program responses that potentially make sense, given consumer concerns and public health information; and to discuss the extent to which a policy or program response, such as that embodied in the IPM Initiative, can be responsive and successful. The panelists were selected to represent a diversity of perspectives and expertise. Panel participants included Eileen van Ravenswaay, Michigan State University; Molly Anderson, Tufts University; Fred Kuchler, Economic Research Service; and Allen Rosenfeld, Public Voice for Food and Health Policy.

The policy elements that establish the context for the departmental IPM Initiative include:

- public concerns of the 1980s and 1990s about pesticides in food, water, and the environment as well as concern about worker/operator exposure;
- the 1993 Administration policy to reduce pesticide use;
- the Administration policy to support achievement of IPM on 75 percent of crop acreage; and
- the EPA's policies to reduce risk from pesticide use and encourage environmental stewardship.

The Economic Research Service (ERS) sees its role, in support of the policy goal of reducing the risks from pesticide use, as one of assuring that the assessment methods and mechanisms are put in place to test the logic and establish the outcomes of the policies and programs that are implemented. In the end, ERS seeks to be able to answer whether IPM methods can be developed for 75 percent of U.S. crop acreage; where they are adopted, if adoption reduces chemical use; and if the reductions in chemical use are well-targeted so that areas of highest water-quality vulnerability, chemicals with the highest toxicity, and chemicals with the greatest environmental or public health risk are most affected. These are not simple results to know, but only by systematically targeting programs and evaluating their success will we truly understand if the IPM Initiative approach will have the intended payoffs.

The first panelist, Eileen van Ravenswaay has conducted extensive research in the area of consumer perspectives on pesticide use, chemical residues in food, and their implications for public policymakers. The first major finding from her research is that perceptions of risk from pesticide residues differ greatly among members of the public. One implication is that there are major differences in information needs, policy preferences, and market niches among the public, although these differences are not very systematic. A second is that the risks from pesticide residues are, and are perceived to be, broader than cancer alone. A corollary here is that the sole focus of risk communicators on cancer does not address these concerns. A third is that the concern about agrichemicals is not limited to residues, but includes concerns about the environment and about farm workers. A corollary here is that the focus of risk communicators on cancer from residues does not address these concerns. A fourth is that trust in the government, industry, and scientists is very low and may be more important than risk perceptions. A corollary here is that restoring trust should be a high priority, and there should be a focus on the process of ensuring safety for consumers and the environment in order to do so.

van Ravenswaay also discussed perceptions of the benefits of pesticides and their implications. The public generally believes that pests need to be controlled and economical alternatives to pesticides already exist. The implication is that they expect IPM to be used. Many consumers are willing to pay more for less pesticide use, but product price differences are important. An implication here is that the public is willing to pay for IPM research; also, there are some market-niche opportunities. Public views on organic foods indicate confusion. One implication is that selling "less pesticide" (as opposed to organic "no pesticides") to the public will require a major marketing effort. Processes used by growers, shippers, and handlers may be important.

Molly Anderson reported field research on consumer reactions to IPM certification, her conclusions, and her experience working with the Massachusetts IPM apple growers. She noted the importance of learning about consumer reactions to IPM certification, particularly in light of evident public interest and government support. Because Massachusetts is the first State with an active IPM-certification program and label, it was a good venue to test response to IPM-labeled foods and to find out if consumers buy IPM-grown foods preferentially. The IPM certification method in Massachusetts consists of a checklist of practices, from which farmers must accumulate at least 70 percent of possible points.

The study investigated consumer awareness of IPM and the effects of a "passive" and an "active" marketing strategy. Thirty customers were interviewed at each of six farm stands and six farmers' markets in eastern Massachusetts, selected to allow comparisons between income levels and ethnic mixes. The short questionnaire probed purchase motivation, IPM awareness, certification awareness, and personal characteristics. The IPM definition used stressed environmental benefits, with no mention of food safety.

Results indicated little initial consumer awareness of IPM (only 19 percent). However, 50 percent of consumers "cared" how their food was grown, and some 85 percent said they would prefer IPM, after explanations. Many consumers associated IPM with food safety, even though the educational messages did not mention food safety, only environmental protection. Demographic characteristics were insignificantly correlated with IPM support, and the point-of-purchase educational strategies used were relatively ineffectual. Nonetheless, Anderson concluded: high percentages of customers claim to prefer IPM-certified products after hearing a definition; consumers will accept necessary pesticide use; potential advantages of IPM certification are strong; IPM certification programs must be combined with consumer education programs to be effective.

Fred Kuchler presented newly available analysis based on recent data from USDA's Pesticide Data Program. The program allows analysts to trace pesticide residues on fruit and vegetables to four sources: on-farm pesticide use; post-harvest pesticide use; pesticide use on imported foods; and canceled pesticides (canceled registrations for use) that persist in the environment. The data show that post-harvest pesticides capture the largest share of residue detections.

The data show that farmers' pest-control choices influence consumers' pesticide dietary intake, but the way in which food is marketed and the history of pest-management techniques used on farms may have greater influence. Agricultural research intended to develop on-farm pest-control alternatives will not address all of the sources of pesticide risks in consumers' diets.

Allen Rosenfeld addressed public-policy concerns related to pesticide residues in foods and in the environment. He also provided an update on developments related to the farm bill. He noted that pesticide policy reform was not directly involved in the farm bill discussion. He pointed out challenges in communicating the benefits of IPM to a public concerned about pesticides, given the diverging philosophies associated with pesticide use among IPM users and within the IPM community.

One issue evident from the discussion was that while the public is concerned with pesticide residues in foods, the majority, but not all, of those residues of concern (according to the ERS analysis) result from post-harvest use, use on imports, and canceled pesticide use or residues. IPM is unlikely to have an impact on those sources of dietary exposure. One implication is that IPM may be most likely to gain strong public support if it can achieve and demonstrate accomplishments in the realm of environmental stewardship and if it can be expanded to include health benefits from reducing occupational exposure. A final issue discussed was producer acceptance of certification programs that are needed to accompany any label or promotion efforts. Whereas some producers see an advantage to certification and participate voluntarily, others see a potential problem. Some Massachusetts producers had concerns that IPM certification standards would become mandatory and progressively more restrictive to producer autonomy over time.

Areawide IPM as a Tool for the Future

C. O. Calkins
Agricultural Research Service, USDA
Moderator

Participants in this session were: R. M. Faust , J. R. Coppedge, L. D. Chandler, D. D. Hardee, and M. R. Bell, Agricultural Research Service, USDA, and J. F. Brunner, Washington State University.

Overview, Goals, and Premises

The areawide pest-management program administered by ARS involves a coordinated program with active grower participation to suppress or maintain a low-level pest population over large definable areas, as opposed to on a farm-to-farm basis, through environmentally sound, effective, and economical approaches. To gain participant support, this type of partnership program must include a meaningful list of benefits, such as lower costs and increased profits. A benefit to the grower should include more sustainable pest control at costs competitive with insecticide-based programs. A reduction in chemical insecticide use is, of course, one goal. Our partners include other Federal agencies, university research and extension, State departments of agriculture, and the private sector as well as the growers, commodity groups, and other stakeholders.

The ARS, in the USDA IPM Initiative under the Strategic Implementation Plan, is charged with "establishing a program to support the IPM needs through implementation of areawide pest-management projects." Scientists working in support of IPM have also been requested to proactively increase their linkages and partnering with the State and private sectors actively involved with IPM in general and with the USDA IPM initiative specifically. The overall mission and goals of the areawide pest-management program are to establish and implement areawide pest-management research and action programs for key pests and crop systems that have been identified as high priority. These research and action programs are to (1) result from a stakeholder partnership and collaboration dedicated to the development and adoption of improved crop-management technologies; (2) demonstrate the positive impacts and advantages of such a program over a large area through enhanced grower profits, reduced worker risks, an enhanced environment, and a proven superiority of an areawide IPM strategy as compared to past and current control approaches; and (3) achieve a mature areawide pest-management system so farmers, consultants, and local organizations will be left with an operational program that will meet the overall goals through its adoption. These research and action programs will require a unified effort among Federal, State, local, and private interests, and the participants will be involved in this voluntary program from conception to adoption.

The success of an areawide pest-management program depends on several premises. To achieve the goals, pest-specific management tools are needed and should be available and implementable. The tools must control the pest, be economical, impact little else in the environment, and not form residues on the food product where they could be a hazard to the health of the consumer. Many pest-specific management tools are most effective when used areawide because of the dispersal characteristics of certain target pests, as opposed to simply using them on a field-by-field basis. The program is to consider other pests in the system. Also, the management of pests areawide implies that communities become involved in the process. In addition to grower groups, local representatives from several agencies of USDA, EPA, and other organizations need to be involved in the planning and implementation of the projects.

Finally, some of the generic criteria that are considered to be important in terms of site selection for the projects include some or all of the following, depending on the scope of the program: (1) The participants should support the concept of areawide pest management and be willing to allocate people and resources over and beyond the ARS support to the extent possible. (2) The large-scale pilot test sites identified must be typical production settings with representative pest problems and be definable by biological criteria. Each selected area should be sufficiently large that meaningful data can be extracted on efficacy as well as on economic and environmental benefits. (3) Populations of the key pest should occur consistently in the proposed area, and the study should attempt to determine the infestation levels at which treatment is economical. Site-specific IPM-based treatment measures should attempt to account for the spatial and dynamic nature of the key pest as well as of other associated pests that may come into play. (4) Producers and producer groups within the proposed test area should have a cooperative stance and be willing to share costs, where needed, for the technology used to mitigate pest problems that would normally be dealt with at the producer level. (5) There should be interest and participation by local representatives of federally and State funded groups, such as the EPA, Farm Service Agency, Natural Resources Conservation Service, Extension, and others, as appropriate. (6) The locality and the participant-partners in the areawide project should have (or be able to find and train) the technical support personnel (e.g., private consultants, Extension specialists, scouts, applicators, and others) needed to help conduct the study. (7) The State or region has (or can develop) the organizational structure to support and establish the enhanced IPM systems in the local community.

Areawide Management of Bollworm and Budworm with Pathogens

Research to develop improved methods of managing serious insect pests of delta crops, especially cotton, by use of natural insect pathogens was begun in 1987 at the USDA-ARS's Southern Insect Management Laboratory (SIML) at Stoneville, Miss. Previous research had shown that noncrop hosts, particularly early-season weeds, act as hosts for the tobacco budworm, *Heliothis virescens* (F.), and cotton bollworm, *Helicoverpa zea* (Boddie), prior to the presence of crop hosts. It was theorized that tobacco budworm and cotton bollworm populations could be managed by either controlling the insects on the weeds with insecticides, or by controlling the early season hosts themselves via herbicides or mowing. Because insect pathogens (microbial insecticides) are considered to be among the safest methods of insect control, research was begun to investigate their use in a management scheme. Positive results of small-field and cage tests led to large-area studies, beginning with a 64,000-acre test in 1990 and culminating in 215,000-acre tests in 1994 and 1995. Results of tests to date indicate that virus application could be accomplished at a reasonable cost and that such treatment consistently reduced the number of moths emerging from weed hosts by more than 70 percent.

Areawide Management of Codling Moth

The western States produce 54 percent of the total U.S. apple production (236,000 acres with an annual crop value of $1.5 billion) and 97 percent of the pear production (70,000 acres and $0.2 billion). This economically important fresh-pome-fruit-growing industry suffers significant annual pest-related losses. Crops in this region are sprayed with nearly 2 million pounds of insecticides (excluding petroleum distillates and *Bacillus thuringiensis* products) to control a large number of insect pests. The codling moth *Cydia pomonella* L. (CM), the key pest of pome fruit, is the target of many of these sprays and, if not controlled, causes the majority of damage. Traditional pest-control methods, chiefly multiple sprays with organophosphate insecticides, have led to the development of resistant strains of codling moth, reduced populations of beneficial insects, and increased secondary-pest outbreaks while contributing to environmental degradation and increased concerns over farmworker safety. Intensive use of pesticides has eroded consumer confidence in the safety of pome fruits, particularly for infant consumption. In addition, some countries impose quarantine import restrictions on fruit produced in the western region because of the existence of codling moth with the potential for serious financial consequences and a negative impact on the balance of trade.

There have been active research programs on mating disruption with the sex pheromone of CM for several years in the Pacific Northwest. Collective experience indicates that mating disruption can provide population suppression and control when low densities of moths are present but may require supplemental applications of insecticides under moderate to high populations. The potential to use mating disruption over large contiguous areas as part of a CM-population-suppression strategy formed the basis for the USDA-ARS project for management of CM in the western United States.

The goal of the Areawide Suppression Program for Codling Moth is to marshall a western-regional, multi-institutional program to assess, test, and implement an integrated strategy for the management of codling moth populations on fruit orchards that will alleviate the impact of neurotoxic pesticides on natural enemies and will open the opportunity for use of more environmentally friendly control tactics for secondary pests.

Areawide suppression uses all of the technological tools available, including mating disruption, biological control [parasites, predators, granulosis virus, and *Bacillus thuringiensis* (B.t.)], the sterile-insect technique, and orchard sanitation. The earliest tool may be a chemical or a B.t. pesticide applied to lower the initial moth population, followed with mating disruption and release of biological agents (such as parasites) on apples and pears. By applying the protocol in successive years, the natural enemies would increase, and the popu-lation should be kept under control with reduced pesticide usage and at a low cost to the growers.

The objectives were: (1) to enhance the efficacy of nonpesticidal systems for the control of codling moth and other major fruit pests by reducing nonessential neurotoxins in IPM programs for fruit pests; (2) to demonstrate that mating disruption of codling moth works better when applied over large areas because less pheromone can be used and the cost thus reduced; (3) to aid fruit producers in the transition to production systems less reliant on neurotoxic pesticides by developing an incentive program for the adoption of mating-disruption techniques by growers that will result in lower pest-control costs; (4) to drastically improve chances for biological control and other population-regulation tactics for secondary pests; (5) to develop alternative management tactics that will complement the use of mating disruption, such as sterile-insect technique, B.t. sprays and mass release of selected parasitoids; (6) to develop an areawide monitoring program for mating disruption of codling moth with traps, damaged fruit, tethered females, etc.; (7) to establish treatment thresholds for use of alternative control means, including organophosphate insecticides, when needed; (8) to use GIS and conventional aerial photography to map fruit production in the States and to develop specific areawide pilot demonstration projects; (9) to improve the perception that fruit production is based on environmentally friendly methods and that the fruit has the highest safety standards for consumers; (10) to improve the environment for orchard workers by reducing the level of organophosphate insecticide use, thus removing restrictions on reentry because of organophosphate residues.

To demonstrate the feasibility of areawide suppression, pilot test sites were established at Randall Island, Calif.; Medford, Ore.; Yakima, Wash.; Howard Flats, Wash.; and Oroville, Wash. The test sites were managed by University of California, Berkeley; Oregon State University; Washington State University; and USDA-ARS. The growers at each site contributed heavily to the expense of conducting these studies.

The results of the first year of the 5-year program revealed that natural-enemy populations recovered rapidly in the program of reduced use of CM insecticides. Little or no pesticides were required for control of leafhoppers, leaf miners, and aphids. Parasite levels increased dramatically over those in conventionally treated control areas.

Codling Moth Pheromone-Based IPM in Washington

One site established in Washington was at the Howard Flats growing area near Chelan, a fairly isolated production area of about 1,200 acres. Thirty-six growers farm at Howard Flat, packing fruit at four cooperative warehouses, and 16 crop consultants provide advice on pest control and horticultural practices. Codling moth mating disruption was used on 1,150 acres in 1995. Insecticides coupled with pheromones limited crop loss to an average of less than 0.1 percent by midsummer. Harvest samples indicated that the average codling moth fruit injury in blocks from Howard Flats was 0.55 percent, even with no insecticides applied during the second half of the season. Leafrollers were identified as a potential pest of concern for 1996, but other secondary pests were below treatment thresholds in all orchards. The use of codling moth mating disruption to radically alter pest management in the apple orchards of Washington appears to hold great promise for reducing reliance on broad-spectrum insecticides. A pheromone-based pest-management system for apples and pears would allow growers to take greater advantage of biological controls for many pests, rely on "soft" chemical controls to suppress pests when needed, and reserve the fast-acting broad-spectrum insecticides to stop pests that cannot be controlled with other means. This should lead to a stable, safe, environmentally friendly, and (it is hoped) economical pest-management system.

Corn Rootworm Areawide Management Technology

In response to many problems associated with traditional corn rootworm (*Diabrotica virgifera virgifera* LeConte and *Diabrotica barberl* Smith & Lawrence) management practices, scientists with USDA-ARS and the agricultural experiment stations of several midwestern States developed a new management concept to suppress beetle populations with a semiochemical insecticide-bait. The insecticide-bait uses behavior-modifying chemicals that are specific for corn rootworm beetles and that induce them to feed compulsively on the bait formulation. These baits have been developed as either dry-flowable microspheres or polymer-based tank mixes. The primary components of these baits are cucurbitacins, bitter tasting tetracyclic triterpenoids that attract beetles and repel nontarget insects. They are found in high concentrations in roots of the wild-growing buffalo gourd, *Cucurbitia foetidissima* H.B.K. Dried and ground roots of this plant mixed with a small amount of toxin (carbaryl) and a nontoxic edible carrier are the basic components of these formulations. Recent research at two sites in South Dakota has demonstrated that, because of the high mobility of adult corn rootworms, management of beetles with these baits is more effective when done over a relatively large area. The use of semiochemical insecticide-baits in combination with other rootworm-management tactics (crop rotation, biological control, etc.), state-of-the-art population-monitoring technology, and new corn-management technology will greatly improve chances of successfully implementing a corn pest-management system on some of the estimated 1 million acres of corn production with significant corn rootworm populations.

USDA-ARS, with the cooperation of partner universities and other Federal agencies, is currently developing a program to evaluate an areawide management system for pests of corn, specifically on acreage where the corn rootworm is a key pest. Study sites will be developed to evaluate the concept of areawide IPM with semiochemical insecticide-baits as primary rootworm-management components and biologically based management approaches for other economic pests, as needed. ARS recognizes that areawide management of corn pests must be compatible with ongoing or emerging corn IPM systems to be an acceptable management approach. ARS, therefore, feels it is appropriate and desirable to investigate the impact of an areawide management initiative for primary corn pests as part of an IPM program. Three regions are under consideration during 1996 for development of full-scale programs in 1997: 1)Illinois/Indiana; 2)Minnesota/Iowa/South Da-kota; and 3)Kansas/Nebraska. These regions repre-sent the wide diversity in corn production systems found across the Corn Belt. Each region also has significant and unique problems related to the management of corn rootworm. Within each region, ARS expects to develop a single evaluation site with a cooperative approach among partner State research institutions.

Areawide Pest Management of Mexican Corn Rootworm and Cotton Bollworm

The USDA-ARS Areawide Pest Management Research Unit (APMRU) at College Station, Tex., is involved in two areawide pest-management studies: (1) the Mexican corn rootworm (MCR) areawide pest-management pilot study in the active stage and (2) the cotton bollworm (corn earworm) project in the development stage.

The MCR project involves the use of adult control with attract-and-kill pesticide formulations (attracticides) as a replacement for soil-applied or broadcast pesticide applications. The successful transfer of this attracticide technology to producers would represent a 95- to 98-percent reduction in pesticide use for this pest. In 1996, the unit will be conducting a pilot study in Bell County (Central Texas, near Temple) to evaluate this management approach on 3,000 acres of corn. The corn in the test area will be intensively monitored and treated, as needed, based on the number of adult MCR present. If successful, this new technology will be transferred to producers in 1997 or 1998. The adoption of this technology has the potential only to not reduce pesticide use but also increase yield and reduce production cost.

The APMRU is also developing a program for the areawide management of cotton bollworm (also known as corn earworm). The crop damage from this pest exceeds $1 billion a year. The corn earworm overwinters in only the southernmost part of Texas and northern Mexico. It emerges from overwintering each year and completes one generation on corn in the source (overwintering) zone. The progeny of this generation infest corn, cotton, tomatoes, and other crops in Texas, Oklahoma, and much of the midwestern United States. The APMRU is conducting research on population dynamics of the corn earworm in the source and recipient regions, movement and migration times and pathways, an attract-and-kill formulation for reduction of adults in the source regions, and natural markers for corn earworm. The research group plans to have an areawide pest-management strategy in place within the next 5 years.

Exotic Pest Plants, Biological Control, and IPM: A Trio with a Date for the Future

Gary R. Buckingham
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Moderator

Biological control of immigrant weeds, or exotic pest plants, has been used for more than 90 years. Two early successes were the programs against prickly pears in Australia and Klamathweed in California. The prickly pear success was actually a cluster of successes. Several species of prickly pears were controlled by multiple species of insects in various countries. In Australia, a South American moth, *Cactoblastis cactorum*, was released in 1926 and within 14 years most of the infested land had been reclaimed. A total of 48 species of insects were sent to Australia during that project, although not all were released. Small sucking insects, the cochineals, *Dactylopius* spp., controlled several prickly pear species not controlled by the moth, both in Australia and elsewhere. The Australian success stimulated a program in California in 1940 by the USDA-ARS and the University of California to control Klamathweed, *Hypericum perforatum*. Almost a million hectares were infested before two leaf-eating beetles, *Chrysolina* spp., brought the plant under spectacular control, reducing it to less than 1 percent of the original infestation. Later, in the sixties, the aquatic alligatorweed, *Alternanthera philoxeroides*, was controlled in the southeastern United States by a leaf-eating beetle, *Agasicles hygrophila*. Weeds of pastures, wastelands, and waterways have been the traditional targets for biological control programs, but future targets must include plants that are rapidly invading natural areas. Examples of these new exotic pest plants include climbing euonymus, kudzu, and vinca in the Great Smoky Mountains National Park; honeysuckles and privets along roadsides and natural areas in the eastern States; melaleuca, Brazilian peppertree, and hydrilla in Florida; purple loosestrife and Eurasian watermilfoil in the northern States; and saltcedar in the western States. Increasing amounts of herbicides and manpower are used to contain this invasion. To accomplish our IPM goals, greater effort is needed to control these natural-area weeds and crop weeds with biological controls, including plant pathogens, and to integrate biological controls with other controls.

Integrated Management of Tansy Ragwort in Oregon, D. L. Isaacson, Oregon Department of Agriculture

Tansy ragwort was first detected in Oregon in 1922, and by the mid-fifties had become recognized as a serious pest, causing poisoning of livestock and competing with desirable forages in 16 western Oregon counties. In 1974, the Oregon Department of Agriculture initiated an interim control program, and in 1975, the Oregon Legislature passed a law formalizing the program and provided funding support. Control in western Oregon originally emphasized biological control especially distribution of the cinnabar moth and the ragwort flea beetle, with the goal of effecting complete distribution of these agents over the entire range of ragwort as quickly as possible. By 1978, cinnabar moth populations had been established within 350 of approximately 400 infested townships (approximately 10 x 10 km) by redistributing cinnabar larvae to approximately 5,580 sites. By the early eighties redistribution of flea beetles was also essentially complete. Another agent, the ragwort seedfly, dispersed throughout western Oregon with limited redistribution efforts.

Field monitoring and experimentation documented marked reductions in ragwort densities by the cinnabar moth and the flea beetle. Herbicide recommendations for ragwort control were developed and demonstrated, and pasture management practices that reduced ragwort infestations were distributed. By the late eighties, incidence of livestock losses were reduced, and in 1992, economic benefits of ragwort control in western Oregon were estimated at $4 - $5 million annually.

In eastern Oregon, pioneering infestations of ragwort were discovered with increasing frequency, with ten discovered in 1975. In 1979, an employee was reassigned to eastern Oregon with the primary responsibility of detecting and controlling new infestations of ragwort east of the Cascade Mountains.

Tansy ragwort remains below economic thresholds on almost all sites in western Oregon where it had once been a severe problem, and only four of the several hundred sites found in eastern Oregon are not considered eradicable.

Biological Control: The Indispensable Element in Integrated Management of Leafy Spurge, P. C. Quimby, Jr., J. L. Birdsall, and A. J. Caesar, USDA-ARS; H. McNeel, USDA-BLM; N. E. Rees USDA-ARS; R. Sheley, Montana State University Extension Service; and N. R. Spencer, USDA-ARS

Leafy spurge infests more than 5 million acres of rangelands and pastures in a least 23 States. To manage leafy spurge, all available strategies must be applied in an integrated system to achieve the goals desired for the land. These strategies include education, prevention, containment, and reclamation and restoration. Education (i.e., technology transfer) is a strategy in and of itself, but it also applies to all other strategies. Prevention is an appropriate strategy for managers of clean, uninfested lands. For large stands of existing leafy spurge, containment tools may include prescribing fire, applying chemicals, and grazing sheep or goats. Without additional treatment, fire will only temporarily slow leafy spurge and then stimulate new growth. Properly applied herbicides can temporarily contain leafy spurge, but these chemicals are prohibitive in cost and are probably limited to peripheral and spot treatments.

Some herbicides may produce environmental risks in the long term, especially to desirable native forbs. In general, herbicides are a static answer to a dynamic problem. Sheep and goats can be managed as domesticated "biological control" tools to contain leafy spurge, but once the animals are removed from the system, the weeds will return to their original density and expansion rate. The strategy of reclamation and restoration may include the tools of reseeding competitive vegetation and biological control. For most low-value rangelands, reseeding is prohibitive in cost and in some cases replaced one exotic plant species with another. For the dynamic, wide-area invasive leafy spurge problem, only a comprehensive, dynamic biological-control program can produce near-restoration of native plant communities. The classical biological control approach provides a self-perpetuating, economical solution to manage-ment of leafy spurge in low-value rangelands.

Examples of insects and plant pathogens working together are now available that suggest an incipient success story is on the horizon for biological control. These examples provide evidence that biological control will be the indispensable element in the integrated management of leafy spurge. The whole process of learning how to manage leafy spurge can be accelerated by more research to fully integrate biological control with management tools. Education and technology transfer are critical to the success of the process.

Management of Exotic Aquatic Plants, Alfred Cofrancesco, U.S. Army Corps of Engineers, Waterways Experiment Station.

The Rivers and Harbors Act of 1899 directed the removal of aquatic vegetation that was hampering the operation of navigable waterways in Florida and Louisiana. This was the first effort by the United States to manage aquatic vegetation.

Three general methods are available to manage exotic aquatic plants: mechanical or cultural, chemical, and biological. All of the methods have positive and negative aspects that need to be considered when determining which control strategy will be employed. The oldest method is mechanical or cultural removal; it can be as simple as the manual removal of individual plants or as sophisticated as the use of specialized equipment specifically designed to remove a certain type of vegetation. This method gives rapid results but usually is costly and difficult to conduct in the aquatic environment.

The use of chemicals to regulate populations of exotic plant pests has progressed through many phases. In general, chemicals are effective in reducing nuisance aquatic vegetation. However, many chemicals affect a broad target population so their impact may not be limited to just the nuisance plant. The action of the chemicals is usually rapid, requiring only a few weeks to see extensive impact. Chemical applications are usually less expensive than mechanical or cultural control methods but may have to be repeated on an annual basis.

Biological control is based on the concept that the target plant has natural control agents present in its native range and the introduction of these natural enemies will reestablish the pressure that the noxious plant normally experienced. In this approach, control agents (natural enemies) are introduced into areas that are not part of their native range to manage an introduced noxious plant. In general, these agents are host-specific arthropods, nematodes, or plant pathogens. This control method is usually very cost effective. Once agents are released and established, their populations are maintained without cost, and the agents usually disperse to other infected areas.

In dealing with any of the target plants, the resource manager must understand exactly what types of options are available for management of a target pest and the extent of management that is needed. If a waterway needs to be completely clear of a particular type of vegetation in 1 to 2 months, then mechanical or cultural or chemical control methods are the only choices. However, if long-term management of a target is required and a biocontrol agent exists, then a management program that uses the biological agent needs to be implemented.

Plant Pathogens for Biological Control of Weeds, William L. Bruckart, USDA-ARS-NAA
Plant pathogens have a proven track record for biological control of weeds and are clearly suitable for integration with other pest-control strategies. More than 50 percent of the important weeds in North America are introduced, many without plant pathogens or insects in their new habitats. Generally, the inoculative (classical) approach is considered for these, which involves introduction of a pathogen collected from the native range of the weed. Successful control of *Chondrilla juncea* (rush skeletonweed) by the rust fungus, *Puccinia chondrillina*, was achieved in this way. Other weeds occur in row crops. Some pathogens can be grown on artificial media and applied in a high concentration when the weed is most vulnerable. This, the inundative (bioherbicide) approach, results in a rapid and highly effective plant kill, similar to that from chemical herbicides. Successful use of the product Collego, which contains spores of *Colletotrichum gloeosporioides* f. sp. *aeschynomene*, involves this approach. This product also can be integrated with chemical herbicides by tank mixing to control several weeds with one application. Broad-spectrum weed control is a new idea pursued with plant pathogenic fungi, either as weak pathogens in special carriers or as mutant strains of broad-spectrum pathogens. Improved efficacy and reduction in chemical herbicide requirements may result from genetic engineering of weed pathogens. Other new areas include development of plant pathogenic bacteria and viruses. All of these pathogens are studied and used under regulation of either the USDA, Animal and Plant Health Inspection Service (APHIS), or the Environmental Protection Agency (EPA).

Limitations to Implementation of Biological Control for IPM

Michael Benson
North Carolina State University
Moderator

Impediments to Biological Control: A California Perspective, Robert F. Luck, University of California

Fundamental to the development of an IPM program is an ecological understanding of the organisms involved and their interactions with one another. These organisms include the plant, the organisms inhabiting the plant's rhizosphere, and those inhabiting the aerial portion of the plant (i.e., the microorganisms, saprophytes, phytophages, and predators). This understanding defines the biological potential that can be realized in managing the commodity. It also provides the foundation for an economic analysis of the commodity and for its management in a particular context. With respect to managing arthropod pests, this understanding requires a tritrophic perspective. The lack of this perspective and the absence of ecological knowledge about this interaction has impeded the development of a sustainable pest-management program. This ignorance is especially apparent at the third and higher trophic levels. I wish to illustrate the consequence of this ignorance with a practical example.

Host selection by a parasitoid may seem arcane as an example of an impediment to biological control, but it is not. It is an ecological process of fundamental interest, and the linkage between the fundamental and practical aspects of this process is the foundation of pest management and of biological control. Unfortunately, the fundamental aspects of host selection are all too frequently viewed as irrelevant to pest management.

In host selection, a parasitoid chooses an insect stage as a host on (or in) which to produce offspring. (Hereafter, I will refer to this insect stage as a host.) The host it chooses for its offspring will die during the offspring's immature development. In selecting a host to parasitize, a parasitoid is making a choice about the quality of its offspring arising from this host. The host is the only package of resources that will be available to the developing offspring. Research has shown that the parasitoid's choice of a particular host individual depends on the host's attributes. An important attribute on which this choice is based is host size (e.g., Klomp and Teerink 1982, Luck et al. 1982, Luck and Podoler 1985, Waage and Ng 1984, Schmidt and Smith 1987). Host size is correlated with the size of the parasitoid's offspring at maturity (e.g., Waage and Ng 1984, King 1987). Offspring size (that is, the size of the daughter) is correlated with the offspring's probability of finding hosts for its offspring in the field (Kazmer and Luck 1995). Thus, the manner in which a parasitoid exploits a host resource for the production of offspring is crucial to understanding and forecasting pest suppression to be expected from the third trophic level.

A second behavior of importance to pest suppression in most ectoparasitoids is the size of host on which it produces daughters versus those on which it produces sons. Daughters are the sex that is responsible for pest suppression, the sex that lays the egg on the host and programs that host's death. Knowledge of the host attributes that result in the female parasitoid allocating daughters to the host are important in understanding this interaction and its consequence for pest suppression. And parasitoids can determine the sex of their offspring at oviposition. If the female parasitoid fertilizes the egg as it is laid, the egg will become a daughter: if she does not fertilize the egg, the egg will become a son. Most female parasitoids mate once and store the sperm from this mating in a spermatheca for the rest of their lives. Thus, by controlling whether or not the egg is fertilized, the female parasitoid chooses whether to produce a daughter or son. The attributes of the host that entice the female to produce are crucial to the evaluation of biological control and the determination of pest suppression. And the proportion of daughters that are produced and their relative abundance determines the success of biological control. Daughters are produced mostly on larger hosts, whereas mostly sons are produced on smaller hosts (King 1987). In the case of the citrus system in which I work, more than 90 percent of the daughters are produced on hosts larger than a particular size (0.39 mm^2 in area) (Luck and Podolar 1985). Thus, in the field, the size of the host at the time it is contacted by the female will determine, in large part, whether the host is parasitized and, if it is parasitized, whether it will be allocated a daughter or a son.

Several factors influence the size of the host in the field. First, the host's size is determined by its age (stage); the older it is, the larger it is. Second, the size of the host also depends on the time of the year during which it grows. If the host grows in the spring or autumn it will be larger at a given age than if it grows during the summer (Luck and Podoler 1982, Hare et al. 1990). Finally, the size of the host depends on the part of the tree in which it grows. If it grows on fruit (in this case an orange) it is larger at any given age than if it grows on a branch. A host that grows on a leaf is of intermediate size (Luck and Podoler 1985, Hare et al. 1990).

Thus, the size range of the host during development varies with age, season, and location within the tree (Luck and Podoler 1985, Hare et al. 1990). These variables affect the length of time during which the host is available to the parasitoid for the production of daughters and its probability of being parasitized. From the parasitoid's perspective, the upper size limit of the host is set by the size of the host when it transforms from the last immature stage to an adult. [In the case of the host with which I work, the upper limit occurs when the host mates. With other host species of insects, it is most often the size of the host at pupation (Luck 1995).] A host that grows during the summer or on branches will reach this stage at a smaller size than one that grows during spring or autumn or on the fruit. From the wasp's perspective, the lower limit to the size of the host is that on which it can produce daughters. Thus, the window during which the host resource is available for the production of daughters is narrower in summer or on the branches than it is during the spring or autumn or on the fruit. Moreover, in summer and on branches, the size range of the scale as it passes through this window in summer or on branches is smaller than it is during spring or autumn or on the fruit. Thus, during summer, the scale is at less risk to parasitization because the wasp is less interested in it than during spring or autumn or on fruit. It is not as high in quality as those in spring or autumn or on fruit. Clearly, this window size has implications for the likelihood of biological control and for the prospects of pest suppression.

Understanding the interaction between host size and the production of daughters has two additional consequences of practical value for pest management. First, it allows us to assess the seasonal availability and quality of the host resource from the parasitoid's perspective. This assessment, when coupled with the host and parasitoid phenology, provides one element that determines the intervention thresholds. We have translated this understanding into a brochure and a training program for pest managers and growers (Forster et al. 1985). The second consequence for pest management is in the use of parasitoids as augmentative biological control agents. In our case, the parasitoid can be grown inexpensively in large numbers and released in citrus groves for suppression of the host (pest) (DeBach and White 1960, Moreno and Luck 1992). Knowledge of the host attributes that result in the commercial production of quality wasps (principally daughters of large size) and in efficacy of the field releases allows us to maximize the efficiency of this tactic of pest suppression.

At this point, one might be asking, can we afford the expense of developing this understanding for each and every parasitoid– host interaction? The answer, of course, is that we cannot. It requires too much detailed biology. But this question assumes that the same research knowledge must be obtained for each host–parasitoid interaction with the same research effort. It does not. The linkage between the fundamental and practical aspects of ecological research in pest management makes such detailed research for each interaction unnecessary. The body of theory and the principals that emerge from the research testing the theory reduce the need to duplicate this research. What I have outlined above is a research program that tests hypotheses arising from foraging theory (Stephens and Krebs 1986) and sex allocation theory (Charnov 1982; see also Godfray 1994). As this body of theory is tested and the results are found to meet predictions and experience, the theory then becomes a shorthand way to project what can be anticipated from a tritrophic interaction. In a practical sense, it provides the guidelines within which to judge whether pest suppression can be expected. It provides the specifics of what to look for in the field to recognize whether such suppression is occurring (Forster et al. 1995). Departures from expectation, when they occur, become a focal point for additional research to understand why the expectations were not met. This approach makes research efficient. Moreover, it provides the feedback loop that leads to steady progress in understanding the ongoing ecological relationships and interactions in the commodity of interest.

Unfortunately, much of the research in IPM during the past decade or two has fallen short of this goal, especially ecological research. (I will note here that the degree to which a tritrophic interaction exists in a commodity will clearly vary with the commodity and its location. I am well aware of the complexity in these systems but my point is that a way exists to understand this complexity. Unfortunately, the pest-management community has not used it very often, and this lack of use has impeded the development and application of biological control and of ecologically based pest management in many commodities.)

There are at least two implications to this linkage between practical and fundamental research. The first implies a long-term commitment to conducting research in the commodity. The effort must involve a team of people, comprising growers, extension personnel, pest control advisors (privately employed advisors hired by the grower to advise him on pest conditions within the commodity), and university researchers. All of these individuals must be involved in the design and review of the research. These teams are difficult to establish because their success depends on the membership having individuals with a particular set of personality traits and shared values. Moreover, small teams are more likely to succeed than large teams, as was clear from the National Science Foundation's International Biological Program during the sixties and seventies.

The second implication regards funding. Developing an ecologically based pest-management program implies a major commitment of funding to support research over a substantial period of time. This support must include commodity support and funding from some of the traditional sources, such as the USDA competitive grant program; IPM regional research funds; and, in the case of California, such resources as the University of California Integrated Pest Management program. Without such a funding commitment, continuity will be lost. But such funding must be contingent on rigorous peer review that has two purposes: to evaluate the quality and progress of the research program and to provide an additional source of expertise in developing and improving both research objectives and design. In other words, such a review should have the ideal of the free and positive exchange of ideas. Without this process, little prospect exists for the development of a sustainable, ecologically based pest-management program.

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Bioherbicides: Limitations and Promise, G. J. Weidemann, University of Arkansas

Because herbicides account for approximately 85 percent of the pesticides used in field crops, significant reductions in pesticide inputs will have to come from the reductions in herbicide use. However, alternative technologies for weed control (including various types of cultural management, such as tillage, and biological control) are limited. Naturally occurring plant pathogenic fungi can be used as so-called bioherbicides to control problem weeds much like a herbicide. In the bioherbicide approach to weed control, indigenous fungi are commercially produced, applied with conventional application technology and integrated into existing weed-management programs.

Two fungi commercialized in 1982 for control of specific weed problems generated a great deal of interest in the bioherbicide concept. One, Collego, was developed for control of the leguminous weed, northern jointvetch, in rice and soybeans in a cooperative program between the University of Arkansas and the USDA, ARS. The other, DeVine, was developed at the University of Florida for control of stranglervine in citrus groves. Both fungi offered a number of positive features for weed control, including high specificity for the target weed, lack of toxicity to crop plants or other nontarget organisms in the environment, and relatively low cost of production. Despite the excellent efficacy of both agents and high expectations for other biological agents, no new bioherbicides have been commercialized since then. In part, other successes have been limited by a number of biological, technological, and economic constraints shared by many other biological-control agents. Future success in biological control will be dependent on overcoming these constraints.

Biological constraints to the use of bioherbicides include a host range that may be too broad or too narrow for effective use, pathogen virulence that is too low to achieve the desired level of weed control, and environmental limitations to effective use. However, research has shown that it may be possible to alter host range and modify pathogen virulence through the use of formulation or tank-mix additives, such as surfactants, host extracts, or herbicides at sublethal concentrations. For example, the fungus *Pyricularia grisea* is a common pathogen of crabgrass but applications of the fungus alone generally provide limited mortality. However, a tank mix of the fungus and the crabgrass herbicide, fenoxaprop, at 0.1 times the recommended rate gave excellent control comparable to the herbicide alone at the full rate. Use of this combination would give good control of crabgrass yet reduce chemical inputs from the herbicide by 90 percent.

For biological agents, environment often is limiting, reducing the consistency of performance. In particular, free moisture of up to 12 hours often is required for spore germination and plant infection. However, the addition of crop oils and emulsions has been shown to minimize the free-moisture requirement and improve overall infectivity of the fungal agent.

Fermentation and formulation technology has proved to be a major constraint to the successful development of many biological agents. For many fungi, fermentation and scale-up with traditional liquid fermentation systems has proved to be difficult, expensive, and technologically problematic. Formulation is another area that has limited commercialization of several biological agents. Formulations must be developed that assure high viability, have a long shelf life, maintain pathogen virulence, and remain economical. Formulation of a biological agent is relatively new technology requiring a high investment and considerable risk for a commercial firm.

Finally, economics often limit commercial development of an agent. For many biocontrol agents, market size remains a serious limitation. Often, the potential market proves to be too small to justify the cost and risk of development in comparison to chemicals.

Despite the limitations to the successful development of bioherbicides, research continues to find ways to overcome many of these limitations, and continued technological improvements will minimize many of the current constraints to use. To achieve greater use of biologicals, an improved public-private partnership is needed to help overcome the problems of technological limitations and small market size.

EPA's Pesticide Environmental Stewardship Program: Making a Difference Through Partnerships

Janet Andersen
U.S. Environmental Protection Agency
Moderator

The Pesticide Environmental Stewardship Program (PESP) was launched in December 1994. The goal of the program is to reduce pesticide risk. PESP is a voluntary program that forms partnerships with pesticide users. There are two categories of membership in PESP, partner and supporter. Partners are those organizations that are direct pesticide users. Supporters are organizations that work with pesticide users. Both organizations make decisions about which pesticides to use and when to use them. Participants in PESP make a commitment to reduce pesticide risk and exhibit this commitment through a strategy that directs their implementation of risk reduction.

A key role of PESP is its grant programs. During the past two years, despite budget difficulties, PESP was able to award several small grants to many of its partners and other organizations demonstrating pesticide risk reduction. Through the National Integrated Pest Management Foundation for Education, eight PESP partner grants were awarded in 1996. The grants were awarded to those organizations because they best demonstrated pesticide-risk reduction and innovative IPM techniques. Some of the grants were also awarded to support the development and implementation of the partner's risk-reduction strategies. There were also EPA regional grants awarded that were designed to support original research and promote IPM and the goals of PESP. Finally, through a partnership with the USDA, grants were awarded through the ACE Program (Agriculture in Concert for the Environment).

Our partners and supporters of PESP are making a difference. The Mint Industry Research Council, is reducing risk by using innovative techniques including: (1) using disease-free rootstock to establish fields, thereby reducing the spread of insects, diseases, and weeds; (2) development and use of economic thresholds and economic injury levels to their crops; and (3) conservation and augmentation of natural-enemy populations through the use of selective pesticides as well as the release of predators. Another PESP Partner, New England Vegetable and Berry Grower's Association, is working on the development of IPM standards and an IPM Certification Program.

Through a cooperative effort, the University of Massachusetts and the Massachusetts Department of Food and Agriculture have developed crop-specific IPM standards and the first IPM certification program in the United States. The standards address key parts of a successful IPM program that includes soil management, nutrient management, and cultural practices. Within each category, specific practices and actions are listed that, if followed, result in a successfully integrated approach to crop production. Growers accumulate points that result in the designation of a crop as "IPM Certified," which they can use as a marketing tool. There is an ongoing effort to expand the number of crops in this program. The U.S. Department of Defense has made a commitment to reduce pesticide use by 50 percent by the year 2000, thereby reducing risks. One of the key ways they are reducing risk is by developing alternative strategies for pesticide use. The Strategic Environmental Research and Development Program awarded funding for a multiyear, major research demonstration project with USDA to develop "precision targeting" risk assessment and alternative IPM technologies for managing and reducing risks from pests and pesticides.

For more information on PESP, call our PESP INFOLINE at 1-800-972-7717 or find us on the Internet at EPA's Home Page under New Innovative Initiatives.

The following lists show the partners and supporters who have joined EPA's Pesticide Environmental Stewardship Program (as of 11/8/96).

Partners

American Association of Nurserymen
American Corn Growers Association
American Electric Power
American Mosquito Control Association
Arizona Public Service
Atlantic Electric
California Citrus Research Board
California Pear Advisory Board
California Pear Growers
California Tomato Board
Carolina Power & Light
Cranberry Institute
Delmarva Power
Duke Power Company
Eastern Utilities
Edison Electric Institute
Florida Fruit and Vegetable Association
Global Integrated Pest Management
Golf Course Superintendents Association
Hawaii Agricultural Research Council
Hood River Grower-Shipper Association
Mint Industry Research Council
Monroe County School District
National Potato Council
New England Vegetable & Berry Growers Association
New Orleans Mosquito Control Board
New York State Gas & Electric
Northern Indiana Public Service Company
Northwest Alfalfa Seed Growers Association
Oregon-Washington-California Pear Bureau
Oregon Wheat Growers League
Owen Specialty Services
Pear Pest Management Research Fund
Pebble Beach Company
Pennsylvania Electric
Pennsylvania Rural Electric Association
Pineapple Growers Association of Hawaii
Processed Tomato Foundation
Professional Lawn Care Association of America
Sun-Maid Growers
South Dakota Cattlemen's Association
Tennessee Valley Authority
Texas Pest Management Association
U.S. Department of Defense
U.S. Apple Association (formerly the International Apple Institute)
Utilicorp
Virginia, Maryland, Delaware Association of Electric Cooperatives
West Virginia Power
Wisconsin Ginseng Growers Association
Wisconsin Public Service Corporation

Supporters

Aqumix, Inc.
Bay Area Stormwater Management Agencies Association
Campbell Soup Company
Del Monte Foods
Farm*A*Syst/Home*A*Syst
Gempler's
Gerber Products Company
Glades Crop Care, Inc.
General Mills
U.S. Golf Association

Emerging Issues Influencing Integrated Pest Management (IPM)

Michael Fitzner
Cooperative State Research, Education, and Extension Service, USDA
Moderator

Precision Farming, C. R. Amerman, USDA, ARS

I would like to acknowledge the valuable help in collecting material for this talk of Dr. Gerald Anderson, ARS Subtropical Agricultural Research Laboratory, Weslaco, Tex.; Dr. Edward Barnes, U.S. Water Conservation Laboratory, Phoenix, Ariz.; Drs. Alan Olness and Frank Forcella, ARS North Central Soil Conservation Research Laboratory, Morris, Minn.; Dr. Edward Schweizer, ARS, Ft. Collins, Colo.; Dr. Kenneth Suddeth, Cropping Systems and Water Quality Research Unit, Columbia, Mo. Any errors in fact or interpretation are mine.

IPM has been defined as "a systems approach that combines a wide array of crop production practices with careful monitoring of pests and their natural enemies. Practices and methods vary among crops and among different regions of the country" (U.S. Department of Agriculture 1994).

The term precision agriculture is popularly used to refer to the juxtaposition of several technologies. They enable or enhance site-specific management, where the word site may be taken to mean an area of relatively uniform characteristics or conditions in terms of the particular management target. Another way to look at it is that precision farming is expressed as varying rates of inputs according to the varying needs of different areas of a field.

For example, the management target might be a specific weed whose density of occurrence is influenced by such factors as soil texture, crop-plant density, and soil-water regime. Soil texture and topography are relatively constant over time and easily mapped. For some soil textures, the weed density may never be great enough to warrant the expense of control measures. For other textures, one may possibly control the weed by varying crop planting density according to the map of texture. An area at the toe of a slope or along a geologically controlled seep line may stay wet for extended periods and require the use of herbicides for effective control, where the herbicide application is controlled according to the mapped position of the wet spot or spots.

We have practiced precision farming at some scale since our ancestors began encouraging the first food or medicinal plants to grow better by removing the competition from around them. It is probably only in recent, mechanized time that we have expanded the scale of our control over inputs to whole-field size. As mechanization took over, land areas tended by a single farmer increased, and both time and labor requirements forced us to manage by large land units and largely ignore the in-field variations. What is happening now is that technology has developed to a point that again enables us to feasibly address field variations over short distances.

Why do we want to do this? It is expected that site-specific management will optimize agricultural production and minimize agricultural insults to the environment. Whether or not this expectation is fully realized will depend greatly on the crop and animal production expertise and philosophies of producers that are using the technologies and on the information base available to them. Precision farming is not so much a philosophy of farming as it is an application of technology to do things that we have not been able to do easily since we began climbing on tractor seats. As the tractor has become ubiquitous, so, I think, will the tools of precision farming.

So the question for this group is which of these tools offer possibilities for the furtherance of IPM objectives?

Feasible implementation of precision farming today is made possible by geopositioning systems (GPS) tools that enable one to locate oneself fairly precisely on the landscape. Among other things, it can be used for mapping purposes and for relocating to a mapped point, like signaling to a sprayer that it is over a wet spot.

Geographic information systems (GIS) have been under development for more than a decade. GPS technology makes GIS more useful in the precision farming context. GIS is a database that looks like layers of maps. Map several characteristics or conditions over a field, and you create a GIS for that field (soil types on one map, textures on another, and problem areas of weed or other pest infestations on still another). Then, queries to the GIS by a computer that is fed real-time location information from a GPS-equipped field machine, enables the computer, with access to appropriate decision aids, to determine the specific treatment for that location and transmit control instructions to the machine.

Many farmers who using precision farming have harvesters equipped with computers, GPS receivers, and yield monitors so that they may map crop yields as they harvest. With the yield maps, they can identify and investigate both low- and high-yielding areas of their fields for possible modifications in treatments on those areas.

Roberts et al. (1993) discuss the uses to IPM of GIS in a large-area context. Weisz et al. (1995) write about Colorado potato beetle mapping in the context of site-specific IPM. They observe that to use this technology effectively, entomologists will need to develop new sampling and analysis methods.

Of course, the ability to vary the rate of input application under computer control requires equipment that can accept and act on the computer's commands. Four-bay fertilizer spreader trucks are now in operation that can mix fertilizers or other granular substances to a computer-specified recipe and spread at computer-controlled rates. Spray rigs are now capable of mixing varying amounts of pesticides from several carboys prior to spraying.

A number of efforts are underway to develop real-time sensors of various types. Organic matter sensors, for example, are being developed for use in controlling herbicide rate applications. Artificial vision with pattern recognition probably will enable spotting, identifying, and spraying individual pests if that is what is needed. We already have remote sensors that can evaluate leaf moisture stress and control irrigation.

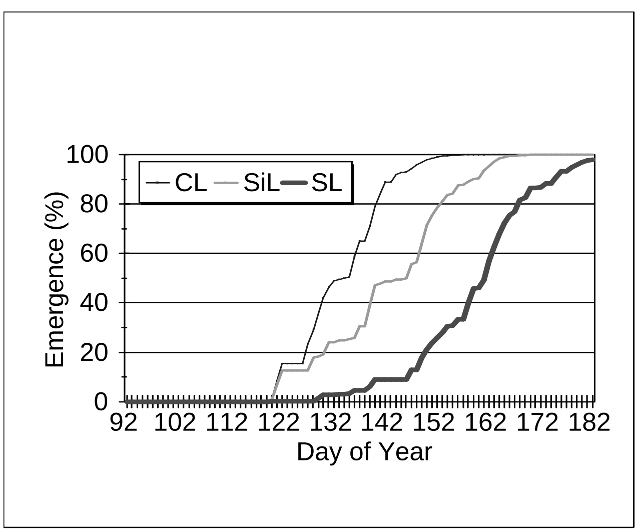
Precision agricultural tools are rapidly appearing; companies and lines of equipment are proliferating. A number of farmers already have several years of precision-farming experience. It seems probable that precision farming is going to require its practitioners to know more than they do now in terms of a much wider variety of conditions on their farms and, particularly, of what to do to optimize their operations under each of them. This has implications for information systems development and marketing. A Minnesota study described the timing of redroot pigweed emergence as influenced by soil texture, as in the accompanying figure. I quote from the material provided with the figure (Forcella 1996): “Postemergence herbicides quickly are becoming the most popular form of weed management in agronomic crops, despite their relatively high expense. These herbicides typically are effective only if they are applied after the weeds have germinated and emerged. They usually are applied about 3 to 4 weeks after sowing (about days 141 to 147 on figure 1). At that time, the pigweed emergence model predicts about 10-percent, 50-percent, and 90-percent seedling emergence on the sandy loam, silt loam, and clay loam soils, respectively.”

If a contact-type postemergence herbicide (e.g., acifluorfen or Blazer) were used, the high level of seedling emergence on the clay loam soil at the time of application would be expected to provide excellent control because most of the seedlings had emerged. In contrast, control with the same herbicide would be expected to be only fair to poor on the silt loam and sandy loam soils because of correspondingly lower emergence percentages.

How could growers overcome this problem of spatially variable weed control? One solution might be a timed sequence of site-specific spot spraying of pigweed on the differing soil types with acifluorfen. This would help ensure high and consistent levels of control. Another solution would be to select a postemergence herbicide with residual soil activity, like imazethapyr (Pursuit). A blanket application of this herbicide over the entire field would control both emerged and emerging pigweed (Forcella et al. 1992; Harvey and Forcella 1993; Forcella 1993).

Forcella's example illustrates two aspects of dealing with site-specific knowledge. The first is, knowing the variability across a site, what does one do with it? The pigweed seedling emergence curves given in the figure were derived from a weed-seed-emergence model, a decision aid that can be made available to any farmer with a computer. Such decision aids, models of weeds, crop development and growth, and so on, may be the principal means of helping producers manage inputs in dealing with site-specific issues. For greatest effectiveness, these decision aids will reflect state-of-the-art science and thus may become a major way of delivering scientifically based knowledge to farmers and ranchers.

The second aspect is ready access to a good database or information base, in this case a pesticides information base. Often, as in this example, such information will be enhanced by expert interpretation of what is in the information base--a major challenge for information providers that in many cases will require significant scientific input.Site-specific management also has many implications for research; more detailed questions are going to be asked. There is a suggestion, for example, that differential responses to soil chemistries may become important in dealing with germination and emergence patterns and with subsequent competitiveness between crops and weeds. Soil chemistry may be one of the factors responsible for the differences in weed indices and soybean yields for four soils as seen in table 1. These are preliminary data from the first year of a study being conducted in Minnesota (Olness 1996).



Schweizer (1996), referring to Vandeman et al. (1994) observed that a number of IPM components (practices) clearly relate to precision farming, but some do not. Chemical methods, as discussed earlier, lend themselves well to variable-rate application technologies. A cultural control, such as cultivation, by the relatively inflexible nature of the tools involved, does not presently appear to relate well to precision farming. Table 2 presents Schweizer's preliminary ideas on the subject and may serve as a starting point for discussion.

The adoption of IPM principles and of precision farming are, of course, influenced by farm financial considerations. In considering precision farming as a technology within which to apply IPM, scientists will need to consider socioeconomic impacts and ways to ameliorate those that are negative. In this regard, we may do well to consider multiple IPM/ precision farming implementations. For example, implementation designed for vegetable production may be quite different from one designed for large wheat producers, which, in turn, may be different from one designed for a small multicrop/animal producer. Socioeconomic impacts of IPM/precision farming should be a fruitful research field.

Table 1. Soil-weed interaction

Soil Type	Weed Index	Yield Soybean Variety 9091	9061
		---(Mg/ha)---	
Barnes	0.02	3.54	3.38
Hamerly	0.09	3.37	3.15
Parnell	0.11	3.12	2.97
Buse	0.16	3.14	2.89

Table 2. How does IPM relate to precision farming?

	Are these IPM practices related to precision farming for these pests?			
IPM Practices	Diseases	Weeds	**Insects**	**Nematodes**
A. Chemical methods used in IPM programs				
1. Fungicides	Yes			
2. Herbicides		Yes		
3. Insecticides			Yes	
4. Nematocides				Yes
B. Nonchemical methods used in IPM programs				
1. Cultural controls				
a. Cultivation	No	No	No	No
b. Crop rotation	?	?	?	?
2. Biological controls				
a. Biopesticides (mycoherbi cides)	---	Yes	---	---
b. Natural enemies (beneficials)	No	No	Yes?	No
c. Semiochemicals (i.e., pheromones)	No	No	???	No
3. Strategic controls				
a. Planting location	No	No	No	No
b. Planting date	No	No	No	No
c. Timing of harvest	No	No	No	No
d. Plant density	Yes	Yes	Yes	Yes
e. Row spacing	Yes	Yes	Yes	Yes
4. Host-plant resistance				
a. Crop varieties	Yes	No	Yes	Yes
5. Genetically engineered crop varieties	Yes	Yes	Yes	Yes
6. Irrigation, pivot	Yes	No	Yes	?

Precision farming with IPM approaches may be expected to provide for highly desirable environmental benefits. This claim can be validated only by environmental impact research.

The tools for precision farming may give us some amazing capabilities in terms of positioning, sensing, and control. Will we be able to match such mechanical precision with precision in prescription?

Perhaps the more relevant question is, do we need to? Just as there are economic thresholds for pests, there are most likely economic thresholds on the precision necessary for optimum crop and land management.

For IPM purposes, we may be some distance from understanding the economic threshold for prescription precision. That is for the attendees at this conference to decide. If we are not very close to it, then you may have some challenges ahead.

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The National Organic Program: Status and Issues, Harold S. Ricker, Agricultural Marketing Service, USDA

Organic sales have grown from about $1 billion in 1990 to $2.3 billion in 1994 averaging about 22 percent per year. In addition to growth in natural-foods supermarkets, major conventional retail food chains are beginning to add organic products into their retail mix, especially in neighborhoods where successful natural foods stores are thriving. Premium prices on some organic products reflect the fact that demand still exceeds supply.

We do not have a good estimate of the total number of producers producing organic foods because many are still self-certified, but the number of certified organic farms has increased to 4,050 in 1994, up from 3,500 in 1993 and 2,841 in 1991. This number is still less than 1 percent of all U.S. farms. Five hundred handler/processors were certified in 1994.

In terms of a marketing opportunity, we view organic products as representing a niche that will eventually become a mainstream market opportunity. The Agricultural Marketing Service (AMS) does not make a food-safety claim for organic food, because it is not residue free, nor does it claim that it is better for the environment.

The Organic Foods Production Act (OFPA) was requested by the organic community after they had observed a number of problems developing in the marketing of organic products. For example: There was and continues to be fraudulent use of the term "organic," resulting in the mislabeling of products.

Consumers are confused about what the term organic really means. They think it represents “pure food,” even though it is not necessarily residue free, or that it is more nutritious, when there is no scientific basis to prove it.

There are currently 33 private and 11 State certifiers. Each has its own standards and seal and wants the seal on the products from processes it certifies. As a result, there are reciprocity problems creating difficulty for multi-ingredient manufacturers and reciprocity issues among certifiers.

The purposes of the Act are threefold:

1. establish national standards governing the marketing of certain agricultural products as organically produced;
2. assure consumers that organically produced foods meet a consistent standard; and
3. facilitate interstate commerce in fresh and processed food that is organically produced.

Note that the Act calls for one national standard; it does not call for certifiers to have enhanced standards. It calls for a consistent standard to get away from the confusion of private and State organizations’ having different standards. The Act calls for the program to facilitate interstate commerce. We expect it to facilitate international commerce as well. One national standard with USDA oversight of the certification process will open up international markets and facilitate international trade in organic products. Other countries are eagerly waiting for the U.S. organic program to be in place.

Organic agriculture is complex in that it touches on activities of all of the agencies in USDA; several in FDA, EPA, and BATF; and most State departments of agriculture. Every day we hear from consumer groups, environmental groups, input suppliers, and the organic community. We are concerned that the principles of organic agriculture are not compromised.

There will be no mandatory requirements for those eligible for the less-than-$5,000 small-farmer sales exemption, but a qualifying farmer should have a signed declaration on the premises indicating compliance with the production and handling practices provided for in the OFPA.

The Act called for the Secretary to establish a National Organic Standards Board (NOSB) to advise him on the development of a National List of approved and prohibited substances and any other aspects of implementing the program. The Secretary appointed the NOSB on January 24, 1992. The Board is composed of: four farmer/growers, two handler/processors, one retailer, three consumer/public interest representatives, three environmentalists, one scientist, and one certifying agent. The NOSB has met 11 times as a full Board, has held 11 separate committee meetings at locations around the country, and has received public input at all of its meetings. The NOSB has now completed recommendations covering all of the program, and the National Organic Program staff is drafting the proposed rule.

The Board still needs to approve a definition of organic, and until it does, the following represents a draft policy statement:

> Organic agriculture is a sustainable production-management system that promotes and enhances biodiversity, biological cycles, and soil biological activity. It is based on minimum use of off-farm production inputs, on management practices that restore and enhance ecological harmony, and on practices that maintain organic integrity through processing and distribution to the consumer.
>
> The term “organic” on the label refers to products that have been certified as produced in accordance with the requirements and standards of the National Organic Program

These documents represent the recommendations of an advisory Board, and the Secretary of Agriculture may make some modifications in the regulations that are developed. But, the Department is indebted to the Board for the hard work expended in providing this information for consideration in implementation of this program. The recommendations from the Board can be summarized under five topics.

Crops

An organic farm plan that includes livestock is the keystone of organic certification. For the producer, the farm plan provides a flexible, useful, and affordable tool for developing an ecologically sound resource-management system on her or his farm. It allows the producer to plan and evaluate farm-management practices and make tangible improvements in the farming operation. For the certifying agent, the plan provides essential information for assessing compliance.

Split farming operations (conventional and organic) are allowed, provided that appropriate measures are taken to ensure the integrity of the organic production. In a farming operation where both organic and nonorganic fields, crops, and livestock are managed, the time table and level of transition to organic production is at the discretion of the producer.

Specified procedures should be followed for securing seeds, seedlings, and planting stock that are to be allowed in organic production. Emphasis is placed on use of organically produced planting stock and untreated seed to the extent they can be obtained, as verified by the certifying agent. Seed treated with pesticides and other substances prohibited by the Organic Foods Production Act (OFPA) shall not be allowed, with the exception of fungicides in cases where the producer can document to the certifying agent that untreated seed is not available. Seed originating from recombinant DNA technology shall be prohibited.

Organic products subjected to emergency sprays that are a direct result of intentional local, State, or Federal emergency spray pest eradication programs shall not be sold as organically produced or fed to organic livestock. The certifying agent will determine the need for residue testing for subsequent crops in the following 3 years. Subsequent crops shall not have pesticide residues that exceed the FDA action level or 5 percent of the EPA tolerance for any prohibited pesticide to be labeled as organically produced or to be fed to organic livestock.

Provisions similar to those under the Emergency Spray program apply to drift of prohibited pesticides or fertilizers from the intended target site onto a certified organic farm. Misapplication is when these materials are directly applied to the farm by someone who is neither the producer nor a person working under the direction of the certified producer.

The certifying agent shall conduct periodic residue testing of agricultural products to be sold as organic in cases of pesticide drift, when there is suspicion of residue problems, during the 36 months following an emergency spray, and in response to complaints. Produce shall not contain residues in excess of the FDA action level or 5 percent of EPA tolerance.

Processing

An organic handling plan shall include a general description of the handling/processing operation with procedures for handling organic foods and maintaining organic integrity. It requires record keeping, pest management, livestock care, and material inputs (to be developed) and contains an optional section on waste management. It also includes good manufacturing practices, general guidelines applicable to the handling of all organic food at handling and processing facilities.

Labeling will identify the total percentage of organically produced ingredients, foods that are organic, and foods that are made with organic ingredients.

Livestock

A livestock-production farm plan will contain specific references to livestock health, care and breeding practices, manure management, animal and feed sources, handling practices, housing, and living conditions. It will be incorporated into the organic farm plan.

A livestock health plan will contain general provisions for the treatment and management of animals, including a focus on the production environment.

The use of synthetic antibiotics as medication or growth promoters is prohibited in slaughter stock. Restricted use of antibiotics will be allowed in breeder stock, and milk products from a cow that has been treated with antibiotics cannot be labeled as organically produced during 90 days after treatment. This policy will be reviewed in 2 years.

The use of parasiticides is prohibited for slaughter stock, restricted for breeder stock, and limited in dairy stock, with a 90 day withdrawal period. Deviations from the above will be done on a species-specific basis.

Conditions for production of organic breeder stock are defined. Each animal or flock must be traceable throughout the life cycle with documented records, and, to the extent possible, obtained from organic stock. Feed fed to organic livestock shall be certified organically produced feeds and supplements, except under the conditions specified in the emergency-feed-availability provision.

Accreditation

The approved accreditation program for private certifying bodies seeking to be accredited identifies the competencies, transparency, and independence required of agents. The AMS will accredit State and private persons to become certifying agents for the Department to perform the certification of producers and handlers to the national standards. AMS will provide the oversight for the program to ensure that the purposes of the program are followed and perform other administrative functions in accordance with the National Organic Program, such as determination of equivalency of foreign programs for imports into the United States; participation in the development of international standards; accreditation of certifying agents; coordination of enforcement activities with other agencies that have responsibility for specific aspects of the program; operation and conduct of the petition process for materials review; provision of support for the National Organic Standards Board; and development and operation of the user fee program.

Materials Process

The NOSB has undertaken the required review of botanicals and placed strychnine, tobacco dust and nicotine on the proposed National List as prohibited naturals. The NOSB has also made recommendations for a number of allowed synthetic substances to be used in organic production and processing.

While not a part of the NOSB recommendations, IPM will continue to be an important tool in the organic plan to help reduce dependency on other off-farm production inputs. There has been some success in using trichogramma wasps for control of european corn borer, but some of the species that have been reported by researchers to be most successful are still not commercially available. The twelve-spotted lady beetle (*Coleomegilla maculata)* is a distinctive, pinkish, lady beetle that preys upon european corn borer eggs as well as aphids. It can cause significant reduction in both pests, depending on its numbers. Several drops of mineral oil applied directly to the neck of each ear on the silk (applied once, after pollination, when the silk just begins to dry) have been effective for some farmers. It is laborious, but makes the difference between marketable and unmarketable corn. It controls the borer as well as the worm. In another trial, vegetable oil mixed with B.t. had 95-percent control. Pheromone traps have also been used to trap corn earworm and fall army worm moths. These examples relate to reducing damage to sweet corn, but organic farmers are using similar beneficials or treatments to control other pests.

We do not know what the costs will be, but are working to establish reasonable fees, because we are required to operate on user fees.

Many are impatient that it has taken us so long to get our program in place. Part of the reason for the delay is budgetary problems, but a major reason is because we have involved the organic community in developing the program. They have provided a lot of public input that has helped to develop recommendations by our National Organic Standards Board and that provides the framework for the national program.

Because we are dealing with other government agencies, portions of the program must be reviewed by them. For example, the Food and Drug Administration reviews rules supporting processed food labeling that uses the word “organic,” and materials being considered for the National List.

USDA must also consult with the Environmental Protection Agency to determine the potential impacts of materials on the environment.

When it is ready and cleared, the proposed rule for the National Organic Program will be released for a 90-day comment period before preparing the final rule. The proposed and final rules will have an implementation and phase-in period.

Upon implementation:

- The program will have the force of law.
- USDA will establish controls for the use of a seal, probably on a licensing basis to demonstrate certification and compliance to the national program.
- Enforcement of the program can begin.
- Federally backed organic standards will facilitate the marketing of organic products in international trade.
- FDA will begin to recognize the definition of organic as a common and usual term with a specific meaning and to allow the term on organic labels.

One of the benefits to consumers and the organic community will be a consistent national standard, so that the term “organic” will have meaning for consumers, processors, handlers, retailers, and international traders.

New Computer Technology: Focusing GIS and Expert Systems on IPM, W. P. Kemp, Agricultural Research Service, USDA

Space and IPM

An understanding of the geographic variability in distributions and densities of pests is required for any IPM program. Pest densities influence the intensity of sampling required to define the area infested and the timing and economics of various management options. However, until recently there has been a general lack of analytical and data management tools that pest managers and researchers could use in IPM planning and execution. Among several new methods currently being evaluated and demonstrated in a variety of IPM systems are geographic information systems (GIS), global positioning systems (GPS), and expert-system (ES) technologies.

First Consider GPS

GPS refers to an advanced navigational system that was developed primarily for military applications. GPS consists of a number of satellites orbiting the Earth. These satellites have the ability to communicate with any appropriately equipped plane, ship, vehicle, or individual and to indicate the geographic position on the face of the Earth and the elevation of the receiver. Position accuracy within feet may be obtained with appropriate equipment.

Because of the obvious improvements in guiding or tracking for commercial uses, some portions of the GPS have been made available to the public. Hand-held GPS receivers are finding wide usage throughout the public and private sectors. For the purposes of IPM, the GPS offers several capabilities. The advanced navigational capabilities afforded by GPS are increasingly exploited by the participants of IPM programs in the guidance of aircraft and precision farming equipment as well as in field scouting.

On to GIS

A GIS is a set of computer programs that can store, use, and display information about places of interest to us. Examples of places of interest to a pest manager might be a 20-acre field, a 20,000-acre watershed, or the 2 million square miles of rangeland or forest in a particular State. Examples of information for any place of interest are soil types, rainfall and temperature patterns, land use, ownership patterns, roads, vegetation types, and topography (landform). A GIS stores two types of data that are found on a map, the geographic definitions of Earth surface features (spatial reference) and the attributes or qualities that those features possess. It is generally agreed that a true GIS is capable of several characteristic activities: (1) the storage and retrieval of information with a spatial reference (point A is located in Section 20 of Township 5, Range 8, and has soil type B), (2) the input, (3) analysis, and (4) reporting of spatially referenced information in digital form.

GIS Applications and IPM

Liebhold et al. (1993) described GIS as “enabling technology” because GIS provides pest managers with the capabilities to store, retrieve, process, and display spatially referenced data. It seems only logical that GIS technology will be rapidly embraced because so many questions from insect ecology to pest management have a spatial component. Whether studying the patch dynamics of host and herbivore or predicting a multistate pest hazard, GIS technology provides today's researchers and pest managers with the ability to answer questions that frustrated their predecessors.

Now it is possible to identify two general areas where GIS technology has been used in entomology: applied insect ecology research and insect pest management. Within the general area of applied insect ecology, perhaps the major use of GIS is in the relation of insect outbreaks to environmental features of the landscape (Cigliano et al. 1995). Using grasshoppers as an example, investigators in Canada used GIS products to examine the relationship between historical grasshopper outbreaks and soil characteristics (Johnson 1989a) and between weather and survey counts (Johnson and Worobec 1988). From these geographically referenced data, Johnson (1989a) found that grasshopper abundance in Alberta was related to soil type, but not to soil texture. Furthermore, a significant association was found between rainfall levels and grasshopper densities. Populations tended to decline in areas receiving above average rainfall (Johnson and Worobec 1988).

Future efforts to characterize habitat susceptibility probably will use remotely sensed data extensively because of its high spatial resolution and its availability in virtually every portion of the globe (for a complete review of remote sensing in entomology, see Riley 1989). For example, Bryceson (1989) used Landsat data to determine areas in New South Wales, Australia, that were likely to have egg beds of the Australian plague locust. Through the use of an index that indicated the general greenness of local vegetation, Bryceson (1989) was able to geographically identify resulting nymphal bands through changes in the greenness index that resulted from rains during March. (Nymphal bands tend to be associated with green areas that result from rain.)

Similar “greenness mapping” exercises have been conducted in Africa for grasshoppers and locusts (Tappan et al. 1991). In addition to illustrating the apparent ecological association between nymphal bands of grasshoppers or locusts in Australia and Sahelian Africa and changes in greenness indices, studies of Bryceson (1989) and Tappan et al. (1991) have immense practical utility because they produce rapid estimates of the location and extent of potential pest problems. Through such methods, it has been possible to vastly improve sampling efficiency for detection of problems as well as to reduce the guesswork involved with planning and execution of pest-management programs.

The second major area where GIS products have been used is for compilation and analysis of insect census data that are collected regularly by the USDA’s Animal Plant Health Inspection Service (APHIS). One example of this application for rangeland insects in the United States is the use of a GIS for developing a distribution atlas for grasshoppers and Mormon crickets in Wyoming (Lockwood et al. 1993). Additionally, Kemp et al. (1989) and Kemp (1992) provide methods for the development of rangeland grasshopper GIS coverages and hazard forecasts, that use annual adult grasshopper survey data collected in Montana. [See Johnson (1989b) for similar studies for grasshoppers in Canada.]

The Expert System Connection

The compilation and interpretation of spatially referenced insect and habitat data is a complex process, if for no other reason than the sheer volume of information. Although GIS software is designed to successfully handle this complexity, these systems often are not easy to use. To make a GIS more accessible to applied problems, GIS is increasingly being linked as a part of a larger decision support system (DSS). These systems typically use a GIS to manage habitat, geophysical, political, and census data. The DSS uses these data, along with other data as input to mathematical models and other modeling methods to produce useful abstractions or recommendations (Power 1988). These outputs might be maps of high damage hazard or even maps of proposed control areas. Hopper, a DSS for rangeland grasshoppers (Berry et al. 1991) currently has the ability to display density coverages. Future plans include a closer link to GIS procedures. Coulson et al. (1991) use the term "intelligent geographical information system" (IGIS) to describe systems that use a GIS and rule-based models to combine landscape data and knowledge from a diversity of scientific disciplines.

GIS: The Growth Years

GIS brings a great deal of analytical horsepower to the complex tasks associated with managing our natural resource base. However, expectations frequently associated with bringing GIS activities into the IPM realm frequently result in frustration for both pest managers and GIS professionals. Two major reasons why frustrations develop are: (1) People generally underestimate the resources required to get information into a GIS, and (2) GIS products are, at present, frequently complex enough to require specialized training. Another confounding problem that we should add is communication. Pest managers frequently lack in-depth familiarity with computer systems and at times may distrust all the apparent complexity involved with GIS activities. GIS technicians, on the other hand, frequently lack the biological expertise necessary to assist the pest managers with creative solutions to a particular problem. These communication problems can be frustrating to those on both sides of the table and may result in little advancement toward the solution to the current pest-management problem. Nevertheless, when properly developed, GIS, GPS, and ES technologies will offer solutions to future IPM programs that we have only begun to understand.

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Part VI. Working with Customers to Identify IPM Research and Implementation Priorities

Introduction

Research and technology transfer are an important component of USDA's approach to achieving IPM adoption in agriculture, nurseries, and other pest-management settings. The importance of identifying and responding to the needs of customers, setting priorities, and building teams with diverse stakeholders are the session topics of this final part of the workshop.

In the first session, the advantages of teams for IPM research and implementation programs, which was the topic of a preconference workshop at the symposium, are outlined. Teams successful in integrating a broad array of interests and skills generate the potential for garnering additional support and expertise for IPM, finding new sources of funding, and making broader research accomplishments possible through collaboration. Participants in this preconference workshop identified more than 161 potential stakeholders (producers as well as consumers, taxpayers, legislators, consultants, and others) in IPM programs as sources of "good ideas, synergy, funding, political clout," and other program needs.

The second session contains reports on priority needs for IPM research and implementation that were made in nine commodity-based workshops held at the symposium, with seven focused on agricultural crops and two examining homes and landscapes. Numerous, specific needs were identified in some workshops (71 for nurseries and urban ornamentals, about 100 for tree fruits, and 339 for vegetables) while other points of discussion addressed generic or key priority needs.

The need for more fundamental, component, and systems research was identified in all of the workshops. Definitions for these three types of research were noted in the potato workshop. A wide range of specific biointensive and nonchemical pest-management research needs were also identified across most of the workshops. The workshops also identified numerous education- and information-delivery needs and goals, with demonstration farms and garden-center booths among the priorities that were mentioned in most of them.

Although an enormous amount of IPM research and implementation needs have been identified by customers in these workshops, at least one workshop reported significant progress in expanding the set of biointensive tools available to farmers since the early 1990s. Participants in the tree-fruit workshop reported that research had been expanded nationally for the use of predators, parasites and microbial biopesticides, host-plant resistance, cultural control, and semiochemicals.

Team Building for IPM Research, Implementation, and Outreach/Education

Ed Rajotte and Lynn Garling
The Pennsylvania State University
Moderators

A preconference team-building workshop was held during the National IPM Symposium/Workshop. The purpose of the workshop was to discuss the rationale and skills necessary to mount a participatory approach to IPM program development and implementation. Approximately 140 people attended. Written materials and an in-depth information packet were provided to each participant.

The workshop opened with five diverse testimonials citing challenges and real-world successes in IPM teamwork. The bulk of the session actively involved participants in practical exercises with specific techniques to identify barriers to team building and to discuss collaborative solutions.

Goals of Workshop

Specific goals of the workshop activities were to:

1. Stress the importance and scope of team building for IPM programming.
2. Use hands-on activities with specific small-group techniques.
3. Provide a format for participants to discuss their negative experiences with teams.
4. Illustrate how principles of teamwork arise from individuals' stated experiences.
5. Stress the importance of managing group dynamics for successful team building.
6. Identify stakeholders and their potential contributions to IPM programs.
7. Discuss the choice of appropriate group techniques for various situations.
8. Provide written materials in support of workshop activities and team building.

The following is a summary of the workshop content and results. Complete texts of speeches and results are available from Pennsylvania IPM Program, The Pennsylvania State University, Department of Entomology, 501 ASI, University Park, PA 16802; 814-863-8884; or lyn_garling@agcs. cas. psu. edu.

Why Teamwork?

Five speakers representing differing perspectives on the value of teamwork gave presentations at the outset of the session to provide an overall context for team building. The speakers were all intimately familiar with and/or actively involved in IPM research, implementation, and/or policy. Perspectives presented were private industry, independent crop consultant, private sustainable agriculture organization, land-grant-institution IPM coordinator, and government agricultural agency. Speakers were Steven S. Balling, Director, Environmental and Analytical Service, Del Monte Foods Research Center; Madeline Mellinger, President, Glades Crop Care, Inc.; Kathleen A. Merrigan, Senior Analyst, Henry A. Wallace Institute for Alternative Agriculture; Larry Olsen, IPM Coordinator, Michigan State University; and Larry Elworth, Special Assistant for Pesticide Policy, Natural Resources and the Environment, USDA. The following selected quotes highlight key points that were made.

Marketing and Politics

"Your customer is the grower. If he or she does not buy your product (your IPM program), it will languish on the shelf. In today's era of limited resources, if your product does not sell, your funding will disappear. After 40 years, IPM has finally gained some momentum, but is still missing one thing: funding. Without increased funding, IPM will simply not be able to meet the needs of its customers. Teamwork will (1) build a constituency of voters to support your programs at both the State and local levels and (2) build a constituency of funders to support your programs directly. For too long, we in agriculture have acted like ants without the genetic coding for socialization and colony building. We are industrious but have no organization. Even if a small percentage of that energy can be harnessed as an IPM constituency, your influence will grow immeasurably" (Balling).

Handling Complexity, Assuring Accuracy of Information, and Implementing

"The game that is being played by our team is agricultural production. Logic tells us right away the game is too big for a narrowly focused team. We need to bring together a strong, diverse group of players, including independent consultants. Consultants make careful observations on a site-specific basis over our entire service area. We synthesize this information into useful production-management recommendations. We are able to identify and prioritize the most important problems from our whole-crop-system approach because of our field-based, intimate familiarity with crops, populations, infrastructural issues, etc. We can communicate and advocate for our growers' specific needs for public research. We must understand and help our clients use a holistic systems approach when we introduce new technology to agricultural production" (Mellinger).

Political Divisiveness Does Not Serve the Needs of Agriculture; Invite Everyone to the Party and Work Together

"The foundation of a healthy agriculture is diversity: diversity of crops, production systems, geographic locations, and people. One of the most striking things that happens at every sustainable-agriculture meeting is that at some point, participants look around the room and ask "who's missing?" Do we have women, people of color, scientists as well as farm laborers, consumer and environmental activists, and geographic diversity? There is clear recognition of the need to broaden participation, that this is a necessary part of any solution we can devise. In contrast, I argue that the IPM community is not as inclusive, although great progress has been made. As you meet this week, look around the room and ask yourselves the question of who is missing? The bottom line is that team building and partnerships are not nice things to do, optional exercises that precede a conference. They must be at the very core of all activity and decision-making if IPM is to be sustainable" (Merrigan).

Teams at the Land Grant, Is it Possible?

"It is important that we articulate what our vision of IPM is in order to be able to find common ground and work together. Each person sees the need differently, but all know that we are in this together and that it is the land-grant university's mission to help growers solve their pest-management problems. In spite of the risks, there are many potential and real benefits associated with the formation of teams of commodity groups and others and with the networking required with the IPM effort. Funding, staff support, and legislative voice are all areas in which we have experienced increases as a result of our collaborative efforts. We were able to fund 10 IPM minigrants in 1995 by pooling and leveraging funds. We are able to make long-term financial commitments because of the diversity of contributors. [The Michigan IPM Alliance] was considered impossible just one year ago. The commodity groups have never been able to come together on any topic before. When Phil [Korson] approached Gerbers, Michigan Department of Agriculture, Michigan Potato Growers, the MSU Department Chairs, and the Dean of the College of Agriculture, they all thought it would not be possible, but thankfully, due to Phil's commitment it was!" (Olsen).

Group Activities

Participants were divided into 12 small groups, each with a facilitator. In structured exercises, they defined team dynamics and functional components from their own experiences. Following these observations, each small group was presented with a preestablished, well-documented IPM-implementation constraint and provided with a stepwise process to discuss constructive uses of collaboration to address the constraint. Lists and charts generated by these processes are available with the full report.

Summary and Results

Team Dynamics and Functional Components

Participants were asked a specific question aimed at revealing what works, what does not, and why in a team setting. Because negative experiences and misgivings are common when people are faced with teamwork, we took the approach of encouraging expression of these strong feelings. Besides allowing controlled "venting," the usefulness of this approach is that the ideas come quickly and easily and any articulated negative experience can be reversed to illustrate a positive element needed to create a better functioning team. Techniques for fostering positive team interaction exist and can be learned.

Question 1, "How did you *feel* in the worst team situation you were involved in?" produced 128 responses, including many repetitive expressions of frustration, anger, feelings of futility, powerlessness, anxiety, personal insult, and alienation.

The significance attached to these responses is:

- These types of feelings about teams (or even meetings) are widespread.
- Such emotional disincentives produce an invisible undercurrent of resistance to teamwork.
- If team leaders do not attend to resolving such feelings within a group, morale drops, team members' talents are not fully used, or they give up, and task goals suffer.
- Understanding the existence and source of such feelings can be used to help set up supportive, productive atmospheres for teamwork.

Question 2, "What was *not working* in that team?" produced 159 suggested dynamics that conspired to derail the team function. Specific remarks seemed to fall into roughly eight categories:

- lack of team atmosphere
- team makeup and involvement
- lack of clear vision or goal
- lack of effective team leadership
- poor facilitation
- lack of buy-in by key leadership
- lack of ability to see results
- poor communication

The contributing factors to these dynamics can be examined and reconstituted to create your own principles of successful teamwork. ("We have met the enemy and he is us!")

Location and Alleviation of Team Dynamics Problems

With the list of their group's team difficulties before them, participants were asked to locate the source of the team's problem. Specifically, they were asked, "Is the problem internal or external to the team itself? Further, is it a task or people process difficulty?" Once sources of problems were located, participants were asked to suggest ways to improve the situation. Results were tabulated by each group in a chart provided. For example, "Hidden agendas" was identified as an internal team problem with suggestions for improvement being "working in consensus mode and valuing all perspectives." As an external problem to team function, "Changing of rules by appointing authority" was cited. Possible amelioration included "written charge to group, mission statement, and written promise of support for team."

The problem of "bad team dynamics" can seem amorphous and overwhelming. This activity demonstrated how such dynamics, which usually come from many sources, can be analyzed and broken down into bite-size units. Identifying components serves as a starting point for designing solutions that can be achieved.

IPM Constraints: Constructive Uses of Collaboration

Each of 11 small groups was provided with a different key IPM constraint. Participants were given a stepwise series of questions aimed at helping them think about positive collaborative approaches to the constraint. Question 4 first asked, "Who is a potential stakeholder in the outcome of this constraint?" Groups listed 151 potential stakeholders, averaging 14 for each IPM constraint. Stakeholders listed might be lumped into 29 distinct groups. Consumers, including "general public, taxpayers, neighbors, urbanites, and housewives" were mentioned as stakeholders 15 times in the 11 groups. Producers and environmentalists were both mentioned 10 times. The one constraint for which producers were not mentioned as stakeholders was "Society's concern over pesticide use." Other high-ranking stakeholders by frequency of mention were agribusinesses (10), researchers (9), legislators (9), consultants (8), and Extension agents (7). Participants then looked again at the IPM constraint before them. For each identified stakeholder in that constraint, they considered: (1) What are the specific potential benefits of collaboration for you and for the stakeholder in remedying this constraint? (2) How do you identify legitimate representatives of this stakeholder group? (3) What are potential ways to involve the stakeholder group in your program? Each group tabulated the results in a chart that was provided.

This exercise demonstrated that stakeholders in IPM implementation consist of people representing a wide variety of socioeconomic positions. It also sensitized the participants to the importance of diverse stakeholders as a source of good ideas, synergy, funding, political clout, priority setting, public relations, and outreach during program implementation. Productive stakeholder involvement in program design and imple-mentation requires forethought and attention to team dynamics to produce these desired results.

Supporting Materials

Take-home materials for participants included two books and folders of selected publications on collaboration and teamwork, group processes, and conflict management. A detailed annotated list of packet contents is in the full report.

IPM Programs for Cotton Producers

Allen Knutson
Texas A&M University
Coordinator

The workshop opened with a review of the research and extension needs for cotton IPM as determined by more than 225 cotton producers, consultants, and Extension and research faculty participating in 17 assessment meetings held in 1995 and 1996 in North Carolina, Mississippi, Oklahoma, and Texas to identify the needs in research and extension education for cotton IPM as part of Phase 1 of the USDA IPM Initiative. The results of this assessment are summarized below and will provide part of the foundation to develop a proposal for implementation under Phase 2 of the IPM Initiative.

Because cotton losses from insects were at record levels during the 1995 growing season ($1.68 billion), it is not surprising that growers and consultants focused on insect and mite management. Identified research needs included a greater understanding of natural enemies and their use as biological control agents of cotton pests, better defined economic thresholds, and improved sampling and forecasting methods for cotton pests, an evaluation of the economics of transgenic cotton varieties containing the B.t. gene for bollworm/budworm resistance, and tactics for resistance management to preserve the effectiveness of this new technology. Other research needs focused on changes in the boll weevil eradication program to minimize disruption of natural enemies and secondary pest outbreaks, methods to manage insecticide resistance, improved management tactics for plant bugs, early season thrips and budworms, and understanding the impact of different tillage systems on pest infestations and crop productions. Participants also expressed the need for improved communication and interaction between researchers, growers, and consultants to better target research and implement research results.

In addition to entomological problems, growers voiced the need for developing management tactics for using transgenic varieties with herbicide resistance and determining the economic value of the technology. Developing economic thresholds and improved herbicide-application technology were also key needs in weed management. Regarding cotton diseases, identified needs in-cluded methods to forecast the need for fungicides to control seedling diseases and information on the effective use and economic return of fungicides to control seedling disease. The development of sampling methods, treatment threshold, and control tactics, including resistant varieties, for nematodes were also priority concerns.

In addition to research needs, growers and consultants were asked to address the extension and educational needs in cotton IPM. The identified needs included the expansion of current extension programs (such as in-depth workshops, in-field meetings, and field demonstrations) and the increased use of print publications, newsletters, and electronic methods (e.g., the World Wide Web and the direct satellite television network) to rapidly disseminate cotton IPM information. Extension was also encouraged to expand its unique role as an unbiased source of IPM information and to interact more with consultants and industry to facilitate technology transfer.

Other concerns were the need for more trained consultants and an increase in training and educational opportunities for consultants, a need to educate the public on the environmental stewardship practiced by agricultural producers, and the education of growers and practitioners about the goals and practice of IPM. And finally, growers and consultants said the long-term economic and biologic stability of IPM programs should be evaluated and demonstrated.

Following this presentation, workshop participants were divided into three discussion groups and asked to address one of the following issues. The assignment for each group and their responses are summarized below.

Issue 1. Develop an organizational structure for a community-based pest-management program. Describe how cotton IPM teams could be formed and function to meet the needs of research, education, implementation, and evaluation.

The program would be conducted by a steering committee composed of two to three growers; two to three consultants; a ginner; and one representative each from industry, Extension, and research for a total of about 10 individuals. It was felt that a committee of 10 to 12 would be optimum. Commitment by growers and consultants would be important to identify local needs and facilitate implementation and evaluation at the farm and community levels. A technical committee would consist of the research and extension specialists (agronomist, economist, weed scientist, etc.) and others involved in the IPM program. The steering committee and technical committee would meet three to five times each year to identify local research and extension needs, coordinate collection of field data with consultants to validate IPM practices, identify grower cooperators, plan and sponsor educational meetings to highlight program accomplishments and projects, identify and seek other funding sources, set annual goals, and measure program progress and impact.

Issue 2. Determine the communication needs that would improve delivery of IPM information and adoption.

Priorities are to provide current, real-time information that is well organized and synthesized, can be rapidly searched, is targeted to the user (client-based), and provides for feedback from the user. Workshops are needed to train those developing information-delivery systems and those using these systems. Important channels of communication are print on demand, cellular and mobile phones, electronic media (e-mail, CDs, fax, and the WWW), workshops, radio, and direct satellite television. Considerations concerning content are accountability, accessibility, commercial vs nonprofit institutions, timeliness, and mechanisms for feedback. Target audience can include consultants, producers, industry, retailers, colleagues, and bankers.

Issue 3. Describe how a community-based cotton IPM program can be organized and function to develop IPM programs, encourage their implementation, and assess the economic and environmental impact.

Success of a community-based program will depend upon producer buy-in. The size of a community will depend on biological, sociological, and economic factors (the target pest, what is manageable, the amount of funding available, and political boundaries). It is important to have baseline information on cropping practices, pest levels, pesticide use patterns, etc. to measure change.

Resource needs include a mission and goal (e.g., bollworm management in a two-county area); a steering committee composed of growers and consultants; a technical committee of research, Extension, consultants, growers, industry, and agribusiness personnel; an operational plan and budget; a project coordinator; interaction with an IPM team; an educational activities plan; and funding sources (State, Federal, and industry).

Research could be conducted first on experiment station plots, then moved to grower fields for validation and demonstration, then to whole farms and communities for adoption. Communication would be very important and could include stakeholder meetings, publication of white papers on program objectives and results, publicity of educational meetings, direct producer contacts, and frequent updates and progress reports.

Assessments of economic, environmental, and social impacts would be determined from data collected from grower cooperators' enterprise budgets. Environmental impact could be measured by comparing densities of beneficial insects, pesticide use (including shifts in use of pesticide classes), and movement of pesticides off-target. Social impact could be measured by surveying producers, consultants, the public at large, and field workers. Constraints include maintaining stakeholder support and enthusiasm; funding; and developing practices and technology that will actually be economical, practical, and implemented by the grower/consultant community.

IPM Programs for Wheat Growers

Greg Johnson
Montana State University
Coordinator

The focus of this commodity workshop was to discuss research and education needs that pertain to wheat production in the United States. Admittedly, this is a big challenge because of the complexity of the production system, the diverse farming practices used across the country, and variable abiotic factors that influence wheat production. In preparation for this workshop and to meet Phase I objectives of a National IPM Implementation project "Pest-Management Strategies for Dryland Wheat Systems in Northern Great Plains and Mountain Farm Production Regions," a Strategic Planning Workshop was held in February 1996 in Bozeman, Mont. This workshop, attended by 45 participants (including producers, consultants, Extension agents, researchers, and Extension specialists from Idaho, Montana, Nebraska, Wyoming, and South Dakota) focused on identifying strategic issues facing wheat producers in the northern Great Plains, developing solutions to these issues, and developing a plan of targeted activities to address these issues. The information collected at this workshop served as a starting point for initiating discussions at the wheat commodity workshop at the Third National IPM Symposium.

Pests and Factors of Production

An extensive list of disease, insect, and weed pests was developed for the northern Great Plains wheat-production region. Pests included on such a list change relative to the wheat-growing region of the United States. Perhaps more relevant to a large geographic region were nonpest problems. The nonpest problems encountered by wheat producers include grain-marketing strategies, crop-residue management, farm-program provisions, an increasing cost of inputs, water and soil manage-ment, viable crop rotations, risk management, limited variety selection, and transportation. While much attention is dedicated to research and education relative to solving pest problems, many producers consider nonpest problems of equal importance and worthy of attention.

Myriad factors influence disease, insect, and weed problems encountered in wheat production. These factors include: residue management and compliance, susceptible varieties, a monoculture system, cropping-system management, pest resistance, chemical fallow, lack of rotations, cultural practices, and pesticide reliance. Areas of research that were considered germane to addressing these factors include cropping-system management emphasizing the systems approach, developing resistant varieties, developing action thresholds, determining fertility responses, developing noncereal rotation crops, developing pest-management options for rotations, developing marketing strategies for rotation crops, and determining economic benefits of IPM.

Objectives Identified

Targeted objectives to expedite achieving IPM research and education needs include: (1) a cropping-system approach to pest management, (2) diversified crop-rotation systems, (3) residue-management programs, (4) IPM training and education, (5) farm-policy programs, and (6) measuring IPM profitability.

Objective 1. Cropping-system approach to pest management. This objective should focus on investigating system-level reactions to pest-management practices and optimize long-term economical and ecological pest-management practices. Targeted activities to achieve this objective include forming interdisciplinary research and extension teams; investigating system-level reactions to specific pest-management practices; developing practices from a water-conservation standpoint; emphasizing development and evaluation of resistant varieties; developing action thresholds; and exploring flex cropping; develop on-farm post-harvest management practices.

Objective 2. Diversified crop-rotation systems. Systems developed by integrated teams of researchers, Extension personnel, and producers must agronomically complement each other, be regionally adaptable, and be marketable. Activities identified by workshop participants include: identify and evaluate viable, noncereal rotation crops; conduct long-term rotational studies; investigate the impact of companion crops on fertility rotational benefits; determine the impact of rotational systems on pest populations, investigate rotational influences on disease, insects, and weeds; and identify uses, storage, transportation, and market opportunities for rotational crops.

Objective 3. Residue management. A point of clarification was made that residue-management activities can be beneficial or detrimental to wheat-production systems. The targeted activities for this objective include: develop on-farm demonstration plots to determine the impact of plant residue on selected pest populations; determine varietal responses in high-residue systems; investigate alternative methods to conserve soil and water; compare effects of no till, minimum till, and conventional till to selected agronomic parameters (moisture and erosion), pests, and economics.

Objective 4. IPM training and education. The primary goal of a wheat-production IPM program is to increase the understanding and implementation of IPM through enhanced education of producers, advisors, and consumers. Targeted activities for this objective include: improving multiple methods of educational delivery (on-farm demonstrations, and multidisciplinary teaching at workshops); form "wheat clubs" with progressive growers; use producers as trainers; increase electronic media use; and develop an effective marketing strategy for IPM.

Objective 5. Farm-policy provisions. This objective was identified because farm programs (rules, regulations, and policies) can prevent and/or inhibit adopting farm-specific IPM practices. Targeted activities include: explore local or regional control in implementing farm policy; educate consumers relative to farm policies; and develop rewards and incentives for producers adopting IPM practices.

Objective 6. Measure IPM profitability. To be adopted, IPM must be economically profitable with recognizable risks and uncertainties. Targeted activities include: conduct economic-profitability studies; focus activities on economic efficiency; and identify and examine risks and uncertainties through research and education.

Implementation and Assessment

To facilitate adoption and implementation of IPM practices in wheat production, the following methods were identified: on-farm demonstration plots, producer participation in planning activities, development of IPM producer groups, and increased electronic-media use. Workshop discussion focused on the method of assessment to determine the degree of adoption of IPM in wheat production. It was understood that the degree of adoption would be based on field scouting. It is important that criteria be developed for wheat on a regional basis; field monitoring is not a good measurement of IPM use in this commodity. The following constraints toward adopting IPM were identified: age of producers that may influence adapting to change, USDA farm programs, lack of incentives, lack of research on the cropping-system approach, misperception of IPM, risk of changing practices, marketing factors, and economics.

IPM Programs for Corn and Soybean Producers

Ken Ostlie
University of Minnesota
Coordinator

Corn and soybeans are planted on more than 124 million acres in the United States. Pesticides are an important management component of corn- and soybean-production systems. More than 93 percent of the acreage is treated with one or more herbicides, and more than 25 percent of the corn acreage is treated with insecticides. Intensity of pesticide use, concern over environmental and health issues, and emerging pest problems necess-itate a closer look at IPM implementation. IPM adoption has been estimated at from 17 to 65 per-cent for corn and from 13 to 59 percent for soy-beans (Vandeman et al. 1994; Cate and Hinkle 1994). The objectives of this workshop were to review, discuss, and suggest improvements to three IPM efforts:

- Defining the key components of IPM in corn and soybeans for use in measuring IPM progress
- Measuring IPM adoption through survey activities of the Agricultural Resource Management Study (ARMS)
- Establishing clientele-based priorities for IPM research and extension.

Defining IPM for Corn and Soybeans

Dr. Wendy Wintersteen summarized the Government Performance and Reporting Act and its implications for federally funded IPM programs. Defining IPM for corn and soybean production systems is critical to establishing baseline data on IPM usage in these crops and to measuring the future performance of IPM programs. Beginning with results of an earlier workshop, participants produced the following list of key IPM components.

General IPM Practices

1. Regularly receive pest- and crop-management information during the growing season.
2. Attend meetings on pests, their identification, and management.
3. Keep field records (including weed and disease maps).
4. Conduct off-season crop-management planning.
5. Scout crops for key pests and general problems.
6. Use cultural practices (tillage, row spacing, seeding rates, planting dates, and cultivars) that reduce and/or control pests.
7. Use prevent measures that reduce the spread of pests.

Weed Management

1. Tailor weed management in individual fields based on in-season and fall scouting.
2. Reduce herbicide use by one or more of the following methods appropriate to your situation: mechanical control (tillage, rotary hoe, or cultivation), cultural measures, herbi-cide banding and cultivation, spot treatments, below-label herbicide rates timed by field scouting, and herbicide applications based on in-season scouting and weed thresholds.
3. Practice strategies that reduce herbicide resistance.

Insect Management

1. Routinely scout for key insects (e.g., in corn for the European corn borer, corn rootworms, black cutworms, and others appropriate to local conditions and in soybean for stand reducers, defoliators, and pod feeders as appropriate to the local situation).
2. Base insecticide decisions on economic thresholds.
3. Minimize adverse insecticide impacts through judicious selection of insecticides, rates, areas to be treated , and timing.
4. Use cultural and weed-control practices that minimize risks from key insects.

Disease Management

1. Use crop rotations that reduce disease incidence and severity.
2. Plant resistant varieties.
3. Perform soil sampling for nematodes.
4. Submit diseased plants to diagnostic clinics for identification.

IPM adoption is viewed as a continuum so discussion ensued on the degree of adoption necessary for a farmer to call himself an IPM practitioner. The geographic variation in key pests and appropriate pest-management practices were other key discussion points, with one resolution to define IPM for various corn- and soybean-production systems on a State or area basis.

Measuring IPM Practices

Ms. Cathy Greene, Economic Research Service (ERS), reviewed progress on ARMS, the Agricultural Resource Management Study. ARMS developed from combining the old Cropping Practices Service and the Farm Costs and Returns Survey conducted by the National Agricultural Statistics Survey (NASS). She discussed several proposed questions for the new ARMS survey to be conducted among corn and soybean producers in 1996. To gather feedback on the proposed survey, several smaller workgroups discussed the survey questions with ERS and NASS representatives.

Extension and Research Priorities for IPM Implementation

Dr. Ken Ostlie presented the outcome of a regional workshop held to determine Extension and research priorities for IPM in corn and soybean. A broad cross-section of farmers, crop consultants, agronomists, agricultural-chemical-industry representatives, environmental activists, Extension educators, government staff, and university professors met in February 1996 to tackle this task. The following priorities from this workshop were presented for review and discussion:

Research

- Develop weed thresholds and optimal management systems.
- Explore the economic and risk-management implications of IPM.
- Plant cropping systems that minimize pest problems and maximize profits.
- Adopt alternative management strategies to pesticides.
- Improve scouting techniques and tools.
- Investigate the implications of new technologies (geopositioning, geographical information systems, statistics, and variable-rate application) for IPM.
- Examine the factors influencing adoption of IPM.
- Conduct a survey of IPM adoption.

Extension

- Provide real-world information to producers.
- Conduct more on-farm applied research and demonstrations.
- Form strategic alliances with industry and growers to promote IPM messages and practices.
- Emphasize the holistic context for IPM programs.
- Use electronic media for IPM-information delivery.
- Use community-based educational efforts.
- Educate “nonfarm” audiences about IPM.
- Market IPM more effectively.
- Evaluate IPM programs to identify what works and what does not, and then share the results.
- Develop an IPM recognition program for farmers.

Small groups discussed these priorities with the general consensus that these priorities truly captured their own personal priorities for IPM research and education in corn and soybeans. No substantive additions were offered.

IPM Programs for Forage-Crop Producers

Bill Lamp
University of Maryland
Coordinator

The workshop was organized to address the research and extension needs for forage crops. Forage crops differ from most of the cropping systems discussed at the IPM Symposium for several reasons:

1. The crops are of relatively low value, and therefore the economics of IPM on forage crops differs from other crops.
2. A number of plant species (legumes, grasses, and crucifers) are used as forages, and concomitantly a wide range of pest species reduce the growth, development, and persistence of forage crops.
3. Forages can be used singly or in mixtures and range from closely managed hay systems to relatively little-managed prairie systems.
4. Forages are an integral part of a wide variety of sustainable farm systems, although they rarely serve as the major economic resource of a system.
5. Forages are usually perennial and persist in stands for several years; thus, they provide a consistent habitat for many pest species, although cutting may cause frequent disruption of habitat suitability of other species.

These qualities make forage-crop protection from pests unique among crop systems and result in special challenges to IPM implementation.

The workshop was conducted as a discussion of questions, led by four panelists, and included audience participation. The four panelists were: John Dantine, Consultant, Lancaster, Pennsylvania; Alan Gotlieb, Plant Pathologist, University of Vermont; Phillip Mulder, Extension Entomologist, Oklahoma State University; and David Liewehr, Ph.D. Student Entomologist, University of Maryland.

The following is a summary of the questions posed and some of the key points made during the discussion.

1. Producers need specific answers to questions with regard to their pest problems. From the perspective of the producers, what research is needed to answer these questions?

- A need exists to integrate forages from the perspectives of crop growth and animal requirements. The current focus is IPM; we need to move toward integrated crop management (ICM) and integrated farm management (IFM).

- An often-suggested need is voiced as “stand decline,” yet stand persistence is a result of complex interactions of crop genetics, management practices, abiotic factors, as well as biotic factors (especially pests).

- Generally, producers need clearly defined thresholds and easily implemented control alternatives, including the use of crop-management practices for managing pests.

- Producers desire economic data to support their decision making.

2. Various barriers currently impede the transfer of information across disciplines and research/ extension/industry sectors. How can we enhance the communication of forage-crop IPM?

- Because of the low crop value and shifting paradigms at universities, no one State has all the expertise necessary to implement forage-crop programs. Yet, all States need to transfer information because of the integral nature of forages within many farm systems. Thus, more emphasis should be placed on regional or national approaches to forage-crop IPM.

- Conversely, there remains the need for local expertise in forages who understand local problems and needs.

- A more holistic approach to planning is needed (i.e., a team approach involving multiple disciplines and/or industry/university partnerships). These teams force a shift from parochial to more holistic perspectives.

- Not all producers are willing to listen to new information; perhaps we should accept that we cannot reach all producers.

3. New technologies are being developed to control pests in forage crops. What are the major problems (and their solutions) for the adoption of new pest-control measures?

- Most new technologies are too expensive for use on forages. The major exception is the development of new crops and new varieties.

- For new crops, growers need to know the pests and how they can be managed. Regional differences are critical because problems will vary locally and regionally.

- Intensive grazing has become a new technology because of fencing; research is needed to assess its use for forage-crop IPM.

4. IPM is a knowledge-based strategy for managing pests, and therefore education is critical for IPM implementation. How is education of forage-crop IPM programs best achieved?

- Communication is needed among all participants in understanding the forage system.

- Education should focus on specific issues and provide recommendations with regard to economic costs and benefits.

- Simply stated, farmers want answers, not statistics.

- Educators need to understand the audience to market their information successfully.

5. We have a stated goal of 75-percent implementation over the next 5 to 6 years. How can we measure the level of implementation of forage-crop IPM on the basis of economic, environmental,, and social impacts?

- Although we are making progress in increasing awareness of scouting, the awareness of more complex, multiple-pest issues, such as forage-stand persistence, is difficult to assess and even more difficult to quantify.

- We need to assess change over all forage species. For example, a switch from legume to grass will reduce the economic losses to pests, the use of pesticides, and the preservation of nutrients for animal production.

- Measures include pesticide-use reduction and pesticide-use efficiency; economic measures include yield, quality, and stand persistence.

- In the short term, IPM has increased pesticide use because of the awareness of the losses associated with certain pests. In the long term, these pests have become targeted for nonchemical controls, such as the use of natural enemies, host-plant resistance, and cultural controls.

- Progress needs to occur along multiple lines by providing options to growers.

- Again, a more holistic view is needed to consider nontraditional components of IPM and how they fit into crop and farm management as a whole.

IPM Programs for Potato Growers

Mary Powelson and Carol Mallory-Smith
Oregon State University
Coordinators

The purpose of the commodity workshop was to identify the key research, technology transfer, and extension-education needs for implementation of IPM for potatoes on 75 percent of the crop acres. Our charge was to look 5 to 6 years ahead when making our recommendations. Our approach was to organize the workshop into two primary topical areas: research needs and technology and extension needs. Each topic was the subject of a separate work session that lasted about 45 minutes with each participant having the opportunity to contribute to both sessions. This report identifies the key research and extension needs.

Key Research Needs

To analyze the full range of research needs in IPM, we agreed that the three categories frequently used to describe agricultural research were fundamental, component, and systems research. **Fundamental** research produces new knowledge, leading to understanding of basic principles, processes, and mechanisms. **Component** research is the study of one or more factors that affect the performance of an agricultural system. The process by which the nature of interactions among the components of a system are discovered is systems research. **Systems** research results in knowledge that is distinctly different than the sum of results for component research. More importantly, systems research is not distinct from fundamental or component research. Because systems involve different kinds of components, systems research requires an interdisciplinary approach. These definitions, taken from a report of an AIBS-sponsored workshop on Research in Support of Sustainable Agriculture, are also applicable to research on IPM.

Listed below are the key research areas that emerged during the course of the discussion as having potential to contribute significantly to the future success of IPM on potatoes. These themes were common to the three pest disciplines (i.e., diseases, insects, and weeds).

Fundamental Research

- host resistance to pests
- biological control
- pest/potato interactions
- microbe/potato interactions
- pest biology

Component Research

- traditional breeding
- genetic engineering for pest resistance
- management of transgenic plants
- pesticide resistance management
- alternative methods to soil fumigation
- environmentally benign compounds for pest control
- economic thresholds
- pesticide application technology

Systems Research

- interrelationships of cultivars, pests, and agronomic practices
- long-term rotational studies
- pest threshold x cultivar x fertility interactions

Technology-Transfer and Education Needs

Several broad areas were identified that can serve as a starting point for discussion of strategies to enhance IPM on potatoes.

- Development of computer databases, knowledge-based systems, and networks that provide state-of-the-art information about pests, pest-control recommendations, and weather. Examples include bulletin boards, 1-800 networks, and expert systems. With the 800 numbers, pest alerts and timely information on control measures must be updated frequently.

- Production and distribution of up-to-date educational materials. Examples include videos on specific IPM practices growers can adopt, field books with picture keys for identification of seedling and mature weeds, insect pests, and diseases. This same information should also be available on CD- ROM. The picture key books should be of the quality that if they get wet, the ink does not wash away. For paper-based newsletters to be effective, they should be easily recognizable by a farmer.

- Stakeholder education of IPM strategies. Examples include on-farm demonstration plots, field days when farm activity is low, training sessions during the field season (pest ID and IPM), and educational meetings during off season. The importance of one-on-one interactions for problem solving was stressed.

There is a perception that the gap between the research community and its stakeholders (potato grower and processor) is large. For IPM to be successful, the need for better communication and meaningful participation by a larger group of stakeholders was stressed.

One major concern was how to define adoption. Acres under production with IPM and pesticide use are often mentioned as measures of adoption, but defining what are IPM practices and the amount of use of those practices have been problematic at times, leading to questionable results. A rating system was discussed as a potential approach, similar to what is already being done in Massachusetts for IPM certification. It was suggested that we should start with what is agreed to be IPM, recognizing it is a series of "things" not just a single thing. The percentage of growers practicing defined IPM activities is possible to measure. It was also recognized that the level of adoption will change as the cropping system changes and as new pests occur or practices become available.

Because IPM is knowledge, it might be possible to test growers at meetings for understanding of IPM concepts. An example of this was given from cranberries. Testing understanding might also permit analysis of why practices are not used. If a concept is understood by growers yet is not being practiced, what would it take to adapt the practice for use? Further research or overcoming some other constraint might be suggested.

IPM certification was discussed, but the discussion led to the issue of whether the market would drive the need. Does a market exist? If a sufficient market does not exist, could one be created?

Summary

In the end, it was concluded that if 75-percent adoption of IPM becomes reality, it will occur only because growers actually do it. Research is needed to provide the knowledge of what is possible in IPM. Extension adapts this basic IPM knowledge for growers and their consultants to use. It is up to growers to actually put IPM knowledge to use in a practical and economical way.

IPM Programs for Fresh-Market and Processing Vegetables

Larry G. Olsen
Michigan State University
Coordinator

The purposes of this workshop were to identify the key research, technology transfer, and extension education needs for implementation of IPM on 75 percent of the crop acres; determine how to assess the economic, environmental, public-health, and social impacts of IPM implementation; and determine how we can achieve greater IPM implementation in the next 5 years.

To set the stage, the Workshop started with panel presentations discussing IPM needs from different viewpoints, including a major food processor and a diversified family farmer. The speakers presented an overview of their operation and their short- and long-term extension and research needs from the land-grant-university system.

Todd DeKryger represented Gerber Products, Inc., a major processor of vegetables with special very-low-pesticide residue and no-pest-contamination requirements in the end product. They have developed a very strong IPM program working with growers to assist them in raising high-quality vegetables and fruits with minimal pesticides.

Kurt Alstede is from New Jersey and was Rutgers Vegetable Grower of the Year in 1995. Kurt markets almost solely to the roadside fresh market. He has real IPM needs because of the large diversity of crops he grows and the quality demanded by his customers. He needs more scouts in more crops to keep him informed about pest development and is convinced growers will pay for scouting if the service is good. Kurt stresses that research and demonstrations must be done on the farm to match real situations. Lastly, the university must educate citizens in IPM and what growers are doing to reduce chemical use for their own environmental and food-safety reasons.

Discussions

After the presentations, the audience of processors, consultants, growers, academics, and agency people was divided into three groups based on commodity groupings. An interactive workshop format was used with small groups reviewing, discussing, and prioritizing needs. The groups used flip charts, markers, and dots for voting to ease the process. Three facilitators and the MSU IPM staff helped organize the handouts and visuals for the discussions. The groups worked for 3 hours to respond to the following three items.

I. Identify Key Research, Technology Transfer, and Extension Education Needs for Implementation of IPM in Both the Short (1 to 3 Years) and Long (4 to 5 Years) Terms

IPM needs identified through the needs assessment process by 18 State IPM coordinators on 34 vegetable crops were summarized and presented to the appropriate group. The work groups then added other priorities and ranked the needs; 339 needs were identified. The highest-ranking needs follow in descending order. (Each person had three votes to rank their priority needs.)

II. Define How to Measure Impact of IPM Implementation

The second charge to the groups was to define ways to measure the impact of IPM implementation.

Group 1, instead of identifying the impacts of IPM implementation, defined how to measure IPM implementation. All their comments are summarized below in a prioritized listing with the total votes received for that method. Each participant voted twice. Several of the items listed received no votes.

Votes	Crop	Comments
10	Cucurbits	Develop better foliar-disease-management programs, including action thresholds, weather-based monitoring systems, and application technology.
6	Sweet corn	More systems research to solve all problems
4	Cucurbits	Conduct multidimensional on-farm demonstrations of IPM practices
4	Tomato	Interaction of soil, water, and cultural practices with diseases and weeds
4	Tomato	Better control of aphid-transmitted viruses
3	Cucurbits	Develop better management for gummy stem blight
3	Snap Beans	Improve insect control by better monitoring systems, thresholds, transgenic Bt plants, and cultural and chemical controls
3	Snap Beans	Improve weed control with thresholds and effective alternatives
3	Sweet corn	Develop better information on pest biology, crop phenology, and their interaction
3	Sweet corn	Develop better understanding of beneficials and their augmentation and preservation
3	Sweet corn	Develop alternative (nonchemical) controls for corn earworm
2	Cucumber	Develop threshold for striped cucumber beetle
2	Cucurbits	Investigate aphid-vector population dynamics, virus epidemiology, and cultural-control tactics
2	Cucurbits	Develop better management for powdery mildew
2	Pepper	Provide better bacterial-leaf-spot control recommendations
2	Pepper	Improve scouting techniques and decision guidelines for management of European corn borer
2	Pepper	Improve monitoring system for pepper maggot
2	Sweet corn	More IPM field implementation personnel
2	Sweet corn	Develop resistance-management programs

1. Number of acres under IPM and degree of implementation; must define IPM/levels of adoption first (11 votes)
2. Use the Environmental Impact Quotient to measure risk (3 votes)
3. Record the increase in scouts and consultants (2 votes)
4. Cost per acre and cost benefit of IPM (2 votes)
5. Number of growers using IPM
6. Environmental risk reduction
7. Worker safety measured as man hours at risk
8. Increase of natural enemies
9. Biodiversity increase
10. Pesticide use:
    active ingredient per acre (poor measure)
    cost per acre
    toxicity ratio
11. Acres scouted
12. Quantify pesticide residue in end product

Groups 2 and 3 listed ways to measure the impact of IPM implementation. Again, each participant had two votes, with the total votes for each measure indicated. Several methods received no votes. Similar comments from the groups were merged into one list.

1. Number of growers and acres using a defined IPM system (10 votes)
2. Positive enterprise budget, which measures "return of investment for IPM system" (9 votes)
3. Reduce use of a "risky" pesticide (4 votes)
4. Use of Environmental Impact Quotient (EIQ) (2 votes)
5. Lower active ingredient of chemical per acre (2 votes)
6. Lower pesticide residue in packing house and waste water (2 votes)
7. Grower willingness to pay for IPM practices; do they raise risk (2 votes)
8. Consumer satisfaction (1 vote)

9. Pesticide residue on raw and processed products (1 vote)
10. Dietary risk (1 vote)
11. Maintain pesticide onsite
12. Using resistance-management program
13. Grower satisfaction with IPM program
14. Will they work on-farm when privatized
15. Improved or equal quality as market demands
16. Reducing number of sprays per season
17. Enhanced soil structure
18. Adopting reduced-cost practices
19. Number or percent of workers trained in pesticide safety
20. Preservation of open space
21. Better relation to nonfarm neighbors
22. Establish baselines for environmental quality, worker exposure, etc. and measure changes over time
23. Measure worker exposure
24. Marketplace willingness to pay for IPM practices
25. Cost of food to consumers
26. Groundwater contamination
27. Maintain health of pesticide handlers

III. How Can We Achieve Greater IPM Implementation in Five Years?

The last discussion topic was to list ways we can achieve greater IPM implementation in vegetables in the next 5 years. This list is not prioritized but provides numerous excellent techniques the IPM coordinators and programs can use to enhance implementation. Many of these techniques assist in measuring the impact of IPM programs and will be required for reporting for the Government Performance and Results Act.

1. Local demonstrations are a must. They can be twilight tours and must be on-farm with key-farmer involvement. Demonstrations might include things such as TOMCAST or reflective mulch for aphid repellent.
2. Measure and promote "dollars saved" by producers by implementing IPM.
3. Train more scouts and private consultants, who are necessary to increase greater adoption of IPM.
4. Obtain grower/commodity group seed money for crop management associations and grower IPM associations.
5. Conduct research that helps farmers solve problems.
6. Public demand for IPM-grown produce may increase IPM adoption.
7. Develop more useful IPM publications (bulletins, notebooks, and fact sheets) and share knowledge of pest conditions and management options by multiple means (radio programs, code-a-phones, FAX, and the Internet).
8. Explain economics of time allocation for own scouting versus buying scouting services.
9. Deliver information differently (new packaging and marketing); use groups like the Natural Resources Defense Council, World Wildlife Fund, sustainable agriculture groups, and environmental groups; the key message for us to get across to these groups is softer and fewer pesticides with IPM and biointensive IPM (as it becomes available).
10. One-on-one visits on farm will increase IPM adoption slowly.
11. Develop IPM programs for the whole farm with tools like expert systems that are grower friendly.
12. Intensive training for agents in all aspects of IPM, including technology, economics, and marketing for IPM.
13. Commodity-based IPM teams need to be established with a spectrum of participants from basic scientists to growers.
14. University infrastructure needs to include an IPM coordinator, commodity-focused program leaders, and a diagnostician that provides quick and accurate information.
15. Regional sharing of information is essential because each State does not and will not have all the IPM expertise necessary to implement effective IPM programs on all commodities. This sharing begins with Regional Planning Grants (Phase 1) and may continue with IPM Regional Centers.
16. Seek additional support. State support is mandatory!

What Is an IPM Program?

Kurt Alstede mentioned during his panel presentation that Rutgers has a very good sweet corn IPM program but does not have one for pumpkins. This partial coverage is likely true for every State and territory of the United States. We all have commodity programs that are strong because of strengths of the university and grower demand, but it is not possible to have IPM programs for every commodity. It is likely we have components of IPM programs. Specific components include:

- Training materials, such as notebooks, fact sheets, and videos
- Training programs
- Scouting services, public or private
- Monitoring schemes, techniques, and time lines
- Economic thresholds
- Alternative pest-management techniques
- Evaluation tools that measure level and impact of adoption of IPM
- Demonstrations
- IPM team of specialists and agents
- IPM commodity steering and advisory committees
- Data-management systems

Each IPM coordinator must decide which of these IPM program components to have for each commodity and how many are needed before deciding if an IPM program is available for that commodity.

IPM Programs for Tree-Fruit Growers

Frank G. Zalom
University of California
Coordinator

The primary charges to the Tree Fruit Workshop participants were to identify key research, technology transfer, and Extension education needs for implementation of IPM on 75 percent of crop acreage and to address how impacts of IPM implementation could be measured.

Resources used for reviewing the status of IPM in tree fruits included the status of apple IPM research and implementation, which had been determined for the National IPM Forum in 1991, and a summary of responses to the recent USDA survey "Farmer-Identified Priority Research and Extension Needs," which was facilitated by State IPM coordinators.

Dr. James Tette presented the summary compiled for the National IPM Forum, which indicated that considerable research was under way nationally on biological controls with predators, parasites, and microbial biopesticides; on host-plant resistance with both traditional and transgenic breeding approaches; on cultural control methods; and on semiochemicals for insect control. Several workshop participants noted that research activity related to these approaches had expanded nationally in the five years since the study was completed. Methods in use by apple growers at that time included biological control of mites (13 States), biological control of insects (6 States), use of insect virus (1 State), mating disruption (2 States), and mass trapping (1 State) with pheromones, biological control of pathogens (2 States), cultural control methods (16 States), and sterile-male releases (1 State).

Responses to the USDA survey of "Farmer-Identified Priority Research and Extension Needs" were summarized for all fruit crops, and indicated general areas of research (r) and Extension (e) needs that were identified across States and commodities. Table 1 presents that information.

Drs. Harvey Reissig and Joe Kovach of Cornell University, Dr. William Coli of Massachusetts, and Dr. James Walgenbach of North Carolina discussed their experiences in developing IPM teams through "Phase 1" IPM planning grants they had received. Participants in that process helped to identify lists of priority pests and of research, Extension, and infrastructure needs, but the emphasis was different in each case.

James Cranney of the International Apple Institute and David Benner, an apple grower from Pennsylvania, discussed the importance of the apple-industry research committee, which helps link growers, Congress, the USDA, and the land-grant universities. Such diverse teams, which function to identify grower needs, can also help to identify how to deal with the lack of research, education, and funding needs.

Many innovative ideas were mentioned by workshop participants as currently being studied, including disease forecasting for several pathogens; manipulating plant defense chemicals through cultural management; the use of bees to distribute a biological control agent to control *Botrytis* of strawberries; development of interactive websites on the Internet, such as the virtual orchard in New Hampshire; research on host-plant resistance and resistant rootstocks; pheromone-based mating disruption; canopy management for disease control; a trap-out strategy for apple maggot that uses toxicant-baited spheres; use of various orchard-floor-management approaches, including cover crops for weed and insect control; and implementation of arthropod biological controls through the release of beneficial organisms and in-field insectaries.

Measuring IPM adoption was a focus of considerable discussion in the workshop. The need to involve social scientists or evaluation specialists in IPM evaluation was recognized.

Table 1. Farmer-identified priority research (r) and education (e) needs.

Grower-Identified Needs by State	Need		Fruit Crop
Alternative management strategies for arthropod pests:			
Low-toxicity, selective, and biological pesticides (W.Va., Penn., Ore., N.Y., Wash., Conn., Calif., Ala., N.C., Mich.)	r	e	Apple, peach, tree fruit, pear, citrus, raspberry, nectarine, almond, fig, pecan, blueberry, grape, strawberry, sweet and tart cherry
Biological control (W.Va., Ky., Penn., Ore., N.Y., Conn., Calif., Ala., N.C., N.H., Mich.)	r	e	Apple, peach, tree fruit, plum, pear, almond, pistachio, cling peach, citrus, prune, plum, grape, blueberry, tart cherry
Effect of cover crops on beneficials (N.Y., Mich.)	r		Apple, grape
Action thresholds (N.Y., Calif., N.C., Mich.)	r	e	Apple, pistachio, blueberry, tart cherry, grape, plum, prune
Resistance management and resistance assays (W.Va., Calif., Mich.)	r	e	Apple, peach, citrus
Efficient sampling, monitoring methods, and traps (W.Va., Ky., Penn., Ore., N.Y., Wash., Calif., Ala., N.C., N.H., Mich.)	r	e	Apple, peach, tree fruit, pear, pecan, pistachio, cling peach, raspberry, blueberry, tart cherry, grape
Degree-day forecasts and phenological modeling (Penn., Ore., N.H., Ky., Mich.)	r		Tree fruit, pear, peach, apple, blueberry
Host-plant resistance, phytochemical studies, and biotechnology (N.Y., Conn., Ala., Mich.)	r	e	Apple, pecan, strawberry, blueberry, raspberry
Evaluate bagging fruit as control (Ky.)	r		Apple
Mating disruption:			
Codling moth (Ky., Ore., N.Y., Wash., Calif., N.C., Mich.)	r	e	Apple, pear, walnut
OBLR (N.Y., Wash., Mich.)	r	e	Apple
Spotted tentiform leafminer (N.Y.)	r	e	Apple
Omnivorous leafroller (Calif.)	r	e	Nectarines
San Jose scale (Calif.)	r		Stone fruit
Oriental fruit moth (Calif.)	r	e	Cling peach, nectarines
Peach twig borer (Wash., Calif.)	r	e	Tree fruit, cling peach, almond
Borer complex (Mich.)	r		Tart cherry
Physical barriers and spatial isolation (N.Y., Conn.)	r		Apple
Disrupt overwintering habitat (Calif., N.H.)	r	e	Almond, apple, pistachio
Effect of spray adjuvants (Penn.)	r		Tree fruit
Incidence of quarantine pests (Penn., Calif.)	r	e	Tree fruit, citrus
Alternative to carbaryl for thinning (Mich.)	r		Apple
Trap crops (Mich.)	r		Grape
Cultural-control information (Mich.)	r		Raspberry
Improved management of diseases:			
Alternative control strategies (Ky., Penn., Conn., Wash., Calif., N.H., Mich.)	r	e	Apple, tree fruit, cling peach, blueberry, prune, strawberry
New-product R&D (W.Va., Mich.)	r	e	Apple, peach, grape, blueberry

Environmentally friendly application methods (W.Va.)	r	e	Apple, peach
Resistance management (N.H., Mich.)	r	e	Apple
Improved sampling, monitoring, and detection techniques (N.Y., Mich., N.H.)	r		Apple, blueberry
Strong nursery management (W.Va.)	r	e	Apple, peach
New bioagents and biocontrols (W.Va., Ore., N.Y., Calif., Ala., Mich.)	r	e	Apple, peach, pear, almond, pistachio, grape
Disease resistance and biotechnology (W.Va., Ky., Penn., N.Y., Calif., Ala., Mich., N.H.)	r	e	Apple, peach, cling peach, almond, pecan, tree fruit, blueberry, tart cherry, plum, grape, strawberry, prune, raspberry
Methods for identifying and controlling viruses (W.Va., Wash.)	r		Apple, peach, cherry, tree fruit
Disease epidemiology and forecasting (W.Va., Penn., Ore., N.Y., Calif., Ala., Mich., N.C., N.H.)	r	e	Apple, peach, pear, almond, cling peach, blueberry, grape, sweet, and tart cherry, strawberry
Natural products for inhibition (N.Y.)	r		Apple
Disease-severity ratings (N.H.)		e	Apple
Exploit detritovores to destroy leaf litter (N.Y.)	r		Apple
Effect of spray adjuvants (Penn.)	r		Apple, tree fruit
Alternatives to methyl bromide for postharvest control (Wash., Calif.)	r		Stone fruit, cherry, prune
Postharvest controls (biocontrols and modified atmospheres) (Penn., Mich., Ore., N.Y., Wash., Calif.)	r		Tree fruit, pear, apple
Revise application schedules (Mich.)	r		Blueberry, strawberry
Cultural-control information (Mich.)	r		Raspberry
Improved management of nematodes:			
Nonchemical management techniques (W.Va., Calif.)	r		Apple, almond, tree fruit
Alternatives to methyl bromide (Calif.)	r	e	Cling peach, apple
Green manures (Penn.)	r		Tree fruit
Resistant rootstocks (Calif.)	r	e	Apple
Suppressive cover crops (N.Y.)	r		Apple
Damage thresholds (W.Va.)	r		Apple, peach
Alternate weed control strategies:			
Noncultivation alternatives to herbicides on slopes (Mich.)	r		Grape
Cover crops for weed suppression (Ore., N.Y., Mich.)	r		Apple, pear, blueberry, grape
Low rates of herbicides and growth regulators to suppress ground-cover growth (N.Y.)	r		Apple
Synthetic and natural mulches (N.Y.)	r		Apple
Assess flaming as a control (N.Y.)	r		Apple
Selective herbicides to manipulate ground cover (N.Y.)	r		Apple
Develop weed thresholds (N.Y.)	r		Apple
Hot water (steam) (N.H.)	r		Apple
Alternatives to preemergence herbicides (Conn., Calif., N.H., Mich.)	r	e	Apple, prune, strawberry, sweet, and tart cherry
Less damaging methods of in-row cultivation (N.Y.)	r		Apple
Barriers (Penn.)	r		Tree fruit
Herbicide-resistant plants (Mich.)	r		Blueberry

Register new herbicides for resistance management and less residue (Mich.)	r		Blueberry

Alternative vertebrate control strategies:

Nonchemical alternatives (N.H.)	r	e	Apple
Assess effect of raptor perches (N.Y.)	r		Apple
Assess effect of predator odors (N.Y.)	r		Apple
Mechanical and chemical bird repellents (N.Y., Mich.)	r	e	Apple, blueberry, grape
Damage thresholds (N.Y.)	r		Apple
Vole-resistant rootstocks (N.Y.)	r		Apple
Diversionary crops (distant to target crop) for deer control (N.Y.)	r		Apple
Economical deer control	r		Grape
Alternatives for vole control (Mich.)	r		Grape

Improved IPM systems:

Arthropod and disease pests in high-density orchards (W.Va., Ky.)	r	e	Apple
Single/double pest economic thresholds (W.Va., N.Y.)	r	e	Apple, peach
Effect of trap crops and cover crops (multidisciplinary) (N.Y.)	r		Apple
Understand changes in pest complex with IPM (W.Va.)	r	e	Apple, peach
Nutrient management (Penn., Calif., N.C.)	r	e	Cling peach, tree fruit, prune
Tree architecture (Penn., N.C.)	r	e	Tree fruit
Prevent practices for management (Conn.)	r	e	Apple
Orchard management at urban/rural interface (Penn.)		e	Tree fruit
Costs/benefits of IPM implementation (W.Va., N.Y., Wash.)		e	Apple, peach, raspberry
Effect of earthworms on scab and leafminers (N.H.)	r		Apple
Integrated, multidisciplinary, and ICM studies (Mich.)	r		Blueberry, tart cherry, grape

Improved pesticide application techniques:

Evaluation of electrostatic sprayers (N.Y.)	r		Apple
Better spray coverage (Calif.)	r	e	Apple
Adjust volume (N.C.)		e	Apple
Alternate rows (N.C.)		e	Apple
Reduced rates (Mich.)	r		Blueberry
Better application technology (Mich.)	r		Apple, blueberry, grape, tart cherry
Minimize off-target contamination (N.Y.)	r		Apple

IPM information dissemination or infrastructure:

Regional coordinator (clearinghouse) (W.Va., N.H.)	r	e	Apple, peach
Expert systems (W.Va., Ky., Penn., N.Y.)	r	e	Apple, peach, tree fruit
Fax on demand (N.Y.)		e	Apple
Hands-on workshops (Wash.)		e	Apple, raspberry
IPM manuals (Wash., Mich.)		e	Apple, sweet and tart cherry, raspberry
Role and needs of IPM consultants and training of consultants (Penn., N.Y., Mich.)	r	e	Tree fruit, apple, and sweet and tart cherry

Promote on-farm research and demonstration (N.Y., Wash., Mich.)	r	e	Apple, raspberry, blueberry
Weather data for pest management (W.Va., N.C., Mich.)	r	e	Apple, peach, and sweet and tart cherry
Information on beneficial insects (Mich.)		e	Apple
Grower and public-information classes (Mich.)		e	Apple, blueberry, raspberry
IPM tactics for sustainable orchard production (W.Va.)	r	e	Apple, peach

IPM Programs for Nurseries and Urban Ornamentals

Michael J. Raupp
University of Maryland
Harry Hoitink
Ohio State University
Moderators

Workshop Organization and Goals

Individuals from all geographic regions of the country and representing the varying perspectives of nursery producers; landscape maintenance companies; public landscape managers; homeowners; industries serving homeowner pest-management needs (e.g., garden centers); environmental interests; and professional horticulturalists, plant pathologists, entomologists, and weed scientists participated in this effort to identify nursery and landscape IPM priorities. The focus of the structured workshop discussions was on the production and maintenance of woody plants (trees, shrubs, and ornamentals). Some minor issues on turf- and lawn-pest management and floricultural pest-management also were discussed.

This workshop built on the foundation provided by earlier meetings that sought to identify major research and extension needs in the nursery and urban-landscape arenas. These meetings were conducted as part of a Phase I planning exercise conducted by representatives of the Northeast and North Central regions. The workshop sought to incorporate ideas from regions and groups that did not participate in the Phase I exercise. The contributions of these groups have been incorporated into the summary report presented below.

The specific goals of the workshop were to:

1. identify and rank major pest-plant complexes in the nursery and landscape settings,
2. identify critical nursery and landscape IPM research needs, and
3. identify critical nursery and landscape IPM information-transfer needs.

Key Pest Problems

The Phase I activity identified 71 plant-pest complexes and pest-related problems of key importance in nursery production as a result of quarantine regulations and/or in landscape maintenance. Some key pests were identified as being problematic across all three settings (production, quarantine, and maintenance), while others were problems only in one or two of the different settings.

A pest-problem prioritization process revealed general agreement among participants about the most critically important of the identified pest problems. Table 1 lists the top "dirty dozen" pests receiving highest rankings of importance from participants and indicates the settings in which the pests are judged to be of particular importance.

Other pests ranked by the group at this workshop group as "very important" in either the nursery production or landscape-maintenance setting for additional regions were (for the southeast) roots and wilts, problems associated with sandy soils, nematodes, and fire ants and (for the southwest) cultural problems, including installation, mulching, fertilizing, and watering.

Nursery and Landscape IPM Research and Information-Transfer Needs Assessment

Participants added research and information-transfer needs to the initial list identified by the Phase I activity; 36 generic and 52 pest-specific research needs were specified by both activities. These have been restructured into five categories entitled basic and applied research; development

Table 1: The Twelve Most Important Pests for Nursery and Landscape IPM in the Northeastern and North Central United States.

	Setting(s) within which the pest problem is most important		
	Production	Maintenance	Quarantine
Root rots and wilts	*		
Cankers/dieback		*	
Weeds	*	*	*
Japanese beetles	*	*	*
Black vine weevil	*		*
Borers	*	*	
Gypsy moth	*	*	*
Spruce spider mite		*	
Winter injury		*	
Conspicuous leaf spots	*	*	
Lace bugs		*	
Armored scales	*	*	

of pest-management tactics; monitoring and decision-making tools; pesticide efficacy, safety, and off-site effects; and economic and social studies. In addition to the five areas of critical research needs, twelve major information-transfer needs were identified. The organizers of the planning session have added to the document a list of approaches to address the information-transfer needs.

1. Basic and Applied Research

A. Ecology

1. Urban ecology studies to understand the setting in which much landscape-maintenance IPM must take place
2. Comparisons of pest-host dynamics in natural versus managed ecosystems
3. Basic weed-ecology studies
4. Determination of the relationships between weed populations/weed management and insect and disease problems in production and maintenance settings

B. Biology

1. Basic biological studies and systematics of cankers
2. Life-cycle studies of bitter cress and other emerging nursery-production weed pests
3. Better determine Japanese beetle adult host preference (especially in relation to naturally occurring nonvalued plants)
4. Studies of host-plant attractiveness, susceptibility, and resistance to borers, including work on the role of semiochemicals
5. Replication/validation of gypsy moth migration rates by wind and land
6. Understand the basic biology of the Asian gypsy moth
7. Study the biology of imported pests in their countries of origin

C. Plant Stress

1. Assess the relationship between moisture stress and canker development
2. Assess the relationship between plant stress and borer attack

2. Development of Pest-Management Tactics

A. Biological Control

1. Development of systems for the conservation of natural enemies in nursery and landscape settings
2. Development of predator-enhancement techniques for gypsy moth natural control
3. Development of borer biological-control alternatives
4. Research on weed pathogens as nursery bio-control alternatives
5. Development of more and better microbial-control alternatives for Japanese beetle grubs
6. Development of biological-control strategies for adult Japanese beetles
7. Development of biological-control strategies for spruce spider mite in the landscape setting
8. Development of biological-control alternatives for lace bugs
9. Development of biological-control alternatives for scales
10. Study mechanisms of biocontrol of phytopthera root rots, verticillium wilts, black root rot, and other important root rots and wilts

B. Alternative Controls

1. Development of mating-disruption techniques for borers
2. *Any* effective method for black vine weevil grub control
3. Effective pheromone trapping lures/techniques for dogwood, Zimmerman, flat-headed apple tree, bronze birch, and two-line borers
4. More and better gypsy moth management tools, including more effective chemicals, chemicals more suitable for use in urban environments, cultural strategies, and better microbials

C. Host-Plant Resistance

1. Need continuous characterization of resistance/susceptibility by species
2. Expand hybridization programs for pest resistance
3. Study Japanese beetle grub feeding preferences to determine susceptible species
4. Study systemic acquired resistance (of host plants) to leaf spots, particularly as affected by cultural practices
5. Develop specific cultivar resistance to leaf spot
6. Study plant susceptibility/resistance to lace bug infestation and damage
7. Study host-plant resistance/susceptibility to scale infestation and damage

D. Cultural Control

1. Determine the relationship between landscape design and mite outbreaks
2. Evaluate container media and soil augmentation/formulation with respect to plant health and suppression of pest problems
3. Assess the relationships among irrigation practices and pest and nutrient management
4. Determine the effectiveness of fertilization strategies for borer control
5. Assess the relationship between fertilization (and other cultural practices) and spruce spider mite infestation/damage
6. Develop cultural practices for dealing with winter injury
7. Cultural control/allelopathy (cover crops) for weed management in the production setting

3. Development of Monitoring and Decision-Making Tools

A. Detection and Monitoring

1. Develop detection methods for root rots and wilts and a framework for assessment of root health
2. Develop techniques for black vine weevil population detection and monitoring
3. Develop effective borer-infestation predictive indicators

B. Modeling and Expert System Development

1. Need forecasting and predictive models specific to both the nursery and the landscape settings
2. Development of computer software for analysis of landscape conditions and trends
3. Predictive population modeling for mites

C. Development of Effective Treatment Thresholds for Key Pests

1. Studies to determine the relationship between pest population levels and losses (economic losses and/or aesthetic-quality losses) in both the production and the landscape settings
2. Development of black vine weevil treatment thresholds
3. Improved gypsy moth threshold development in the homeowner setting
4. Development of spruce spider mite threshold levels
5. Need treatment (aesthetics-related) thresholds for leaf spots
6. Development of threshold levels for armored

scales

7. Studies of public perceptions and preferences regarding woody-plant aesthetic quality, how these relate to the psychological basis for pest management, and what that implies for perceived tradeoffs between pest management and landscape quality.

4. Pesticide Use, Efficacy, Safety, and Off-Site Effects

A. There is a need for baseline data on pesticide use in the nursery and landscape maintenance settings.
B. IR-4 Program-related research for expansion of pesticide labels to “minor uses” critical to nursery and landscape pest management
C. Studies of pesticide fate and transport in the landscape setting
D. Development of equipment for assessing pesticide fate and transport in landscape settings
E. Assessing the nontarget and off-site effects of homeowners' pesticide use and disposal practices
F. Development of improved and/or adaptation of existing pesticide-delivery systems and equipment for the nursery and landscape settings
G. Better pesticide-efficacy studies under a wider variety of environmental conditions faced in nursery and landscape IPM
H. Research on pesticide resistance in nursery weed species
I. Studies of the phytotoxicity of herbicides in nursery and landscape settings
J. Investigation of bark-feeding scales' tolerance to systemic insecticides
K. Gauge the effect of pesticide material/timing on scale predator and parasite conservation
L. Efficacy studies of biorational products including neem and diatomaceous earth

5. Economic and Sociological Studies

A. Studies of public perceptions and preferences regarding woody-plant aesthetic quality, how these relate to the psychological basis for pest management, and what that implies for perceived tradeoffs between pest management and landscape quality.
B. Research on sociological factors influencing IPM acceptance/adoption
C. Determine degrees of homeowner awareness and comprehension of pesticide labeling and elements of proper use and disposal of pesticides
D. Studies of the landscape-maintenance labor market (because labor availability is a limiting factor to expanded pest-management programs in the landscape setting)
E. Applied economic/interdisciplinary research to determine the cost-effectiveness of alternative IPM strategies in the nursery-production setting
F. Studies of nursery and landscape business profitability with respect to IPM use and services
G. A “full-cost accounting” (private costs plus environmental and other societal costs) of nursery and landscape pest-management alternatives
H. Economic assessments of weed-management alternatives in both the nursery and landscape settings
I. Assess the commercial feasibility of Gypcheck production for use on public landscapes

Information-Transfer Needs and Approaches

Workshop participants catalogued 12 major information-transfer goals and identified several specific needs and possible actions that could be taken to further each goal. The planning group recognized that the nursery and landscape-maintenance professionals’ needs would be largely addressed by extension delivery systems currently in place. The group recognized that market demands of consumers would drive the patterns of goods and services provided by the nursery and landscape-maintenance industries. Therefore, the demand for IPM goods and services depends on consumers informed of the relative costs and benefits of IPM. As consumer demand increases, the nursery and landscape-maintenance industries will respond.

Information-Transfer Goals

1. Enhance the General Public’s Awareness and Knowledge of IPM

A. Develop or coordinate available home and garden IPM modules for K through 12 science curricula (emphasizing positive aspects of IPM; biological relationships rather than threat)
B. Market plant materials to emphasize pest-related

sustainability/long-run maintenance costs in the landscape (label plants according to their pest-related sustainability in the landscape setting)

C. Use public-interest announcements and popular videos to get the message across
D. Inform and coordinate with public-interest groups (e.g., environmental groups)
E. Develop and use Internet home pages, websites, other computer- based information resources for the general public (take better advantage of existing channels; link/integrate with horticultural-information sources)
F. Capture media personalities to assist in delivering the IPM message
G. Interface closely with the Cooperative Extension System's Master Gardener Program

2. Increase the Level of Confidence of Landscape and Horticultural Professionals in IPM's Effectiveness

A. To the degree possible, increase Extension specialists' face-to-face contact with landscape and horticultural professionals
B. Involve professionals who do practice IPM in extension forums and demonstrations as principal spokespersons.
C. Create more practical, comprehensive, and up-to-date sources of information on IPM options (this relies on additional research and increased availability of research results)

3. Demonstrate IPM Profitability to Landscape and Horticultural Businesses

A. New funds must be committed to demonstration projects (especially in landscape-maintenance and garden-center settings)
B. Use trade associations as a principal conduit for landscape IPM information

4. Improve the Flow of Information among Researchers, Extension Professionals, and Industry and Public-Interest Groups

A. Provide scout-training programs and networking opportunities for industry and public-interest groups
B. Use Extension IPM (3d) enhancement funds to develop and implement working groups among researchers, extension personnel, and IPM users
C. Establish an e-mail network for nursery and landscape IPM

5. Create Better Incentives for the Adoption of IPM

Create an ad hoc IPM certification process, form, or check-off list for consumers' information.

6. Increase Public Awareness

Make homeowners aware of the potential environmental/health impacts of their own or their contractors' landscape pest-management actions.

7. Provide Marketing Tools

To improve the ability of landscape and horticultural businesses to market IPM to their end users/customers, materials that help landscape professionals "sell" IPM to their customers need to be produced.

8. Educate Landscape Architects and Landscape Designers and/or Their Clients about the Pest-Management Implications of Design and Design Aspects of IPM

A. Insert IPM in undergraduate curricula for landscape architecture and horticulture
B. Develop extension IPM materials targeted to the landscape-design industry (and call it an element of "environmental stewardship" in landscape design)

9. Increase Information Flow among Landscape Professionals, Homeowners, Health-Care Professionals, and Veterinary Professionals

Develop information for display in veterinary offices about the pet-health implications of home and garden pesticide use.

10. Improve the Efficiency of Extension IPM Information-Transfer Technology, Methods, and Approaches

A. Develop and install automated (unmanned) booths at garden centers, public parks, other sites where visitors can easily access useful information on pest management
B. Develop cheap, attractive IPM educational products for display on garden-center and hardware-store shelves (this might include videos or CD-ROMS and require substantial developmental funds)

C. Create an attractive, user-friendly source of pest-control information for use at garden centers
D. Develop Extension materials that "give answers" to pest-management questions.
E. The Extension Service should recommend "plants of the year" (by region) as a way of emphasizing the IPM advantages of various landscape plant species.

11. Provide Information That Encourages the Development of Public Policies That Are Sympathetic to IPM

A. Create a Friends of Extension (and Friends of IPM Research and Friends of IPM Teaching) to relay information and messages to politicians
B. Disseminate regulatory-impact-assessment information specific to landscape-pest management

12. Provide Professional Development

Individuals' and companies' abilities to anticipate, plan for, and respond to trends in policy, economics, and technology with relevance to IPM need to be enhanced.

Acknowledgment

This report was first composed by Dr. Kitty Reichelderfer Smith of the Economic Research Service as part of the report of the Phase I planning activity. Dr. Clifford Sadof, Department of Entomology, Purdue University, had significant input into this report. To these people we are indebted.

IPM Programs for Urban Arthropods

Faith M. Oi
Auburn University
Coordinator

The other workshops were titled "Developing and Delivering IPM for ... ." Our section was simply titled "Developing IPM Approaches for Urban Arthropods" because there is no cohesive IPM strategy for the urban environment. We are still at the development stage. Urban pest management is important because urban pests are not merely a nuisance; they can pose health risks by biting, stinging, being the source of potent allergens as well as causing severe structural damage to our homes and other structures. Urban pest management affects everyone, not only those who live in urban environments.

Seven invited presenters were asked to address various topics that would be used to stimulate discussion on key urban-pest-management issues. Each of the speakers comments are briefly summarized below.

Progress Report on IPM Initiative, Phase I, Faith Oi, Auburn University.

Industry representative Jim Stephens indicated that IPM fails in urban environments because consumers do not understand it and do not demand it. We have also failed to focus efforts at educating the building construction industry, mortgage companies, and realtors to the pest risks associated with certain construction types. Discussion focused on how to define IPM for the purposes of this project and to devise sampling and monitoring methods that could realistically be used by consumers and pest-control operators. Urban IPM is different from agricultural IPM because we deal with zero tolerances and the preservation of biodiversity under a sink is not an issue.

The Status of Urban Pest Management: Research Opportunities Dan Suiter, Purdue University

Purdue's current funding initiative has focused efforts toward obtaining Federal support with the objective of "legitimize(ing) 'urban' as a funding category" within the existing USDA programs, such as (1) Regional IPM, (2) Alternatives to Pesticides, (3) IPM Implementation, and (4) the Natural Resource Inventory. The Purdue funding initiative suggests that it is the responsibility of researchers to target their department heads, experiment station directors, and the USDA to create an "urban" funding category in the programs that already exist. In the long term, the goal is to create new USDA money; in the near term, the objectives are (1) lobbying to set up new funding programs in USDA/CSREES and/or (2) lobby(ing) to include "urban" in Sen. Lugar's new Agricultural Competitiveness Initiative. Mike Linker also commented that the cotton producers show up at the legislature but the average voter (who is most likely to be affected by "urban" research) does not show up. He also asked why EPA and HUD were not included in the plan to secure funding sources.

A Vision for Urban IPM, Arthur Appel, Auburn University.

Urban-pest-management problems are broad with multiple layers. Context specific goals and definitions for urban IPM are needed. In most IPM systems, we talk about managing pests; with urban-pest management, we talk about eradication. Some people may disagree with the goal of eradication, but in urban situations, where the goal is pest management of inside structures, we are faced with questions such as "should we make people tolerate allergens or should we tolerate our houses being eaten? However, can we manage cockroaches, etc., outside so they do not come into the house? Yes. Context-specific goals should consider the area of control and the pest being controlled.

Comparative Risk Assessment and Precision Targeting, Richard Brenner, USDA-ARS, Gainesville

The Strategic Environmental Research and

Development Program (SERDP) funded a grant to do comparative risk assessment of pest-control practices and precision targeting of pests in the urban environment. The USDA, DOD, universities, and consumer groups are involved. It focuses on reduced-risk pest management, including better use of existing toxicants and developing better alternatives through contour maps (monitoring and GPS technology) of pests and human activity. Regardless of the target pest, greater knowledge of the pest is needed to standardize and decrease the skill level needed to do urban IPM.

IPM in Schools, George Bird, Michigan State University

The group was led through a case-study exercise to demonstrate the difficulty of establishing an IPM program in schools. The case-study facts included the dilemma of a school superintendent whose schools had received public-health citations because of a serious cockroach problem. The public health authority had declared that IPM was not suitable. The superintendent had 30 days to solve the problem. Various solutions were discussed. The questions "Is IPM suitable for use in human living environments, and is biological control suitable for use in human living environments?" were posed.

Building Construction Problems and Urban IPM, Julian Yates, University of Hawaii

The Formosan subterranean termite is a major urban pest in Hawaii. Alternative, reduced-chemical methods of control are slow to receive acceptance because of the liability involved. The Basaltic Termite Barrier, basaltic rock crushed to a specific range of sizes small enough so that the termite bodies cannot squeeze through the spaces between the rocks and large enough so that the termite mandibles cannot grasp the rocks to pull them away, has been commercially available since 1987. There has been minimal acceptance of this method because pest-control operators view it as competing with chemical control, and homeowners are wary of the up-front costs of installation. Studies on termite control with Termi-mesh, a patented physical barrier of steel were also discussed. Advantages, disadvantages, product development, and technology transfer to the building construction industry were discussed.

Technology Transfer in Urban IPM, Nan-Yao Su, University of Florida

One reason technology transfer is difficult is because research institutions, such as universities and private companies, have conflicting goals. Taxpayer-funded research is not in the interest of private companies because companies want exclusive rights to the information and technology. But if the product is developed with public funds, everyone will have access to that information, and it is no longer exclusive. Questions that developed during this section included: how to define the public demand for urban IPM and related technologies, and who was going to decide who got what money to do development research and technology transfer in urban-pest management.

The discussion group concluded that an urban IPM definition should include the following characteristics:

- Concern about pest management in human living environments
- Use of a context-specific systems approach to pest management
- Use of the most selective management technique/strategy against a properly identified pest
- Include risk reduction
- Include reduced reliance on pesticides

The primary stakeholders are the members of the general public. The key priorities that were identified were:

1. Consumer education on urban IPM should be carried out through the National Pest Control Association, Cooperative Extension Service, public forums, and schools.
2. Risks to humans and the environment associated with urban-pest control should be decreased.
3. A national certification program in urban IPM should be developed for applicators.

Among the identified incentives to change were increased reports of multiple-chemical-sensitivity cases and liability.

Part VII. Focus on the Future

Introduction

USDA's 1994 IPM Initiative, which was designed to rally support and develop the strategies needed for IPM adoption in U.S. agriculture, was the basic frame of reference for this symposium. Many of the commodity reports on farmer/stakeholder IPM needs presented in Part VI, for example, were funded through the Initiative. The IPM Initiative also represents the Department's national strategic plan for carrying IPM into the next century.

In the closing plenary session of the IPM Symposium/Workshop, three speakers focused on the future of IPM. Jim Cubie, Democrat Chief Counsel, Agriculture, Nutrition, and Forestry Committee, U.S. Senate, proposed some innovative institutional mechanisms (e.g., marketing orders doubling as pest-management districts and crop insurance for new IPM technologies) to help build support for IPM.

Barry Jacobsen, USDA IPM Coordinator, presented a progress report and strategic-planning update on the IPM Initiative. Some of the accomplishments that were mentioned include the involvement of thousands of farmers in identifying research and extension priorities for IPM and increased Congressional funding for areawide biologically based IPM technologies. Finally, the closing remarks at the Symposium by Eldon Ortman, who chairs the Experiment Stations' steering committee on pest management, are also offered here. His comments provide a link to previous IPM symposia and to a major objective that has been shared by all of them: to increase the usefulness and visibility of IPM to a broader segment of the American public.

Institutional Support for IPM

Jim Cubie
Agriculture, Nutrition, and Forestry Committee, U.S. Senate

For the first time ever, USDA and EPA have agreed to work cooperatively to meet the objective of helping farmers to reduce pesticide risks. Instead of battling, they have agreed to identify the products that the farmers are most concerned about losing and to work cooperatively to help farmers find alternatives. This is called the “alternatives development” process. The Administration has backed this effort with requests for funding this program.

The Administration has also shown leadership in establishing a goal of reaching 75-percent IPM use by the year 2000. It needs assistance in developing the institutional support to meet that goal. IPM is broadly supported by sensible agricultural and environmental groups. The following are proposals to help the Administration meet that goal.

Institutional Support

Successful IPM requires that the community of growers work together in a cooperative fashion. The social support for a cooperative IPM will break down if there are “free riders.” Also, “rogue” growers can destroy a successful IPM project just as they can destroy a successful marketing-order system. These principles are already inherent in marketing orders. Federal marketing orders represent 25 percent of the fruit and vegetable production in the United States.

Proposal: Support legislation to permit Federal marketing orders to operate as IPM districts.

Research and promotion orders also cover millions of acres of crop, fruit production, and range. Under these orders, producers are annually assessed a fee on a unit-of-production basis. These fees are used to promote the product and for research related to the production of the product. In addition to the federally established research and promotion orders, there are 261 research and promotion orders in 43 States representing 55 commodities.

Proposal: USDA could issue a notice to all research and promotion orders that it will look favorably on operating plans that include a proposal to participate in the alternative-development strategy.

The recent issue of *ARS Agricultural Research* highlighted the need for widescale cooperative action to make grasshopper IPM control strategies work. Grasshoppers now infest 55 million acres. Controlling them on one property while adjacent land remains infested can be a hopeless task. The Beef Promotion Order assesses cattle producers for advertising of beef. Cattlemen are the chief beneficiaries of grasshopper control. At the same time every western State has “weed-management districts” in which landowners are required to cooperatively work to control weeds and other pests.

Proposal: Develop a cooperative program between the Beef Promotion Order and the weed-management districts to implement a multistate grasshopper IPM program.

As the cotton boll weevil program shows, effective IPM requires that the program be undertaken on an area-wide basis. The Fillmore Citrus Protective District has operated as such a pest-management district in Ventura County since 1922.

Proposal: Authorize the establishment of pest-management districts in the same fashion as marketing orders are established.

Risk Management

Farmers will greatly increase their willingness to accept new IPM technologies if they do not risk their crop. Crop insurance should be provided on a demonstration basis to help the introduction of new IPM technologies in farmers' orchards and fields. The first demonstration of using crop insurance for this purpose is now beginning.

Proposal: Establish a nationwide demonstration program providing IPM insurance to growers for research-proven IPM projects targeted to the pesticides that the farmers are most likely to lose or that have the greatest environmental or health significance.

To reach the goal of 75-percent IPM adoption, qualified field practitioners are absolutely necessary. Currently, there are not enough of these practitioners. A major obstacle to the growth of this service is the severe risk practitioners face in the absence of affordable professional liability insurance. Such insurance, based on the skill and experience of certified consultants, could also promote innovative recommendation beyond the current status quo.

Proposal: Support legislative and administrative efforts to use the Federal Crop Insurance Corporation or other vehicles to make professional liability insurance available and affordable to certified consultants.

Achieving the National IPM Goal

Barry J. Jacobsen
Cooperative State Research, Education, and Extension Service, USDA

On September 21, 1993, the USDA, EPA, and FDA called for a national commitment to develop and implement IPM methods on 75 percent of total U.S. crop acreage within the next seven years. In response to this challenge, on December 14, 1994, USDA announced an IPM Initiative and with the land-grant universities developed a strategic plan based on two premises: (1) Involving farmers and practitioners in the development and assessment of IPM programs increases implementation of IPM practices. (2) Increasing the use of IPM systems enables farmers to achieve both economic and environmental benefits, including reducing risks to human health and the environment associated with pesticide use. Achieving the goals of the IPM Initiative requires an active partnership among the USDA, land-grant universities, farmers, consultants, agribusiness, public-policy interest groups, and other stakeholders. It is critical that we focus on broad involvement in setting and achieving goals for the development and implementation of IPM systems for specific crop-production areas and in reporting the results to all who have invested in the Initiative. The National IPM Strategic Plan outlined below provides a mechanism to achieve the national IPM goal. This National Plan represents input from USDA agencies, land-grant-university research and extension scientists, crop consultants, and farmers. The four objectives of the plan and progress on each of the four objectives follow:

Objective I. Involvement of Stakeholders in Needs Assessment and Implementation

A process should be established and conducted for identifying the IPM implementation needs of producers, and the support and resources necessary to conduct a coordinated program of research, development, and delivery of education and information should be provided to meet producers' IPM implementation needs.

Progress: In 1995, an increase of $25,000 in Smith-Lever 3(d) Pest Management Education funding was provided to each State and territory to conduct a process with farmers and other stakeholders to identify and prioritize needs for IPM implementation for key commodities in each State. As of March 1996, more than 4250 customers, including 3205 farmers, are currently involved in identifying priority research and extension needs for IPM implementation for key commodities at the State level. This process will continue and help assure congruence between producers' needs and Federal funding for IPM research and education.

In addition to the State-level needs assessment process, 23 production-region IPM teams were funded at approximately $20,000 per team for one year to identify the IPM implementation needs for specific crop-production regions. These teams, with representation from 44 States, have identified needs for crop production systems in regions. These teams involve 154 farmers or crop consultants, 36 food processors or marketers, State and national level commodity organizations, agribusinesses, USDA and EPA field personnel, and research and extension faculty at cooperating land-grant universities. This approach to "buy in by researchers, farmers and others involved in all phases of the development and implementation of IPM programs" was complimented in the 1995 Office of Technology Assessment study, *Biologically Based Technologies for Pest Control*, as being a proven method to ensure the expeditious flow from research projects into applications by farmers and private practitioners.

This participatory needs-identification and priority-setting process has created high expectations for implementation of the USDA IPM Initiative by U.S. farmers, agribusiness, and environmental and public interest groups. A common statement made by farmers and others involved in this process is "not only are these things important, we want them done!" Funding currently available for research and extension is insufficient to comprehensively address these producer-identified needs in a timely manner. Again, the 1995 Office of Technology Assessment Study, *Biologically Based Technologies for Pest Control*, concluded that the USDA IPM Initiative addressed a number of criticisms raised in the report on moving from research to implementation. This report concludes that, "Ultimately the impact of the USDA IPM Initiative will depend on sustained commitments from USDA, the Administration, and the Congress."

The budget request for the USDA IPM Initiative is based on meeting farmer and other stakeholder-identified research and extension education needs for 75-percent IPM implementation within 6 to 7 years. For research and extension programs in the Cooperative State Research, Education, and Extension Service (CSREES), an investment of $27.5 million (a budget increase of $12 million) is required in FY 1997. In FY 1998, we will propose an increase of $8.0 million (to a total of $35.5 million) to provide the IPM research and extension education support needed to implement basic to advanced IPM strategies on 75 percent of the nation's crop acres. This level of support will need to be sustained for 6 to 7 years to successfully address the pest-management needs identified for selected major cropping systems representing more than 75 percent of the nation's cropland. In addition, ARS has requested increased funding for the Areawide Pest-management Programs to a level of $6.0 million, an increase of $2.2 million over FY 1995.

Areawide IPM programs focus on management of pests where existing technologies (including pheromones, biocontrols, and alternatives to pesticides that disrupt natural control systems) are most effective when used over a multistate area. Control of codling moth with mating disruption on apple and pear in the western United States is an example. Other pest/crop systems are currently under evaluation, and a corn rootworm areawide program is scheduled to start this summer in the Midwest. The areawide programs are coordinated with land-grant-university extension and research programs. (The 1997 budget request is $6.0 million, an increase of $2.2 million.)

The Pest-management Alternatives Program is a new competitive grants program that addresses the memorandum of understanding between the EPA and USDA that commits these agencies to: (1) provide farmers with chemical pesticides, biological control products, or cultural tactics to replace agricultural chemicals lost because of regulatory action, under regulatory consideration, or voluntarily canceled by registrants and for which producers do not have effective alternatives; (2) provide alternatives where pest resistance limits IPM options; and (3) help farmers implement new alternative pest-management tactics. This program will require $4.5 million in FY 1997. The process to identify critical needs at the State level for this program is supported by the National Agricultural Pesticide Impact Assessment Program and State Extension IPM coordinators. Registration of new biological or other pest-control products is coordinated with the IR-4 Minor Crop Use Registration Program and the USEPA. Pest-management-information decision-support system software has been developed to bring together related but separate pesticide and pest-management databases that facilitate the process of identifying critical needs for research and extension funding.

Funding for the IPM Initiative has been requested in the IPM and Biological Control Research, Pest Management Education, USDA Agricultural Research Service, National Research Initiative, and Emerging Pest and Disease Issues budget lines. These resources will support (1) ongoing core regional and State programs, (2) new production-system IPM development and implementation projects, and (3) the development of alternative management technologies. Funding for new IPM component research and extension education and technology-transfer programs is provided in the four regional IPM competitive grants programs. These programs are funded through the IPM and Biological Control Research (PL 89-106, Special Research) and the Pest management Education [Smith-Lever 3(d)] budget lines. The four regional competitive grants programs will be supported with $3.8 million from the IPM and Biological Control Research budget line and approximately $700,000 from the Pest Management Education line in FY 1997 and are responsive to the needs and priorities identified by production region and State IPM teams. In addition, the Pest Management Education budget line supports the critical basic education and technology-transfer infrastructure necessary to transfer IPM research to farmers via Extension Service programs in every State and county at approximately $10.1 million per year. The 75-percent goal will not be achieved without strengthening this basic education and technology-transfer infrastructure. The fundamental research supported by the National Research Initiative and the USDA Agricultural Research Service undergirds the IPM component and systems research program.

A three-phase process to develop and implement IPM for crop-production systems has been planned. This process is essential in developing and providing the right tools for farmers to implement IPM methods on 75 percent of the nation's crop acres. The three phases are:

First, formation and development of IPM project-development teams that address cropping systems in crop-production regions. These crop-production regions typically address more than existing administrative regions. In 1995 and 1996, 23 production region IPM teams composed of farmers, consultants, research and extension staff, State and Federal agencies, and others identified priority research, education, and technology-transfer needs to implement new and improved IPM programs for specific crop-production systems. In FY 1997, we envision expenditure of $400,000 to develop approximately 20 new production-system teams that will address cropping systems not addressed previously. These teams will develop implementation project plans for funding in FY 1998. These teams plus those formed in 1995 will address IPM implementation for 40 to 45 major cropping systems in the United States and will incorporate needs and priorities from the State-level IPM teams.

Second, initiation of IPM development and implementation projects for specific crop-production systems, projects that address the research and extension education needs identified in Phase I. To achieve the needs identified, we envision that approximately 30 to 35 production-system projects will be needed to achieve the 75-percent goal. These projects will fund the research and education needed to develop and implement IPM for regional cropping systems and will be based on proposals developed by IPM teams submitted for funding through a competitive process in FY 1997 and FY 1998. Requested funding for FY 1997 will competitively fund approximately 16 projects at up to $500,000 per project per year; these projects will be funded for up to 6 years with a mandatory midpoint review. Approximately 16 additional projects will be initiated if Congressional funding is approved in FY 1998 for cropping systems not addressed in projects initiated in FY 1997.

Third, privatization of IPM systems in regional cropping systems. Experience has shown that implementation of IPM and privatization by farmers, crop consultants, IPM cooperatives, or pest-management associations has occurred where adequate IPM tools have been developed and economic and environmental benefits are identifiable. Phase II projects will provide these prerequisites for privatization. Core-formula extension and research programs plus ongoing base IPM support for regional IPM grant programs will provide the needed education and technology transfer to farmers, crop consultants, cooperatives, and agribusiness plus the development of IPM tools for existing and new pest problems. Extension educators associated with the Health, Environmental, and Pesticide Safety Education Program will be critical in educating pesticide applicators and operators in IPM based pest-control technologies.

Objective II. Coordination

The USDA IPM programs and policies should be effectively coordinated across USDA agencies and cooperation should be facilitated with non-USDA entities (public and private) to meet the national goals for IPM implementation. The key coordinating mechanism is the USDA IPM Program Subcommittee, which is chaired by the USDA IPM Program Coordinator. The IPM Program Subcommittee has representation from the Agricultural Research Service (ARS), Animal and Plant Health Inspection Service (APHIS), Forest Service (FS), Farm Services Administration (FSA), Agricultural Marketing Service (AMS), National Resources Conservation Service (NRCS), Cooperative State Research Education and

Extension Service (CSREES), Economic Research Service (ERS), National Agricultural Statistics Service (NASS), Office of Budget and Policy Analysis (OBPA), and EPA. This broad working group assures coordination of Federal research, education, and regulatory programs with land-grant-university and State- based USDA programs in every State.

Progress: This committee has effectively coordinated IPM-related activities across nine USDA agencies and the EPA. Important progress has been made in grant coordination, assessment, strategic planning, integration of Federal and land-grant-university programs, crop insurance, cost sharing, increased funding by Extension and EPA for regional IPM competitive grant programs and implementation of the new Pest Management Alternatives Program.

Objective III. Measure IPM Implementation

Methods should be developed and programs should be conducted to accurately measure progress toward the 75-percent IPM goal and assess the impacts of IPM implementation on the public and private sectors as measured by economic, environmental, public-health, and social factors.

Progress: During the past year, ERS, CSREES, ARS, APHIS, and Extension and research scientists have begun to identify the parameters and methods to measure IPM implementation and impacts. A key focus of this symposium was measurement of IPM impacts and methods for measurement. This meeting was preceded by the
Big Sky conference attended by individuals with IPM-implementation experience and expertise in pest control, economics, rural sociology, and program assessment. As a result of that meeting, white papers presented at this symposium were commissioned. In addition, plans were developed for the assessment component of the Phase II request for proposals and for a national overall assessment team to develop national-level impacts and to work with regional projects.

ERS and NASS have begun modification of NASS survey instruments to provide IPM implementation and impact data. This year, modified survey instruments will provide the most comprehensive data to date for IPM implementation on corn, soybean, wheat, cotton, and potato. This will provide critical baseline information and will complement the data from the 1994 ERS study on IPM adoption. In addition, several commodity groups are developing IPM implementation self-studies with the assistance of the EPA Pesticide Environmental Stewardship Program and land-grant-university scientists.

Objective IV. Communication

A communication and information-exchange program involving stakeholders should be implemented to increase public and policy-maker understanding of the USDA IPM Initiative and its objectives, progress, impacts, and benefits.

Progress: The State and production-region IPM planning teams have involved a wide range of stakeholders in priority setting for IPM programs. Those involved understand that the IPM Initiative is based on developing a strong connection between producer needs and research and extension education programs of USDA and the land-grant universities. In addition, we have directly involved commodity groups, consultants, public-policy interest groups, and others in national, regional, and State-level IPM Initiative planning. This symposium has also been a major component of the IPM communication plan. This symposium has been attended by a more diverse group than previous IPM symposium/workshops. The first session of “Putting Customers First” provided critical input directly from producers, consultants, and the environmental public policy community. The sessions on the second and third days involved a diverse group of economists, rural sociologists, public-health specialists, and technology-transfer specialists. The Third National IPM Symposium/ Workshop has been attended by 634 registrants who presented 161 posters.

The IPM Initiative approach to reduction in risks from pesticide use and development of more sustainable agricultural production strategies was adopted by USDA and EPA rather than the mandated-use-reduction strategy adopted by several European governments in the early 1990s. Since the first coordinated Federal funding for IPM was provided for the Huffacker project by EPA, NSF, and USDA in 1972 and for Extension Pest Management Education [Smith-lever 3(d)] funding in 1973, the Federal investment in all IPM- related research and education programs has been approximately $180 million per year. As a result of the IPM Initiative strategy, an increase of $25,000 in Smith-Lever 3(d) Pest Management Education base funding was provided to each State and territory to conduct a continuing process with farmers and others to identify and prioritize needs for IPM implementation for key commodities in each State. The Clinton Administration first requested increased budget support for the IPM Initiative in FY 1996. In FY 1996, Congress appropriated increased funding of $2.0 million for the Pest Management Alternatives Program, one component of the IPM Initiative. Funding for the complete USDA IPM Initiative was again requested in the executive budget for FY 1997. The total investment requested for FY 1997 is $204.9 million, an increase of $15.1 million over the appropriated FY 1996 budget.

Achieving the IPM goal will require the cooperative work of farmers, crop consultants, agribusiness, State and Federal agencies, research and extension scientists and educators associated with the land-grant universities, public-policy interest groups, other IPM stakeholders, and the executive and legislative branches of Federal and State governments. The USDA IPM Initiative Plan sets forth a new paradigm for connectivity between producer-identified needs and the research, education, and regulatory agencies at the State and Federal level. Achieving the 75-percent IPM-implementation goal is clearly within reach if we work together.

Summary Comments: National Integrated Pest Management Symposium/ Workshop

Eldon Ortman
Purdue University

The Pest Management Strategies Subcommittee (PMSS) is one of the national committees appointed by the Experiment Station Directors Committee on Policy. The membership is composed of multiple disciplines, it represents different commodity interests, and it includes representation from across the United States. The committee is advisory to the experiment station directors on issues related to IPM. The primary role is to keep the land-grant administrators informed and engaged in an area of priority for agriculture: IPM. PMSS was very much involved in the identification, development, and promotion of the National IPM Task Force. The joining of PMSS and the Task Force preceded the reorganization of the Cooperative State Research, Education, and Extension Service (CSREES).

One of the areas of emphasis and initiative for IPM has been the matter of relevance and utility to those stakeholders and entities that are served by IPM. In that respect, we are pleased to see the current effort that is being made by many States to identify the IPM needs through dialogue with the stakeholders in their States. We would urge that this be a continuous process and that those who have not yet engaged in this assessment of needs, through consultation with the user community, find the opportunity and means to pursue this activity. One of the continuing strengths of IPM is its attention to addressing problems of importance, relevance, and need.

This symposium/workshop program has had many highlights, and it is certainly somewhat hazardous to select any items for reiteration. However, let me call our attention to the comments made by several of our speakers from the opening session. Deputy Secretary Rominger made a special point of the importance of putting customers first. I believe IPM does put customers first. Under Secretary Karl Stauber indicated that IPM is a model for agriculture. The things he identified as setting IPM apart were a combination of characteristics: producer profitability; social concerns and needs; and broad collaboration across disciplines and the country. Terry Nipp of ESOP Enterprises indicated that, in his view, IPM was uniquely configured and positioned to address a combination of issues and items that have a broad constituency. Namely, IPM has a positive impact on agriculture and on the environment. Thus, it should be possible to identify a win-win situation because for a combined agriculture/-environmental initiative.

This is the Third National IPM Symposium. Each had its highlights, and each has provided innovations and new topic areas. This third symposium had a special emphasis on assessment and economic impact. In this symposium we had a greater, a broader disciplinary involvement and also an increased presence of the producer and the user communities. Special credit goes to the Washington-based staff of the Federal State Partnership in initiating, developing, and coordinating an excellent symposium/workshop.

IPM is in a unique and exemplary position. That status, I believe, is based on a combination of situations:

1. IPM is based on solid science and the development of appropriate technology.
2. There are many outstanding, dedicated, hard-working scientists contributing to IPM.
3. IPM is outcome oriented; that is, it seeks to find a better way to address pest problems.
4. There has been a significant level of creativity and innovation.
5. The program has been flexible and opportunistic.
6. Discovery research through application has had a focus on service to customers and to society.

It is important that we maintain these aspects of the program to continue to be dynamic and to prosper and to make contributions to the future of agriculture and society.

Appendix: Poster Abstracts

Abstracts of posters presented at the Third National IPM Symposium/Workshop are pre-sented in this section. These abstracts were first printed in the Symposium/Workshop program and are reproduced without change here. Papers are in alphabetical order based on the last name of the first author.

Developing and Delivering an IPM Program for Hot Pepper Growers in Mexico. M. Saul Alarcon, Hasan A. Bolkan, Robert K. Curtis, and Dennis J. Larsen. Campbell Soup Company, 28605 Country Road 104, Davis, California 95616

Traditionally, pests and diseases of hot peppers (*Capsicum spp*.) are controlled with protectant fungicides and contact insecticides applied on calendar base. Depending on the target organism, the number of sprays can range from 5 to 15 per season per crop. The preventive strategy is successful in protecting yields and quality. Public concerns, however, about pesticide residues is forcing processors and growers to find alternative control strategies to reduce the use of synthetic pesticides. To help growers make the switch from calendar base pesticide applications to only when needed, Campbell Soup Company has initiated an aggressive IPM program for pepper weevil (*Anthonomus eugenii* Cano), yellowstriped army-worm (*Spodoptera ornithogalli* Guenee), and virus-transmitting insects. Campbell's Jalapeno IPM Program has three interrelated components: cultural practices, monitoring, and treatment. The cultural practices include crop rotation and field sanitation to eliminate weed populations to prevent potential migration and infestation of pests and viruses. The second component of the IPM program is monitoring and scouting for pest populations. Campbell's IPM specialists provide hands-on training to growers' field personnel and help them monitor twice a week for insects and diseases. When it is determined through monitoring and scouting, that pest populations have reached the level which will cause economic damage, the grower is encouraged to apply selective or biorational pesticides such as *Bacillus thuringiensis*. In 1995 growing season, overall pesticide reduction (kg. active ingredient/acre) for growers using IPM ranged from 27.1 to 55.3 percent compared to non-IPM growers. For the same IPM growers, the number of spray applications declined 15 and 30.6 percent, respectively, depending on the location of the field.

Manipulation of Orchard Ground Covers for Enhanced Arthropod Management. Diane G. Alston, Department of Biology, Utah State University, Logan UT 84322-5305

Diversity and density of species of ground cover plants influenced arthropod abundance and dispersal in Utah apple orchards. Certain broadleaf weeds present in ground covers increased densities of phytophagous and predaceous mites. Mite abundance and timing of their dispersal from ground cover into trees was strongly influenced by presence of certain broadleaf weeds and ground cover management practices, such as frequency and timing of mowing, herbicide application, and cultivation. In addition, the ground cover species composition and biomass were influenced by frequency of mowing. Percent horizontal cover of field bindweed a prominent host species for phytophagous mites, was greater in plots mowed every two weeks (10-23 percent of total cover) than in plots mowed every three weeks or left unmowed (1 -7 percent) during July and August. Ambulatory dispersal of phytophagous mites into tree canopies was two times greater in plots mowed every two weeks than in unmowed plots. The presence of apple rootsuckers on the base of tree trunks increased the abundance and dispersal of phytophagous mites into canopies. The type of ground cover in a tart cherry orchard was found to influence the pupation success of western cherry fruit flies in the soil, and the time and rate of emergence of adults in the spring. Ground covers of companion grass and weeds resulted in the least pupation. Greatest pupation success and earliest emergence of adults was seen in bare ground plots. Soil temperature may be a better predictor of adult emergence than air temperature.

Consideration and Management of Pesticide Resistance by the U.S. Environmental Protection Agency. Neil Anderson, Tobi L. Colvin-Snyder, Frank Ellis, Paul I. Lewis, Sharlene R. Matten, Robert I. Rose, Douglas W.S. Sutherland, and Steve Tomasino U.S. Environmental Protection Agency Office of Pesticide Programs Pesticide Resistance Management Workgroup 401 M Street S.W. Washington, DC 20460

Pesticide resistance management is a worldwide problem and is an important aspect of IPM. The U.S. Environmental Protection Agency has considered the development of pesticide resistance and pesticide resistance management in its regulatory decisions and believes that it is very important to implement effective resistance management strategies. How the Agency has considered pesticide resistance management under the Federal Insecticide Fungicide Rodenticide Act (FIFRA) when making emergency exemption, special review and registration decisions plus new Agency pesticide resistance management initiatives will be discussed.

Management of Plant-parasitic Nematodes in Cotton Production Systems with Poultry Litter and Winter Rye. K.R. Barker', S.R Koenning', RL. Mikkelsen[2], K. L. Edmisten[3], D. T.Bowman[3], and D.E. Morrison[4], 'Departments of Plant Pathology, [2]Soil Science, and[3] Crop Science, North Carolina State University, Raleigh, NC, 27695, and [4]North Carolina Cooperative Extension Service, Scotland County 231 E. Cronly St., Laurinburg, NC 28383

Cultural practices often are neglected as an option for nematode management in cotton. Use of animal wastes and other organic amendments or green manure crops such as a winter rye crop have promise for controlling many plant-parasitic nematodes. Field experiments were initiated in North Carolina to evaluate the influence of rates and dates of poultry litter application and (or) a winter rye cover crop on Columbia lance nematode, *Hoplolaimus columbus,* and cotton yield. Fertility levels for all plots were adjusted to those recommended by a soil test. A rye cover crop fertilized with various rates of chicken litter tended to suppress numbers of Columbia lance nematode, but also had a negative impact on cotton yield. There was a negative correlation (P=0.05) between seed cotton yield and the amount of rye incorporated into the soil. However, high rates of chicken litter increased (P=0.10) cotton yield and resulted in low numbers of this nematode in September. Early application (December) of litter tended to improve nematode control and enhance yield more than late application (April). Numbers of root-knot nematodes, *Meloidogyne incognita,* were lowest in plots receiving chicken litter, regardless of the date of application. The increased cotton yield in response to chicken litter application can be attributed to nematode control, since it is unlikely that fall-litter applications affected soil fertility during the growing season. Poultry litter also enhanced numbers of microbivorous (non-parasitic) nematodes, indicating increased microbial activity when this material was added to the soil. Overall, results from field as well as greenhouse tests show that these soil amendments were more effective in suppressing population densities of the plant parasites M. *Incognita* and *Paratrichodorus minor* than H. *columbus* and *Rotylenchulus reniformis*.

Spatial Analysis Technology Applied to the Regional Assessment of Plant Pests and Diseases. John H. Barnes, USDA/CSREES, Washington DC; Hasan Bolkan and Saul Alarcon, Campbell Corp., Davis. CA.; Merritt Nelson, David Byrne, and Tom Orum, Univ. of Arizona, Tucson, AZ

We have been assessing the benefits of analyzing plant disease and pest severity on a regional scale using the tools that are also being applied to precision farming, such as geographic information and global positioning systems (GIS and GPS). These two technologies are extremely useful in developing a computer map based record of the location of disease and pest outbreaks. In addition, these data may be analyzed spatially using geostatistics to show how and where regional patterns vary. When the concepts of "Landscape Ecology" are applied to the heterogeneous landscapes that are characteristic of most plant dominated ecosystems, including agroecosystems useful conclusions regarding cropping pattern influences on the severity of diseases and pests may be generated and used in the design of management programs. This approach to the assessment of disease and pest risk requires that all data be associated with map coordinates. Inexpensive hand-held GPS units now available make this possible. Such data can be entered into the GIS database for geostatistical and other spatial analysis procedures. Outcomes of this approach to assessing plant disease and pests include an easily accessible record of disease occurrence, identification of recurring patterns and association of landscape features with recurring pattens of diseases and pests. Such information displayed in an attractive format can be a powerful tool in promoting a program that requires some significant cultural changes in pest management practices. Thus far this technology has been used in the management of tomato virus and fungal disease and insect pests, cotton viruses and whitefly vectors, and cotton aflatoxin occurrence. Computer hardware and software developments in the past five years of significance to these applications have been explosive. These developments herald a new era in the processing and analysis of information used in IPM programs.

The Au-Pnut Peanut Leaf Spot Advisory: Effective Range And Control of White Mold and Limb Rot. Ellen M. Bauske, Horticulture, Auburn University, AL 36849, Paul A. Backman, Plant Pathology, Auburn University, AL 36849, Larry Wells, Assistant Superintendent Wiregrass Substation, PO Box 217, Headland, AL 36345; and Stephen Adams, Meteorologist, Southeast Agricultural Weather Service Center, Wire Rd., Auburn, AL 36849

The AU-Pnut peanut leaf spot advisory uses the number of days with precipitation greater than 2.5 mm and five-day precipitation probabilities to predict periods favorable for development of leaf spot diseases (*Cercospora arachidicola* and *Cercosporidium personatum*). Studies were done to determine the effective range of the AU-Pnut advisory and to incorporate tebuconazole (Folicur 3.6F) for control of white mold (*Sclerotium rolfsii*) and limb rot (*Rhizoctonia solani*) into the spray program. Dry land and irrigated tests were done. Three AU-Pnut programs were generated using the regional five day precipitation forecast and precipitation measured on-site, 1.6 km off-site or 12.9 km off-site from both tests. The performance of the AU-Pnut spray programs was compared with a standard 14-day spray schedule. Half of the plots in each test were sprayed with chlorothalonil (Bravo 720F) at the recommended rate (1.0 kg a.i./ha) and half were sprayed with a chloro-thalonil-tebuconazole tank mix at 0.34 and 0.1 kg a.i./ha, respectively. All diseases were more severe under irrigation. The number of fungicide applications was 7, 6, 6, and 5 for a 14- day program, AU-Pnut on-site, AU-Pnut 1.6 km off-site, and AU-Pnut 12.9 km off-site, respectively. Spray schedules were identical in the on-site and 1.6 km treatment. Control of leaf spots, white mold, and limb rot was more effective and yields were highest when the chlorothalonil-tebuconazole tank mix was applied with AU-Pnut on-site or 1.6 km off-site. Disease control was less effective with AU-Pnut at 12.9 km. Treatments with tebuconazole were more effective against white mold and limb rot. Presently AU-Pnut uses rainfall data to schedule a 100 ha area. These studies indicate the potential for a control area larger than 256 ha.

Development of a Strategic Plan for Implementation of Tomato IPM Practices. Ellen M. Bauske, Horticulture; Geoffrey W. Zehnder, Entomology; Edward J. Sikora, Plant Pathology; and Joseph M. Kemble, Auburn University, AL 36849

An IPM planning project was initiated to increase the implementation of IPM practices on fresh-market tomatoes in the southeastern region. Tomato IPM teams were formed in Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, and Tennessee consisting of researchers, extension specialists, producers and industry personnel active in and familiar with tomato production in each State. The teams met at Auburn University in early November 1995 to develop a working definition of tomato IPM based on all currently available tomato IPM practices, and to discuss methods to measure the economic, environmental, social and public health impacts of IPM programs. This multi-state meeting facilitated a valuable exchange of information on tomato production practices in each State (i.e., States with established tomato IPM programs shared ideas on tomato IPM that benefitted States with less developed IPM programs). The list of available tomato IPM practices was used to develop a tomato IPM grower survey to (1) determine baseline levels of IPM adoption in each State, (2) develop a prioritized list of grower-identified research and extension needs, and (3) increase grower awareness of currently available IPM technology. The survey questions will be explained in detail to growers at a series of production meetings held in each State to increase producer awareness and understanding of tomato IPM practices. Thus the surveys will serve as an educational tool in addition to a means of collecting data on IPM adoption. Information from the surveys will be used to develop an overall plan to increase adoption of IPM by tomato growers in the southeastern region**.**

ESCOP/PMSS Biological Control Working Group: Vision and Activities. D. Michael Benson, Dept. of Plant Pathology, NC State University, Raleigh, NC 27695; and Harold W. Browning, University of Florida, Citrus Research and Education Center, Lake Alfred, FL 33850

The Biological Control Working Group (BCWG) fosters the development and implementation of biological control of pests, weeds, and pathogens as the central component of an ecologically-based approach for integrated pest management (IPM). The goals of the BCWG are to establish linkages among current operating regional committees concerned wholly or in part with biological control for pests and pathogens to improve information exchange, to define and give visibility to biological control for agricultural and urban pests and pathogens as distinct components of crop protection systems, to provide input in budget building processes, to encourage application of new molecular tools to biological control research, and to plan and organize interdisciplinary workshops and symposia.

Currently, four broad objectives, including promotion/communication, regulation, funding and coordination, have been developed and pursued by members of the working group. Discussion is underway to develop a linkage with industry in support of a workshop on commercialization of biological control agents. A web site (http:// ipmwww.nesu.edu/biocontrol/biocontrol. html) has been established to communicate working group activities and coordinate biological control efforts among groups and individuals. Members have promoted incorporation of biological control into extension programs by participation in workshops and discussion sessions with extension specialists at State and regional levels. The working groups developed a statement to discourage the approach taken by APHIS in the recent proposed rule for introduction of non-indigenous organisms that subsequently was withdrawn. The BCWG supports the development of biological control regulations wherein natural enemies are not defined as plant pests. The working group has been involved at the Federal level to assist in coordination of a National IPM Initiative. As commodity-based IPM initiatives develop in the next few years, the working group will assist in the setting of priorities for funding by technical evaluation of resources needed for inclusion of biological control in IPM strategies. Important activities of the BCWG have included sponsorship of an AAAS Symposium and a UCLA Symposium on biological control, a National Workshop on regulations and guidelines, and workshops on biological control at IPM Symposiums.

Vermont Apple IPM Program: Integration of Research & Extension Produces Innovation and Success. L.P. Berkett, J.F. Costante, A. Gotlieb, J. Clements, D. Schmitt, D. Heleba, J. Bergdahl, T. Bradshaw and G. Neff, Department of Plant and Soil Science, University of Vermont, Burlington, VT 05405

An active and effective research and extension program has been developed on apples using a team approach. The team includes faculty and staff representing the disciplines of horticulture, plant pathology and entomology. Members of the team have both research and outreach responsibilities. The team works directly with apple growers and knows first-hand the concerns and issues which confront the apple industry, both for the short-term and the long-term. The program involves:

- An extension program which includes one-on-one interactions with apple growers, workshops, meetings and publications. The University of Vermont's Apple Press newsletter, which has over 250 paid subscribers including commercial orchardists, consultants, extension agents, and researchers in 24 States and 3 Canadian provinces, contains a section entitled "IPM NEWS," which includes information on pest status, monitoring techniques, thresholds, life cycles, and management strategies. Our newest and most exciting information transfer tool is the "Virtual Orchard," a World Wide Web (WWW) site devoted to tree fruit production, marketing, and information exchange. Visit the "Virtual Orchard" at http://orchard.uvm. edu.

- An active horticultural research program which focuses on the commercial potential of new apple varieties that have been bred for resistance to apple scab, the major disease of apple.

- Pest management research and demonstration targeted at reducing pesticide use. An exciting, new project on apple scab was initiated in 1995 which for the first time utilizes crop insurance as a "safety net" in IPM implementation. Orchards in Vermont and New Hampshire are participating in this Apple Scab IPM Project. This new application of crop insurance is viewed as an important step in stimulating the adoption of new IPM techniques. This innovative project is made possible through the support of the Honorable Senator Leahy, the USDA, and the Consolidated Farm Service Agency.

Vermont Extension IPM Program: New Initiatives. Lorraine P. Berkett, Alan R. Gotlieb, Margaret Skinner, Sidney Bosworth, Ann Hazelrigg, Department of Plant & Soil Science, University of Vermont, Burlington, VT 05405

With the previous level of Smith-Lever 3(d) funding, Vermont has been able to develop an effective, interdisciplinary apple extension program. The Supplemental Extension IPM funding received in 1995 has enabled us to initiate two new IPM programs in Vermont: (1) a Diversified Vegetable and Small Fruit IPM Program; and (2) a Greenhouse Ornamental IPM Program. The overall objectives of these programs are to develop effective multi-organizational, interdisciplinary IPM Implementation Teams to identify extension and research priorities and to focus extension and research on those priorities.

(1) Diversified Vegetable and Small Fruit IPM Program: During this past summer, an interdisciplinary IPM Implementation Team was formed to develop a pilot extension program which targeted 8 diversified vegetable and small fruit farms. On-site farm visits were conducted throughout the growing season to provide education on disease, insect and weed identification and biology, and training on scouting techniques and IPM practices. Currently, an assessment is being conducted on what practices and techniques were adopted and their impacts. A short course is being developed for this winter, based on grower-identified educational needs.

(2) *Greenhouse Ornamental/ IPM Program:* This program addresses one of the fastest growing agricultural sectors in terms of grower cash receipts. Consumers are demanding high-quality plants. But since efficacious alternatives are few and often complicated to use, growers rely heavily on agrochemicals to suppress a range of pests and diseases. During the first year of this program, baseline data are being collected on current usage of

IPM practices and pesticides along with estimates of loss due to pest damage. From this information, an IPM implementation strategy will be developed for Vermont and the tri-state region (i.e., VT, NH, ME).

In addition to the above programs, we are developing a Forage IPM Program which focuses on management strategies to prevent premature stand decline of alfalfa due to a complex of factors. Future funding will enable this program to be fully implemented.

Grasshopper IPM on Western Rangelands. S. Berry, USDA, APHIS, 4125 E. Broadway, Phoenix, AZ 85040, W. P. Kemp and J. A. Onsager, USDA, ARS, Rangeland Insect Lab, Bozeman, MT 59717 and M.D. Skold, DARE, Colorado State University. Ft. Collins. CO 80523

Grasshoppers are the most important insect pest on over 770 million acres of rangeland in the western U.S. Since the 1930s, publicly assisted control programs used an intervention level of 8 grasshoppers per square yard as a guide to initiating control programs. A decision support system, Hopper, developed under the Grasshopper Integrated Pest Management project incorporates an economic threshold (ET) into the grasshopper management decision. The ET necessary to justify management programs varies between locations and over time. It changes with the grasshopper species (Berry, Kemp, and Onsager 1992), rangeland productivity, cost of replacement forage, and the cost and efficacy of treatment options (Davis et al. 1992). Implementation of grasshopper IPM will require full use of preventive actions such as: hot spot treatments of potential breeding grounds to prevent larger outbreaks, range management practices which maintain vegetative canopy and thereby prevent or delay microhabitats preferred by many pest grasshopper species (Onsager 1995), ranch forage management such as using additional hay stocks as a hedge against grasshopper outbreaks (Skold, Davis and Kitts 1995), and biological controls. Additional research and demonstration is needed to incorporate the options into an IPM strategy. If preventive actions are not successful, management would involve therapeutic action to use of one of the approved chemical control options. It can also be expected that if continued public funding of rangeland grasshopper programs is not available, alternative ways to finance these programs will have to be found (Skold and Davis 1995). Finally, once preventive and therapeutic strategies are included in the IPM for rangeland grasshoppers, IPM training for grasshopper program and land managers will be required.

A Bioherbicide for Control of Dodder. Dr. Thomas A. Bewick, Horticultural Sciences Dept., University of Florida, PO Box 110690, Gainesville, FL 32611-0690

An important component of IPM programs is to have available control measures for a specific target pest. Satisfactory dodder (*Cuscuta* spp.) control strategies do not exist for most horticultural crops. Two fungal pathogens of dodder were isolated in 1984. A patent was issued in 1990, and in 1991 HACCO, Inc, a subsidiary of United Agri-Products, signed a standstill agreement to develop a commercial bioherbicide for dodder control. Since that time, the IR-4 Project has provided funding and regulatory guidance that has served to move the product toward EPA registration. In 1995, a stable formulation of the bioherbicide was field-tested in Massachusetts and Wisconsin cranberry plantings. Dodder control exceeded commercially acceptable levels in both locations. Additional field tests are planned for 1996. An Experimental Use Permit is being sought with the guidance of IR-4 that will allow for large scale field testing. The registrant is projecting that a commercial product will be available for growers within three years. Without the efforts of IR-4, this project would not have advanced to commercial viability and there would be no possibility of IPM programs in horticultural crops for dodder control.

Integrated Pest Management in Montana Cereal Grains Cropping Systems. S. Blodgett, G. Johnson, Dept. Entomology, Montana State University, Bozeman, MT 59717; B. Maxwell, Dept. Plant, Soil & Environmental Science,

Montana State University, Bozeman, MT 59717; R. Stougaard, Northwestern Agriculture Research Center, 4570 MT 35, Kalispell, MT 59901; W. Kemp, USDA, ARS, Rangeland Insect Laboratory, Bozeman, MT 59717

Sixty four percent of Montana's 92.9 million acres is in farm or ranches, with total assets of $21.2 billion. The 17.5 million acres of cropland is responsible for about $ 1 billion in cash receipts for all crops; with 80 percent of the cash value from cereal grains. A recent survey (Blodgett et al. unpublished) indicated that wheat stem sawfly, grasshoppers, and wheat streak mosaic virus were the most damaging cereal grain insect and disease pests to Montana producers. Economic losses due to plant diseases and arthropods can be dramatic. In 1993 and 1994, wheat streak mosaic virus, vectored by the wheat curl mite, was responsible for losses estimated at $35.7 million (J. Riesselman, MSU personal communication). Wild oats have been identified as a significant weed pest, with annual herbicide costs of $10 million in Montana alone. Research at MSU has focused on these and other important pest concerns. Wheat curl mite *(Aceria toshicella)* research has focused on evaluating quality of alternative grass hosts, within plant mite distribution, and mite population dynamics in mixed cropping systems (Blodgett). Russian wheat aphid *(Diuraphis noxia)*, drought stress, and their interaction has been examined for effects on wheat yield and quality (Johnson). Preliminary results indicate that both wheat curl mite and Russian wheat aphid are influenced by a cover cropping system utilizing annual legumes. A strategic issue of the USDA, ARS, Rangeland Insect Laboratory (RIL) has been to develop sampling and forecasting strategies for integration of pest management options into farm/ranch and crop/range situations (Kemp). Non-chemical control of wild oats *(Avena fatua)* and within-farm distribution and population dynamics have been an important research focus (Maxwell & Stougaard). Plans in 1996 include spatial analysis of multiple pest distributions and interactions with implications for management.

Corn Rootworm Beetle Emergence, Female Fecundity, and Egg Viability Associated with Labeled and Reduced Soil Insecticide Application Rates. Mark A. Boetel and Billy W. Fuller, Plant Science Department, Box 2207-A, 219 Agricultural Hall, South Dakota State University, Brookings, SD 57007

Environmental concerns and the economics of agricultural production during the past decade have prompted evaluations of reduced soil insecticide application rates for managing northern (NCR) and western corn rootworm (WCR), *Diabrotica barberi* Smith and Lawrence and *D. virgifera virgifera* LeConte, respectively, larvae. These studies (conducted throughout the north central Corn Belt) have indicated that acceptable control can be attained using reduced rates. However, the long-term repercussions of such management practices on rootworm populations have not been investigated. Our objective was to assess the potential impacts of reduced application rates on corn rootworm sex and species ratios, fecundity, and viability of eggs collected from surviving females.

Field plots were established with full labeled (1X), and reduced (0.75 and 0.50X) application rates of three soil insecticides [I) terbufos, a traditional organophosphate; 2) tefluthrin, a pyrethroid; and 3) chlorethoxyfos, a phosphorous triester organophosphate], and an untreated check. Traps were used to live-capture emerging beetles from insecticide-treated soil zones in treatment plots for use in fecundity and egg viability assessments.

Female NCR emergence was reduced by 33.5, 29.7, and 46.9 percent using 0.5, 0.75, and 1X rates of tefluthrin, respectively, in comparison with the untreated check. These reductions provided by the insecticide treatments, however, were not significantly ($P > 0.05$) different from each other. No further sex ratio- or species-specific differences in survival were detected among treatments. Terbufos applications resulted in significantly more eggs produced per NCR female than that observed in untreated plots, however beetles surviving the high rate (1X) deposited 86 percent more non-viable eggs than those emerging from reduced-rate and untreated soil.

Our results indicate that lower rates of these insecticides will result in no significant shifts in corn rootworm gender, species, or the production of viable eggs. Thus, with no apparent negative ecological implications, the lowest insecticide application rates that consistently maintain corn rootworm damage below the economic injury level should be considered for implementation into current corn production systems.

Spatial Distribution and Sampling Plans for Cereal Aphids Infesting Spring Wheat. Philip J. Boeve and Michael J. Weiss, Department of Entomology, North Dakota State University. Fargo, ND, 58105

Three cereal aphids, *Rhopalosiphum padi* (L.), *Schizaphis grarninum* (Rondani), and *Sitobion avenae* (F.) invade wheat fields in the northern Great Plains each spring and occasionally reach economic status. Cereal aphid populations need to be estimated for pest management decision making. This study was conducted to develop sampling plans based on either the number of aphids per stem or based on the percentage of infested stems. Forty-five population estimates were collected from eastern North Dakota spring wheat fields during 1993-1995. The number of aphids per stem were counted on 100-350 stems per field. Taylor's power law, Iwao's patchiness regression, and the negative binomial k were used to analyze the spatial distribution of the aphids. Taylor's power law provided a better fit to the data than the other methods. All three species exhibited an aggregated distribution. The slope from Taylor's power law regression for each aphid species ranged from 1.18 to 1.24, and were not significantly different from each other ($P > 0.05$). Sample size requirements for fixed levels of precision were estimated with Taylor's regression coefficients. Parameters from the regression of ln(mean aphids/stem) on ln[-ln(proportion of uninfested stems)] were used to develop a binomial sequential sampling plan. The sampling plan with a fixed level of precision should be used by researchers developing economic thresholds for cereal aphids in spring wheat. The binomial sequential sampling plan should be used by growers and crop scouts to determine if an insecticide application is warranted.

Disease Resistant Variety Trial and Farm Demonstration Plots for Pepper IPM in New England. Jude Boucher, Gianna Nixon and Richard Ashley, Department of Plant Science, University of Connecticut, U-67, 1376 Storrs Road. Storrs, CT 06269-4076

Since 1989, bacterial leaf spot (BLS) has occurred on 90 percent of the farms that have participated in the University of Connecticut's Pepper IPM Program and accounts for 66 percent of the pesticide used on this crop. *Phytophthora* blight (PB) and cucumber mosaic virus (CMV) are not as common on New England farms as BLS, but may reduce yields substantially when present. Resistant varieties offer an important new alternative to chemical controls for these diseases and are a crucial component of pepper IPM. In 1995, we compared the horticultural characteristics of one PB, one CMV and 12 BLS resistant varieties to two popular commercial peppers in a replicated trial at the University of Connecticut. Fruit were graded for size and shape and yields were separated into early- and late-season harvests. Other parameters measured were plant height, canopy width, and fruit wall thickness, length to diameter ratio, number, weight, and the percent marketable. Unreplicated demonstration plantings with three or four resistant varieties each were conducted at 12 commercial farms in 1994/1995 and yields were quantified at the University's research farm in 1994. Several resistant varieties were judged to be equal or superior to the two popular cultivars based on a combination of characteristics including observations on disease susceptibility at local farms. IPM program participants are encouraged to utilize a variety of techniques for pepper disease control including hot-water seed treatment, proper sanitation, crop rotation, resistant varieties, weekly scouting and chemical controls if necessary.

New Pathways: an Education Proposal For IPM/ICM Practitioners. Dan E. Bradshaw, CPCC-I, Crop Aid Agricultural Consultants. 2806 Western Acres, El Campo, Texas

Over the years, a number of constraints to the more widespread adoption of IPM have been identified. One constraint widely discussed is the lack of targeted education programs to attract and train future practitioners. With increasing environmental concerns, economic considerations, and the general complexity of agricultural production management, the need for this type of training for practitioners is greater than ever before. This is especially true if the stated goal of having 75 percent of the U.S. cropland under IPM is likely to be met with credible IPM. However, an important aspect of an education system is that the training must meet the applied needs of these potential practitioners. To be effective, practitioners must be able to function in a truly multidisciplinary setting. IPM is only one facet of the broader integrated crop management (ICM) environment in which most individuals actually must practice. Current doctoral level degree programs in the sciences related to crop production/ protection are all narrowly focused at the discipline and subdiscipline level. A new degree program (often called the Doctor of Plant Health) patterned after the veterinary medicine model is proposed for practitioners in crop production/protection. A new method of teaching is proposed -- the New Pathways concept -- based on programs at several medical schools. These programs recognize that it is impossible to teach everything a person might need to know in classroom programs. These medical schools emphasize problem solving and mastery of basic principles rather than extensive memorization. In the agricultural New Pathways proposal, training from agronomy, soil science, entomology, weed science, plant pathology, horticulture, plant physiology and other essential disciplines would be combined with the applied skills such as problem solving, communication, diagnostics, systems integration and management and other practical knowledge essential for practitioners to function in the business world. Teaching applied subjects would emphasize problem-based learning. Crop consultants would serve as adjunct professors and team teach with professors from the various disciplines using case studies, cap stone courses and internships. Pilot programs at several major universities are being discussed and developed with significant input from the crop consulting profession.

Multi-disciplinary Study of Crop Production Systems for the Canadian Prairies. S.A. Brandt, O. Olfert, & A.G. Thomas, Agriculture & Agri-Food Canada 107 Science Place, Saskatoon, SK, Canada S7N 0X2

Most of the grassland ecozone of the Canadian Prairies has been cultivated, with only small remnants of native prairie remaining. All of the cultivated land base has incurred soil degradation, over the past 100 years. To address the issues of profitability and soil degradation farmers are encouraged to diversify their production away from a cereal monoculture and to reduce fallow and farm inputs. Climatic limitations favor cropping options such as small grain cereals, cool-season oilseeds and pulses, and perennial forages. Economic constraints dictate that most of the land base is used for field crop production. Livestock production is restricted to marginal lands. The current study was initiated to monitor and assess alternative input use and cropping strategies for arable crop production on the Canadian Prairies with respect to (1) biodiversity, (2) insect, weed and disease dynamics, (3) farm level profitability, (4) soil quality, and (5) food safety.

The experimental framework is a matrix representing three levels of input use (organic; reduced; high) and three levels of cropping diversity (wheat based with fallow; diversified using cereals, oilseeds and pulses; diversified grains with perennial forages). Crops are wheat, barley, oats, rye, canola, flax, lentils, peas, alfalfa, sweet clover, brome grass. The design is based on a six-year rotation, and include all phases in each year. The study utilizes 40m X 77m plots in a split-plot design, replicated four times, and is located on the transition zone between semi-arid and sub-humid prairies at Scott, Saskatchewan (52° 22; 108° 50 near the geographic center of the Canadian Prairies. Small areas in each plot are reserved for destructive sampling and detailed experimentation while the bulk of the plot area is retained to preserve treatment integrity.

Evaluations are either annual or on a cyclical basis (6-year) to determine direction and rate of change over time as a result of the treatments. The design, data collection and evaluation of the study are a result of the collaborative efforts of scientists representing soils, pests, crops, and economics The anticipated impact of these activities is to provide guidance for development of systems that maintain overall levels of food production and quality, without increasing inputs of non-renewable resources.

Small Grains IPM in the High Plains: an Initial Russian Wheat Aphid Effort and Prospects for Expansion. Michael J. Brewer, Univ. of Wyoming, PO Box 3354, Laramie, WY 820711, Frank B. Peairs, Colorado State Univ., Fort Collins, CO, 80523, Gary L. Hein, Univ. of Nebraska. Panhandle R&E Center. 4502 Ave 1, Scottsbluff, NE, 69361, and Stephen D. Miller, Univ. of Wyoming, PO Box 3354, Laramie, WY, 82071

In collaboration with related activities in the region, we are striving to integrate and implement host plant (resistance and enhanced competitiveness) and natural enemy regulation of pests that are sustainable and part of an economically viable production system. To best allow for short-term success while establishing an implementation structure to address multiple pests in a whole farm system, we partitioned our efforts into two overlapping parts.

PART I. Regulation of Russian wheat aphid by plant resistance and natural enemies occurs and is in various phases of implementation. Wheat resistant to Russian wheat aphid has been planted in one acre on-farm plots in the region side-by-side with preferred commercial varieties (in collaboration with the CSU on-farm testing program). Parasitoids have been introduced into the region, and spread of *Aphelinus albipodus* have been confirmed (in collaboration with USDA APHIS and ARS). In lab tests, this parasitoid performs well on Russian wheat aphids infesting resistant or susceptible commercial plants. Will such synergy of regulating agents occur in the on-farm system and lead to a more sustainable pest management system to control Russian wheat aphids? To address this issue, our team is composed of growers, researchers, and outreach educators.

PART II. Our team from the onset is also composed of weed scientists, plant pathologists, and economists. Creating an implementation structure using the well-focused structure of PART I, we aim to expand to other pests identified by growers and public sector personnel in our team: principally winter annual grasses and selected plant pathogens. Economics and Comprehensive Pest Management suggest comparing the traditional wheat-fallow system with a wheat-alternate crop-fallow system that uses pest management strategies such as host plant and natural enemy regulation of pests. We aim to partner our pest management team with existing interests in alternative crop systems to address viability of crop production and protection.

Practical Surveillance for Resistance to Insecticides Is an IPM Responsibility: Onion Thrips And Lygus Bugs. William A Brindley and Diane G. Alston, Department of Biology, Utah State University, Logan, UT 84322-5305

IPM for many crop systems will benefit from greater involvement of extension, pest managers, and growers in practical surveillance for resistance to insecticides. To help achieve this goal, simple resistance bioassay methods for use in the field were developed for onion thrips, *Thrips tabaci*, and western tarnished plant bugs, *Lygus Hesperus*. Individuals of both species were collected into disposable plastic bags with self-locking seals. The bags had been previously treated with microgram quantities of technical grade insecticides and provided with a bit of leaf material and a spacer. LC values were calculated from mortalities observed after 4 hours for the thrips and after 8 hours for the lygus bugs. Probit analysis was based upon Finney's procedures via a new Excel spreadsheet format.

Tests of insecticide tolerance for onion thrips to cypermethrin, bifenthrin, malathion, or methyl parathion were conducted in 1992 and more intensively in 1993 in northern Utah. Spot checks with cypermethrin and methyl parathion in 1995 indicated major shifts in insecticide tolerance had not occurred. Results in 1993 suggested grower practices could influence insecticide LC values. Tests of metasystox-R and capture were conducted with lygus bugs in Washington, Oregon, Idaho, and California. Again, grower practices were strongly implicated in the extent of resistance selection.

The practical success of these bioassay methods and continued indication that grower practices influence resistance, makes it very clear that tests for and research on resistance to insecticides should begin before resistance appears. This, too, is an IPM responsibility, especially for those crop systems that continue to require insecticide use as part of an IPM program.

Influence of Field Oviposition on Populations of Maize Weevils (*Sitophilus Zeamais*) in Stored Corn. Steve L. Brown and Dewey Lee, Extension Entomologist and Extension Agronomist, The University of Georgia, Rural Development Center, P.O. Box 1209, Tifton, GA 31793

Maize weevils are a perennial pest of stored corn in the Southeastern United States. In Georgia, maize weevils have been commonly observed feeding on corn kernels in the field. Research is underway to determine when oviposition occurs in the field, the amount of oviposition that occurs and, therefore, to what extent corn is infested prior to harvest and storage. Observations of adult maize weevil populations in stored corn suggest that numbers of maize weevils emerging soon after storage are too large to be due to postharvest oviposition. In 1995, samples of corn were collected from replicated plots of four corn varieties planted on 6 different dates. After one month in plastic bags, adult emergence was as high as 700 adult weevils per 500 g of field-collected corn. Preliminary data also indicate that adult emergence differs by variety and that late-harvest is conducive to field infestation.

Codling Moth Areawide Management Project Howard Flat. 1995, Jay F. Brunner, Washington State University, 1100 N. Western Ave., Wenatchee, WA 98801

Codling moth (CM) is the KEY pest of pome fruit orchards in the western U.S. Use of broad spectrum organophosphate insecticides (OPs) to control CM represents 50 to 70 percent of insecticides applied to apples in Washington. Replacing OPs with selective alterative controls for CM would open a window of opportunity to radically change IPM in pome fruit. Five Codling Moth Areawide Management Projects (CAMP) were initiated in 1995 through funding from the USDA-ARS. The CAMP site at Howard Flat represents a grass roots initiated effort by growers and crop consultants in an apple-growing area near Chelan, WA. Howard Flat is a geographically isolated fruit production area of 1,200 acres with 36 growers served by 16 crop consultants. Following an organizational meeting in the fall of 1994 and funding of the proposed project, a management board of five crop consultants and three growers was formed. This board managed funding for the project and hired a project coordinator to manage daily activities. Slightly over 1,100 acres of apple and pear were treated with the Isomate C+ pheromone dispenser prior to the blossom period. The cost of the pheromone treatment was subsidized $50/acre by the CAMP; growers paid an additional $60/acre for the pheromone. Insecticides supplemented pheromone for CM control in the first generation in most orchards due to a history of high pest pressure. No insecticides were applied in the second CM generation, relying only on the pheromone for control. Average fruit injury by CM at harvest was less than 0.5 percent at Howard Flat; most orchards had less than 0.2 percent fruit injury. CM populations were reduced throughout the area. Cover sprays for CM control were reduced by 40 percent compared to 1994. Leafroller populations increased in many orchards, and this pest complex will be a main concern for growers in 1996. Biological control of secondary pests, such as aphids, leafminer and leafhopper, was excellent.

Pesticide Use by Chili Farmers in Ellewewa Block Sri Lanka. J. R. Burleigh, V. Vingnanakulasingam, and W. R. B. Lalith, School of Agriculture, California State University, Chico, CA, 95929, and Regional Agricultural Research Center, Aralaganwila, Sri Lanka

Pesticide-use frequency and dose among all chili farmers in the eight units of Ellewewa block, Sri Lanka, are not normally distributed as previously assumed, but rather are aggregated, as evidenced by fit to the negative binomial distribution. That is, each field does not have an equal probability of being treated or nontreated, and information from one field provides information for others. Aggregation may arise from the action of a farmer being influenced by his/her neighbors or from clusters of farmers being influenced by a common factor such as pest intensity, advice from a local pesticide salesperson, or advice from a unit extension agent. We found no association between pest intensity and number of treatrnents. During the dry season (Yala) there was a linear relationship between field size and proportion of fields treated at least once and between field size and number of treatments per field. During the wet season (Maha) no such relationship existed. Sample size less than the population size did not permit accurate estimation of mean values for number of treatments and dose. Fifty-eight and 44 percent of farmers during Maha and Yala seasons, respectively, did not apply pesticides, and the maximum number of treatments by any one farmer was six. Among those who did apply pesticides most treated because of the perceived presence of aphids, mites, thrips, and armyworms. Farmers did not treat for whitefly, which is prevalent during Yala and vectors geminivirus. Few recognized and treated for the diseases, anthracnose and Cercospora leaf spot, which are severe during Maha. Virus symptoms from cucumber mosaic virus, tobacco etch virus and potato virus Y were recognized by farmers but seldom prompted pesticide application for the vectors. The most common pesticides used were the insecticides monocrotophos, profenofos, sulfur, endosulfan, pirimiphos-methyl and methamidophos. Fungicides were seldom used and had no measurable impact on disease incidence. Farmers generally eschew safety clothing while applying pesticides to chili. Of 106 farmers who applied pesticides eight used gloves and mask and one used rubber boots.

Summary of the 2nd Livestock Arthropod IPM Workshop to Access Research and Extension Needs for Future IPM Implementation. John B. Campbell, Research & Extension Entomologist, University of Nebraska, West Central Research & Extension Center, P.O. Box 46A, R.R. 4, North Platte, NE 69101, and Gustave D. Thomas, USDA, ARS, Research leader, Midwest Livestock Insects Research Laboratory, Dept. of Entomology, Lincoln, NE 68583-0938

Fifty-eight federal-university animal health industry scientists and livestock commodity representatives reviewed the current status of arthropod IPM for the commodities of beef, feedlot, dairy, poultry, swine, sheep and goats, and companion animals. The working group for each commodity prioritized arthropod problems and research and extension needs required to enhance or develop IPM strategies used in the management of arthropod pests. The executive summary of the workshop proceedings indicates that major needs are:

- Enhancement of livestock entomology extension and research efforts.
- Development and incorporation of IPM strategies into computer-aided decision management systems for animal production.
- Development of environmentally compatible control strategies/tactics.
- Biology-ecology studies to determine or support decision management systems.
- Develop surveillance/quarantine/control procedures for the introduction of exotic pests.
- Develop interdisciplinary research and extension interactions for development of

livestock arthropod pest management tactics/strategies.

IPM Educational Resource Package With Separate Modules for Commercial, Landscape, And Structural IPM. G.J. Cashion, University of Florida, Institute of Food and Agricultural Science, Palmetto, Florida 34221; and P.G. Koehler, University of Florida, Institute of Food and Agricultural Science, Gainesville, Florida 32611

Through the support of a USDA grant, IPM educational materials were developed for urban and commercial horticulture audiences. These materials are contained in three separate modules: (1) Commercial Horticulture IPM, (2) Landscape IPM, and (3) Structural IPM. Each module contains an array of materials, including slide sets, videos, flash cards, "how-to" manuals, and large color posters to promote the Extension education program to commercial, consumer, and youth groups. The boxed package of modules has been distributed to Extension offices in all 67 Florida counties and every State in the nation.

Factors That Influence The Persistence, Demise, and Transformation of Cooperative Extension Service Integrated Pest Management Programs in Missouri. Douglas H. Constance, J. Sanford Rikoon, and George S. Smith, Department of Rural Sociology, Integrated Pest Management Coordinator, College of Agriculture, Food, and Natural Resources, University of Missouri, Columbia, 65211

In response to the decertification of certain pesticides used for soil insect control on corn in the early 1970s, Federal programs established Cooperative Extension Service sponsored IPM programs in several Midwestern States to promote insect scouting on corn. This paper documents the various factors which facilitated the early growth and steady decline of this program in Missouri and the ongoing transformation of such services into the private sector and other agencies. Research in Missouri regarding pesticide use practices and water quality issues indicates that there is a considerably higher incidence of IPM use in counties that historically had, or still currently have, Extension-sponsored programs. Interviews were conducted with University personnel responsible for implementing these programs, county Extension agents responsible for overseeing the programs, private sector businesspeople who are currently offering IPM services, and farm operators who previously used, and/or now participate in, IPM Extension programs or private services. Interviewees were asked what factors contributed to the success, failure, and/or transformation of the county programs. Results indicate that these factors include quality and turnover of the scouts, commitment of the Extension agent, economic and climatological variables, availability of private sector services, institutional support, and packaging IPM programs with other programs such as irrigation.

An Environmental Impact Assessment System for Judging the Agronomic and Socioeconomic Effects of the Inputs Used by Organic Farmers. Lynn S. Coody, M.S., Principal Consultant, Organic Agsystems Consulting, 1241 E. Jefferson St., Cottage Grove, OR 97424

In 1990, the U.S. Congress passed the Organic Foods Production Act (OFPA) which mandated development of national standards for the production of organic foods. This poster presents the continuing development of an evaluation system designed to assist the Technical Advisory Panel of the USDA's National Organic Standards Board in their effort to develop a National List of materials which are appropriate for use on organic farms. The evaluation system provides a systematic approach to the assessment process and structures the daunting amount of information needed to satisfy the requirements in the OFPA. lts precepts are also firmly rooted in the principles and values which have underpinned organic agriculture for decades.

Design of the evaluation system encompassed three interrelated activities: the development of an Environmental Impact Assessment methodology, the collection of the data required for shaping evaluation criteria and for fueling the evaluations, and the creation of a prototype expert system computer program to support the decision making process.

The program, called Organic Expert, provides a tool for development of evaluation criteria which employs a graphic interface for easy use. It evaluates materials by comparing data about the characteristics of a material against the evaluation criteria related to a wide array of agroecosystem and socioeconomic factors and uses a system of weighted values to produce a final rating for the product. The results of the evaluation are reported at three different levels of detail.

Pesticide Use on Oklahoma Wheat Between 1981 and 1995. Jim T. Criswell, Jerry Dunn,and Gerrit Cuperus, Department of Entomology, Oklahoma State University, Stillwater, OK 74078

Herbicide usage as measured in pounds of active ingredient decreased (603,150 to 263,400), however, acreage treated by herbicides increased greatly (877,000 to 4,825,000). The reason for the increased acreage vs decreased ai was the introduction of sulfonylurea herbicides.

Insecticide usage varied over this time span due to sporadic insect infestations. Insecticide usage measured in pounds active ingredient decreased (2,801,000 to 255,400) as did acres treated by insecticides (3,634, 000 to 902,500). The major shift in insecticide usage was the reduction of ethyl parathion and the increase usage of dimethoate. This was due to EPA regulation actions on ethyl parathion.

Fungicide usage on wheat is minimal in Oklahoma. The primary reason being most years the spring production season is not conducive to foliar fungal growth.

The Cooperative Boll Weevil Eradication Program (BWEP): a Growing Success. Gary L. Cunningham, Coordinator, Bill Grefenstette, Senior Operations Officer, APHIS, PPO, BWEP Coordinator, Plant Protection and Quarantine, 4700 River Road, Unit 138, Riverdale, Maryland, 20737

The cotton boll weevil, *Anthonornas grandis*, moved into the United States from Mexico in the late 1800's and has since cost the cotton industry more than $13 billion in economic losses. The grower-approved and funded boll weevil eradication program has been successful in the southeastern and southwestern portions of the United States and a plan has been developed by the industry to eradicate the pest beltwide by 2003. Program operations consist of trapping, careful and timely treatments, and cultural control. New technologies are being developed to improve control practices in environmentally sensitive areas. Boll weevil eradication results in significant economic and environmental benefits.

Farmer Acceptance of Economic Thresholds For Weed Management. George F. Czapar and Marc P. Curry, University of Illinois, Springfield Extension Center, P.O. Box 8199, Springfield, IL 62791 and Loyd M. Wax, USDA-ARS, Crop Sciences Department, University of Illinois, 1102 S. Goodwin Ave, Urbana, IL 61801

Although economic thresholds are used extensively by farmers to make insect control decisions, the use of economic thresholds for weed management has been limited. A direct mail survey of 988 farmers in central Illinois was used to identify how weed management decisions are made, acceptable levels of weed control, average herbicide costs, and factors preventing the use of economic thresholds for weed control. Of the farmers surveyed, 45 percent based their weed control decisions on the previous year's weed problem, 17 percent relied on dealer recommendations, while only 9 percent of farmers used economic thresholds as a basis for weed management. When asked to identify the major reasons for not using economic thresholds for weed management, the most frequent response was concern about weeds interfering with harvest. Landlord perception, weed seed production, and the general appearance of the field were also identified as limitations.

A survey of agricultural chemical dealers and applicators was also used to help identify the current barriers to adoption of economic thresholds for weed management. In 1994, 143 agricultural chemical dealers and applicators attending a pest management workshop were asked to rank the top five reasons preventing farmers from using economic weed thresholds. The most frequent response identified by commercial applicators was the general appearance of the field. Similar to farmer responses, concern about weeds interfering with harvest, landlord perception, and weed seed production were identified as current limitations. In addition, dealers identified the time required to scout fields as a major limitation to the adoption of economic thresholds for weed management.

What's The Potential For Linking Precision Farming With IPM? Stan Daberkow and Lee Christensen, Economic Research Service, United States Departrnent of Agriculture, Washington, DC, 20005-4788

Precision farming is emerging as a technology to tailor application of agricultural inputs at the sub-field level. Leading precision farming researchers and agribusiness firms were queried about the status and potential of precision farming as part of IPM. These individuals were selected from Universities, Federal agricultural research agencies, and agribusinesses dealing with precision technology, hardware and software, and consultative services. All were in agreement that precision farming applications in pest applications are far behind developments in seed and fertilizer applications, particularly for phosphorous and potash. The original precision farming/IPM focus was driven by water-quality concerns from soil-applied pre-emergence pesticides applied to environmentally fragile cropland. The focus in now on detecting spatial weed population density/species/size and varying the application rate accordingly. This focus fits the IPM philosophy to verify that a pest problem exists before treatment rather than a prophylactic approach. Precision farming is more applicable in fields with significant variation in soil characteristics, such as soil type or organic matter. However, reduced use of herbicides in fields is not guaranteed. Total field use with variable application rates may be greater, particularly if uniform application rates are below label rates. Precision farming offers a potential to apply pesticides on a very localized basis within a field. While scouting leads to an average application rate over an entire field, subfield information collected via hand-held locators used by scouts or yield monitors on harvesting equipment can be used to pinpoint areas within the field needing treatment. The applicability of precision farming to herbicide applications will likely vary with pre-and post-emergence applications and the weed species(s). The development of sensors and other techniques for differentiating size, species and density of pests in an on-the-go or other dynamic method or use in IPM is in its infancy. Federal and State funding of precision farming projects linked to pest management in FY 1994 are estimated at nearly $3 million.

IPM Improves the Efficiency of Peanut Production in Oklahoma. John Damicone and Ken Jackson, Department of Plant Pathology, Ron Sholar and Gerrit Cuperus, Depts. of Agronomy & Entomology, respectively, Mark Gregory and Wayne Smith, Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, OK 74078

The Oklahoma Peanut Commission and OSU IPM Program have supported field research which has served as the basis of IPM demonstration and implementation across the State. The major impact has been in the management of diseases, which are the principal limiting factors in peanut production. Sclerotinia blight is a disease that affects about 25 percent of the State's 100,000 acres. Prior to the release and demonstrated effectiveness of the resistant varieties Tamspan 90 and Southwest Runner, growers applied 4-6 lb./acre fungicide at a cost of $50-100/acre. Nearly total adoption of resistant varieties has increased yields by 20 percent and profitability by 33 percent in problem fields, and has reduced the tonnage of fungicide applied in the State by over 50,000 lb. Early leaf spot is a problem state-wide. Historically, growers have either applied up to six fungicide applications per season on a calendar schedule, made fewer poorly timed sprays, or have not controlled leaf spot. A weather-based advisory program was developed and demonstrated which allows growers to time sprays to coincide with disease-favorable weather. The Oklahoma MESONET, a state-wide network of automated weather stations, has permitted broad implementation of the advisory program. Since 1994, daily advisories have been available to growers in seven counties which contain 75 percent of the state acreage. Program adoption within counties has reached 65 percent, resulting in improved disease control for low-input growers and a 30-percent reduction in fungicide use for high-input growers. The Texoma Crop Management Program is a grower association established in the Red River Valley in 1987 that is dedicated to improving crop management practices in a five-county area historically plagued by low yields and profitability, and a declining grower base. Extension programs have focused on improving soil fertility and pest management. Program impacts have been a 50 percent increase in soil testing, an 84,000 lb reduction in needless usage of in-furrow fungicide. and an increase in yields from 75 to 83 percent of the State average.

Impact of Manuring and Soil Insecticide Use on Corn Profitability in New York. Paula Davis, Hamish Gow, & Wayne Knoblauch, Depts. of Entomology & Agricultural, Resource & Managerial Economics, Cornell University, Ithaca, NY 14853

The western corn rootworm, Diabrotica virgifera virgifera, is a key pest of corn, causing significant lodging and yield losses as a result of feeding injury on corn roots. Of chief concern to dairy farmers in the Northeast is the vulnerability of corn in a typical 4-year corn/4-year alfalfa rotation used by many dairy producers to supply high-quality feed. Although an extensive data base is available concerning the effectiveness of soil insecticides in reducing grain yield losses, relatively little on-farm data is available concerning economic benefits of soil insecticides in corn harvested as silage. In addition, recent findings concerning the ability of manure to lessen the impact of rootworm feeding on lodging and yield losses raise important questions as to if and when a soil insecticide is justified.

The primary goals of this project were to evaluate effectiveness and reliability of various combinations of manuring and insecticide use in reducing losses from western corn rootworm and to assess the economic impact of these control strategies on farm profitability. Field trials were conducted on 20 New York dairy farms in 1993-1994. Treatments were replicated four times at each field site and included (1) inorganic fertilizer, no insecticide, (2) inorganic fertilizer, soil insecticide, (3) manure, no insecticide, and (4) manure plus soil insecticide. Multiple regression equations were developed to predict silage and grain yield for the various treatments based on available macronutrients, soil characteristics (drainage, pH, soil suitability for corn growth), and planting information (planting date, plant populations, past manure use). To assess the economic impact of manuring and soil insecticide use on an individual field basis, a cost-benefit analysis was conducted which used a partial budgeting format. In addition, a stochastic simulation model is being developed to evaluate how manuring and soil insecticide uses affect long-term farm profitability. Initial simulations will be presented to illustrate the effects of cow numbers and land to cow ratios on profitability of our four management approaches.

Research and Implementation of IPM Strategies at Gerber. Todd De Kryger, Research Horticulturalist, and Jim Brienling, Agricultural Research Manager, Gerber Products Company, 405 State Street, Fremont, MI 49413-4001

A “whole-system" approach is the basis for the implementation of IPM strategies at Gerber. Concern over pesticide residues in our finished product has driven us to lake a look at our whole system to see where the critical areas of concern are hidden. We see Integrated Pest Management at the farm level as an integral part of our pesticide elimination program.

The Gerber IPM program stands on three strong legs: support for IPM research, demonstration at the farm level and "grower ownership" of an IPM program. The support for IPM research can be found in a number of different programs. Direct funding of research at the university level to study specific aspects of a certain pest and "whole-system" projects that piece together all of the parts of the IPM puzzle are two ways that we support research. Participation in the Michigan IPM Alliance through direct funding helped to secure the Statewide IPM Coordinator position at Michigan State University.

Demonstration at the farm level includes such programs as the azadirachtin efficacy trial on Pear Psylla and the Oriental Fruit Moth and Codling Moth mating disruption programs offered to our growers in both 1994 and 1995. The best approach that we have found to develop "ownership" in an IPM program is the crop management association concept. The Westcentral Michigan Crop Management Association (WMCMA) was formed by a small group of growers, MSU Extension agents, and processors. Gerber has provided leadership to the group from the beginning and has encouraged other processors to join the group. The WMCMA has received financial support from Gerber as well. Gerber has used the scouts directly for data collection and fruit maturity studies. The scouts have helped guarantee Gerber a high-quality raw product with as little pesticide residue as possible.

Wisconsin Cranberry IPM and its Impact on Changing Growers' Perceptions of Insect Pest Problems. T. Dittl & L. Kummer, Agriculture Scientists, Ocean Spray Cranberries, Inc. P.O. Box 155, Babcock, WI 54413

With the aim of developing a better understanding of Wisconsin growers' perceptions of insect pest problems and how IPM has impacted their views, we have compared surveys from 1985 and 1995. Since the inception of cranberry IPM in Wisconsin in 1986, our comparison of data provides some insight into how IPM has influenced grower perceptions, how well past pest concerns have been addressed, and what insect problems are becoming more important as cranberry culture and its pest complex continue to evolve. This study helps us in concentrating research efforts on problems perceived as important by growers.

Forest Insects And Their Damage. Photo CDS: Vol. I and 11, G.K. Douce, B.T. Watson, and D. J. Moorhead, The University of Georgia, Cooperative Extension Service, P.O. Box 1209, Tifton, GA 31793 and G. J. Lenhard, Louisiana State University, Department of Entomology, Baton Rouge, LA 70803

The Southern Forest Insect Work Conference (SFIWC) was organized by Federal, State, university and private sector southern forest entomologists and has met annually since 1956. The SFIWC has maintained a slide series of forest entomology-related images expanded by voluntary member contributions since the early 1970s.

Forest Insects and Their Damage contains two hundred images in Kodak Photo CD format that were selected from the SFIWC slide set. Photographer credits, image identification and descriptions, and a miniaturized representation of each image are given in the reference booklet enclosed in the double jewel-cased set.

Kodak Photo PCD format provides five resolutions ranging from 128 x 192 up to 2048 x 3072 pixels of each image, thereby providing users with images suited for a wide array of applications ranging from World Wide Web and on-screen multimedia presentations, to offset printing for both Windows PC and Macintosh platforms. PC files can be accessed directly by a number of software applications, or may be converted to other graphic formats as needed. For convenience, special arrangements have been made with Kodak to provide the Kodak Access Plus Software on each *Forest Insects and Their Damage* CD.

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Southern Cooperative Series Bulletin 383, *Forest Insects and Their Damage* is available for $25.00 per two volume set from The University of Georgia through the senior author.

Areawide Resistance Management of Codling Moth Using Pheromone Mating Disruption. John E. Dunley and Stephen C. Welter, Washington State University TFREC, 1100 N. Western Ave., Wenatchee, WA 98801, and Dept. of ESPM, University of California, Berkeley, CA 94720

Azinphosmethyl (Guthion) has been used for over thirty years to control codling moth in apple and pear. Azinphosmethyl resistance in codling moth was first found in 1989 in pear orchards in the Sacramento Delta of California. While azinphosmethyl resistance is still at levels that do not confer field failures, growers in areas with resistance experience difficulty controlling codling moth, resulting in increased Guthion use. Lab and field studies have demonstrated a wide range of correlated cross-resistance, including pyrethroids, carbamates, chlorinated hydrocarbons, and insect growth regulators, making the use of alternative chemicals difficult.

The need to manage resistance regionally has coincided with areawide management efforts for codling moth using pheromone mating disruption. Use of pheromone mating disruption for codling moth control provides a nonchemical alternative to Guthion. This is useful in managing Guthion resistance in codling moth; complete reversion has occurred in the lab in 6 to 7 generations without exposure to Guthion.

The establishment of areawide pilot projects for the management of codling moth using pheromone mating disruption provides a unique opportunity to practice regional resistance management. To determine the effects of using areawide mating disruption on Guthion resistance levels, a western regional azinphosmethyl resistance monitoring effort was started in 1995. Cooperators in the five USDA Areawide Codling Moth Management Pilot Project were identified to bioassay resistance levels in each of the five areawide sites (WA: Oroville, Howard Flat, and Parker Heights; OR: Medford; CA: Randall Island). In four sites (all but CA), 1995 was the first year of areawide management, thus baseline resistance levels were obtained. The areawide project in California was in its third year.

Undergraduate Education in Pest Management at The University of Florida. R. A. Dunn and J. R. Strayer, Departments of Entomology and Nematology, F. W. Zettler, Plant Pathology, K. L. Buhr and D. S. Wofford, Agronomy, and P. G. Koehler, Departments of Entomology and Nematology, University of Florida, Gainesville, FL 32611

Merger of the undergraduate programs in Agronomy, Plant Pathology, and part of Entomology and Nematology has produced a unified Plant Science major, under which students can choose from among three specializations (Agronomy, Plant Pathology, Plant Protection), and which share a common core curriculum in General Education, Lower Division requirements, and selected Upper Division requirements. Students in the Plant Protection Specialization take courses in entomology, nematology, plant pathology, and weed science, emphasizing understanding of the crop/plant ecosystem. The curriculum, which also includes economics and agronomic and horticultural sciences and production, focuses on theory and application of biological, cultural, and chemical approaches to integrated pest management compatible with maintaining a quality environment. Those interested in the growing field of urban pest control have an Urban Pest Management Specialization in the B.S. Degree program of the Department of Entomology & Nematology with a similar intent as the Plant Protection Specialization in Plant Science. The curriculum requires courses in pest biology and identification, ecology of pests and principles of pest management both surrounding and inside structures in the urban setting, and business and economics. All of the above curricula are designed to earn the student a B.S. degree in a standard 120-credit program. Demand for these curricula is high among students and employment prospects for their graduates are excellent.

Implementation of IPM Strategies to Control Potato Late Blight in Maine. James D. Dwyer, James F. Dill, Leigh S. Morrow, Heidi A. Currier, University of Maine Cooperative Extension, P.O. Box 727, Presque Isle, ME 04769

In 1993, the Maine Potato Industry experienced a major potato late blight epidemic. The University of Maine Cooperative Extension and the Maine Potato Industry undertook a major effort to implement a potato late blight control program in 1994 and 1995, based on integrated pest management strategies. The program focused upon grower education, which featured the development of a late blight video tape which was distributed to growers, plus a month-by-month grower check list which highlighted the strategies and timing of on farm control action. The program also emphasized inoculum reduction through seed testing, cull disposal and volunteer potato plant control. Within the program, a network of 150 weather stations for disease forecasting and fungicide scheduling was implemented in conjunction with formalized field scouting educational effort.

Orchard Floor Management Systems to Reduce Herbicide Use and Improve Nitrogen Management in Tart Cherry Production. C.E. Edson, Fruit and Vegetable IPM Program Leader; J.E. Nugent, NWMHRS Coordinator; G.E. Thornton, Fruit IPM Extension Agent; T.L. Loudon, Professor, Agricultural Engineering; G.W. Bird, Professor, Nematology; D.R. Mutch, Weed Science/IPM; J.W. Johnson, Associate Professor, Entomology; J.A. Flore, Professor, Horticulture: E.J. Hanson, Associate Professor, Horticulture; S.M. Swinton, Assistant Professor, Agricultural Economics; A. Middleton, IPM Research Technician, Michigan State University, East Lansing, MI 48824; D. Gregory, Fruit Grower; and F. Otto, IPM Consultant, Cherry Bay Orchards, Suttons Bay, MI 49684

Michigan is the leading producer of deciduous tree fruits in the north central region of the United States and is the national leader in tart cherry production. Tart cherry growers who report utilizing a formal IPM program emphasizing orchard scouting currently apply 5 to 6 total sprays compared to the industry average of 8 to 9. Further reductions in fungicide and insecticide use are likely to require new technology or the development of new IPM strategies. Interestingly, IPM practices used by Michigan tart cherry growers do not normally include alternatives to herbicides or ground applied nitrogen. Growers currently utilize herbicide strips under the tree row with sod row middles to minimize soil erosion, provide effective ground cover management at a reasonable cost, and maintain acceptable tree growth, yield, and cold hardiness.

In 1995, we initiated a study to examine alternatives to standard orchard floor management. Twelve alternative orchard floor management systems were established in a mature commercial tart cherry orchard (*cv* Montmorency) where an IPM program using intensive scouting was an integral part of orchard management. The systems include both mulch and ground covers and utilize legumes, compost, and variable fertigation scheduling to supply nitrogen. Lysimeters monitor herbicide and nitrate leachate. The objectives are to identify practical, effective, and economic alternatives to herbicides and improve nitrogen management. This study will determine the impact and interactive effects of the orchard floor management systems on: the arthropod complex (emphasis on mites); plant parasitic and entomophagous nematodes; plant species diversity; tree growth, yield, nutrition, and cold hardiness; total pesticide use; efficacy of target pest control; and production profitability.

The Dramatic Shift of The Western Corn Rootworm to First-year Corn: IPM Responding to Changes in Pest Dynamics. C. R. Edwards, L. W. Bledsoe, J. L. Obermeyer, and R. L. Blackwell,

Purdue Pest Management Program, 1158 Entomology Hall. Purdue University, W. Lafayette, IN 47907-1158

Over the past several years, agriculturists in Indiana and Illinois have observed a substantial increase in first-year corn fields (corn and soybean in rotation) showing economic damage due to western corn rootworm, *Diabrotica virgifera virgifera* LeConte, larval feeding. In the year prior to larval damage in corn, significant numbers of beetles have been observed in some soybean fields during the primary egg laying period. This represents a significant change from what was observed in the past. Since the late 1970's, crop rotation has been the primary pest management strategy used for managing this insect. With this change in pest dynamics, new pest management research and extension programs are needed to address this situation.

Reduced-herbicide Weed Management Systems. M. J. Else and P. C. Bhowmik, Dept. of Plant and Soil Sciences, University of Massachusetts, Amherst, MA 01003

Weed IPM can result in reductions in herbicide use, but in a different way than insect IPM has produced reductions in insecticide use. Scouting, economic thresholds, and biological control agents have enabled insect IPM practitioners to reduce unneeded insecticide use and substitute biorational controls for chemical insecticides. Weed populations, however, are seldom below threshold. The decision growers make about weeds is not *whether* to control them, but *how* to control them. In addition, non-chemical controls are often either unavailable for weeds, or considerably more expensive than herbicides. The most promising means of reducing herbicide use in row crops, therefore, may be to develop methods of applying these materials at reduced rates. Several methods of using herbicides at greatly reduced rates have been tested in Massachusetts. In the *delayed application of reduced rates* (DARR) technique, herbicide application is delayed until shortly before weed emergence. Half rates of metolachlor and atrazine have been found to produce control of weeds in sweet corn when application is delayed until shortly before or after crop emergence. In herbicide banding plus cultivation, herbicide is applied in a band over the crop row. Weed control between rows is achieved with cultivation. Herbicide amount reductions of two-thirds are readily achieved. Combining DARR and banding results in even greater reductions. Tthese techniques have been found to be effective both in plot studies and in on-farm trials with growers. Adoption has occurred on some farms. A primary obstacle to adoption is the relatively minor savings achieved compared to the potential costs of a failure to control weeds. A third tactic studied was herbicide reduction with partial mulch cover. In this technique, a winter-killed oat cover crop is used to reduce weed growth. Corn is planted without tillage into the killed oats. Control of weeds emerging through the oats is obtained with reduced rates of postemergence herbicides. Research-farm trials of this method showed reduced herbicide rates to be less effective than full rates. Further study will be needed before this technique can be tested in on-farm trials.

National Agricultural Pesticide Risk Analysis Implementation Trial in New York. Anthony J. Esser, Water Quality Coordinator and Frederick B. Gaffney, Agronomist USDA-NRCS, Syracuse, NY and J. Keith Waldron, IPM Coordinator for Field, Forage and Dairy, Cornell Cooperative Extension. Cornell University, Ithaca, NY

The National Agricultural Pesticide Risk Analysis (NAPRA) risk screening process provides a climate-based probability of exceeding specific toxicity criteria as well as pesticide loading. NAPRA uses the Ground Water Loading Effects of Agricultural Management Systems (GLEAMS) water quality computer model to predict edge of field and bottom of root zone pesticide losses. The NAPRA process includes a toxicity analysis because small losses of highly toxic pesticide may pose greater risks than larger losses of less toxic products.

USDA-NRCS in New York has conducted a six-month implementation trial to test its applicability and acceptance as a held level planning tool. This tool would be used by both NRCS District Conservationists and Cooperative Extension Service (CES) Agents in order to provide growers and landowners alternatives to their current pesticide program. Seven crops and two sites for each crop were selected from various counties statewide. At each site growers were interviewed to obtain specific crop and pesticide information. NAPRA input yielded baseline results for each field or plot. Cornell Integrated Pest Management managers provided alternative chemical or chemical usages to provide variables for a second NAPRA run. District Conservationists, Agents, and growers were then revisited for reaction for comparison between the baseline and alternate results.

Farmer's pesticide use decisions are based on "The Three E's": Economics, Efficacy, and Environment. At present, farmers have ready access to hard and real numbers for the Economics and Efficacy but not for the Environmental component. The NAPRA process is one approach to attaching values to the third "E." Our preliminary findings conclude that there is great potential at the field office level for the NAPRA process. Although use at the growers' level may not be effective, DC and Agent use is. Additionally, NAPRA is most effective on field crops, and has limitations when analyzing fruit, vegetable, and other specialty crops.

Adoption of Nebraska's Decision Aid for Weed Management in Missouri Soybean Production. F. M. Fishel, G. S. Smith, and M. H. O'Day, University of Missouri, Integrated Pest Management, 45 Agriculture Bldg., Columbia MO 65211; D. L. Schuster and L. Kabrick, NRCS, Macon, MO

Computer software decision aids have become available from several sources in recent years. In Missouri, there has been some grower interest in this type of technology based on the increasing complexity of weed management. The University of Nebraska recently released its version of a decision aid software package, NebraskaHERB®. Several verification trials were established in private producers' soybean fields for evaluating the practical use of this software in Missouri. Based on species, densities, and growth stages of weeds present, the software recommends postemergence herbicides options either ranked by potential net gain or percent of the potential maximum yield. Several treatments, as recommended by the software, were evaluated in these trials. The treatment with greatest interest was that recommended by the software as greatest potential net gain. Although NebraskaHERB is an aid in sorting through the vast number of options for postemergence weed control, several aspects of the software may not make this particular package feasible for ready adoption in Missouri. Modification of the current software may prove to be a valuable decision tool available for Missouri producers.

California's UC IPM Pest Management Guidelines: A Short History of Delivering Time-dated Information Electronically. Mary Louise Flint and Joyce F. Strand, UC Statewide IPM Project, University of California, Davis, CA 95616

In the 1970s, the University of California's major publications relating to pest management were pest and disease control pamphlets listing pests in tabular format with suggested pesticides keyed into time of year or crop growth stage. These pamphlets were gradually taken off the shelves in the early 1980's because of the difficulty in keeping pesticide recommendations up-to-date and lack of author interest in revising them. In 1984, the UC Statewide IPM Project began to put brief pesticide guidelines on a central computer. Taken from 250 old or existing publications, the computer database helped confirm the problems inherent in the pamphlet system--information was often conflicting, inconsistent, incomplete or obsolete. Professional-looking, cohesive publications with a common format and style that would be easy to keep up-to-date, that could also be accessed through a searchable computer database, and whose authors would be recognized in the merit review process, became a goal. The result was a new publication series, the UC IPM Pest Management Guidelines (PMGs), established in 1987.

PMGs were written and designed to appear simultaneously on the IPM Project's publicly accessible computer and as hard copies created on a desktop publishing system. Frequent updating, emphasis on an IPM program, peer review, and attractive hard copy versions stimulated interest but many potential users had no access to PMGs electronically, since computers were relatively rare and computer communications tools were difficult to use. Use increased after 1989, when a free program, CALLIPM, was distributed to automatically connect a PC to the UCIPM computer through a modem and phone line, and even more after 1993 when the database became available through the Internet. In 1990, subscriptions to the hardcopy version of the PMGs also increased visibility and accessibility. In 1995, the UC IPM Project made its debut on the World Wide Web (http://www.ipm. ucdavis. edu) with the PMGs as a central feature. Guidelines for more than 1,000 pests on 34 crops, turf and home and garden situations are represented. The WWW allows us to combine some of the best features of both electronic and hard copy publications
simultaneously in the same format. These include quick, easy access to a large audience; frequent updates; color photographs and graphics; attractive printed copies; ability to access in-depth information; quick search features; centralized pest management information; and low or no cost to users. Electronic IPM information has finally come of age!

IPM and Sustainable Agriculture in Mid Atlantic Cash Grain Farming Systems. Raymond Forney, DuPont Agricultural Products, Remington Farms 7321 Remington Drive, Chestertown, MD 21620 Joanne Whalen, University of Delaware, Department of Entomology, Townsend Hall. Newark. DE 1971 7-13()3. Michael Spray. Mikes Crop Scouting Service. 109 Lime Landing Road. Millington, MD 21651; Terry Patton IPM Extension Assistant, Department of Entomology, University of Maryland, College Park, MD 20740; and Charles Walthall, USDA/ARS, Remote Sensing Lab, Bldg. 7, Rm. 116, BARC-West, Beltsville, MD 20705-2350

Pest management is a critical component of most farming systems, including the four cash grain systems under evaluation at A Sustainable Agriculture Project at Remington Farms. These systems represent a continuum of increasing reliance on rotation diversity, in-season management and labor, and decreasing reliance on purchased inputs. They consist of corn, wheat, and soybean rotations that represent realistic production options for mid-Atlantic farmers. This long-term research, education, and demonstration project is conducted on four field-scale watersheds and a replicated small-plot experiment on Maryland's Eastern Shore. IPM scouting supplies data on the incidence and severity of crop pests in all four systems, and serves as the basis for pest management decisions in two of the systems. During two years of scouting, 21 insects, 8 diseases, 33 weeds, and 6 other pests have been monitored. Our two-year corn-wheat/soybean rotation, managed with IPM including total postemergence herbicides, leads in productivity (measured in cash grain receipts). Our corn-soybean rotation with preprogrammed management leads in profitability. Beginning in 1995, remote sensing is being explored as an aid to IPM scouting. Aircraft or satellite based devices capture images of the reflectance of various spectral bands of radiation, offering the opportunity to monitor vegetation type and health over large geographical areas. Geo-referenced data will be correlated with on-ground observations of crop stresses based on IPM scouting procedures, as well as soil types and, ultimately, crop yield. Substantial communications efforts expose large numbers of farmers, community members and agricultural policy decision makers, to the concepts of sustainability and the benefits of IPM.

Status of IPM Implementation on Cotton in Texas. Thomas W. Fuchs, Professor and Extension LPM Coordinator, Texas A&M University System, 7887 N. Highway 87, San Angelo, Texas 76901

Texas producers grow in excess of 6 million acres of cotton. Extension IPM programs in Texas began with a pilot program in 1972. This study was conducted to determine the percentage of producers that are IPM producers and the percentage of cotton acres they farm.

An IPM producer was defined as one who uses scouting for insects, weeds and/or diseases, uses economic thresholds in making treatment decisions and 70 percent of the weighted value of IPM tactics available.

A 1994 survey of 1,533 Texas cotton growers provided data on which IPM tactics are being used. A rating scale of the importance of IPM tactics in 4 production regions was developed from expert opinions of consultants, University IPM specialists and producers. A point system was developed which assigned a given number of points for using an IPM tactic based upon its importance to the IPM program in the region.

Producers who scored 70 points or more on a 100 point system and used scouting and economic thresholds were considered IPM growers. Based upon this definition 64 percent of Texas cotton producers are IPM producers and they farm 68 percent of the cotton acres in the State.

Grasshopper IPM Research in South Dakota from 1989 to 1994. Billy W. Fuller, Michael A. Catangui, Tie Wang, Mark A Brinkman & Mark A. Boetel, Plant Science Department, and Michael B Hildreth, Department of Biology & Microbiology, South Dakota State University, Brookings, SD 57007

South Dakota's rangeland grasses are often subjected to arid weather conditions that typify climate of the western plains of North America. Unfortunately, these conditions may coincide with severe grasshopper outbreaks. These grasses are often unable to rebound from grasshopper feeding damage due to stresses associated with low rainfall levels, thus, contributing to a rapid decline in forage quantity and quality. During major grasshopper outbreaks these problems spill over into nearby croplands. Our research from 1989 through 1994 has evaluated chemical and biological control alternatives to aid in control of these pests, there by offering ranchers and farmers the most economical and environmentally sound means of implementing grasshopper IPM in South Dakota.

Chemical control for rangeland grasshoppers is often costly. Additionally, a low profit potential for the vast areas that require treatment can prove economically unsound. To reduce costs, our efforts concentrated on: (1) lower rates (excellent control with carbaryl at 50 percent of standard rate), (2) buffer or barrier sprays (effective with liquid applications), (3) bran baits laced with 1 to 2 percent active ingredient (highly effective with several compounds, but little residual action) and (4) ULV application of diflubenzuron, a chitin-synthesis inhibitor (effective and safe to nontarget organisms). The biologicals investigated included *Nosema locustae* Canning,which failed to provide quality or consistent control, and *Beauveria bassiana* (Bals) Vuillemin, which provided excellent control (70 percent reduction) with little effect on most nontarget arthropods.

Comprehensive investigations into the impacts of carbaryl, difulbenzuron and *B. bassiana* on non-target arthropods in both laboratory and large plot (160 acres per treatment) studies were conducted. Laboratory bioassays with *B. bassiana* caused high mortality in leafcutter bees, *Megachile rotundata* F., however, this was not observed with other bee species found in field studies. Other tested materials appeared to have no significant impact on nontarget arthropods.

IPM On the World Wide Web: The National IPM Network - Northeast Regional Server. Carl Geiger, Dept. of Entomology, Purdue University, W. Lafayette, IN 47907-1158 http://info.aes.purdue.edu/ipm_index.html

The transfer of information from the researcher to the end-user is vital in facilitating the adoption of any new technology. World Wide Web (WWW) sites on the Internet have rapidly become an important information tool for a wide variety of topics. This increased popularity results from a number of factors: the software to access the information on WWW sites is essentially free to noncommercial users, the software's interface makes the transfer of text and graphic information 'user-friendly' and simple, and access to the Internet through commercial providers is becoming easier and less expensive. Commercial interests are taking advantage of the WWW for a number of purposes but are motivated by economics; WWW is an inexpensive and effective way of reaching a widely distributed body of consumers. In addition, WWW sites are easily developed and rapidly modified. The increased popularity of the WWW presents an opportunity to provide information of Integrated Pest Management techniques to a wide audience of end users at a minimal cost.

The National Integrated Pest Management Network (NIPMN) has established a system of regional servers containing IPM information and resources. These sites also provide real-time weather data, market reports, and pest alerts; the most recent pesticide label information; and numerous other types of IPM-related data. In addition, they will incorporate interactive resources such as keys to pest species and expert systems for identification and decision support.

Demonstrations of the resources available on these servers will be provided and future resources and potential uses discussed. An assessment of the economic advantages provided through electronic publication of extension materials will be presented.

Plant Banding: an Alternative Approach to Controlling Banks Grass Mites *(Oligonychus Pratensis)* in Corn. Robert E. Glodt, Research Manager, Agri-Search, Inc., HCR 1, Box 20A, 3 l 36 Dimmitt Rd., Plainview, Texas 79072

Plant banding was developed by Agri-Search, Inc. in cooperation with the Texas Corn Producers Board as an alternative approach for controlling Banks grass mites, *Oligonychus pratensis* Banks, in corn. Plant banding differs from conventional mite control strategies in the following ways: (1) plant banding involves treating only a specific zone on the plant rather than the entire plant, (2) Comite, a registered miticide produced by UniRoyal Chemical Company, reduces mite populations to a low enough level that naturally occurring predators will prevent a late season mite resurgence, (3) Plant banding is applied by ground equipment, and (4) plant banding is less expensive than conventional mite control strategies.

In the early plant banding research it was discovered that Banks grass mites migrate to corn from alternate hosts over a relatively short period of time. This migration to corn normally occurs prior to the time that corn is three feet tall. Since the mites migrating from alternate hosts to corn only inhabit the undersides of the bottom leaves; miticide applications were directed only toward this zone on the plant. Plant banding therefore, results in a 50 percent reduction in the amount of Comite that is required to control mites under a conventional application approach. Research on plant banding has also shown that the miticide Comite provides the initial knockdown of mites while key predators prevent resurgence of the mites later in the season.

Plant banding has offered growers an economic alternative to controlling mites in corn where no economic alternative existed. As compared to conventional approaches used for controlling mites in the mid 1980's, plant banding has reduced miticide applications to corn by approximately 50 to 75 percent.

Measurement of Knowledge and Miscomprehension of Integrated Pest Management. Carroll J. Glynn and Daniel G. McDonald 315 Kennedy Hall, Cornell University, Ithaca, NY 14850

The Economic Research Service of the U.S.D.A. has identified four subject areas requiring multidisciplinary efforts to assess the impacts of IPM practices or policies: farm-level profitability, the environment, public health, and social structure. This paper addresses the fourth of these areas, with particular attention to sources of information and access to information.

A number of studies have begun developing our knowledge about growers' behaviors and farm economics. A few have begun to explore growers' attitudes toward pesticides, the environment, and IPM. Very few have examined what the farmer actually knows about IPM. Instead, most studies are content to examine specific adoption behaviors and assume that the farmer knows what to do and how to do it when it comes to specific components.

The project's research objectives include four objectives. The first objective is to estimate New York growers' knowledge of four IPM components: (1) scouting/monitoring, (2) natural enemies (exotic species, augmented or conserved species), (3) cultural controls (rotation, plowing, resistant varieties, etc.), and (4) pesticides (thresholds, measurements, applications and selection). The second objective is to identify specific dimensions of comprehension and miscomprehension of IPM tool knowledge. The third objective is to correlate dimensions of comprehension and miscomprehension of IPM tool knowledge with the type of question (e.g., closed or open-ended) and with reliance on particular information sources. The fourth objective is to provide an overview of clusters of comprehension and miscomprehension and the information sources associated with each of the clusters to enable development of more appropriate questions in ascertaining growers' pest management practices.

This paper will analyze data collected through a United States Department of Agriculture Hatch Grant (accession 153595). Correspondence should be directed to the first author: Carroll Glynn, Dept. of Communication, 321 Kennedy Hall, Cornell University, Ithaca, NY 14850 (607) 255-8460.

Bringing People Together to Address Complex IPM Issues: Cotton IPM in the San Joaquin Valley. Peter B. Goodell, IPM Advisor, UC Cooperative Extension, Statewide IPM Project, Kearney Agricultural Center, 9240 S Riverbend, CA 93648

Cotton IPM in the San Joaquin Valley of CA has a long and respected history. The progress made during 50 years is based on communication and mutual respect between the public and private sectors. Research-based IPM technologies developed from input from producers and private consultants have provided the foundation of an IPM program noted for its intensive biological monitoring and low insecticide/acaracide usage.

This private/public partnership between research, extension, producers, PCAs, and allied associations and industries was called into action in 1995. After three years of increased arthropod pressure and costly chemical treatments, the cotton industry requested a review of current practices and identification of issues and needs. On November 1, 1995 a meeting was held which included 30 key producers and 30 PCAs in order to build a consensus which identifies the key pest management issues. This facilitated workshop was jointly sponsored by the University of California Cooperative Extension and California Cotton Growers Association

The meeting was well attended with over 80 percent response to the invitation and represented a cotton acreage greater than 500,000 acres. The participants first profiled individual growing regions within the San Joaquin Valley to identify any production and pest management practices which might be causing arthropod outbreaks. Next PCAs and growers were asked to identify solutions or knowledge gaps which might be constraints to solving the key issues identified in the first session. These were ranked by voting and the producer list was compared to the PCAs. A single list was developed and used as a basis for discussion of research and extension priorities for 1996. A summary of issues and results was provided to the industry. In addition, a list of specific extension and research programs and resources which address priority items was provided.

Improving Forage Legume Persistence Through Ecologically Based Pest Management. Alan R. Gotlieb and William O. Lamp, (respectively) Plant Pathologist, Plant and Soil Science Department, University of Vermont, Burlington, VT 05405, and Entomologist, Department of Entomology, University of Maryland, College Park, MD 20742

Pastures and hay crops are benefited by forage legumes which fix nitrogen, improve seasonal distribution of yield, and enhance animal nutrition. Although forage legumes such as alfalfa and birdsfoot trefoil are capable of persisting in stands for many years, ecological and physiological factors acting in concert with the pest community significantly shorten the life of a stand. The lack of persistence (caused by insects, diseases, and weed competition) has important economic ramifications. In severe situations, pests prevent the profitable use of legume species as forage crops.

A forage legume team, representing 12 U.S. States (central, southern, and northeastern), was organized as part of the planning process for the National IPM Implementation Program. The team has met and identified five pest complexes (competitive weeds, insects, root/crown diseases, foliar wilt diseases, and seedling diseases) which contribute to stand decline of six common legume species (alfalfa, red and white clover, common and sericea lespedeza, and birdsfoot trefoil).

To date, much of forage IPM has focused on short term (seasonal) effects of pests. Our team's goal is to expand forage legume IPM research and extension to focus on long-term strategies that will maintain strong healthy stands to resist pests and to postpone the cascade of events that result in stand deterioration.

Pest Resistance Management and IPM. L. Reed Green, Crops Consulting Director-Texas, SF Services, Inc., 824 North Palm Street, P.O. Box 5489, North Little Rock, AR 72119-5489

A completely integrated crop management (ICM) system was developed during the period 1976-1995 in response to resistance of *Heliothis/Helicoverpa* to organophosphate and pyrethroid insecticides in the Upper Texas Gulf Coast. This program is based upon the use of low rates of conventional and biological insecticides to manage the buildup of both beneficial and pest species found in cotton production. Resistance of tobacco budworms to pyrethroid insecticides in 1986 and 1987 resulted in the average number of applications rising from 2-3 at their introduction into cotton production, to 5-6 per season at highest labeled rates in 1987. The end result has been the formation of an environmentally friendly insect control program that reduces usage of pyrethroid and conventional insecticides by over 80 percent without sacrificing yields. Consequently, an effective ICM program should include the following basic principles: (1) No single individual has all the answers to the solution of a complex problem such as insect resistance at the farm level; (2) Cooperation of growers and private practitioners is necessary to successfully develop a pest management plan; (3) Control of the pest species should be completely integrated into the cropping system; (4) Whenever possible, natural selectivity of low dosages of conventional and biological insecticides should be used to enhance the buildup of beneficial insect predators of pest species, while effectively controlling the damaging pests; and (5) The solution to the problem is ever evolving and must be altered as the agronomic system changes with time.

Apple Production Without the Input of Broad-Spectrum Insecticides. Larry Gut, Jay Brunner & John Brown, Washington State University, Tree Fruit Research & Extension Center, Wenatchee, WA 98801

This was the initial year of a 3 to 5 year SARE (Sustainable Agriculture Research & Education) project investigating the production of apples without the input of broad-spectrum insecticides. The study is a direct comparison of the ecology and economics of Delicious apple orchards managed without using broad-spectmm insecticides (NBSI) or managed conventionally (CONV). Six orchards were selected for the study, three in north central

Washington (Bridgeport, Chelan, Orondo), two in the Yakima Valley (Wapato,Yakima) and one in Oregon (The Dalles). Each orchard was divided into a 10-acre CONV block and a 10-acre NBSI block. In addition, a no class I (NOC1) management program was evaluated in a third l0-acre block at the Bridgeport, Orondo and Wapato sites. Pheromones were used as the primary control for codling moth (CM) in the NBSI orchards. This treatment alone was as effective as conventional azinphosmethyl sprays at two sites. High CM population densities at the other four sites necessitated supplementing the pheromone treatment with two other "soft" controls, mineral oil and parasitoid releases. This combination provided good control of CM in two orchards, but greater than 2 percent CM fruit injury was recorded at harvest in the other two NBSI orchards. Adjacent CONV orchards sustained over 1.0 percent fruit injury at harvest. Most of the CM damage in NBSI blocks was found along the orchard edge. Insufficient control of CM in NBSI orchards was primarily associated with the inability of selective materials to control border infestations of this pest. Leafroller populations were well controlled in all of the CONV orchards but reached damaging levels in half of the NBSI orchards. Detecting the build-up of leafroller populations in time to control them with Bacillus thuringiensis (B.t.) was difficult. Development of effective methods for sampling leafroller populations will be a major research component of the SARE project over the next two years. Other secondary pests were generally at low levels in NBSI orchards. Natural enemies contributed to the suppression of many of these potential pests. Three species, white apple leafhopper, green apple aphid and tentiform leafminer, reached population densities that required intervention with insecticides in at least one of the CONV orchards. Detailed yield, packout and spray records have been kept for each pair of NBSI and CONV orchards and will be used to compare the economic risks and benefits of these two management programs.

Influence of Selected Management Practices on the Severity of Southern Stem Rot and Peanut Root-knot Nematode and the Yield of Peanut. A. K. Hagan, J. R. Weeks and L. Sanders, 106. Extension Hall. Auburn University, AL 36849-5624

Studies were conducted in 1993, 1994, and 1995 to determine the influence of planting date, cultivar, and rate of Temik 15G on the severity of southern stem rot *(Sclerotium rolfsil)* and peanut root-knot nematode *(Meloidogyne arenaria)*, and the yield of an early (Andru 93), intermediate (Florunner), and a late maturing (Southern Runner) peanut *(Arachis hypogaea)* cultivar. Planting dates were mid-April (early), late April to early May (optimum), and mid-May (late). Temik 15G was applied either in-furrow at 0.9 kg a.i./ha or at 1.35 kg a.i./ha banded over the row center at-plant and 40 DAP. A non-treated control was included. A RCB, split-plot design with planting date as the main plot, cultivars as subplots, and Temik 15G rate as sub-subplots was used. The hull-scrape method was used to determine optimum digging date. Planting date, cultivar selection, and Temik 15G rate had a significant impact on the severity of stem rot and peanut root-knot nematode as well as yield. Of the three cultivars, Southern Runner generally suffered the least stem rot and heaviest nematode damage. Despite similar levels of nematode damage, stem rot severity was lower in 1994 and 1995 on Andru 93 than Florunner but not Southern Runner. In two of three years, Andru 93 yielded higher than Florunner and both cultivars out yielded Southern Runner all three years. Stem rot severity generally declined from the first through the last planting date on Andru 93 and Florunner. In 1993 and 1995, the least nematode damage was seen across cultivars at the optimum planting date. Across cultivars, yields at the early and optimum planting dates in two of three years were similar, but sharply lower yield was noted in 1994 and 1995 at the late planting date. Among peanut cultivars, planting date had no influence on the yield of Southern Runner but did impact on the yield of Andru 93 and Florunner all three years. Temik 15G had little effect on stem rot severity but nematode damage and yield were inversely related to application date.

IPM in Texas Schools. Philip J. Hamman, Associate Head and Extension Program Leader, Dept. of Entomology; and Suzanne Deatherage Hyden, Extension Pesticide Applicator Training Coordinator, Texas A&M University, 412 HEEP Bldg. MS 2475, College Station, TX 77843

As of 1995, public school districts in Texas must make a written policy commitment to IPM as the basis for all pest control operations at school facilities. In addition, Texas law requires that (1) each school district appoint an on-staff IPM coordinator; (2) pest control treatments be conducted by a licensed pesticide applicator; (3) a 12-hour child re-entry period be observed after all pesticide applications; (4) a pesticide selection be based on the conditions of a state classification system, which places products on one of three lists:

- Green List--EPA Category III and IV pesticides that are among the following: botanical insecticides, insect growth regulators microbials, containerized baits or low-toxicity inorganics (i.e, silica gels, boric acid, diatomaceous earth).

- Yellow List--Category III and IV pesticides excluded from the Green List.

- Red List--pesticides with Danger or Warning signal words.

To help schools adopt IPM, faculty of the Texas Agricultural Extension Service, including Michael E. Merchant and Don Renchie, produced instructional video conferences, a resource guide and one-day training programs for school IPM coordinators. Curriculum modules for national distribution are in production and should be available by late 1996.

California's Integrated Pest Management Innovators Program. Lyndon Hawkins and Madeline Brattesani, Department of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, Room 161, 1020 N Street Sacramento, California 95814-5624

As a leader in agricultural production, California has a longstanding commitment to the development of IPM. Since the 1880's, the State of California, the University of California, and the United States Department of Agriculture have pioneered biological approaches to pest management in California. In 1972, the State was charged with developing and implementing pest management systems and in 1977, California formally established its IPM program.

More recently, the IPM Innovators program was established as part of Department of Pesticide Regulation's (DPR) commitment and legal mandate to encourage the development of environmentally-sound pest management programs and to give recognition to groups that have demonstrated leadership in voluntarily implementing reduced-risk pest management systems. By giving recognition to "innovators," we hope to encourage others to form IPM groups. To identify IPM Innovators, DPR developed guidelines to characterize innovative systems. Each IPM Innovator is typically a voluntary association or public organization that employs IPM practices and stresses the application of biological, mechanical, and cultural pest control techniques. The association has good pest managers who not only look at the pests at a particular site, but considers the influences of neighboring crops and landscapes and other pest control practices in the same region. This is why some of the best pest management systems involve growers working together to share ideas and practices.

Once an IPM Innovator has been identified, DPR works with them to strengthen their program and to increase adoption of their approach DPR also identifies groups that would like assistance in developing reduced-risk pest management systems. In addition, DPR strives to help established groups share their knowledge and methods with others so that new groups will form.

DPR also administers a competitive grants program to provide funds for implementation and demonstration of new pest management systems.

A Multi-disciplinary Approach to Managing Agronomic and Pest-induced Stress During Alfalfa Establishment. G. D. Hoffman, D. B. Hogg, C R. Grau, D. J. Undersander, J. D. Doll, K. A. Kelling, J. L. Wedberg, Dept. of Entomology, Dept. of Plant Pathology, Dept. of Agronomy, Dept. of Soil Science; Univ. of Wisconsin, Madison, WI 53711

We examined the direct and interactive effects of two agronomic practices and pest-induced stress on the vitality and competitiveness of three alfalfa stands at the end of the initial growing season, the following spring, and after a year in production. The four treatments were establishment method (direct seeded, and three variations on companion seedling with an oat crop), a preplant manure application (20T/a), *Empoasca fabae* (potato leafhopper) control, and a late summer application of a spore suspension of *Phoma medicaginis* (spring black stem) to increase disease severity. Plots were established in 1994 and 1995 at three sites in southern and central Wisconsin. We used a spit-split-split plot design with four blocks to incorporate the four experimental factors and the constraints imposed by their application.

Results from Hancock, WI, seeded in 1994, and a 1995 site (to be selected) will be presented in detail. At Hancock in 1994 the amount of alfalfa harvested during the seeding year was: influenced by establishment method (direct seeded>oatlage, herbicide>grain); lower in the manured plots; higher in the leafhopper control plots. The significant establishment method by manure interaction resulted from the fact that higher oat and weed abundance in the herbicide and grain plots suppressed alfalfa growth. When Hancock was harvested in spring 1995 we found that plots with less plant stress (minimal oat competition, high fertility, leafhopper control) had higher yields than plots with higher levels of stress. However, plots with higher levels of stress had more roots, but they were smaller and had fewer stems than plants from low-stress plots. Because of this pattern, stem densities were similar among treatments. These differences in plant population structure may have implications for the long-term persistence of alfalfa stands.

Integrated Pest Management For Diversified Fresh Market Vegetable Producers in New Jersey, New York & Pennsylvania: An IPM Initiative Project. M. Hoffmann, Dept. of Entomology, Cornell University, Ithaca, NY 14853, C. Petzoldt, NY IPM Group, NYSAES, Geneva, NY 14456, D. Prostak, Dept. of Entomology, Rutgers University, New Brunswick, NJ 08903, S. Fleischer and S. Spangler, Dept. of Entomology, Pennsylvania State University, University Park, PA 16802, T. Zitter, Dept. of Plant Pathology, Cornell Univ., S. Reiners, Dept. of Hort. Sciences, NYSAES, Geneva, R. Bellinder, Dept. of Fruit & Vegetable Science, Cornell Univ., and A. Shelton, Dept. of Entomology, NYSAES, Geneva

Fresh market vegetable producers in New York, New Jersey and Pennsylvania produce an array of valuable crops that are sold through many channels. The demand for these fresh and wholesome vegetables has been increasing in recent years because of their known health benefits. But at the same time, vegetables are plagued by a complex of pests that often requires intensive pesticide intervention. Progress has been made in developing and implementing cost-effective and environmentally-sensitive IPM programs for this system, but many challenges remain. Increased development and adoption of IPM practices is needed and could be achieved with a concerted public-private sector effort.

The objectives of this project are to assess the pest management needs of the producers and build teams of consultants, grower associations, environmental groups, researchers and Extension staff, producers, and others that will foster the development and adoption of IPM. To achieve the first objective, a survey has been sent to >1,000 vegetable producers in the three States to determine the vegetables they grow and the pest management (insects, weeds, diseases, vertebrate) needs of each. This information will be valuable in strategic planning and resource allocation for the region. The second objective is being achieved through a series of meetings that place IPM in the context of other issues of importance to producers (labor, marketing, etc.) and through constructive dialogue with environmental groups, produce buyers, and others attending these meetings, identify opportunities that can help address grower needs.

Toward the Development of Regional Apple IPM Guidelines in New England. Craig S. Hollingsworth, Department of Entomology, University of Massachusetts. Amherst. MA 01003; William M. Coli, U. Mass.; Lorraine M. Los, U. Conn.; Alan T. Eaton. U. N.H.; Heather Faubert U. R.I.; James M. Dill, U. Maine; Glenn Koehler, U. Maine

Extension-led committees of apple growers in five New England States were provided with copies of the 1994 Massachusetts IPM guidelines. From these guidelines, each committee developed a set of IPM guidelines which they felt was appropriate to their State. One grower from each committee was selected to demonstrate the applicability of their State's guidelines during the 1995 growing season.

Sixty-three different IPM practices were identified. These were classified into the categories of soil management and cultural practices, pesticide application and records, insect management, disease management, weed management, vertebrate management, weather and crop monitoring, and education. Twenty-three practices (37 percent) were cited by all five States as appropriate in their locality and 34 practices (54 percent) were cited by four or more States. Eleven practices (17 percent) were identified by single States.

Four States maintained the weighted point system of the original guidelines, which allow a grower to be assessed as practicing IPM or not. Growers in New Hampshire, citing apprehensions of government regulation of IPM, chose only to list applicable pest management strategies.

Long Range Tracking of Spray Drift. Ellis Huddleston, New Mexico State University, Las Cruces, NM 88003, David Miller, University of Connecticut, Storrs, CT 06269, Max Blieweiss, US Army Research Laboratory, BED, White Sands Missile Range, NM 88002

New technologies show considerable potential for tracking spray drift. The technologies are scanning LIDAR (Light Detection and Ranging) and thermal sensors (ATLAS). The LIDAR works similar to a scanning radar but uses laser light rather than microwaves. A laser beam is scanned through the spray cloud and the back scattered light from the droplets is received in a telescope. The time of return of the light is used to determine the distance to the target droplet. The system will detect droplets of all sizes down to a fraction of a micron in diameter. Its range is from 2 to 20 KM, depending on the power of the laser. The prototype LIDAR was developed by Los Alamos National Laboratory. The ATLAS was developed by the US Army Research Laboratory. It is a wide angle video system that records light in the infrared wave lengths (8-14 microns). The picture recorded of a moving spray cloud can be quantified as the integrated cross-plume concentration. Preliminary projects to date have demonstrated that a portable LIDAR can easily and accurately detect and map, in three dimensional space, the smallest droplets of spray materials released from spray planes out to distances of several kilometers from the LIDAR location. The ATLAS system has been used to visualize the spray in wingtip vortices and resulting drift. Two different LIDARs will be used this summer in an EPA sponsored project on Visualization and Quantification of Spray Drift from Orchards.

Aerial Spray Drift Mitigation. Ellis Huddleston, Mark Ledson, Robert Sanderson and James Ross, New Mexico State University, Las Cruces, NM 88003

Data are presented on several factors affecting aerial spray drift. The single most important factor is the judgment of the applicator. Flying height has been shown to be a very important variable in sensitivity analyses using the FSCGB model.

Droplet size is highly significant and can be modified by correct choices of nozzle type and orientation. Pressure is less important in aerial application than in ground application.

Adjuvants and their concentrations can affect droplet size and, under certain circumstances, lead to increased drift. Certain polymers make the big droplets bigger, reducing coverage, and make the little droplets smaller, increasing drift. Non-ionic surfactants vary greatly in their effect on droplet size.

Classical Biocontrol of the Citrus Blackfly in Corpus Christi, Texas. Raymond Huffman, Extension Agent-Entomology, Texas Agricultural Extension Service, P.O. Box 871, Robstown, TX, 78380 and J. Victor French, Texas A&M University Citrus Center P.O. Box 1150, Weslaco, TX 78599

The citrus blackly (CBF), *Aleurocanthus woglumi* Ashby, has been a pest of citrus in Florida and southern Texas since the middle 1950's. In 1992, the CBF became a serious pest for the first time on dooryard citrus in the large urban area of Corpus Christi. A database of citrus owners in the city was established. Two parasitoids *(Encarsia opulenta* and *Amitus hesperidum)* specific for the CBF, which had been previously used in other areas with success, were transported to Corpus Christi from the Texas A&M University Citrus Center in the Lower Rio Grande Valley after it was determined that these parasitoids most likely did not occur in Corpus Christi. Using volunteer Master Gardeners, a total of 4 releases at 27 different citrus locations over a 16 month period from 5/93 to 9/94 were made. Subsequent collections and evaluations indicated that by 9/94, the parasites had dispersed widely and populations had become established Parasitized CBF samples were collected at several locations where releases had not been made. Numerous citrus owners noted a dramatic improvement in the CBF situation during this period. Continued evaluation and monitoring is planned.

Strategic Planning for Enhancing IPM Adoption in Processing Vegetable Crops: The National IPM Initiative. William D. Hutchison, Coordinator, Department of Entornology, University of Minnesota, St. Paul. MN 55108

This IPM project for processing vegetable crops (sweet corn, snap beans and peas) is one of 23 funded planning projects of the National IPM Initiative. Because of close cooperation with the Midwest Food Processors Assoc. (MFPA), the geographic focus for this project is the upper midwest, specifically Minnesota, Wisconsin, Illinois and Indiana. The project includes decision-makers and all major parties involved in assisting growers and processing companies in making IPM decisions. Specifically, representatives from all major processing companies in the upper midwest (active mernbers of MFPA), growers, Departments of Agriculture (MN and WI), and research and extension specialists covering all pest disciplines from each of 4 universities (Minnesota, Wisconsin, Illinois & Purdue) are involved. The IPM team met January 3-5, 1996 in Madison, Wisconsin, to begin the formal planning process, with specific goals of identification of current obstacles for implementation in processing crops, a review of the current status of IPM, and priorities and action plans for research and IPM implementation and assessment over the next 5 years. Specific needs included: hybrid-specific response (tolerance/ resistance) to insects, pathogens and herbicide-insecticide-pest interactions, region-wide use of standardized forecasting models (e.g., degree days), centralization of models, weekly insect monitoring (e.g., trap networks) info., use of GIS-based pest maps, adaptation of WISDOM decision-making software (Univ. of Wisconsin) for sweetcorn/snap beans, and more use of internet resources (e.g., WWW) to deliver information to decision makers in a timely manner. Planning for a complete 5-year project is in progress.

Alternative Pest Control for the Home Garden. Douglas W. Johnson, Department of Entomology, Patty L. Lucas, Integrated Pest Management Program, Winston Dunwell, Department of Horticulture and Landscape Architecture, University of Kentucky Research and Education Center, P.O.

Box 469, Princeton, KY 42445 and Ricardo Bessin, Department of Entomology, University of Kentucky, Lexington, KY 40546

As society places more emphasis on pesticide reduction, IPM programs are making pesticide reduction a major goal. To aid commercial producers in reducing pesticide usage, Kentucky offers Integrated Pest Management information and formal trainings for field crops, apples and tomatoes. Tho IPM information and training programs are provided free of charge and are open to everyone, however, the information provided has been geared toward commercial producers. Based upon the number of requests received by specialists, it was determined that a need existed for IPM training and demonstration programs for the home garden. Two popular crops, tomatoes and sweet corn were selected for use in demonstrations. Tomato plots were used to allow home gardeners to view different types of mulch, their ability to control weeds and their durability. Additionally, the techniques of applying rubber bands (for ear tip closure) and mineral oil were demonstrated as alternatives to insecticides for control of earworm in sweet corn. Seeing is believing has become the guideline for developing home garden demonstration programs.

Small Grain Cover Crops as an Alternative Method of Weed Suppression in Soybeans. Thomas N. Jordan and Brad A. Miller, Department of Botany and Plant Pathology. Purdue University. West Lafayette, IN 47907

Environmental concerns as well as State and Federal regulations have caused an increase in both the awareness of pesticides in the environment and the need to produce soybeans without tillage to prevent soil erosion. These two contrasting concerns have lead to research investigations into the use of small grain cover crops to reduce erosion as well as reduce weed species which are common in soybean fields. Earlier research has shown that small grain cover crops will suppress weeds in no-tilled soybeans while eliminating the need for many of the soil applied residual herbicides. The objective of this research was to compare different small grain crops for their weed control properties when compared to tilled and no-tilled conventional soybean production systems using herbicides. Four small grains were used in no-tilled systems: spring planted winter wheat spring planted winter barley, fall planted winter wheat and fall planted rye.

The Relationships Between IPM Adoption and Natural Resource Characteristics in Corn Production. Catherine Kascak and Sharon Jans, Natural Resources and Environment Division, Economic Research Service/USDA, 1301 New York Avenue, NW, Washington, DC 20005-4788

The overall objectives of this project are to: 1) identify if environmental factors influence the decision to adopt integrated pest management (IPM) techniques for corn producers in different regions of the U.S. and (2) to identify those areas that would realize the greatest environmental benefits from adopting IPM practices. Because not all areas are equally vulnerable to pesticide leaching, the effectiveness of any reduced chemical use associated with IPM practices will depend in part on the distribution of soil, land, and climatic properties facing a farmer.

Using data collected from the USDA Area Studies Survey, we will explore how IPM adoption varies by resource base. The Area Studies data is unique in that it coincides with National Resource Inventory (NRI) points. The NRI provides data on soil, water, and related natural resource properties. This link to a resource base will enable us to identify areas prone to leaching and the probability that they would voluntarily adopt IPM practices. Using GIS technology, we will then display areas with vulnerable soil and land properties that are not currently using IPM technologies.

Planetor: An Environmental and Economic Planning System. Kevin Klair, Department of Applied Economics, University of Minnesota, St. Paul, MN 55108

Planetor is a comprehensive environmental and economic farm planning software program. It combines site specific environmental models with individual farm economic planning data to evaluate the impacts of changing pesticide, nitrogen, phosphorus and manure applications, tillage systems, and crop rotations.

Planetor evaluates alternative management plans for individual farms and compares the impacts on soil erosion, nitrate leaching, phosphorus runoff, pesticide movement, and whole farm profitability.

Implementing Integrated Farm Management Systems for Winegrape Production. Karen Klonsky, Extension Specialist Dept. of Agricultural Economics and Frank Zalom, Extension Specialist. Dept. of Entomology, University of California-Davis

This project is being conducted with growers of the Lodi-Woodbridge Winegrape Commission and researchers from the University of California. The Lodi-Woodbridge Winegrape Commission is comprised of more than 600 winegrape growers producing dozens of varieties of grapes on 45,000 acres in California's San Joaquin Valley. In 1992, the Commission embarked on an IPM program with the dual objectives of promoting effective and rapid adoption of sustainable winegrape production practices, and promoting economic and social development in San Joaquin County by implementing a marketing program designed to create a market niche for winegrapes which are produced using environmentally sound viticulture practices.
The purpose of this project is to determine energy and production costs for vineyards of growers who are high users of energy efficient and sustainable production practices, to implement sustainable practices on vineyard blocks of growers who are not currently high users of such practices, and to educate all growers within the District on how they may adapt these findings to their operations. To accomplish this, ten vineyards have been selected on which replicated trials of innovative insect and weed control practices could be demonstrated. Cultural operations performed by the cooperating growers were recorded to estimate production costs for economic comparisons and to characterize vineyards in terms of high use to low use of both energy efficient and sustainable practices.

The cost of disease and insect control pesticides ranged from $13 to $507 per acre across the project vineyards. We had anticipated this extreme variance as the growers were chosen based upon their variation in production practices. High costs were attributable to the use of sterol-inhibiting fungicides rather than sulfur. Floor management costs ranged from $34 to $185 with most of the variation due to herbicide treatments along the vine rows. The total cost of production ranged from $1,487 to $2,664 per acre, averaging $1,998. Net returns averaged $1,176 per acre with only one vineyard showing a negative return. Interestingly, the vineyards with moderate costs showed higher net returns than the high-or low-cost vineyards.

Dispersal of Diamondback Moth, *Plutella Xylostella* L., From Cruciferous Weed Hosts. Peter Kmec and Michael J. Weiss, Dept. of Entomology, North Dakota State University, Fargo, ND 58105

Cruciferous weeds are suitable hosts for the first generation of the diamondback moth (DBM) in the northern U.S. We studied the dispersal of DBM from field pennycress, *Thlaspi arvense* L., into neighboring weed patches and the crop host, *Crambe abyssinica* Hochst. Adult males marked with Uvitex OB and Blaze Orange powders were released and recaptured in pheromone traps. The first release of 1,200 males was done before the crop emergence when the weeds were in the flowering stage. A total of 35 moths were recaptured, out of which five were recovered in the neighboring weedy patches. On the second release of 2,400 males, the crop was in the fourth leaf stage and the weeds were fully mature. A total of 20 moths were recaptured, out of which one was found in an adjacent weedy patch and two were found in the crop. During the second recapture experiment, there was an increase in trap captures of unmarked moths in the crop, which coincided with a period of southerly winds. The population in the crop may have been established be immigration rather than by dispersal movement from the weeds.

Applying Trichogramma to Cotton for Control of Bollworms in Texas. Allen Knutson, Extension Entomologist. Texas Agricultural Extension Service, Texas A&M University, 17360 Coit Road, Dallas, TX 75252

Several species of minute wasps of the genus Trichogramma parasitize eggs of bollworms and budworms in cotton. However, these beneficial insects are often not abundant enough to significantly reduce pest numbers. Several commercial insectaries promote and sell Trichogramma for release in cotton, although there is little research information on how to use best use these natural enemies. With the reduction in insecticide use in the southeast following boll weevil eradication and the continued problems of pesticide resistance and secondary pests throughout the Cotton Belt, there is renewed interest in biological control of cotton insect pests. One constraint to the evaluation and use of Trichogramma has been the lack of a machine to apply Trichogramma to field crops such as cotton.

Recently, the USDA invented a tractor-mounted machine, termed the biosprayer, that can be used to rapidly and uniformly apply Trichogramma to row crops. This machine, now under commercial development, was evaluated in this study. Results showed that application through the sprayer reduced Trichogramma emergence from host eggs by about 22 percent. Modifications of the sprayer are underway to reduce this mortality. Additional mortality resulted from predation, primarily fire ants. In the absence of predators, rain and dew, 88 percent of the applied host eggs were retained on cotton leaves for three days. Most (79 percent) of the host eggs recovered in the cotton canopy were deposited in the plant terminal. Application of 100,000-200,000 Trichogramma per acre twice a week did not consistently increase parasitism of bollworm eggs in field plots. The high cost of Trichogramma and the variable level of control are current constraints to the adoption of this practice by cotton producers.

Cropping Sequences With Resistant And Susceptible Soybean Cultivars And Nonhost Crops For Management of The Soybean Cyst Nematode. S.R. Koenning and K.R. Barker, Researcher and Professor, Box 7616, Department of Plant Pathology, North Carolina State University, Raleigh, NC 27695-7616

The soybean cyst nematode, *Heterodera glycines*, (SCN) is the most serious soybean pathogen in North Carolina. Rotation with nonhost crops (corn, tobacco, cotton or peanuts) and the use of soybean cultivars resistant to soybean cyst nematode are currently the primary means for managing this nematode. A recent survey of 10 North Carolina counties with significant soybean acreage indicates that more than half of the populations of SCN can be classified as race 2. Cultivars resistant to race 2 of SCN, however, are not generally available. A new soybean variety, Hartwig, has a high degree of resistance to all North Carolina populations tested thus far, including *H. glycines* race 2. A rotation study was initiated in 1993 on a farm in Washington County, NC, on land infested with race 2 of soybean cyst nematode to evaluate the durability of the Hartwig type resistance to SCN. Rotational sequences of Hartwig with a susceptible soybean cultivar and (or) a nonhost crop have been evaluated over 3 years. A total of 24 treatments, arranged in randomized complete blocks with 4 replications, are being used to monitor soybean yield and population densities of H. *glycines* in seven cropping sequences. The yield of resistant Hartwig was slightly greater than that of susceptible Deltapine 105 in 1993, but numbers of SCN eggs were much lower following corn or Hartwig than after Deltapine 105 ($P = 0.05$). In 1994, yields of Hartwig or susceptible Hutcheson were greater following corn than yields of either variety following soybean. The lowest soybean yield occurred in plots with 2 years of Hutcheson. Numbers of cyst nematodes were much lower following corn or Hartwig in 1994, compared to susceptible Hutcheson. Data from 1995 indicated that yields of

Hutcheson soybean were greatest when this variety was grown in a 3-year rotation with either 2 years of corn or corn and SCN-resistant Hartwig as the previous crops. The lowest soybean yield of any rotational sequence in 1995 was with continuous Hutcheson. Although these data are preliminary, the sequence of corn-resistant soybean variety-susceptible variety appears to be a viable rotation when soybean must be grown 2 out of 3 years.

Communicating IPM: a Picture Is Worth a Hundred Words. Carrie Koplinka-Loehr, Writer/ Editor, New York State Integrated Pest Management Program, Box 28 Kennedy Hall, Cornell University, Ithaca, NY 14853 [phone, 607-255- 8879, e-mail, ckk3@Cornell.edu]

Visual aids are essential for conveying IPM methods to all audiences. Yet photographing and drawing such concepts as "pest-resistant varieties" or even "pesticide resistance" is extremely challenging. The New York State IPM Program educates producers, legislators, extension personnel, consumers, and others with the help of drawings, photographs, slides, videotapes, and the World Wide Web. With this interactive poster session I will show some wares and address specific challenges. Workshop participants will be invited to suggest resources that could be of use to IPM educators. After the symposium, the resulting list will be shared with those interested

Role of BPPD/EPA in Regulatory Relief of Biological Pesticides. John Kough, Freshteh Toghrol, Frank Ellis & Roy Sjoblad, U.S. Environmental Protection Agency, Office of Pesticide Programs, Biopesticides and Pollution Prevention Division (7501W), Washington, DC 20460

Two major functions of the Biopesticides and Pollution Prevention Division in the Office of Pesticide Programs at EPA are to apply the best scientific information to the regulation of biological pesticides (biopesticides) and to promote the implementation of reduced risk pesticides. EPA defines biopesticides to include biochemical pesticides, microbial pest control agents and transgenic plants. The criteria used to delineate groups of biopesticides are discussed. Because many biopesticides are essential tools in IPM programs, OPP's efforts to facilitate their registration are presented. Current policy developments to streamline the registration of pheromones include expanding the acreage limit for experimental uses and reducing data requirements for registering lepidopteran pheromones. Rationales for the reduced data requirements for biopesticides are presented. Some biopesticide active ingredients, along with a number of chemical pesticidal active ingredients, are being exempted from health and environmental safety requirements due to their widespread use for non-pesticidal purposes, non-toxic modes of action, lack of probable environmental persistence, insignificant exposure as a pesticide, and/or a previous determination of safety by the Food and Drug Administration. The generic food tolerance exemptions for plant growth regulators and polymeric inerts for pheromones are explained.

Research, Extension, and Implementation of IPM in the Major Apple Production Regions of New York State. Joseph Kovach, NYS Fruit IPM Coordinator, IPM Program, Cornell University, NYSAES, Geneva, NY 14456, Harvey Reissig, Dept. of Entomology, Cornell University, NYSAES, Geneva, NY 14456, Dan Donahue. NYS Horticultural Society, NYSAES, Geneva, NY 14456

The primary goal of this planning project was to increase the adoption of biointensive IPM methods through a public and private partnership so that growers can reduce applications of conventional pesticides while maintaining abundant yields of high-quality fruit. New York has approximately 53,000 acres of apples that are concentrated in three different regions: western New York along Lake Ontario, the Hudson Valley, and the Champlain Valley. Each of these regions has a different climate, soil, pest complex, apple cultivar mix, and marketing strategy. These combined regions form a unique apple production unit compared to other fruit growing areas in the United States and in the northeastern U.S. The NY apple industry has worked actively during the last several years with the International Apple Institute to develop a plan in response to the national commitment by various Federal agencies to develop and implement integrated pest management methods on 75 percent of the total USA crop acreage by the year 2000. Also, Cornell University, in cooperation with NY State Department of Agriculture and Markets, developed a long-range plan to identify research projects and set extension priorities to enhance IPM implementation in apple orchards. To more fully develop a unified plan, an implementation team was created that included Cornell research and extension personnel, growers, private consultants, State regulators, and environmental and consumer representatives with the goal of defining IPM and prioritizing research and extension needs. Growers in the three regions were then surveyed on which of these practices they currently use, so baseline adoption rates could be established. Outputs from these implementation team meetings and grower survey results will be presented.

A Method for Assessment of Integrated Pest Management Practices. Ronald D. Lacewell, Professor, Dept. of Agricultural Economics; George L. Teetes, Professor, Dept. of Entomology and Richard A. Frederiksen, Professor, Dept. of Plant Pathology and Microbiology, Texas A&M University, College Station, TX 77843

To evaluate an IPM program, there must be a baseline for comparison. This is the basis of benefit/cost analysis and quantifying changes in environmental indices. It is important that the test reach over several seasons. Essential to the process is involving a cross-section of disciplines, research and extension at the beginning. It is convenient to discuss evaluation alternatives separately, such as economic, environmental, and technology transfer.

Economic. A basic economic method applicable for IPM evaluation is budgeting. At the level of most detail is a per unit budget (enterprise budget). Partial budgeting involves quantifying only the outputs and inputs that change with the IPM practice. Whole farm analysis involves a firm level study. Watershed or regional level analysis is useful for an environmental evaluation. Macroeconomic analysis provides the expected impacts on cropping patterns across the U.S., potential commodity price impacts and quantification of effects of the IPM program on farmers, profit (surplus) and consumers, well-being (surplus) for major regions, the nation and the world.

Environmental. The art of simulation of natural processes has evolved dramatically in the last few years. Application of simulation models allows estimating a distribution of crop yields over weather patterns as well as percolation and runoff of agricultural chemicals, nutrients and soil erosion. The measurements on chemicals and nutrients leaving a plot of land is best taken as a relative measure between the conventional and the IPM practice rather than absolute estimates. Hydrologic and transport models can then take the micro location simulated data and track fate and transport across a watershed and/or river basin. Again this provides insight into the effect of the IPM program on relative amounts of pollutants leaving the watershed or reaching major watercourses.

Technology Transfer. A recommended goal to be incorporated into transfer of an IPM program is a users, decision aid that includes pest management, agronomic issues, economic and other disciplines as dictated by the specific region and IPM program. The decision aid can be dynamic using interactive compact disk technology.

A Survey of Homeowners to Determine Landscape And Garden Pest Management Practices, Water Quality Awareness, and Preferred Learning Methods. S.E. Lajeunesse, G.D. Johnson, and J.S. Jacobsen, Johnson Hall, Montana State University, Bozeman, Montana 59717

Adult education materials and programs that are designed, produced, and delivered to specifically address areas of learner interest and need can provide incentive for active participation in the learning process. As an initial step in designing a new Urban Pest Management Program at Montana State University-Bozeman, a mail survey of 1,040 households was used for audience analysis and needs assessment. Questions focused on management practices for pests, pesticides, and fertilizers, water resource protection, and preferred methods of learning. Non-response bias was estimated by telephone follow-up. Combined survey response rate was 56 percent. Results show homeowners' primary source for problem-solving information is businesses selling landscape supplies (56 percent). Most are aware (54 percent) or somewhat aware (32 percent) of related water quality issues, and pest control products are considered "safe if used properly" (45 percent) or "somewhat safe if used properly" (40 percent), but few precautions are taken when using pesticides. Most homeowners are "very interested" (43 percent) or "somewhat interested" (38 percent) in learning more about least- toxic methods of pest management. Methods of learning considered most effective are printed materials, hands-on participation, educational videos, and demonstrations by specialists. Workshops, salespeople, radio, and personal computer programs are rated least effective. Preferred types of instructional programs are self- taught (51 percent) and least preferred is learning in a group setting such as a workshop or a short-course (19 percent). As a result of the survey, our audiences' needs and interests have been identified, enabling program design, development and delivery to concentrate on areas with greatest potential for results.

Montana State University Outreach Pest Recommendation Network: Delivering IPM Solutions. Will Lanier, Dept. of Entomology, 324 Leon Johnson Hall, Montana State University, Bozeman MT 59715; Jack Hanson, Agricultural Experiment Station, 213A Linfield Hall, Montana State University, Bozeman MT 59717; and Greg Johnson, Dept. of Entomology, 324 Leon Johnson Hall, Montana State University, Bozeman MT 59715

The importance of information regarding agricultural pest control is evident from the diversity of handbooks, manuals and Extension publications. Historically pest identification and IPM recommendations have been delivered via interactions with specialists and county agents using written, verbal descriptions and advice. These interactions may use static information like publications, or dynamic information, which allows recommendations to be based on current conditions as interpreted by a specialist.

Currently, delivery of dynamic information is limited by physical location and personal interaction. The objective of the MSU Outreach Pest Recommendation Network (PRN) is to remove the physical limitations of dynamic pest recommendation delivery. The PRN facilitates the use of dynamic aspects of IPM recommendations for individuals concerned with pest control. The PRN method employed describes relevant factors leading to a recommendation, general facts about the pest and timely control measures. Comparing old situations to new cases, using a method known as Case Based Reasoning, it is possible to match the user's current situation with IPM solutions.

At MSU there are limitations to delivering pest recommendations to remote users. Currently the PRN project is looking at two delivery methods using the World Wide Web. One option is to deliver the PRN using an Oracle database, PEARL SQL scripts and interactive forms using HTML code. The other option is a Windows 95 Web server, Visual Basic interactive forms and ODBC drivers querying an Oracle database.

A Weather-based System for Scheduling Fungicide Sprays for Control of Alternaria Leaf Blight of Muskmelon. R. Latin and K. J. Evans, Department of Botany and Plant Pathology, Purdue University, West Lafayette, IN 47907-1155

A weather-based system for scheduling fungicide sprays for control of Alternaria leaf blight of muskmelon was developed and implemented in Indiana during the 1994 and 1995 growing seasons.

The system is based on a statistical model that defines the effects of temperature and leaf wetness duration on disease establishment. The number of hours of wetness during a day (24 h) and the mean temperature during the wetness period are used to compute a daily environmental favorability index (EFI). Daily EFI values are accumulated throughout the season. Fungicide sprays are recommended at intervals of 20 cumulative EFI values. The model was programmed into a battery operated microprocessor attached to leaf wetness and temperature sensors in the field. All of the hardware is mounted on a portable frame. The MELCAST (Melon Disease Forecaster) system was tested in commercial fields and experimental research plots. In all field tests, use of the weather-based system resulted in fewer fungicide applications than a conventional 7-day spray schedule, without an increase in disease severity The system was implemented in 1994 and 1995 throughout the melon-growing region of southern Indiana. A communications network was established to post cumulative EFI values on a voice-mail device every day so that area farmers could access MELCAST via a toll free phone number.

The Role of Natural Enemies in Developing Sustainable Landscapes: A Lesson From Azaleas. Paula Leddy-Shrewsbury and Michael J. Raupp, Department of Entomology, University of Maryland, College Park, MD 20742

An analysis of pest occurrence revealed that *Rhododendron* was one of the most pest-prone genera of landscape plants found in the mid-Atlantic region, often with excess of 50 percent of the plants under pest attack. The single most important pest of azaleas in Maryland's landscapes is the azalea lace bug, *Stephanitis pyrioides*. Theories concerning factors that control the abundance of herbivorous insects have been prominent in the history of ecology. Particular attention has been paid to habitat diversity and its effect on phytophagous insects and their natural enemies. The more complex and heterogeneous an environment, the more kinds of species it will hold. Little work has been done on the influence of habitat diversity on herbivores and natural enemies in landscape systems. However, we have found that azalea lace bug infests and damages azaleas located in sunny habitats more frequently than in shady habitats. Preliminary studies have shown that light exposure is strongly, negatively related to architectural complexity (a measure of habitat diversity) in landscape habitats. We examined four hypotheses that explain the distribution of lace bugs in home landscapes. First, we tested the hypothesis that direct or habitat-mediated effects on the host plant influenced the distribution of lace bugs on azaleas and found no support for this hypothesis. Next, we examined the direct effect of temperature on lace bug survival and development and found this too could not explain patterns observed in the field. Previous studies revealed that habitat-related plant stress also did not explain lace bug distributions. Finally, we determined that differences in the abundance and structure of natural enemy communities differed between simple and complex habitats and that these factors combined with slower development of lace bugs in complex sites explained well the distribution of lace bugs. Our study will provide landscape architects and managers with knowledge to facilitate the design of sustainable landscapes that require fewer inputs of pesticides.

A Program That Stimulates Collaborative IPM Efforts in Urban IPM. Anne R. Leslie, Estella Waldman, US Environmental Protection Agency, Biopesticides and Pollution Prevention Division (7501W), 401 M St., S. W. Washington, DC 20460

Concern over the magnitude of urban use of pesticides and resulting effects on human health and the environment have led to a number of community and corporate efforts to establish IPM programs. Community organizations have successfully lobbied for legislative requirements for IPM programs in the schools and are designing training programs for pest control personnel. Many homeowners are questioning the American landscaping ethic that relics on extensive use of pesticides on lawns that occupy more land than any single crop in the United States. Nevertheless, there are great environmental and health benefits to urban landscaping, through the ability of grass to modify extreme temperatures and filter pollutants from the air. IPM programs that reduce pesticide use are a solution to the problem. One program that has been enthusiastically adopted by citizens and by corporate organizations is the Audubon Cooperative Sanctuary Program, designed and implemented by the New York Audubon Society. The program encourages property owners, both corporate and private, to improve wildlife habitat on their property, and to adopt IPM programs to control problems that may occur. The U.S. Golf Association (USGA) Green Section Research Committee, seeking ways to improve stewardship of the environment, initially endorsed and funded the program for golf courses. It has been enthusi-astically adopted by the Golf Course Super-intendents Association of America (GCSAA). More than 1500 golf courses have enrolled, and a growing number have obtained certification as sanctuaries. In addition, the Professional Lawn Care Association of America (PLCAA) is exploring implementation of the program for their member companies. Both PLCAA and GCSAA have become Partners in EPA's Pesticide Environmental Stewardship Program (PESP), and the IPM component of the Sanctuary program is a key part of their strategies to reduce the risk and use of pesticides in the turfgrass industry.

A Criteria and Indicator Matrix of Environmental Impacts: A Tool for Use in Assessing Agricultural Pest Management Products and Strategies. Lois Levitan and Ian Merwin, Dept. Fruit & Vegetable Science, Cornell Univ., Ithaca, NY 14853

What factors should be taken into consideration in assessing agricultural systems? Typically, an accounting is made of direct economic costs, productivity, and the quantity and efficacy of pesticides and other inputs. With the growing concern about non-target environmental impacts of plant protection products and methods, we are now being challenged to develop accounting systems which can assess environmental impacts as well. This raises several non-trivial questions: (1) what parameters should be included as descriptors of the environment? (2) which indicators should be used to register effects on the selected environmental variables? and (3) how should these impacts be measured?

This 'Criteria and Indicator Matrix' provides a framework for organizing information pertinent to answering these questions. The Matrix compiles relevant information about a wide range of environmental indicators that have been proposed for inclusion in assessment systems. It highlights data sources, pinpoints data gaps, and stimulates discussion about how and if missing data can be supplied or imputed. The Matrix is a means of organizing a confusing array of information useful for environmental impact assessment into a transparent format that retains clarity about the assumptions and criteria upon which judgments are based.

For each environmental variable listed as a row item in the Matrix, information is provided in the cells of the Matrix to identify (1) the toxicity tests or other bases for judging the impact of a pest control method; (2) the criteria for assigning a pest treatment to a given category of impact (positive, neutral, or negative); (3) the source of the information provided for each row item; and (4) the source and reliability of datasets relevant to each variable.

Criteria or algorithms for delineating between and describing each category of impact are based upon the expert judgments of specialists, as reported in the scientific literature or personal communication. Categories of impact can be scored to reflect functional impacts on the environment. and compiled scores can be used to index the relative extent and severity of impacts of different pest control products and systems.

Pest Control Environmental Impacts Index: A Method for Assessing Apple Pest Management Practices in the Northeast. Lois Levitan, Ian Merwin, Joe Kovach, Department of Fruit and

Vegetable Science, Cornell University, Ithaca NY, 14853

Conventionally-produced apples in the Northeast US often receive more than twenty pesticide applications annually -- among the highest rates used on food crops. This pesticide use can pose risks to human beings and other non-target biota. However, high temperatures and humidity during the growing season, as well as cultural factors, cause heavy pest pressure and a large pest complex in apple orchards in the Northeast. We describe an assessment system being developed to aid growers and those who advise them in choosing effective plant protection methods which take the least toll on the environment and public health. The system provides information and a relative ranking of the environmental impacts of different pesticides and non-chemical plant protection methods.

The assessment procedure involves (1) specifying the environmental parameters to be considered; (2) identifying criteria for categorizing the extent and severity of impacts; (3) determining scores for the categories; (4) assigning relative weights to the environmental indicators, depending both upon the priorities and exigencies of users and also upon site-specific variables; and (5) establishing a formula for compiling ratings for each impact into a composite score for each pest control product or practice. The list of composite scores constitutes the Pest Control Methods Environmental Impacts Index.

The methodological approach outlined in this five-step process is used to evaluate the relative environmental and economic impacts of alternative apple pest management strategies. The framework of this assessment system is intended to keep the assumptions of the assessment transparent, and to enable situation-specific modifications. This decision model is being applied to an assessment of apple pest management practices in the Northeast U.S. by simulating alternative production scenarios.

Expert System for Integrated Management of Wheat Diseases And Sustainable Wheat Production. Roland F. Line, Agricultural Research Service, U.S. Department of Agriculture, Pullman, WA, 99164-6430

An expert system for managing wheat diseases referred to by the acronym MoreCrop (Managerial Options for Reasonable Economical Control of Rusts and Other Pathogens) was developed for the U.S. Pacific Northwest. The purpose of MoreCrop is to present outcomes that may happen and options for control. The user evaluates the provided information and by a process of reasoning determines the most economical control. MoreCrop was developed using the enormous knowledge base on wheat diseases together with tools from recent technological advances in the computer industry. It provides information, options, and suggestions to help the user make decisions regarding management of wheat diseases. MoreCrop predicts what diseases are likely to occur based on selected geographical regions, agronomic zones, crop managerial practices, cultivar characteristics, prevailing weather, crop history, and disease history and provides the reasons for the disease outcome. The classical disease triangle is used as the overriding principle in predicting the diseases; i.e. a susceptible host, a virulent pathogen, and a favorable environment must exist for the disease to develop. It considers the diseases that are likely to occur and evaluates integrated disease management (IDM) options. It can suggest an IDM program or provide an opportunity to develop a customized IDM program. It evaluates the IDM program, provides a list of diseases that can and cannot be controlled, and provides the rationale for control or absence of control. MoreCrop also provides disease-related information for teaching, research and extension. The concepts of MoreCrop can be extended to include fertility management and management of other pests. Thus, MoreCrop can serve as a prototype in developing a total wheat management program. Its programming structure, visual controls, and principles should be easily adapted for use in IDM of other crops or in other regions of the world. For details about MoreCrop, contact Roland F. Line, Agricultural Research Service, U.S. Dept. of Agriculture, 361 Johnson Hall, Washington State

University, Pullman, WA, 99164-6430, telephone: 509/335-3755. To purchase MCP22 MoreCrop, contact Washington Cooperative Extension Bulletin Office, Cooper Publication Building, WSU, Pullman, WA 99164-5912, Telephone: 509/335-2857.

Influence of Rye and Hairy Vetch Residues On herbicide Fate and Establishment of Selective Broadleaf Weeds. Martin A. Locke and Reid J. Smeda, USDA-ARS, P.O. Box 350, Stoneville, MS 38776

Production of agronomic crops using cover crop residues is one practice of conservation management. The fate of herbicides in soil is affected by their interception on cover crop residues. We evaluated sorption of four herbicides (2,4-D, alachlor, acifluorfen. and fluometuron) to rye *(Secale cereale)*, hairy vetch (*Vicia villosa)*, and Dundee silt loam soil. Initial characterization of herbicide sorption in Dundee soil and partially decomposed rye and hairy vetch involved simple batch experiments. For all four herbicides, sorption was greatest in rye and lowest in soil. In rye, the relative sorption of herbicides was acifluorfen > alachlor > fluometuron >> 2,4-D. Sorption to hairy vetch was the same as to rye, except that alachlor sorption was greater than that of acifluorfen. The order of sorption in soil was alachlor > fluometuron > acifluorfen = 2,4-D. Herbicide sorption in soil was attributed primarily to humic components, but interaction with clay minerals in soil has been observed in other studies. In another experiment. residues of rye and hairy vetch were compared with no cover for suppression of pigweed *(Amaranthus sp.)*, common cocklebur *(Xanthium strumarium* L.), hemp sesbania *(Sesbania exaltata* (Raf.) Rydb. ex A. W. Hill), morning glory *(Ipomoea sp.)* and sicklepod *(Cassia obtusifolia* L.), five significant broadleaf weeds in soybeans. Both rye and hairy vetch were seeded in the fall of 1993 and 1994 and desiccated the following spring with paraquat. In both 1994 and 1995, rye and vetch residues reduced the mean density of the 5 weeds compared to the no cover plots up to l 00 and 64.7 percent, respectively, 4 weeks after desiccating the cover crops. By 6 weeks after desiccation, rye suppressed weed establishment up to 90.5 percent while vetch only provided up to 7.1 percent suppression. Eight weeks after desiccation, rye residues suppressed weed densities up to 46.2 percent, but no differences were measured between vetch residues and no-cover plots. Despite differences between years, residues of rye were clearly superior to vetch and the no cover plots. Full-season weed management in crop production systems using cover crops will require the application of selective herbicides, depending upon the weed species present.

Insecticide Resistance Action Committee. John Lublinkhof, Vice Chairman/Secretary - IRAC, c/o AgrEvo USA Company, 2711 Centerville Road. Wilmington, DE 19808

The Insecticide Resistance Action Committee (IRAC) was formed in 1984 to provide a coordinated agrichemical industry response to the global development of resistance in insect and mite pests. IRAC has been instrumental, along with other groups, in surveying product failures due to resistance; developing practical monitoring methods; publishing management guidelines; and sponsoring fundamental and applied research in several countries. IRAC is now concentrating its resources on local implementation of resistance management strategies by growers; establishing the relationship between monitoring data and level of control in the field; and educating all involved in crop protection.

IPM on The World Wide Web: The National IPM Network - Northeast Regional Server. Ian MacRae & T.O. Holtzer, Dept. of Entomology, Colorado State University, Ft. Collins, CO 80523 [http://www.colostate.edu/Depts/IPM/IPM.html]

The transfer of information from the researcher to the end-user is vital in facilitating the adoption of any new technology. World Wide Web (WWW) sites on the Internet have rapidly become an important information tool for a wide variety of topics. This increased popularity results from a number of factors: the software to access the information on WWW sites is essentially free to non-commercial users, the software's interface makes the transfer of text and graphic information 'user-friendly' and simple, and access to the Internet through commercial providers is becoming easier and less expensive. Commercial interests are taking advantage of the WWW for a number of purposes but are motivated by economics; WWW is an inexpensive and effective way of reaching a widely distributed body of consumers. In addition, WWW sites are easily developed and rapidly modified. The increased popularity of the WWW presents an opportunity to provide information on Integrated Pest Management techniques to a wide audience of end users at a minimal cost.

The National Integrated Pest Management Network (NIPMN) has established a system of regional servers containing IPM information and resources. These sites also provide real-time weather data, market reports, and pest alerts; the most recent pesticide label information; and numerous other types of IPM- related data. In addition, they will incorporate interactive resources such as keys to pest species and expert systems for identification and decision support.

Demonstrations of the resources available on these servers will be provided and future resources and potential uses discussed. An assessment of the economic advantages provided through electronic publication of extension materials will be presented.

The Role of Incentives in the Success of IPM Implementation Projects. Michele C. Marra, Department of Agricultural and Resource Economics, Box 7509, North Carolina State University, Raleigh NC 27695-7509

There have been millions of public dollars expended to attempt to influence farmer decisionmaking in the area of pest management. Strategies for implementation include development of area- wide cooperative plans, such as the cotton boll weevil project, promotion of Best Management Practices, establishment of IPM positions within extension, to name a few. Some efforts have been highly successful, while others have not. The reasons for the unsuccessful efforts may include failure to recognize and allow for the incentive structure involved among the various participants in the process. This poster illustrates the incentive structure in operation when an interdisciplinary group composed of academics, technology transfer personnel (both public and private), personnel from other government agencies and farmers interact. These incentives can be very different, even though the societal goals are the same. Differences can exist even between members of the same subgroup. An assistant professor may have different incentives than a tenured professor in influencing the design and implementation of the project. Both extension and chemical supply per-sonnel have incentives that may be in conflict with researchers and farmers, as well as with each other. Farmers may have motivations not immediately apparent, but that affect the success of the implementation strategy. This disparity must be taken into account when devising strategies for IPM implementation. Several questions should be asked periodically as a project progresses. For instance, when is it appropriate to redirect or aban-don a particular strategy? The goal of the presenta-tion is to outline participants' incentives and institutional factors, such as the tenure system, liability rules, and the market influencing those incentives.

Levels of Analysis in Integrated Pest Management Research. Daniel G. McDonald, Carroll J. Glynn, Michael Hoffmann, Curt Petzoldt, 315 Kennedy Hall, Cornell University, Ithaca, NY 14850

The implicit assumption in promoting interdisciplinary research is that information from disparate sources can be combined so that the conclusion of the study is stronger than any which could have been done if the researchers had each done separate studies. The techniques for the Combination of Information (CI) have been developed and applied in many fields, and a number of these have gained prominence in their usefulness in summarizing large bodies of information (e.g., meta-analysis). However, little work has helped develop or provide application of CI approaches in strengthening interdisciplinary research, where it may be needed most of all.

In addition to being nontraditional, and thus controversial, the use of different levels of analysis may take the researcher into areas in which there is little theoretical or empirical guidance about a particular concept. Even worse, the unit of analysis of data collected by a second scientist may be incompatible with that collected by the first scientist, so that CI cannot be done easily, or may even provide misleading information. In such cases, so-called interdisciplinary research offers little more than a collection of scientists from different disciplines, each doing their own studies. Results of each scientist's efforts then remain within the confines of his or her own discipline and the promise offered by interdisciplinary effort remains largely unfulfilled.

This paper examines the effects which may be obtained in research that attempts to be interdisciplinary or multidisciplinary in accommodating for various levels of analysis. We examine and describe methodological difficulties and potential solutions for combining information in interdisciplinary research on Integrated Pest Management. The paper will describe the types of information which can be combined, fixed effects and random effects models, similarity judgments, exchangeability, robustness and sensitivity analysis, and the conditions under which interdisciplinary data should not be combined.

The research described herein relies upon data collected through United States Department of Agriculture Hatch Grant (accession #153595). Correspondence should be directed to: Daniel G. McDonald, Department of Communication, 315 Kennedy Hall, Cornell University, Ithaca, NY 14850 (607) 255-2603.

Efficacy of *Rhinocyllus conicua* Froellch on Seed Reduction in *Carduus nutans* L. Richard C. McDonald and Aaron O. Robbins, NCDA Plant Industry Division, PO Box 27647, Raleigh, North Carolina 27611

In May of 1993, a total of 1970 flowerhead weevils were released at the Spruill Farm in Franklin County, N.C. The site was characterized as being heavily infested with numerous dense stands of musk thistle. Data were collected from May through July of each year (1993 to 1995). The site was divided into four replicates, based on adequate stands of thistle for sampling. From each replicate, twelve plants were randomly selected and labeled. As flowerheads matured, they were taken from the plant, labeled and placed into envelopes for transport back to the lab. Terminal and the first through fifth lateral flowerheads were sampled. Flowerheads were dissected in the following manner: First, any pappus was removed in order to measure the receptacle diameter; next the outer bracts were cut off with scissors. Using a bone knife, thin slices were made through the receptacle in order to count and record the number of pupal cells and seeds. In 1994 and 1995, seeds were tested for viability using equipment in the NCDA Plant Industry Division's Seed Testing Laboratory. Thistle seeds were placed in a General seed blower, which removed excess debris and light seeds. The remaining seeds were counted again, weighed, and the weight and number was recorded. To determine seed viability, up to 100 seeds were placed in petri dishes on two layers of germination blotter paper. Petri dishes were placed in germination chambers with a photoperiod of 16:8 light:dark hours and alternating day/night temperatures of 25/15 degrees Celsius. Seeds were removed from the petri dish and their numbers were recorded every 48 hours. The mean number of seeds for all flowerhead types was 57.96 in 1994 and 20.90 in 1995 The percentage of viable seeds was 27.13 percent in 1994 and 44.71 percent in 1995. In 1994 the mean number of viable seeds for all flowerhead types was 15.72 and for 1995 it was 9.35 seeds, which is a 40.52-percent reduction in viable seeds per flowerhead. Flowerheads which are not infested with *R. conicus* have an average of 1,000 seeds per terminal and 850 seeds in the laterals with an average viability of 69 percent (Rees 1982). The weevils have brought the average number of viable seeds down from 607.2 (69 percent of average uninfested lowerheads) to 9.35 seeds, which is a 98.46-percent reduction The absolute thistle plant count for 1993, 1994 and 1995 was 3,284, 1,504 and 5,885 respectively. The average number of pupal cells for all flowerhead types combined was 6.23 in l 993 9.35 in 1994 and 21.20 in 1995. This is an increase of 340.29 percent in weevil numbers over a three-year period.

Further Development of an IPM Program for Powdery Mildew of Cucurbits. Margaret Tuttle McGrath, Department of Plant Pathology, Long Island Horticultural Research Laboratory, Cornell University, 3059 Sound Avenue, Riverhead, NY 11901-1098

Research conducted in 1994 and 1995 provided information to improve the IPM program presented at the Second National IPM Symposium/Workshop. Host resistance is becoming more important for IPM programs. Resistant cucumber and melon varieties are commercially available. Recently developed resistant yellow summer squash varieties yielded as well as fungicide-treated susceptible varieties and had the early yielding ability that other resistant varieties lacked. Genetic control was more effective than chemical control for suppressing mildew on under leaf surfaces. Maximum yield was obtained with chemical plus genetic controls. Economic benefits of genetic and chemical controls were documented. Fungicide resistance is a challenge to chemical control especially since the pathogen population can change drastically over a short time. Between 1991 and 1995, the proportion of fungicide-resistant isolates detected before treatment shifted from zero to the majority for triadimefon and vice versa for benomyl. Consequently, triadimefon, the main fungicide currently used in the United States for cucurbit powdery mildew, has become less effective while benomyl has regained its efficacy. Chemical control recommendations are to start treatment after disease detection (examine both surfaces of 50 old leaves), apply both protectant and systemic fungicides (never apply systemics alone), and maximize spray coverage on under leaf surfaces. Based on fungicide resistance data, apply benomyl first and triadimefon subsequently to a crop. Additional disease suppression may be achieved with more than 1 application of benomyl but probably not with triadimefon. Reduced-sprays IPM programs were effective. In summer squash, 4 weekly sprays after disease detection during the first half of the harvest period protected yield as well as full-season IPM programs with 6 to 7 sprays. Biocompatible fungicides have not yet found their niche in IPM programs. Neither AQ-10 (antagonistic fungus), Kaligreen (potassium bicarbonate), nor JMS Stylet-Oil applied every 7 days beginning after disease detection adequately suppressed mildew or protected yield when disease pressure was high. Biocompatible fungicides may be sufficiently effective when used at higher rates, applied more frequently, and/or used in a program with conventional fungicides. Frequent scouting for other diseases is needed because these materials are only effective against powdery mildew.

Certifying Professionals in the Crop Consulting Industry. W.M. McLawhorn, Jr. and R.E. Etheridge, Jr., McLawhorn Crop Services, Inc., P.O. Box 370, Cove City, NC 28523

In recent years, interest in certification programs in agriculture has been increasing rapidly. Officials in government, as well as the general public, want assurance that those recommending and applying pesticides have adequate training and education to do so in a responsible manner. Historically, certification programs for agriculturalists have been oriented to very specific disciplines. The more established of these programs have focused on education and experience with a continuing education requirement, but have been so discipline specific, they often best served only the needs of those in academia. The past twenty years or so has been a time of rapid advances in technology with some pretty dramatic changes down on the farm. New species-specific pesticides that require intensive scouting programs for proper management have allowed IPM principles to be adopted on a wide range of situations, and genetically engineered crops and precision agricultural systems will soon require more intensive management than any changes we have seen yet. The need for more intensive management has caused the young profession of crop consulting to explode. There has never been greater demand for well trained crop production specialists with educational backgrounds in fields ranging from microbiology to agronomy to entomology. Most of these specialists or crop consultants integrate a great number of disciplines into their daily routine, including soil science, agronomy, entomology, plant pathology, weed science, meteorology, etc. The unique needs of this group of professionals led the National Alliance of Independent Crop Consultants to develop the CPCC, or Certified Professional Crop Consultant, and the CPCC-I designation for the Certified Professional Crop Consultant-Independent. This program meets or exceeds the other major programs' requirements in terms of education, experience, continuing education, and adherence to a code of ethics. Further, the CPCC-I is the only designation which certifies independence from product sales. Perhaps most importantly, these are the only programs requiring the applicant to solve a case study essay dealing with specific situations encountered in the field, and thereby demonstrating an ability to integrate various disciplines in the process.

Susceptibility of Adult Western Corn Rootworm Populations to Three Insecticides Used in Nebraska Field Corn. Lance J. Meinke, Blair D. Siegfried, Robert J. Wright, Department of Entomology, University of Nebraska, Lincoln, NE 68583; Laurence D. Chandler, USDA-ARS, Northern Grains Insects Research Lab, Rt. 3, Brookings, SD 57006

Bioassays were conducted to estimate the susceptibility of adult western corn rootworm, *Diabrotica virgifera virgifera* LeConte, populations to technical grade methyl parathion, carbaryl, and bifenthrin. Beetles were collected from 26 July-24 August 1995 from 16 sites in Nebraska. Sites were selected from major corn production areas, from low vs. high insecticide use areas, and where control problems had occurred. Collections were made before any insecticide had been applied and after a significant amount of emergence had occurred. Bioassays were con-ducted from 1 August-1 September, beetles were randomly selected from each colony and insect-icide dilutions in acetone were applied topically to each beetle. Each bioassay per colony consisted of five serial dilutions per insecticide plus an acetone control, replicated four times; this procedure was repeated on two different days. Methyl parathion, carbaryl, and bifenthrin LD_{50} ranged from 0.46-7.83 ng/mg, 7.40-69.77 ng/mg, and 0.248-0.868 ng/mg, respectively (N = 400 beetles / LD_{50}). The maximum methyl parathion LD_{50} and LD resistance ratios were 17 and 21.4 respectively. Maximum carbaryl LD_{50} and LD_{90} resistance ratios were 9.28 and 52.39 respectively. The maximum bifenthrin LD_{50} resistance ratio was only 3.5 although five populations has LD_{90} resistance ratios ranging from 4.7-9.5. The highest methyl parathion and carbaryl LD_{50} and LD_{90}, values were from the same populations in Phelps and York counties and correlate well with reports of unsatisfactory control with formulated organophosphate or carbamate products in these counties during 1994 or 1995. Carbamate and organophosphate insecticides have been used for beetle control in Phelps County for over 20 years. Bioassay data, historical insecticide use patterns and associated selection pressure, and field reports of unsatisfactory control in some locations collectively indicate that adult western corn rootworm resistance has developed to methyl parathion and/or carbaryl in areas of Nebraska.

Management and Dispersal of *Thrips palmi* in Florida. H. Charles Mellinger, Galen Frantz, and Felicia Parks, Glades Crop Care, Inc., 949 Turner Quay, Jupiter, Florida 33458

Our involvement with the melon thrips, *Thrips palmi*, exemplifies the role of consultants in dealing with pest movement and dispersal. During routine scouting activities, Glades Crop Care, Inc. (GCC) personnel discovered this pest in Puerto Rico (1986) and in Florida (1990) These discoveries were the first recorded finds in the western hemisphere and continental U. S. respectively. We reported to and cooperated closely with State and Federal agencies (FDACS and USDA) responsible for this quarantinable pest. Following the 1986 discovery, GCC developed IPM tactics which are still the cornerstone of today's control efforts. Considering the magnitude of crop damage and economic loss this pest has caused worldwide, GCC established three goals to keep our clients up to date on further *Thrips palmi* spread and its threat to their crops:

1. Increase alertness for *Thrips palmi* in our ongoing thrips monitoring program. This involves routine bloom and growing point collections from thrips-susceptible crops for thrips speciation. Field scouts are also trained to make tentative field characteristic-based identification.
2. Increase our knowledge of *Thrips palmi's* host range. We routinely survey weed hosts in and around infested areas.
3. Evaluate seasonal population trends.

The pest is now of major economic importance and endemic in south Florida. In pursuing our goals we have identified factors that decrease the likelihood of thrips injury. These include pesticide choice and use patterns; conservation of predators, such as minute pirate bug; conservation of less damaging thrips species, which compete with *Thrips palmi*; and timing of cultural practices, such as field sanitation and crop destruction.

Integrated Biological Control of Strawberry Botrytis in the Annual Hill Culture of Chandler Strawberry. R. Walker Miller, Professor and Extension Plant Pathologist, and Mike Hood, Extension Apiculturist, Dept. of Plant Pathology and Physiology, 206 Long Hall, Clemson University, Clemson SC 29634-0377

Sutton et al. demonstrated that *Gliocladium roseum* provided adequate control of grey mold (*Botrytis cinerea*) in matted row culture of strawberries in Canada. The biocontrol agent was applied both as inundative sprays and using honey bees to vector the biocontrol agent to the flower. Previous work had shown that primary inoculum for flower infection comes from senescing leaves that become infected alter planting during the fall or winter. Fungicides applied to either prevent or suppress Botryris sporulation were effective in reducing initial inoculum and resulted in less disease. The objective of this work was to produce Chandler strawberries in the annual hill culture system without putting fungicide on fruit by integrating fall/winter sprays to reduce initial inoculum and vectoring the biocontrol agent to the blooms by honey bees.

Three matched pairs of growers were selected in 1992-93 and six matched pairs of growers were selected in 1994-95. Each matched pair represented a replication. In a single blind study, each site received 4 treatments with one of the two matched pairs receiving the biocontrol agent and the other a blank talc. Gliocladium roseum was isolated from all fields in both tests, and the isolate from a specific site was used as the biocontrol agent for that site. Sutton determined that all 16 G. roseum isolates collected for the first test were equally effective against Botrytis. Four treatments were no fungicide sprays, fall/winter fungicide sprays, fall/winter and normal spring sprays, and spring fungicide sprays only (grower standard). In the first experiment, disease pressure was very light and no differences between treatments were observed. Observations during this test indicated that the growers did not suppress initial inoculum, that bees did not appear to work the flowers, the inoculum dispensers did not work as well as hoped, and loss of data made analysis difficult. Disease pressure was better in the second lest with significant differences between treatments and times of observation but no differences with respect to the use of the biocontrol agent. Bees do not appear to be effective vectors of G. roseum in Chandler annual hill culture. A case study is in progress using bumblebees as vectors of the biocontrol agent.

Biological and Ecological Basis for Managing Arthropod Populations by Augmentation of Parasitoids and Predators. Juan A. Morales-Ramos, Research Entomologist, USDA-ARS Biological Control of Pests Research

Unit, 2413 East Highway 83, Weslaco, Texas 78596

Ecological and biological interactions among the host plant, arthropod pest and its natural enemies are highly complex. Understanding such interactions requires many years of expensive field research. An alternative to such an expensive and time consuming solution is the use of simulation models. With basic knowledge on the reproductive and developmental biology and the behavior of the arthropod pest, its natural enemies, and the host plant, a simulation model can be developed. Such a model can be used to simulate interactions among environmental factors allowing a greater understanding of this complex system. The knowledge obtained in this manner can be applied to dictate strategies on the use of the natural enemies against the target pest. An example is presented on the use of simulation models to release *Catolaccus grandis* in an augmentation program against the boll weevil, *Anthonomus grandis*.

Landscape Ecology as a New Framework for Improved Management of the Health of Agroecosystems. Merrin R. Nelson, Department of Plant Pathology, University of Arizona, Tucson, AZ 85721, and John M. Barnes, Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, Washington, DC 20250-2220

Recurring patterns of crop damage due to biotic agents are common on a regional scale. Crop protection and systems science specialists are collaborating on an improved understanding of such patterns with respect to how this understanding may be exploited in the design of improved agroecosystem management programs. Geo-statistics, geographic information systems (GIS), and global positioning systems are rapidly expanding tools that comprise the core of emerging new information processing and analysis technologies. Previous studies on plant pest and disease severity and risk assessment have largely been at within- field scales. The spatial characteristics of plant disease and certain insect pest population dynamics can be studied on any scale, including regional, with the advent of the above technologies. Collaborative studies on the occurrence and spread of tomato virus diseases involving University of Arizona, Mexican and Campbell Corporation scientists in the Del Fuerte Valley of Mexico, focused on a diverse group of viral pathogens. These viruses, except for tobacco mosaic virus, are of a general ecological type characterized by a dynamic aerial insect vector with multiple sources of virus for infection in a climate in which alternate hosts of both virus and vector exist year round. Because of these similarities, a risk assessment process was developed based on general (or landscape scale) virus infection hazards rather than specific viruses. The risk assessment helped to focus on actions that could be taken both locally and regionally to reduce early and damaging infections. Risk assessment and virus disease- incidence data were collected from selected fields in two separate study areas during two production seasons. Geostatistical analysis of risk and incidence showed that both were spatially dependent variables with a variogram range of 20 to 25 km. There appeared to be contrasts in underlying landscape features between two study areas which made one area more conducive to epidemics of plant virus diseases than the other.

Comparison of Simulated and Actual Flea Beetle Injury to Water-stressed Oilseed Rape. Timothy M. Nowatzki & Michael J. Weiss, Department of Entomology, North Dakota State University, Fargo, ND 58105

The crucifer flea beetle, *Phyllotreta cruciferae* (Goeze), is the principal pest of seedling oilseed rape, *Brassica napus* (L.). in the Northern Great Plains when the weather is hot and dry. Crop resistance may be a viable management alternative to chemical control, and identification of an accurate simulated injury technique would improve the resistance screening procedure. This study compared a technique for simulating flea beetle injury to actual flea beetle injury on oilseed rape seedlings grown at three soil moistures. Simulated injury was applied to the cotyledons with a 0.5 mm mechanical pencil and actual injury was obtained by placing seedlings in a chamber with 500 flea beetles for 12 hours. The fresh weight of the seed-lings was measured after seven days of growth. The actual injury reduced the fresh weight more than the simulated injury did at all soil moisture and injury levels tested. There was a curvilinear reduction in growth due to the simulated injury, while the reduction in growth after actual injury was linear. Without the incorporation of a correction factor, the simulated injury technique was not an accurate tool for screening lines of oilseed rape for flea beetle resistance.

Demonstration of IPM in Jordan Valley Greenhouses. Ronald Oetting, Bassam Al-Edwan, Nadi Farraj, Yaacov Hameiri, Abdullah Madi, Yigal Magrill, Ghassam Zuhod, Dennis Kopp. Address correspondence to: D. Kopp, USDA/CSREES, Ag. Box 2220,Washington DC 20250-2220

This multi-national Integrated Pest Management (IPM) program is a cooperative effort by research, extension, and private sector scientists in Israel, Jordan and Palestine. Study, demonstration, and scout training sites are located in each country. The initiation and facilitation of this project arose from a joint effort by the U.S. State Department through the USDA/Foreign Agricultural Service in conjunction with the Ministries of Agriculture and experts from each participating country. The goal of this project is to enhance IPM implementation in greenhouse production systems throughout the Jordan Valley, north of the Dead Sea, and to reduce health risks related to pesticide usage. The whitefly, *Bemisia* sp., is the pest which has accounted for a major increase in pest management inputs in greenhouse tomato production. A scout training component of this project and a pesticide resistance monitoring program has already been initiated. Under development is a communication network and producer information delivery programs.

Commodity Groups Ally to Spur Expansion of IPM Programs at Michigan State University. Larry G. Olsen, IPM Coordinator, Charles E. Edson, Fruit and Vegetable IPM Program Leader, and Joy Neumann Landis, IPM Communications and Publications Associate, 11 Agriculture Hall, Michigan State University, East Lansing, MI 48824

Historically, Michigan State University (MSU) has been a leader in developing and implementing IPM programs. Both extension and research programs have been considered models for the rest of the nation. These efforts contributed to grower success in reducing pesticide use during the decade of the 1980's. However, due largely to cutbacks in Federal funding, MSU lost some momentum during the last decade. While individual researchers and extension personnel continued to address specific critical pest management issues, a coordinated statewide program did not exist.

A consortium of fruit and vegetable commodity groups and processing firms, the Michigan Department of Agriculture, and MSU formed the Michigan IPM Alliance in 1994. The Alliance pledged over $65,000 annually for three years to help spur expansion of IPM efforts at MSU. This pro-active industry response to pesticide issues has strengthened the partnership between industry and MSU and has helped to provide a framework to enhance IPM education and implementation in Michigan. Given Michigan's many minor crops, it is important for commodity groups to band together to deal with critical pesticide and pest management issues.

Recent program expansion includes: a new Statewide IPM Coordinator, a Fruit and Vegetable IPM Program Leader, and an IPM Communications and Publications Associate; $50,000 to fund ten IPM implementation projects; over $133,000 in additional funding for IPM research and education in 1995; increased activity for the MSU IPM Task Force; an assessment of grower IPM needs in Michigan; and increased interaction between MSU scientists, field staff and industry. The Alliance also helped develop an industry-driven legislative proposal to raise over $8 million to support plant-based agriculture in Michigan. If funded, the proposal will include significant support for IPM and food production programs.

Private Efforts Help Develop and Deliver Integrated Potato Management Services in Michigan. Mark A. Otto, Agri-Business Consultants, Inc. 2720 Alpha Acess, Lansing, MI 48910-3608, and Ben Kudwa, Michigan Potato Industry Commission, 13109 Shavey Rd., DeWitt, MI 48820

As potato production systems have become more complex, the need for technical services among potato growers has increased. Public sector efforts have not been able to meet the demand, but private consultants are responding to the opportunities. Agri-Business Consultants, Inc. aims to bring science and service to their clients. Growers adopt IPM research because they profit from it and protect the environment at the same time. We continually work to adapt new technology and integrate it into our clients' management systems. We have tested variety response to chemigation and identified relative varietal tolerance to the potato early dying complex. This has allowed us to reduce the amount of chemigation. We helped develop Colorado potato beetle insecticide resistance test kits and used them widely to improve our ability to select the most appropriate insecticide. Late blight genotype analysis now helps us decide on fungicide use as well. Grower organizations should be looked to for more than just funding research. The Michigan Potato Industry Commission's (MPIC) research committee does an excellent job of communicating industry needs to scientists, regulators and policymakers. MSU hired a visiting professor to work on late blight when the MPIC agreed to backstop the funding. It has been instrumental in convincing growers to respond to pesticide use surveys that have been used to support Section 18 requests.

Adoption of Pest Control Practices in U.S. Agriculture. Merritt Padgitt, David Shank, Economic Research Service, 1301 New York Ave., N.W., Washington, DC 20005

The USDA Cropping Practices Survey provides data about several weed management practices and other production characteristics along with measures of herbicide use. Estimates from this survey provide an indication of how strategies targeted to specific kinds of weed management practices may or may not affect the intensity of herbicide treatments. Nearly all corn, soybean, and cotton acreage receive some form of herbicide treatments whether measured as acre-treatments or total pounds of all active ingredients applied per acre, the totals applied do not differ greatly across most production practices or characteristics analyzed. Land with field cultivations had fewer herbicide acre-treatments for corn and soybeans, but more acre-treatments occurred for cotton. Land using no-till systems had more herbicide acre-treatments than land using moldboard plowing and other conventional tillage systems. Previous crops, including winter cover crops on corn and double-cropped soybeans with wheat, had minimal effect on the number of herbicide acre-treatments. Continuous cotton received more acre-treatments than cotton grown in rotation with other crops. Land that was scouted for any type of pest tended to have more herbicide acre-treatments than land not scouted. Little difference occurred in the number of herbicide acre-treatments between land by erodibility, ownership, or farm program participation categories. For corn and soybeans, the more humid States of Ohio, Indiana, and Illinois, applied larger quantities of herbicides than States to the north and west. For cotton, the quantity of herbicide applied per acre in Arkansas, Louisiana, and Mississippi were double the quantities applied in Texas, Arizona, and California.

Founding of a Non-profit Weather Association to Support a Network of Weather Monitoring Equipment. Curtis H. Petzoldt, T. Weigle, J. Gibbons, C. TenEyck, New York State IPM Program, NYSAES, Geneva, NY 14456

The New York State IPM Program is establishing an affiliated non-profit Weather Association that will ensure the continuity of a growing weather and pest information network. The network has developed over the last 6 years as an informal cooperative venture among several private and public organizations and individuals. The network now includes electronic access to weather instruments at over 20 sites and is rapidly expanding through purchases of instruments by growers, processors, and private consultants. Information on the network includes weather data, pest forecasts, and pest information. The Weather Association will be a membership organization that will collect user fees to ensure the continuation of these services. It will operate across a broad spectrum of crop and commodity groups including grapes, apples, onions, potatoes, processed vegetables, and field crops. It will have a Board of Directors and an Advisory Committee operating in partnership with the IPM Program to make policy decisions including setting fees, determining locations for instruments and computer servers, and applying for grants. The Weather Association will be responsible for the employment of at least one full-time person and possibly several part-time individuals, will pay for phone connections to the weather instruments, will purchase new equipment, and update old equipment and software.

Implementation of a Complete Mating Disruption Program for Oriental Fruit Moth and Peach Twig Borer in Cling Peaches. Carolyn Pickel, Area IPM Advisor, Sacramento Valley, Janine Hasey, Farm Advisor, UC Cooperative Extension, 142-A Garden Hwy, Yuba City, CA 95991 and Bill Olson, Farm Advisor, UC Cooperative Extension, 2270-B Del Oro Ave, Oroville, CA 95965

There are two key insect pests, Oriental fruit moth (OFM) and peach twig borer (OB), in the cling peach orchard system. Commercial products for controlling OFM with pheromone confusion have been available since 1989. About 20 percent of growers have been using OFM pheromone for control. However, the mating disruption program has not expanded past the initial growers, using mating disruption. In 1995, the first commercial PTB product for pheromone confusion became available. The goal of this project is to introduce mating disruption to new growers and to demonstrate a complete mating disruption program to expand adoption resulting in a 90 percent reduction of insecticides. In the first year of the project, there were 16 cooperators representing 155 acres with 10 in Sutter/Yuba and 6 in Butte Counties. Two teams worked on the project. The Demonstration Team consisted of grower cooperators a UCIPM area advisor, farm advisors, researchers, IPM field assistants and pheromone suppliers. The Support Team consisted of the Cling Peach Advisory Board, Canning Peach Association, and processors. This team worked to get an EPA-Partnership Education Grant to expand the program in 1996. Eleven of the growers completed the season without sprays. Four growers with high populations had to spray one time before harvest. None of the growers had damage at harvest. However, the direct costs of this program, including materials and applications is considerably higher, averaging $75-100 more per acre than a conventional spray program. The EPA-Partnership grant will be used to offset the costs giving growers the chance to test the practice while learning about the benefits.

Effects of Lambda-Cyhalothrin on Natural Enemies of Rice Insect Pests. E. D. Pilling and F. J. Lewis[2], 'ZENECA Agrochemicals, Jealott's Hill Research Station, Berkshire, UK, [2]ZENECA Ag Products, 1800 Concord Pike, Wilmington, DE 19897

The effects of lambda-cyhalothrin applications on natural enemies of rice insect pests were investigated during the wet season of 1994 in central Luzon, Philippines. The primary objective of the stud was to evaluate the potential for using lambda cyhalothrin within integrated pest management (IPM) programs in paddy-rice systems. Three application input regimes were studied: low (mid and late season sprays at 6.25 g ai/ha), medium (early, mid and late season sprays at 6.25 g ai/ha) and high (early, mid and late season sprays at 6.25, 9.0 and 12.5 g ai/ha, respectively). Assessments were made on large plots (>l000m^2) for conservation of natural enemy populations, degree of pest control, cost effectiveness and yield production. In general, applications of lambda-cyhalothrin resulted in a limited reduction in the total number of natural enemy populations immediately after treatment. Population densities however started recovering between 7 and 14 days post-treatment and were estimated to completely recover to control levels after 28 days. Of the 40 plus beneficial species identified during the study, 5 groups were obviously important in terms of abundance; spiders, damselflies, ladybeetles, parasitoids and the remaining beneficial species placed in an additional group termed other natural enemies. In all lambda-cyhalothrin treated plots, the predator to pest ratio remained similar to control plots, there by maintaining beneficial capacity. Treatments had very little effect on the relative proportion of the five natural enemy groups and on individual species composition throughout the season. Applications of lambda-cyhalothrin provided good pest control with no hopper resurgence, and significantly increased yield production above the control proving to be highly cost-effective. On a cost-benefit analysis, the small investment in lambda-cyhalothrin provided substantial return to the farmer, and insurance against crop failure from pest damage. It is concluded that lambda-cyhalothrin can be used within an IPM program in rice agriculture, provided farmers are made fully aware of correct use patterns for maximum economic benefits and minimum environmental impact.

Potential Herbicide Savings Using a Light-Activated Sprayer. Timothy S. Prather, UCCE Statewide IPM Project, Kearney Agricultural Center, 9240 S Riverbend Ave. Parlier, CA 93648

Postemergent herbicide applications target weeds but often spray large areas that are not occupied by weeds. Sprayers that are activated by light wavelengths reflected from chlorophyll should increase the efficiency of herbicide application. A light-activated sprayer was tested for efficiency by placing live plant material on a fabric grid to obtain plant cover of 5, 10, 20, 40, 60, 80, and 100 percent. Two field studies were conducted to contrast the amount of herbicide used by the light-activated sprayer and a grower's cotton row crop sprayer. Spraying under controlled conditions demonstrated herbicide use reductions of 85 percent with the light-activated sprayer operating over a plant cover of 5 percent versus 100 percent plant cover (100 percent cover equaling a broadcast application). Spraying of furrows under field conditions resulted in a 78 percent reduction with the light-activated sprayer when contrasted to a broadcast application and a 60 percent reduction when compared to a manual spot-treatment application.

World-Wide-Web Interactive Text For Teaching IPM: a Resource For Students. Educators, Consultants And Growers. Edward B. Radcliffe and William D. Hutchison, Department of Entomology, University of Minnesota, St. Paul, MN 55108

We have initiated development of a new IPM text for the World Wide Web (WWW) that we believe will become an exciting new comprehensive tool for teaching IPM worldwide. This project is co-sponsored by The Consortium for International Crop Protection (CICP) and the National IPM Network (NIPMN). To date, more than 100 nationally and internationally recognized experts have agreed to prepare lectures on various aspects of IPM. Although the current emphasis is with insect and mite pests, we are presently soliciting new contributions from weed scientists, plant pathologists and nematologists. Our purpose is to provide: (1) a venue for easily maintaining up-to-date lectures ("chapters") on all major IPM principles (e.g., sampling, economic injury levels) and applications (e.g., commodities, urban IPM, etc.), (2) student access to an international network of IPM experts, (3) the ability to provide one resource for all possible topics in IPM (i.e., no limits on number of chapters), (4) inexpensive ability to enhance lectures with color photographs, video, sound, down-loading of decision-aid software, (5) an interactive discussion-group forum to facilitate interaction among students, teachers and authors of selected chapters, (6) convenient access to other useful WWW links about IPM, and (7) a resource to facilitate long-distance delivery of IPM courses. Our

goal, by the end of 1996, is to have over 200 lectures posted, including all pest disciplines. Discussions have been initiated to obtain continuing education credits (CEC) for agricultural consultants. More information about this site can be found at "Ted Radcliffe's Gopher State IPM Site", URL: <http://www.ent.agri.umn.
edu/academics/classes/ipm/ipmsite.htm>.

IPM on the World Wide Web: the National IPM Network - Southern Regional Server. F. William Ravlin, Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061
[http://ipm_www.ento.vt.edu: 8000/nipmn/]

The transfer of information from the researcher to the end-user is vital in facilitating the adoption of any new technology. World Wide Web (WWW sites on the Internet have rapidly become an important information tool for a wide variety of topics. This increased popularity results from a number of factors: the software to access the information on WWW sites is essentially free to non-commercial users, the software's interface makes the transfer of text and graphic information "user-friendly" and simple, and access to the Internet through commercial providers is becoming easier and less expensive. Commercial interests are taking advantage of the WWW for a number of purposes but are motivated by economics; WWW is an inexpensive and effective way of reaching a widely distributed body of consumers. In addition, WWW sites are easily developed and rapidly modified. The increased popularity of the WWW presents an opportunity to provide information on Integrated Pest Management techniques to a wide audience of end users at a minimal cost.

The National Integrated Pest Management Network (NIPMN) has established a system of regional servers containing IPM information and resources. These sites also provide real-time weather data, market reports, and pest alerts; the most recent pesticide label information; and numerous other types of IPM-related data. In addition, they will incorporate interactive resources such as keys to pest species and expert systems for identification and decision support.

Demonstrations of the resources available on these servers will be provided and future resources and potential uses discussed. An assessment of the economic advantages provided through electronic publication of extension materials will be presented.

Cooling as the Basis for Stored-grain IPM. Carl Reed & Tim Herman, Department of Grain Science and Industry, Kansas State University, Manhattan, KS 66506-2201

In 1994, demonstrations were established on farms in 16 Kansas counties to show how an inexpensive aeration controller helps the storage manager control insects in wheat by controlling the environment within the grain mass. In each county, a local team (county Extension agent, the farmer, an elevator manager, and the FSA director) monitored the progress of the trial through the storage season. University specialists collected technical data including indices of insect populations in the demonstration wheat and in a comparison bin. The results were summarized and extended to neighbors the following spring. Average grain temperatures were reduced about 10°C within two weeks of harvest (July), and to below 10°C by November 1. In September, pitfall traps placed in demonstration wheat captured about one-fifth as many insects as traps placed in comparison grain, some of which was treated with residue-producing insecticides. Extension materials describing the use of sanitation, aeration, and monitoring (SAM) as an IPM approach support the ongoing efforts of University workers and local teams to promote the substitution of IPM techniques for scheduled applications of insecticides in Kansas stored grain.

Presentation of The Dutch Pesticide Yardstick. Dr. Joost Reus, Centre for Agriculture and the Environment P.O. Box 10015, 3505 AA Utrecht, The Netherlands, Mark Ritchie, President, Institute for Agriculture and Trade Policy, 1313 Fifth Street SE, Suite 303, Minneapolis. MN 55414 [(612) 379-5980, fax (612) 379-5982, iatp@iatp.org]

The Centre for Agriculture and the Environment (CLM) in the Netherlands developed an important and effective new farm management tool, the "yardstick," which farmers all over Holland, and now in France and England, are using to voluntarily reduce the pesticide impact on the environment. Yardsticks are a simple and extremely effective way for farmers to assess the environmental impacts of their current farming practices. They can be used to reduce impacts in relatively easy and straightforward ways. Here is how they work: Farmers keep records of their pesticide application practices, including the kinds of chemicals used, the amount of applications, methods of application, soil type etc. Each factor is given a numerical score which signifies the estimated negative impact on the environment. At the end of each growing season, farmers add up their total scores for a numerical representation of their impact. They then have a "baseline" to begin planning for their next crop season. Using this information, farmers can make specific changes in their farming practices which can reduce their overall score. For example, mechanical weed control (tillage) can sharply reduce the overall impact and thereby lower (improve) a farmer's "score." In the Netherlands, this system has been in place for over four years, with remarkable results. Farmers have been averaging a 10 percent reduction in score each year, with some achieving as high as 70 percent reductions. This progress has not gone unnoticed. For example, water companies who supply drinking water to towns and cities have begun to pay farmers a bonus for reductions in their "scores." The Institute for Agriculture and Trade Policy is working with CLM to adapt the pesticide yardstick to U.S. farming conditions.

Translating Vision Into Action:
A Massachusetts Case Study in the Promotion of Integrated Pest Management. Iliana Rivas-Picon, Environmental Analyst, Massachusetts Department of Food and Agriculture, 100 Cambridge Street, Boston, MA 02202

At a time when downsizing has become the norm, governmental agencies are under increased pressure to demonstrate a capacity for leadership, vision, and innovation in order to adapt to current conditions and fulfill their public mission. Key to these efforts is an organizations ability to build on existing infrastructures, foster alliances, and provide the flexibility required to meet rapidly changing needs. A case in point is the Massachusetts Department of Food and Agriculture's (MDFA) demonstrated commitment toward enhancing the knowledge and practice of Integrated Pest Management (IPM) within the State.

To this end, the MDFA relies on a consensus-driven approach as part of its decision-making process accounting for the specialized leadership of affected parties. Focus groups and advisory committees are examples of this participatory drive. Additionally, an in-house strategy comprised of both educational and marketing principles serves to complement IPM-related initiatives. Components of this dual strategy include the development of a communications plan involving media events, the publication of educational and promotional materials including how-to kits and posters, as well as the use of Geographic Information Systems (GIS) mapping technology. This collaborative approach and use of selected tools aim to complement and advance statewide IPM efforts.

This poster provides a visual presentation of these various initiatives, including detailed information on the State's unique IPM grower-certification program. IPM efforts within less traditional, urban settings are also examined. Additionally; this visual case study walks the reader through a number of educational and promotional tools. In so doing, this poster presentation provides a view into the world of one State government agency and its approach at translating vision into action for the advancement of Integrated Pest Management.

Working Smarter on the Land to Restore the Chesapeake Bay. Lorie S. Roeser, U.S. Environmental Protection Agency, Region III, Chesapeake Bay Program, Annapolis City Marina, 410 Severn Avenue, Annapolis, Maryland 21403, with contributors from Land Grant Universities, and

State and District of Columbia agencies within the Chesapeake Bay basin

The Chesapeake Bay Program is a partnership of governments, citizens, and businesses directing the restoration of the Bay. Leading the program are the signatories to the 1983 and 1987 Chesapeake Bay Agreements: U.S. Environmental Protection Agency, Pennsylvania, Maryland, Virginia, Washington, DC and Chesapeake Bay Commission (a tri-state legislative body). In 1994 the signatories committed to a strategy that will:

- By the year 2000, establish voluntary IPM practices on 75 percent of all agricultural, recreational, and public lands within the Chesapeake Bay Basin.

- By the year 2000, develop and conduct basin-wide education and outreach programs for commercial and household pesticide applicators to promote voluntary IPM practices on 50 percent of the commercial land and 25 percent of the residential land within the Chesapeake Bay basin.

Working together, the State, Federal and District of Columbia partners, with some funding available form the U.S. Environmental Protection Agency are contributing to the IPM program enhancements to accomplish the objectives of the strategy.

Biological Pesticides And IPM. Robert I. Rose, Frank W. Ellis, Jr., Gail S. Tomimatsu, William R. Schneider, Cindy R. Schaffer and J. Thomas McClintock, U.S. Environmental Protection Agency, Office of Pesticide Programs, Biopesticides and Pollution Prevention Division (7501W), 401 M Street, SW, Washington, DC 20460

The U.S. Environmental Protection Agency (EPA) realized the unique characteristics of biological pesticides for IPM more than 15 years ago. Subsequently, EPA published Subdivision M of the Pesticide Testing Guidelines for Microbial and Biochemical Pest Control Agents in 1982 and 1989 to facilitate their registration. This approach has allowed expeditious registration of over 50 microbial pesticides, such as *Bacillus thuringiensis*-based products, and more than 40 biochemical pesticides including pheromones, plant growth regulators, attractants and repellents. Biologically-based pesticides currently registered by the EPA and their use in IPM are presented.

Modeling the Supply Response of Perennial Fruits to Loss of Pesticide Alternatives. Susan G. Rozanski and Scott M. Swinton, Department of Agricultural Economics, Michigan State University, East Lansing, MI 48824-1039

Producers of "minor use crops" such as tree fruits are particularly susceptible to decreased pesticide availability due to manufacturer withdrawal of chemical compounds due to regulatory pressures from the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and the Delaney Clause of the Federal Food, Drug and Cosmetic Act and natural pest resistance. Elimination of pesticide alternatives through regulatory and natural causes could seriously impair the efficacy of pesticide-based conventional and integrated pest management strategies for minor use crops after FIFRA reregistration must be completed in 1997.

Fewer and costlier pest management alternatives will reduce the supply of minor use horticultural crops at any given price and quality level. This research estimates the likely supply and price effects of losing selected pesticide alternatives in apple and tart cherry. Our study explicitly models perennial fruit supply over time using a dynamic recursive programming-econometric model. This framework can be used to predict changes in aggregate and regional supply of tart cherry and apple due to pesticide policies. Changes in pest management practices and the resulting implications for fruit yields, proportion of fruit allocated among fresh and processed markets, crop prices, and farmer profitability can also be examined with this model.

The hybrid mathematical programming-econometric approach explicitly incorporates viable alternative crops and several pest management strategies for each crop. It permits production and input substitutions in response to pesticide availability and associated expected net returns. Interregional and intra-regional effects of pesticide policies can also be investigated through the use of heterogeneous representative farms in the programming model. This framework also addresses the effect of pesticide policies on fruit quality by allowing the proportion of fruit allocated to fresh versus processed markets to vary by pest management strategy. Apart from the economics of supply response, the model can also be used to track chemical emissions into the environment by using pesticide accounting rows in the mathematical programming model.

Site-Specific Weather Forecasts For IPM Decisions. Joseph M. Russo, SkyBit. Inc., P.O. Box 10, Boalsburg, PA 16827-0010

Integrated pest management (IPM) programs are increasingly relying upon pest models and expert systems to support decision making in the field. An important component for the success of such models and systems is the availability of timely and reliable weather data. Today, weather data are available in many forms and for many periods. From text to images and from climatology to outlooks, data reveal historical, present, and future trends and extremes of weather variables. Most important of these forms and periods are weather forecasts serving as numerical input into IPM models and expert systems. The inclusion of forecasts into models and systems gives managers and other decision makers lead time for planning an action. SkyBit, Inc., a provider of an electronic meteorological service for agriculture, has been a leader in the use of mesoscale analysis and forecasting techniques for the generation of short-term weather predictions. Their Mesoscale Atmospheric Simulation System (MASS), a set of computer programs which ingest and process "raw" weather data from the National Weather Service (NWS), serves as the "engine" for their electronic or E-Weather service. The power of MASS is in its ability to manipulate weather information in much the same way as a trained meteorologist but at a much greater speed and efficiency. MASS is capable of generating site-specific weather forecasts for intervals as short as one hour and for periods as far ahead as two days. Site-specific mesoscale forecasts can be generated for weather variables important to IPM programs. These variables include temperature, precipitation, solar radiation, evaporation, relative humidity, wind speed and direction, cloud cover, and leaf wetness. Besides serving as input into pest models and expert systems, forecast data for these variables can also be employed to compute integrated indices such as for drying and spraying decisions. With their capability of revealing hourly changes in weather patterns at the scale of a farm, and their potential to provide input for numerous IPM programs, mesoscale forecasts are truly ushering in an era of new weather information.

Resistance to Zimmerman Pine Moth and Marketability of Scotch Pine Christmas Trees in a Choose and Cut Plantation. Clifford S. Sadof, Department of Entomology, Purdue University, West Lafayette, IN 47907-1158

Zimmerman pine moth bores into Christmas trees and disfigures them by killing the central leader or side branches. Nine varieties of Scotch pine were assessed for their susceptibility to Zimmerman pine moth, and their marketability. Trees were planted in 1986, in a randomized complete block design with 36 trees per plot and 3 replications. Plots were evaluated for insect resistance in August of 1992, 1993, and 1995. Trees were open for sale in 1992, 1993, and 1994. Unsold trees were counted in August of 1995 to compare marketability. Varietial rates of infestation varied between 11 and 75 percent in 1993. Both Belgian and Lake Superior Blue were found to highly resistant to Zimmerman pine moth with < 13 percent of trees infested. Belgian, however, because of its tendency to yellow in the fall, had 54 percent of its trees unsold in 1995. Among the non-yellowing varieties, percentages of unsold trees ranged from 6 to 26 percent. The variety most susceptible to Zimmerman pine moth had 20 percent more trees remaining than the most resistant variety. This study demonstrates the need for marketability studies when breeding for pest resistance.

Fostering IPM Adoption in the Marketplace. Abby J. Seaman, Area Extension Specialist, Cornell Cooperative Extension, 1581 Route 88N, Newark, NY 14513; Curt Petzoldt, Vegetable IPM Coordinator, IPM Support Group, NYSAES, Geneva, NY 14456; Bill Pool, Wegmans Food Markets, 1500 Brooks Ave., Rochester, NY, 14692; and Tom Facer, Comstock Michigan Fruit, Rochester, NY 14602-0670

Wegmans Food Markets, a family owned chain of grocery stores with 47 locations in New York and three in Pennsylvania, has made a corporate decision to encourage growers supplying their fresh "home grown" and store-labeled processed vegetables to adopt IPM practices. In response to a request from Wegmans, a group of Cornell Cooperative Extension field staff and faculty put together a fresh market sweet corn IPM course, which was presented to a group of 12 growers in 1995. The course consisted of three pre-season meetings covering insect, weed, and disease identification and management, cultural practices, nutrient management, post harvest handling, and sprayer setup and calibration among other topics. During the growing season, three in-field meetings provided the opportunity for hands-on scouting, experience with using thresholds for making decisions, and in-field identification of pests and beneficials. A series of split-field demonstrations comparing IPM and grower pest management practices provided a focus for the in-field meetings, and allowed growers to see the results of using IPM practices. Sweet corn from the IPM areas of the demonstration fields was marketed at one Wegmans store under an IPM label. Consumers surveyed in the store responded very favorably to the concept of IPM and the idea of encouraging growers to adopt IPM practices. As a result of this favorable response, Wegmans has expanded the program and initiated a cooperative venture with Comstock Michigan Fruit, the processor supplying their store-labeled processed vegetables. Currently, a series of "Elements of IPM" for six processing and one fresh market crop are being formulated for use next season by Wegmans and Comstock Michigan Fruit, with assistance from the NYS IPM program. The "Elements" enumerate IPM practices for each crop, and include annual goals for adoption of particular practices and a point system for evaluating grower practices to confirm that a minimum level of IPM adoption was met for IPM labeled food.

Recent Research on the Epidemiology and Management of Apple Scab. Robert C. Seem, David, M. Gadoury, Arne Stensvand, and Stuart P. Falk Department of Plant Pathology, Cornell University, New York State Agricultural Experiment Station, Geneva, New York 14456

The apple scab pathogen *(Venturia inaequalis)* produces fruiting bodies (pseudothecia) during winter on fallen infected leaves. Management of apple scab has historically centered upon fungicide use to prevent infection by ascospores from these pseudothecia. Our overall objective has been to exploit certain aspects of pathogen biology to better reconcile fungicide use to the risk of infection. For example, a degree-day model of ascospore maturity was combined with simple rainfall- and temperature-based rules to predict ascospore release. This system allows apple growers to obtain daily on-site estimates of ascospore maturity and discharge; in particular it detects the exhaustion of the ascospore supply. The scab warning system was further revised by incorporating the suppression of ascospore release by darkness, and the reduced rate of infection below 6 °C. Even with these and other refinements (e.g., delay of first application in low-inoculum orchards), current fungicide use patterns do not reflect the large changes that occur in tree growth and tissue susceptibility during the growing season. Our most recent research integrates daily changes in target size (tree growth), target susceptibility (leaf and fruit tissue susceptibility to infection), and inoculum dose (ascospore maturity and release) to yield a quantitative estimate of the risk of infection. First-year results demonstrated a near perfect (>98 percent) correlation between the numerical risk of infection and development of apple scab on the cultivar McIntosh. The numerical risk will eventually be used to adjust the frequency and rate of fungicide use to better reflect the need to suppress infection.

Integrated Pest Management Workshop: Developing a California Strategy. Steve Shaffer, Senior Agricultural Biologist, California Department of Food and Agriculture, Office of Pesticide Consultation and Analysis, 1220 N Street, Sacramento, California 95814

A facilitated workshop was held on December 8, 1994 in Sacramento, California, to develop a strategy to support wider adoption of Integrated Pest Management (IPM) in California. The workshop was sponsored by the California Department of Food and Agriculture (CDFA), the California Department of Pesticide Regulation (CDPR), and the University of California Statewide Integrated Pest Management Project (UCIPM).

Over 90 people representing growers and commodity groups (17), agricultural processors (12), agricultural chemical and service providers (17), government agencies (27), educators and researchers (10), and consumer and environmental organizations (7) participated. In facilitated breakout sessions, participants developed strategies on how to improve (1) basic and applied research, (2) technology transfer, (3) delivery of services, (4) the pesticide registration process, and (5) grower acceptance of IPM.

Key recommendations concerning Federal policy development included: (1) The funding allocation formula for Cooperative Extension should be revised in the new Farm Bill. (2) The USDA IR-4 program must be expanded to meet the pesticide registration data requirements to ensure timely registration and reregistration of minor crop/minor use pesticides, and new, safer pesticides. (3) Strategic planning, program development, and resource allocation to support IPM must include strong grower participation. (4) The new Farm Bill should include USDA and USEPA funded programs for real world on-farm demonstrations of IPM technologies and systems. (5) The new Farm Bill should not only continue, but expand, the Consolidated Farm Services Agency SP-53 Program. (6) More efficient means of developing and disseminating information to the grower and crop protection professionals must be supported. (7) Tax incentives must be provided for companies developing new, safer pest management technologies, and for those who use the new technologies. (8) Consistent interagency coordination between USDA and USEPA, combined with strong stakeholder input, is the most effective means to target limited resources.

How Do Non-chemical Pest Management Practices Affect the Use of Herbicides in Corn Production? Insights Gained from the 1994 Cropping Practices Survey. David Shank and Merritt Padgitt. Natural Resources and Environment Division, Economic Research Service/USDA, 1301 New York Avenue, NW, Washington, DC 20005

There is a common belief that non-chemical pest management practices can substitute for chemical use in production. However, these pest management practices were designed to increase the profitability of a farm through increases in input efficiencies. Determining the effect of these non-chemical pest management practices on the use of herbicides in com production is the focus of this poster. Statistical analysis of production and chemical use data from the Cropping Practices Survey for 1994 are conducted and relationships between production practices and chemical use analyzed. Important practices like tillage, scouting and crop rotation are included in the analysis.

The use of aggregated chemical amounts presents a challenge since the chemicals often have different levels of efficacy and application rates which blur regression results. To account for quality differences and avoid this pitfall, chemicals are grouped by their family or action allowing the analysis of use patterns for a particular group of chemicals. A Heckman two stage system of equations is used to avoid any bias due to latent variables impacting on chemical selection and use. The system uses a Probit analysis of chemical selection to obtain the inverse

Millis ratio which is then included in the OLS estimation.

Analysis of Gypsy Moth Spread in The Central Appalachians. Alexei A. Sharov, Virginia Polytechnic Institute and State University. Blacksburg, VA 24061-0319

Gypsy moth, Lymantria dispar (L.), was introduced into North America near Boston in 1869 and since that time it has been slowly expanding its range to the west and south. In attempting to slow its spread, USDA Forest Service has established several barrier zones in which isolated colonies are detected and eradicated. To evaluate the effect of barrier zones on the rate of gypsy moth spread, I suggested measuring the rate of spread by the average distance between regular population boundaries (regular boundaries have no "islands," gaps or folds) in consecutive years. Population boundaries were estimated using male moth counts in pheromone traps, egg mass counts, and defoliation maps in the central Appalachian Mts. in 1988-1995.

Gypsy moth spread rate declined from 1988 to 1995 by ca. 30-60 percent, as measured from (1) time series of spread rates and (2) boundary "compression" (reduction of the distance between adjacent boundaries). Reduction of gypsy moth spread rate may have been due to eradication of isolated infestations in the barrier zone.

The boundary of 1 moth/trap was on average 110 km from the boundary of defoliation, and male moth capture rate increased 10 times per 29 km perpendicular to the population front. Approximately 11 years separated the time when traps caught 1 moth/trap until defoliation first occurred in the same area. Spread rates estimated using different population thresholds changed almost synchronously from year to year. Local spread rates measured at different locations along the same boundary were significantly correlated within the range of 50 km but they were not correlated in time.

Pheromone R&D for Management of Western Bark Beetles. Patrick J. Shea, Principal Research Entomologist, USDA Forest Service, Pacific Southwest Research Station, Davis, CA 95616

Many insects, including bark beetles, use chemical messages as a means of communication between individuals of the same or different species. Collectively, these unique and biologically powerful compounds are called "semiochemicals." Some compounds attract members of the same species (aggregation pheromone") and some compounds block the aggregation pheromone (anti-aggregation pheromone"). The existence and functional role of some bark beetle semiochemical systems have been known to science for over 25 years. However, research by USDA Forest Service scientists has only recently begun to develop strategies that use these unique compounds to manage forest pests, particularly several species of bark beetles. These beetles are significant pests of forests in the western United States and can have devastating effects on recreational areas, wildlife habitat, and the economic stability of forest dependent communities. Specifically, this research and development effort has concentrated on: (1) understanding the behavior of bark beetle populations and their chemical ecology; (2) isolating, identifying, and synthesizing new aggregation pheromone; (3) field-testing new formulations and delivery systems of pheromone for pest management purposes; (4) and advancing our knowledge of the functional role and impact of bark beetles in forest ecosystems.

Baseline Susceptibility of the European Corn Borer from North America and Europe to *Bacillus thuringiensis.* Blair D. Siegfried and Paula C.R.G. Marcon, Dept. of Entomology, University of Nebraska Lincoln, NE 68583; John F. Witkowski, Northeast Res. & Ext. Center, University of Nebraska, Concord, NE 68728; Kevin L. Steffey, Illinois Natural History Survey, 172 Natural Resources Bldg., University of Illinois, Champaign, IL 61820; R.J. Wright, Southcentral Research and Extension Center, University of Nebraska, Clay Center, NE 68933

Susceptibility to a purified CryIA(b) toxin from *Bacillus thuringiensis* (B.t.) was determined for 12 populations of the European corn borer (ECB), *Ostrinia nubilalis*. Field collections were made from 9 States across the U.S. corner belt. A field population from Italy and two laboratory colonies in culture for at least 10 generations were also tested. Most collections originated from locations where the bivoltine Z strain predominates, but samples of other ECB strains including the multivoltine Z and E strains were also tested. Field-collected larvae were reared for one or two generations in the laboratory, and susceptibility of neonate progeny was determined. Susceptibility was determined with feeding bioassays where increasing concentrations of the toxin were applied to the surface of artificial diet. Mortality and larval weight gain were determined after 7 days. Significant differences in LCso and ECso (based on weight reduction relative to controls) values were observed, but the magnitude of the differences was small (<fourfold). Intense exposure to B.t. is not known to have occurred in these populations, indicating that the observed susceptibility differences are due to natural variation among populations and unrelated to prior selection with B.t. The baseline susceptibility as reported here should provide a means to designate diagnostic concentrations that can be used in monitoring programs to determine the resistance status of field populations.

Management of 1,3-Dichloropropene for Efficacy And Environmental Safety. B. S. Sipes, D. P. Schmitt, R C. Schneider, and R. E. Green, Department of Plant Pathology and Department of Agronomy and Soil Science, University of Hawaii, Honolulu, 96822

A series of experiments determined the effect of application methods on the environmental fate of 1,3-dichloropropene (1,3-D) in pineapple. The goal was to reduce atmospheric emissions of 1,3-D while retaining control *Rotylenchulus reniformis*. In experiment 1, 1,3-D applied with a fumigun at 224 1 a.i./ha was as effective as rates of 337 or 393 1 a. i./ha. Greater soil gas concentrations of 1,3-D occurred in the center of the planting bed with a single-chisel application compared to a dual-chisel application. Soil residue concentrations of 1,3-D were similar along the plant line in single- and dual-chisel applications. In experiment 2, 1,3-D (224 l a.i./ha) applied with a single chisel 45-cm deep, centered in the planting bed, and immediately sealed with a 1.1 m wide x 1.0 mil thick plastic cover, reduced peak ambient air concentrations by 29 percent and interbed soil gas concentrations by 75 percent compared to the same rate applied 40-cm deep with two chisels. Both application methods reduced pretreatment nematode populations by 97 percent. In experiment 3, no differences were found in efficacy or air emissions of 1,3-D when the fumigant was applied with a single chisel in the center of the bed and immediately covered with a 2-m or l.l-m wide plastic film. An environmentally safe and effective application of 1,3-D can be achieved by applying the fumigant 45-cm deep with a single chisel run in the center of the bed, and immediately sealing the soil with a plastic film.

Greenhouse IPM Implementation in Northern New England. Margaret Skinner, Michael Brownbridge & Bruce L. Parker, Univ. of Vermont, Entomology Research Laboratory, P.O. Box 53400, Burlington, VT 05405-3400; James F. Dill, Univ. Of Maine, Entomology Dept., Orono, ME 04473; Alan T. Eaton, Univ. Of New Hampshire, Entomology Dept., Durham, NH 03824; and, Julie Iskow and Jane Kolodinsky, Univ. Of Vermont, Com. De. & Applied Econ., Burlington, VT 05401.

The horticulture industry is the fastest growing agricultural sector in grower cash receipts and the heaviest user of chemical pesticides based on active ingredient per acre in the U.S. Crop production under glass provides important economic opportunities in the Northeast, a region where crop diversification is essential to its agricultural future. IPM can reduce the use of "hard" chemical pesticides but its adoption is slow. A tri-state, multi-disciplinary effort to promote its use in greenhouse ornamentals in Maine, New Hampshire and Vermont has been initiated. These States joined forces because their greenhouse operations share several common characteristics-- they are generally small, seasonal and diversified. IPM development and implementation must be addressed systematically, drawing on the expertise of extension specialists, researchers and growers. A survey of pesticide usage, IPM practices and economic factors related to IPM will be conducted. Results from this survey will be used by the tri-state network to develop a long-term approach for encouraging IPM implementation in these three States.

Crucifer Integrated Pest Management. Kenneth A. Sorensen, Dept. of Entomology, Harry S. Duncan, Dept. of Plant Pathology and Douglas C. Sanders, Dept. of Horticulture Science, Box 7626, N. C. State University, Raleigh, North Carolina 27695-7626

Insects and diseases cost crucifer growers millions of dollars in North Carolina through direct losses, the cost of control and the application of unnecessary sprays. Growers, field scouts and extension agents often cannot recognize or identify causal agents and pests in a timely manner. Some 100 slides of insects, diseases and disorders were selected and reproduced. Enlarged color prints were made from selected examples and mounted on poster display together with objectives, statements of content, results, future efforts and acknowledgments. Notebooks with identifications, departmental insect notes, plant pathology leaflets and horticulture leaflets and selected crucifer production bulletins, vegetable insect manual and biological insect control bulletin were prepared. These notebooks could be used alone in training sessions or used in conjunction with the poster-display. We also conducted a distance learning workshop on Crucifer IPM that used our UNC network of 16 remote sites.

This Crucifer IPM poster display has been shown at National ESA meeting in Las Vegas, at county extension reviews, at annual Extension Conference, at the NC Crop Protection School and at various meetings throughout the State. Thus thousands of growers and practioners will be exposed to Crucifer pest identification, damage recognition and management tactics and strategies.

With these educational resources, growers, field scouts and county extension agents will be better able to recognize and provide IPM information in an efficient and effective manner. Hence grower losses will be reduced, pest control improved, insecticide resistance slowed, and the environment spared needless contaminants and our vegetable industry remain viable and become more competitive in a global environment. Also this educational program will foster improved public relations and professionalism among the University, the Cooperative Extension Service, the county Extension Office, growers, private consultants and the consuming public.

Developing an Integrated Program for Managing Aphids And Aphid-transmitted Virus Diseases of Vegetable Crops in the San Joaquin Valley. James J. Stapleton and Charles G. Summers, Statewide IPM Project and Dept. of Entomology - UCD, Kearney Agric. Center, Univ. of California, Parlier, CA 93648

A serious epidemic of aphid-transmitted virus diseases has developed in the warmer valleys of California. Without multiple virus resistance in the many specialty vegetable varieties grown in the San Joaquin Valley (SJV), crop losses are increasing each year to viruses including CMV, WMV, ZYMV, TEV, ToRSV, among many others. Numerous insecticides, pheromones, and cultural methods have been tested to control the many species of aphids capable of transmitting the viruses, but none has given satisfactory results. Silver reflectorized mulches have been the best management tool for susceptible crops, and have given up to 25-fold increases in yield over nontreated control plots. However, growers in the SJV have not traditionally used mulches, and the infrastructure needed to put a widespread plasticulture system into practice must be developed. We are working with suppliers, growers, and crop advisors to facilitate the transition. Among the key growers spearheading implementation may be those involved with a "biologically-intensive farming systems" project coordinated by UC Cooperative Extension in the central SJV. Efforts are underway to integrate other strategies with the mulch treatments to improve the economic benefit to users.

Urban IPM Training Using the Master Gardener Program. Robert Stauffer, Master Gardener, Robert Morris, Horticulture Specialist and Wayne Johnson, State IPM Coordinator, Nevada Cooperative Extension, 2345 Red Rock Street, Suite 100, Las Vegas, NV 89102-3156

The Las Vegas valley is a rapidly growing area of the country with increasing environmental pressures created by an urban community without an agricultural base. A survey conducted in nursery/garden centers demonstrated that the general public's first choice for pest control were pesticides and that they had little concept of IPM. When questioned about pesticide safety and disposal, none of the respondents could answer the most basic questions. This can be particularly dangerous since the Las Vegas valley is an open hydrological system that ultimately drains into the Colorado River. Recently, the Clark County Sanitation District detected high levels of diazinon in waste water. The first year of a four-year educational program is underway to teach the general public on alternatives to pesticides (IPM) for commonly found urban pests in southern Nevada. The educational program is conducted through extension's volunteer Master Gardener program in cooperation with local nursery/garden centers. An educational curriculum (training manual) is being developed by extension specialists to teach existing Master Gardeners urban IPM techniques, pesticide safety, and proper pesticide disposal techniques. Alternative pest control measures are emphasized as first choice alternatives to the selection of traditional pesticides. Master Gardeners are identifying and prioritizing major pest problems of southern Nevada that could be controlled through IPM. Twelve home horticulture fact sheets are being developed or revised (emphasizing IPM techniques as first-choice alternatives, pesticide safety and pesticide disposal) to address local pest control needs. These fact sheets will become an addendum, tailored to southern Nevada pest problems, to the training manual.

IPM on the World Wide Web: the National IPM Network - Center for IPM (CIPM) Server. Ron Stinner, Dept. of Entomology, North Carolina State University, Raleigh, NC 27607 [http:// ipmwww.ncsu.edu/cipm/VirtualCenter. html]

The transfer of information from the researcher to the end-user is vital in facilitating the adoption of any new technology. World Wide Web (WWW) sites on the Internet have rapidly become an important information tool for a wide variety of topics. This increased popularity results from a number of factors: the software to access the information on WWW sites is essentially free to non-commercial users, the software's interface makes the transfer of text and graphic information 'user-friendly' and simple, and access to the Internet through commercial providers is becoming easier and less expensive. Commercial interests are taking advantage of the WWW for a number of purposes but are motivated by economics; WWW is an inexpensive and effective way of reaching a widely distributed body of consumers. In addition, WWW sites are easily developed and rapidly modified. The increased popularity of the WWW presents an opportunity to provide information on Integrated Pest Management techniques to a wide audience of end users at a minimal cost.

The National Integrated Pest Management Network (NIPMN) has established a system of regional servers containing IPM information and resources. These sites also provide real-time weather data, market reports, and pest alerts; the most recent pesticide label information; and numerous other types of IPM-related data. In addition, they will incorporate interactive resources such as keys to pest species and expert systems for identification and decision support.

Demonstrations of the resources available on these servers will be provided and future resources and potential uses discussed. An assessment of the economic advantages provided through electronic publication of extension materials will be presented.

Establishment of a Multiregional, Computer-Based Crop Disease Forecasting System. Joyce F. Strand, Computer Systems Manager, Statewide IPM Project, University Of California, Davis, CA 95616-8621, Paul H. Gosselin, Assistant Director, California Department of Pesticide Regulation, 1020 N St., Sacramento, CA 95814, Robert K. Curtis, Manager, IPM Programs, Campbell Soup Co., 6200 Franklin Blvd., Sacramento, CA 95824

Management of diseases in many California fruit and vegetable crops relies heavily on the use of fungicides as the most effective means of protecting the crop from quality and yield losses. In many crops, fields are sprayed on a regular schedule, often weekly throughout the growing season. An effective means of reducing fungicide use is to improve spray timing by basing it on evaluation of risk of infection rather than on a calendar spray schedule. In recent years, scientists have made progress in developing models that describe the relationships between environmental variables and disease development. To ensure widespread applicability, the descriptive models must be validated across the variety of microclimates where they will be applied. However, such validation requires a large scale effort in weather monitoring, field data collection, and analysis. Taking advantage of advances in environmental monitoring technology, a project funded by US-EPA, California Department of Pesticide Regulation, University of California, and the California agricultural industry proposes to provide an infrastructure to provide appropriate weather data, facilitate the research and validation of models of diseases, and demonstrate their utility. Based on proposals from industry and scientist participants, regional weather networks, monitoring air temperature, relative humidity, leaf wetness, and precipitation will be purchased and installed, and data will be gathered centrally, quality controlled, stored, and made available to users. The environmental data, along with field scouting reports, will be used in model development, validation, and correction. When ready for implementation, the new technologies will be transferred to growers and pest management consultants responsible for making treatment decisions. Disease indices computed centrally using validated models will be disseminated by computer, fax-on-demand, and voice-synthesized telephone messaging systems, and their use will be monitored as part of the evaluation of adoption of the new technology.

The Impacts of Policy And Institutional Reform on the Agricultural Sector in Sub-Saharan Africa: The Effect of Market Forces on Integrated Pest Management Adoption. Philip Szmedra, Agricultural Economist, USDA/ERS, and Walter Knausenberger, Environmental Advisor, US AID/Bureau for Africa. USDA, 1301 New York Ave. N.W., Washington, DC 20005

Some important impacts of structural adjustment programs on the agricultural sectors of many Sub-Saharan African (SSA) nations have been the removal of government involvement in input subsidization schemes, the introduction of markets where previously State control had existed, and the promotion of non-traditional export crops to help diversify agriculture. Each of these policies has significant import for the availability and use of chemical pesticides which in turn affects the long term environmental and societal well being in the region. The removal of subsidies and the introduction of input markets has caused pesticide prices to increase. This, along with diminished sources of subsidized agricultural credit, has left many farmers without effective access to modern pest control alternatives. Further, nontraditional export crop promotion has generally focused on horticultural and floricultural crops for the European market. Therefore, forces are in place to both stimulate the demand for effective pest management methods while at the same time limiting access to modern chemical pesticides while encouraging the continued use of pesticide materials that have been banned from agricultural use in the developed world. The research and extension of Integrated Pest Management (IPM) practices would do much to address the pest management needs of the smallholder and cash crop producer, as well as the plantation production systems in the region. This paper provides a synopsis of a portion of the work undertaken since 1994 by US AID/Bureau for Africa in Operation with the EPAT Project of Winrock International in assessing the environmental implications of agricultural trade and policy reform programs in SSA. Specifically, the paper gives an overview of the current state of pesticide use and pest management in the SSA region, explores the economic factors involved in assessing pesticide use and judging possible future trends in use in SSA, identifies impediments to IPM dissemination and recommends strategies that would help to promote IPM methods.

IPM on the World Wide Web: the National IPM Network - Northeast Regional Server. Cheryl TenEyck, NYS Integrated Pest Management Program, Cornell University, Geneva Campus, New York
[http://www.nysaes.cornell.edu:80/ipmnet/]

The transfer of information from the researcher to the end-user is vital in facilitating the adoption of any new technology. World Wide Web (WWW sites on the Internet have rapidly become an important information tool for a wide variety of topics. This increased popularity results from a number of factors: the software to access the information on WWW sites is essentially free to non-commercial users, the software's interface makes the transfer of text and graphic information 'user-friendly' and simple, and access to the Internet through commercial providers is becoming easier and less expensive. Commercial interests are taking advantage of the WWW for a number of purposes but are motivated by economics; WWW is an inexpensive and effective way of reaching a widely distributed body of consumers. In addition, WWW sites are easily developed and rapidly modified. The increased popularity of the WWW presents an opportunity to provide information on Integrated Pest Management techniques to a wide audience of end users at a minimal cost.

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Demonstrations of the resources available on these servers will be provided and future resources and potential uses discussed. An assessment of the economic advantages provided through electronic publication of extension materials will be presented.

Multiple Pest Interactions Involving Root-knot Nematodes and Annual or Perennial Weeds. Stephen H. Thomas and Jill Schroeder, Department of Entomology, Plant Pathology and Weed Science, and Leigh W. Murray, Department of Experimental Statistics, New Mexico State University, Las Cruces, NM 88003-8003

The ultimate success of IPM efforts depends largely upon our understanding of the interactions among multiple types of pests and agricultural commodities. The goal of current research efforts in New Mexico is to characterize the interaction between selected weed species, including *Cyperus esculentus* and C. *rotundus* (yellow and purple nutsedge, respectively), the plant-parasitic nematode *Meloidogyne incognita* (southern root-knot nematode), and chile pepper (*Capsicum annuum*). The pest species were chosen because of their concomitant world-wide distribution and severity of effects on crop plants. Our specific objectives are to determine the influence of root-knot nematodes on weed growth, development, and competitive interaction with peppers and to determine the influence of yellow nutsedge, purple nutsedge and selected annual weeds on nematode population development, life cycle, virulence, and winter survival. Field research in which peppers and weeds were interplanted during 1993 and 1994 demonstrated that the presence of perennial weeds increased root-knot nematode reproduction on peppers and decreased pepper root weight, possibly due to weed/chile competition. Annual weeds (*Amaranthus palmeri* = Palmer amaranth; *Anoda cristata* = spurred anoda; *Physalis wrightii* = Wright groundcherry) generally supported greater root-knot nematode reproduction than perennial weeds (yellow and purple nutsedge), but had less effect on nematode reproduction on chile or pepper root weight. Purple nutsedge roots, rhizomes and tubers persisted from the end of the season until field preparation the following year, and maintained root-knot nematode eggs at relatively constant levels. In greenhouse experiments during 1995, tuber production by yellow nutsedge plants increased as root-knot nematode populations increased. These results indicate that the combined presence of nutsedges and root-knot nematodes may enhance survival of both groups of pests. Additional research is underway in which nematode-infested and uninfested treatments are being studied to identify the interactions between peppers, annual and perennial weeds and root-knot nematodes under approximate field conditions.

Naturalyte Insect Control and IPM. G.D. Thompson, P.W. Borth, S.H. Hutchins and L.G. Peterson, DowElanco, Indianapolis, IN 46268

Naturalyte Insect Control is the name for DowElanco's new proprietary biologically based insect control products. Naturalytes are defined as naturally produced metabolites from living organisms that selectively control pests. To qualify within DowElanco's naturalyte class, the metabolites must have a high level of efficacy that is equivalent or superior to commercial standards and at the same time possess human and environmental compatibility that is equivalent to that provided by most biological products. Naturalyte Insect Control products are exciting IPM tools due to the fact that they provide (1) a high level of efficacy that permits waiting until pests reach economic thresholds before treating; (2) selectivity against pests only-leaving beneficial insects for residual control; and (3) a unique mode of action which allows product class rotation to avoid resistance development or the need for higher rates and more frequent applications. Field results are graphed to demonstrate these attributes.

The Commercialization and Implementation of Pheromone-based IPM in Pome Fruits. Don Thomson, Pacific Biocontrol Corp., 400 E. Evergreen Blvd., #205, Vancouver, WA 98660

Mating disruption technology is increasingly being used for the control of codling moth in pome fruit production areas around the world. Some of the countries where codling moth mating technology is used commercially include the United States, Canada, Argentina, Australia, Italy and South Africa. In 1991, Isomate C Plus (Pacific Biocontrol Corp., Vancouver, Washington) became the first commercial formulation of codling moth pheromone to be registered in the United States. The total pome fruit acreage treated with Isomate C Plus has increased from approximately 1,200 hectares in 1991 to approximately 7,300 hectares in 1995.

The successful commercialization of mating disruption technology will depend in large part on the development and implementation of a pheromone- based IPM systems approach. The objective of a pheromone-based IPM program is to effectively manage key and secondary pests in an economically, ecologically and environmentally acceptable manner. In a pheromone-based IPM system, mating disruption is the major tactic used to control the key pest(s). The subsequent reduction or elimination of insecticides for control of the key pest(s) will promote crop or orchard environments that will support higher populations of natural enemies and thus enhance the biological control of both key and secondary pests. The development of monitoring and sampling techniques in conjunction with economic thresholds is essential in order to accurately assess the biological relationships between key and secondary insects and their natural enemies and to implement supplementary controls if required. Pheromone-based IPM should be presented to growers as a long term approach and commitment to pest management. Growers should be encouraged to define yearly objectives and then identify the strategies and tactics needed to achieve those objectives.

Insect Management by North Carolina Potato Growers in 1994. Stephen J. Toth, Jr., Department of Entomology, North Carolina State University, Box 7613, Raleigh, NC 27695 and Kenneth A. Sorensen, Department of Entomology, North Carolina State University, Box 7626, Raleigh, NC 27695

A mail survey of potato growers in 14 counties in North Carolina was conducted by the Cooperative Extension Service in the winter of 1995 to determine the use of pesticides and nonchemical pest management practices by growers on the 1994 crop. Pest management data from this and other grower surveys are provided to the NAPIAP. In 1994, potato growers treated 72 percent of the acreage with Asana XL, while Furadan and Thimet were used on 26 and 24 percent of the acreage, respectively, for Colorado potato beetle management. Other insecticides used to manage Colorado potato beetles included Monitor, M-Trak, Ambush, Vydate, Pounce and Guthion. Seventy percent of the potato growers surveyed felt that Colorado potato beetles in their potato crop had developed resistance to insecticides in 1994. Sevin and Furadan were considered ineffective against Colorado potato beetles by ovcr 40 percent of growers. Between 10 and 25 percent of growers reported beetle resistance to Guthion, Thiodan, Asana XL, Monitor, Ambush, Thimet and Vydate. For European corn borers, Monitor, Furadan and Asana XL were used by potato growers on 27, 24, and 17 percent of the acreage, respectively, in 1994. Growers also used Ambush and Guthion for the management of this pest. Potato growers treated about 40 percent of their acreage with Thimet to manage wire worms. Seventy-six percent of the growers reported that they, a family member and/or an employee scouted their potato fields for weeds, insects or plant diseases in 1994. Nearly 39 percent claimed that a professional scout or consultant performed this service. One grower's potato crop was scouted by a county extension agent. Approximately 86 percent of potato growers indicated that they rotated the fields on which they planted potatoes as a means of pest management. Corn and soybeans were the predominant crops rotated with potatoes. Seventy-four percent of potato growers applied different insecticides to reduce Colorado potato beetle resistance. A Colorado potato beetle resistance monitoring kit developed at North Carolina State University was used by 28 percent of growers in 1994.

Evaluating The Effectiveness of Pest Management Training to Vineyard Farm Workers. Lucia G. Varela, Area IPM Advisor, University of California Cooperative Extension & Statewide IPM Project, 2604 Ventura Ave., Santa Rosa, CA 95403-2894; and Rose Krebill-Prather, Sociologist, University of California Statewide IPM Project, Kearney Agricultural Center, 9240 South Riverbend Ave., Parlier, CA 93648

Early detection of pest problems allows for selection among preventive and control measures. Trained farmworkers can provide the grower with the prompt pest detection needed for an effective IPM program. Through a series of hands-on workshops, I taught 235 vineyard foremen how to identify the most important insect and mite pests in their area, how to diagnose the major grape diseases, how to identify the most important natural enemies found in vineyards, and how to monitor throughout the season. We used hand lenses and the knowledge acquired to practice techniques for identification and monitoring of insects in the field. We provided students with hand lenses and Spanish-language posters, fact sheets, and handouts so that they could train their crews.

We developed two post-training evaluation instruments, one for the foremen and the other for the employers. I conducted face-to-face interviews in Spanish with 100 vineyard workers. Employers were mailed the questionnaire.

Overall, the learning reported by workers was modest. Workers appeared to be most confident about information on disease identification, moderately confident about insect pest and mite identification and least confident about information on beneficial insects. Employer respondents were more positive. About three quarters reported that their workers' knowledge had improved "moderately" to "greatly" with regard to identification of diseases and insect pests. There was a positive correlation between how much the workers reported to have learned in the class and how much responsibility they have on the job. There was no correlation between the number of years of formal education the foremen had and the level of learning. The fact that literacy was not a significant factor in level of learning argues that hands-on training is an effective way of teaching farm workers. Three- fourths of the workers reported that their managers encouraged them to look for disease and insects more after attending the workshop. A majority of employers (88 percent) reported a change in their expectations of how workers perform their jobs. Two- thirds reported a "moderate" to "great" change in pest monitoring skill among workers.

Development And Implementation of a Grape Weather Network Computer-based Bulletin Board System For Grower Use in Making Pest Management Decisions. Timothy H. Weigle, New York State IPM Program, 412 E. Main St., Fredonia, NY 14063; C. Petzoldt, C. TenEyck, and J. Gibbons, New York State IPM Program, NYSAES, Geneva, NY 14456

In response to the reduction in the cost of weather monitoring equipment and the proven effectiveness of post- infection disease management programs, 20 Lake Erie Region grape growers purchased 10 weather units in 1994. These units, combined with the 4 weather stations currently being operated by the Grape IPM program provide weather information from Lake Ontario to Harborcreek, PA. Weather-driven disease management programs for black rot and powdery mildew developed at the New York State Agricultural Experiment Station, Geneva, NY, have been used successfully for timing of fungicides in Grape IPM implementation projects in New York since the 1990 growing season. Eliminating a single prebloom fungicide application of mancozeb + Nova would reduce fungicide use on the 33,000 acres by approximately 107,000 pounds, a potential savings of approximately $860,000 or $26/acre. The increase in weather instruments during 1994 and the increase in the number of growers interested in weather information created the need for a central location to collect, manipulate and disseminate weather data. A computer bulletin board system was developed and implemented for use by growers, industry personnel and extension specialists, faculty and staff in the Lake Erie Region to access information on disease infection periods. pest scouting results, insect identification, pest management protocols and local electronic mail. Wildcat! BBS, a text based BBS software, was used during the 1995 growing season. A new software package is being tested for use in 1996 which will provide a graphical interface similar to the World Wide Web. The BBS prototype used in grapes during 1995 will be replicated in four to five locations across New York State in 1996 in conjunction with a USDA Agricultural Telecommunications grant.

Areawide Management of Codling Moth with Pheromone Mating Disruption: the Randall Island Project. Stephen C. Welter and John E. Dunley, University of California, 201 Wellman Hall, University of California, Berkeley, CA 94720

Pheromone mating disruption was initiated on a regional scale in California pear orchards in 1993 to improve the level of success for mating disruption for codling moth and to address increasing problems with resistance in codling moth to azinphosmethyl. Low levels of resistance to azinphosmethyl were first discovered in California in 1989 that were correlated with increased application rates and frequencies as well as increasing problems with control. Mating disruption also was implemented on a large scale in an effort to manage a genetic problem at the appropriate population level. In addition, implementation at a larger regional scale targeted reducing problems among orchards, improving biological control of secondary pests, and achieving a general areawide suppression. A uniform management program was designed and accepted by growers for a three year period that relied primarily on the use of a synthetic pheromone dispenser (Isomate, Biocontrol, Inc.) for control of codling moth.

The Randall Island Project consists of 760 contiguous acres owned by 5 growers in the Sacramento Delta of California. The project is bordered by the Sacramento River and non-host crops on 2 additional borders. Along the final border that intersected a small portion of adjacent pear acreage, a buffer of pheromone dispensers plus insecticides were used to limit immigration of codling moth.

Overall, the project averaged less than 1 percent infestation for all harvests in all three years. In the first year, azinphosmethyl was used twice against the first generation and eliminated for the second or third generations, resulting in a 50 percent reduction. In subsequent years, azinphosmethyl use was limited to areas considered at risk. As such, azinphosmethyl use was reduced by 85 percent in Year 2 and 75 percent in Year 3 from the traditional number of 4 applications per year. In 1994, approximately 60 percent of the acreage was not treated with azinphosmethyl, whereas 30 percent was not treated in 1995. Despite the 75 to 85 percent reductions in azinphosmethyl, codling moth infestation averaged 0.41 and 0.76 percent in 1994 and 1995 respectively. However, there were untreated sites in both years than exceeded the 2 percent threshold for infestation. In contrast, all sites that received one application of azinphosmethyl timed to increasing codling moth flights achieved less than 1 percent infestation.

Methodological and Institutional Barriers to Farm Practices Assessment. Steven Wolf, University of Wisconsin, Institute for Environmental Studies, P.O. Box 1732, Wilmington, VT 05363. Peter Nowak, University of Wisconsin, Department of Rural Sociology, 1450 Linden Drive, Madison, WI 53706. Robert McCallister, University of Wisconsin Institute for Environmental Studies, 1450 Linden Drive, Rm. 350, Madison, WI 53706

Managing for change and measuring change within agricultural production systems, including IPM, requires rigorous assessment of both the context in which behaviors are examined and the behaviors themselves. We argue that such rigor has been lacking as applied to public sector IPM initiatives. In our assessment, IPM adoption research has been largely ad hoc, politically motivated, and characterized by application of outmoded theories and tools. As a result, base-line data on IPM implementation and our ability to conduct comparative analysis across commodities, production regions, and time are weak. This paper identifies conceptual and empirical constraints to understanding patterns of change in production systems in U.S. agriculture. We go on to suggest a series of theoretical, methodological and institutional innovations that support a more systematic and cost effective approach to tracking how individuals and farming systems respond to changes in agroecological parameters, markets, technology, policy, and public and private sector extension.

Specifically, we argue for integration of primary and secondary data sets through development and application of spatially explicit sampling and inventorying techniques. Similar to the conceptual approach employed in the multi-institutional Area Studies Program, we advocate using GIS technology to support integration of agroecological and socioeconomic data. Such an approach supports evaluation of behavioral change of individuals as well as farming system adaptation within the context of hypothesized IPM "drivers" such as modified pest regimes, resource management conflicts (e.g., odor problem), articulation of consumer preferences (e.g., pesticide-free), technological and economic change, public investment (e.g., SP-53), and development of a competitive crop consulting industry.

Pest Management Practices of Crop Consultants in the Midwestern United States. R. J. Wright and T. A. DeVries, University of Nebraska, South Central Research & Extension Center, Clay Center NE 68933-0066 and S. T. Kamble, Dept. of

Entomology, University of Nebraska, Lincoln NE 68583-4816

A mail survey of crop consultants in 12 north central States was conducted to assess pest management practices on corn, soybeans, alfalfa, wheat and grain sorghum during 1993. Selected information from the survey will be presented, primarily emphasizing insect management. The most crop consultants were identified in Kansas and Nebraska, with fewer crop consultants per State in the eastern part of the region. Kansas and Nebraska had the greatest reported acreage of crops scouted. The greatest scouted acreage was of corn, followed by soybeans, wheat, alfalfa and sorghum. The most common scouting interval reported was l/week; 68 percent reported making visits once a week or more frequently. Consulting fees per acre varied with crops; averaged over all States, the highest fees were charged for alfalfa ($4.80). with less charged for corn ($4.31). sorghum ($4.26). soybeans ($4.07), and the least charged for wheat ($3.74). There was a great range within crops, across the region, (e.g. corn varied from $3.21 to 6.13 per acre). This variation is probably related to the frequency of visits and the range of services offered (from comprehensive integrated crop management to less comprehensive agronomic only [no IPM] services) in different States. Planting time application of insecticides was the most commonly used corn rootworm control practice. Post-emergence applications of insecticides directed at larval rootworms (cultivation time applications, chemigation) were used primarily in the western part of the region. Foliar sprays for adult corn rootworn control were also most common in the western part of the region but some use occurred further east also. Use of crop rotation varied greatly across the region (23.8 to 83.7 percent rotated). Additionally, across all States there was an association between frequency of rotation in corn and insecticide use against corn rootworms; i.e., States with higher frequencies of rotated corn tended to treat a lower percentage of corn acreage for corn rootworm control.

Production And Pest Management Software For Potato Growers. Jeff Wyman, Walt Stevenson, Larry Binning, Tim Connell, Keith Kelling, Dave Curwen, University of Wisconsin, Madison, WI 53706

The Wisconsin potato crop is managed intensively through multiple inputs of pesticide, fertilizer, and irrigation. Beginning in 1979, a multidisciplinary team at the University of Wisconsin developed an effective IPM program to address key management decisions associated with this crop. Results of this research, funded by grower, State and Federal sources, provided the essential ingredients for development of a computer software program, WISDOM, now used for managing the potato crop on 70,000 acres in a multi-state area. The software helps growers determine the need for and timing of critical crop inputs. By reducing unneeded pesticide and irrigation applications, the software improves overall production efficiency and reduces adverse environmental impact.

Farm Size and Use of IPM. Jet Yee and Walter Ferguson, Agricultural Economists, United States Department of Agriculture, Economic Research Service, Room 532, 1301 New York Ave., NW, Washington, DC 20005-4788

This poster uses data from the 1992 Chemical and Farm Finance Survey to analyze the effects of farm size on the use of sustainable pest and nutrient management practices. The surveyed farmers grew corn, oats, soybeans, and wheat in Minnesota, and rice, cotton, and soybeans in Louisiana. Farms were sized using three criteria: crop sales, harvested acreage, and net cash farm income. Sustainable pest and nutrient management practices included scouting, crop rotation, beneficial insects, insect/disease test, pest management strategy, alternative pesticide, manure application, soil test, and nitrogen test. In general, big farms were more likely to use pest and nutrient management practices than small farms in Minnesota. In Louisiana, small farms were more likely to use nutrient management practices. There was no discernible pattern between farm size and use of pest management practices.

Comparison of results to previous studies and policy implications will also be presented.

Enhancing the TOMCAST System Through Expansion and Research. Curtis Young, IPM Extension Specialist, Jim Jasinsk, IPM Extension Specialist, Mac Riedel, Dept of Plant Pathology, Celeste Welty, Dept. of Entomology, Mark Bennett and Bob Precheur, Dept. of Horticulture and Crop Science, Ohio State University Extension, SW District Office, 303 Corporate Center Drive, Suite 208, Vandalia, OH 45377

TOMCAST is a disease forecasting program used in thirteen processing and fresh market tomato field sites throughout southern Michigan, Indiana, and Ohio. The development of warm, wet weather fungal diseases such as early blight, *Septoria* leaf spot, and anthracnose are monitored at each site using environmental dataloggers such as Campbell Scientific CR10 or Omnidata Datapods units. Clearly defined durations of leaf wetness and temperature result in the accumulation of Disease Severity Values (DSV). When specific DSV thresholds are exceeded, growers are recommended to initiate spray treatments to protect the crop from fungal disease. Bacterial and viral pathogens are not affected or predicted by this system. In 1995, late blight prediction was incorporated into the TOMCAST system by adding precipitation gauges to existing CR10 units and acquiring late blight software (BLITECAST module of WISDOM). There are currently ten CR10 units providing late blight prediction information within the tri-state TOMCAST network, in addition to disease prediction for early blight, *Septoria* leaf spot, and anthracnose. Seasonal variation in disease pressure can be tracked using this monitoring system. In 1995, 9 of 13 TOMCAST sites averaged 30 DSV units above 1994 levels. There were also three first year sites in 1995 and one site that accumulated fewer DSV than in 1994. Late blight was not detected in Ohio, but according to BLITECAST conditions were conducive at all locations for its development at various times throughout the State. Late blight warnings were also issued for the sites in both Indiana and Michigan; only Michigan reported having the disease. Efforts to increase the use of TOMCAST throughout the Midwest is dependent upon the proximity of a field to the nearest CR10 unit. In 1995, a cooperative research agreement with Sky bit, Inc., a company that generates weather information using National Weather Service data, remote sensed data, and computer modeling is being looked at as an option to replace CR10's. Preliminary work suggests promise for this "hardwareless" approach to disease management, but requires further research to verify reliability and accuracy.

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