

Pest Management Practices in Crop Production

Throughout history farmers have relied mostly on physical and cultural practices to manage and control the pests that damaged their crops [Smith, Apple, and Bottrell, 1976]. Weeds were controlled with tillage implements, mowing, site selection, planting seeds free of weedseeds, and often even with the use of hands and hand tools. Attempts to reduce losses from insects and disease also included practices such as crop rotations, planting trap crops, adjusting planting dates, and seed selection. Prior to the 1940's, the use of chemicals was limited to a few inorganic chemicals and some natural or organic materials. These controls were for a limited spectrum of pests and often were ineffective. The development of synthetic pesticides following World War II, along with improvements in seed genetics, mechanization, and other production practices, brought about many changes in the way farmers manage pests. Before the development of synthetic chemical pesticides, weed control was primarily limited to mechanical practices. The purpose of this chapter is to report estimates of various kinds of chemical, cultural, and biological practices that are now used to combat the damages caused by pests.

Agricultural pesticide expenditures have grown from \$44 million in 1940 to over \$8 billion in 1997, a 15-fold increase in constant dollars [Aspelin, 1999]. Many studies on the productivity of pesticides give economic justification for increased farm use, but the studies do not account for possible health costs or environmental damages. Studies of agricultural productivity report marginal returns to pesticide use in the range of \$1 to \$3 for each dollar spent on pesticides [Headly, 1968; Padgitt, 1969; Carlson, 1977; Duffy and Hanthorn, 1984; Fernandez-Cornejo and Jans, 1995]. Estimates of marginal returns varied between pesticide types, crops, and regions. Miranowski found higher returns for corn insecticides (\$2.02) than corn herbicides (\$1.23). Campbell (1976) estimates a \$12 return per dollar of apple insecticides while Lee and Langham (1973) reported marginal returns of less than \$1 on citrus. Some evidence has been reported that the model specification of some of the earlier studies tends to overestimate the marginal productivity of pesticides [Lichtenberg and Zilberman, 1986]. Teague and Brorsen (1995) estimated declines in the marginal returns from pesticides between 1949 and 1991, but marginal returns were still above marginal costs. Estimates of marginal productivity are also an indirect measure of the foregone production that might occur should farmers be required to constrain pesticide use to protect human health or the environment.

A pesticide, according to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) [7 USC 136] is "... any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, or weeds, or any other forms of life declared to be pests; and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant." Types or classes of pesticides used in this report are:

- **Fungicides** control plant diseases and molds that either kill plants by invading plant tissues or cause rotting and other damage to the crop both before and after harvesting.
- **Herbicides** control weeds that compete for water, nutrients, and sunlight and reduce crop yields. Herbicides that are applied before weeds emerge are *preemergence herbicides*. Preemergence herbicides have been the foundation of row crop weed control for the past 30 years. Herbicides applied after weeds emerge are *postemergence herbicides*. Postemergence herbicides normally have less residual activity and do not persist in the environment as long as preemergence herbicides. Treatments applied prior to any tillage or planting to kill existing vegetation are referred to as "burndown" applications. Burndown applications are often a part of no-till systems.
- **Insecticides** control insects that damage crops. For this report, pesticides used to control mites and nematodes are classified as insecticides. Products used as soil fumigants, with a broad range of target pests including insects, mites, and nematodes, are not classified as insecticides in this report.
- **Other Pesticides** include soil fumigants, growth regulators, desiccants, and other pesticide materials not otherwise classified. Sulfuric acid, when used as a desiccant on potatoes, is included in this class, but petroleum oils used as adjuvants are excluded.

A Restricted-Use Pesticide is a pesticide product whose use requires special handling because of the toxicity of the product's active ingredients. Restricted-use pesticides may be applied only by trained, certified applicators or persons under their direct supervision. All labeled uses of an active ingredient may not be restricted. In some cases, only certain formulations, concentrations, or uses are restricted. Private and commercial applicators are required to keep records of applications of restricted-use pesticides [Subtitle H, 1990 Federal Agricultural Conservation and Trade Act].

The USDA surveys of pesticide use document recent changes in the quantity of pesticides and selected pesticide ingredients applied as well as differences in pesticide use between crops, geographic areas, and cultural and other pest-management practices [USDA, NASS and ERS, 1996c]. The commodity acreage represented in the USDA surveys accounts for approximately 60 percent of the U.S. cropland planted to crops. Pesticide use and pest management practices on the remaining cropland, pasture, range, forest, or other agricultural activities, including livestock, are not included. Estimates of total agricultural pesticide

use, as well as nonagricultural uses, are reported by the Environmental Protection Agency [Aspelin, 1999]. [See appendix A for a description of USDA pesticide surveys and the commodities and States represented.] Besides pesticide use, the USDA survey data provide estimates of farmers' use of biological and cultural pest prevention practices, scouting and other pest-monitoring activities, and the information sources used to make pest-management decisions.

Pesticide Use

The estimates of pesticide use reported in this section are based on annual surveys since 1990 for five field crops (corn, soybeans, wheat, cotton, and fall potatoes) and biennial surveys that include 24 fruit and 21 vegetable crops. (See appendix A in this report for specific crops and States included in the surveys.) These States and surveyed commodities accounted for about 60 percent of the U.S. cropland planted to crops and about 75 percent of all agricultural pesticides. In all, more than 250 different pesticide active ingredients were reported on these agricultural crops and classified as herbicides, insecticides, fungicides, or other pesticides. Aggregate pesticide use is reported by the weight of the active ingredients and the number of acres treated one or more times. The intensity of pesticide use is reported by application rates (pounds of active ingredient per treated acre) and number of acre-treatments per acre (total number of different pesticide ingredients applied and number of repeat applications of the same ingredient).

Weed Control Accounts for Most Pesticide Use

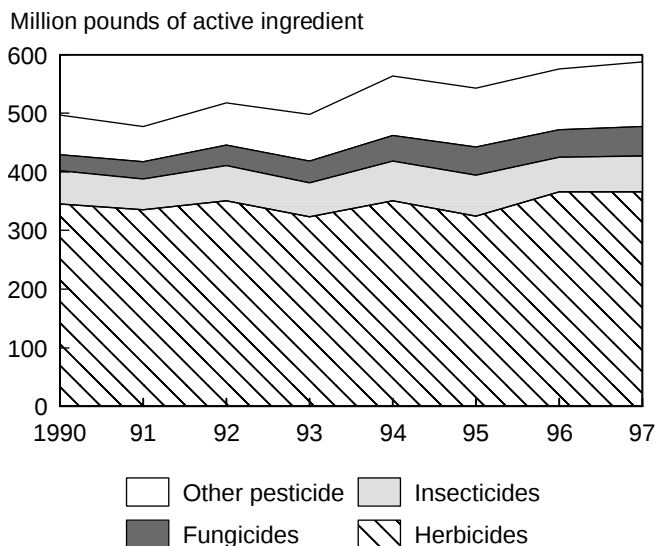
Herbicide ingredients accounted for 62 percent of the 588 million pounds of pesticides applied to the surveyed crops in 1997 (fig. 3A1). About 210 million acres or 86 percent of the surveyed crop area in 1997 received some herbicide treatments. Pesticides in the “other pesticides” category were the second largest in terms of pounds but were applied to only 6 percent of the area. Some ingredients in the “other” category are applied at several hundred pounds per acre compared with herbicides, insecticides, and fungicides, which are normally applied at only a few pounds or even a few ounces per acre. About 18 percent of the crop acres were treated with insecticides. The use of fungicides was primarily limited to potatoes, vegetables, and fruits and represented the smallest use in both total acres treated and total pounds applied.

Total quantities of pesticide use increased about 18 percent between 1990 and 1997 on the surveyed crops, but fluctuated annually with changes in crop acres and other factors. Although the total use increased, the trends varied among pesticide types. Most of the increase in pesticide use occurred in “other pesticides” and largely was a result of a change in products rather than any change in the number of acres treated. There was little change in the pounds of herbicides used between 1990 and 1997, but the share of acres treated edged up while average application rates declined. The use of both insecticides and fungicides increased, with most of the insecticide increase on cotton and the fungicide increase on potatoes and other vegetables.

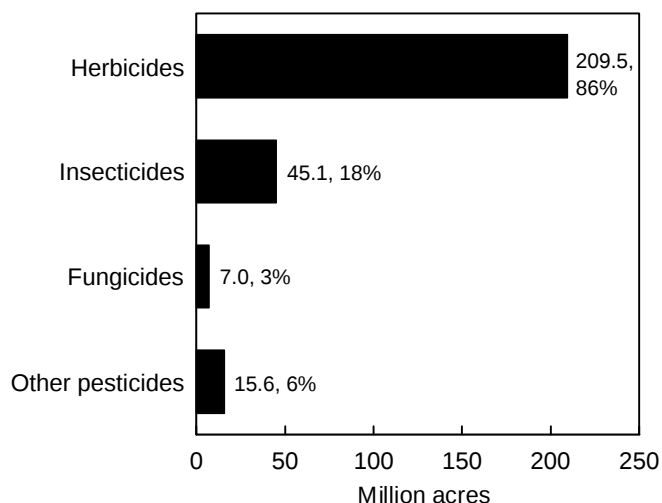
Figure 3A1

Weed control accounts for most pesticide use

Quantity of pesticide active ingredients applied to selected crops 1/



Total acres treated one or more times with a pesticide ingredient 2/



1/ The constructed estimates of pesticide quantity and treated area represent 244 million acres of corn, soybeans, wheat, cotton, potatoes, other vegetables, and fruit. See appendix table B5.

2/ The first value at the end of the bar is acreage treated, and the second value is the percentage of the total crop area treated.

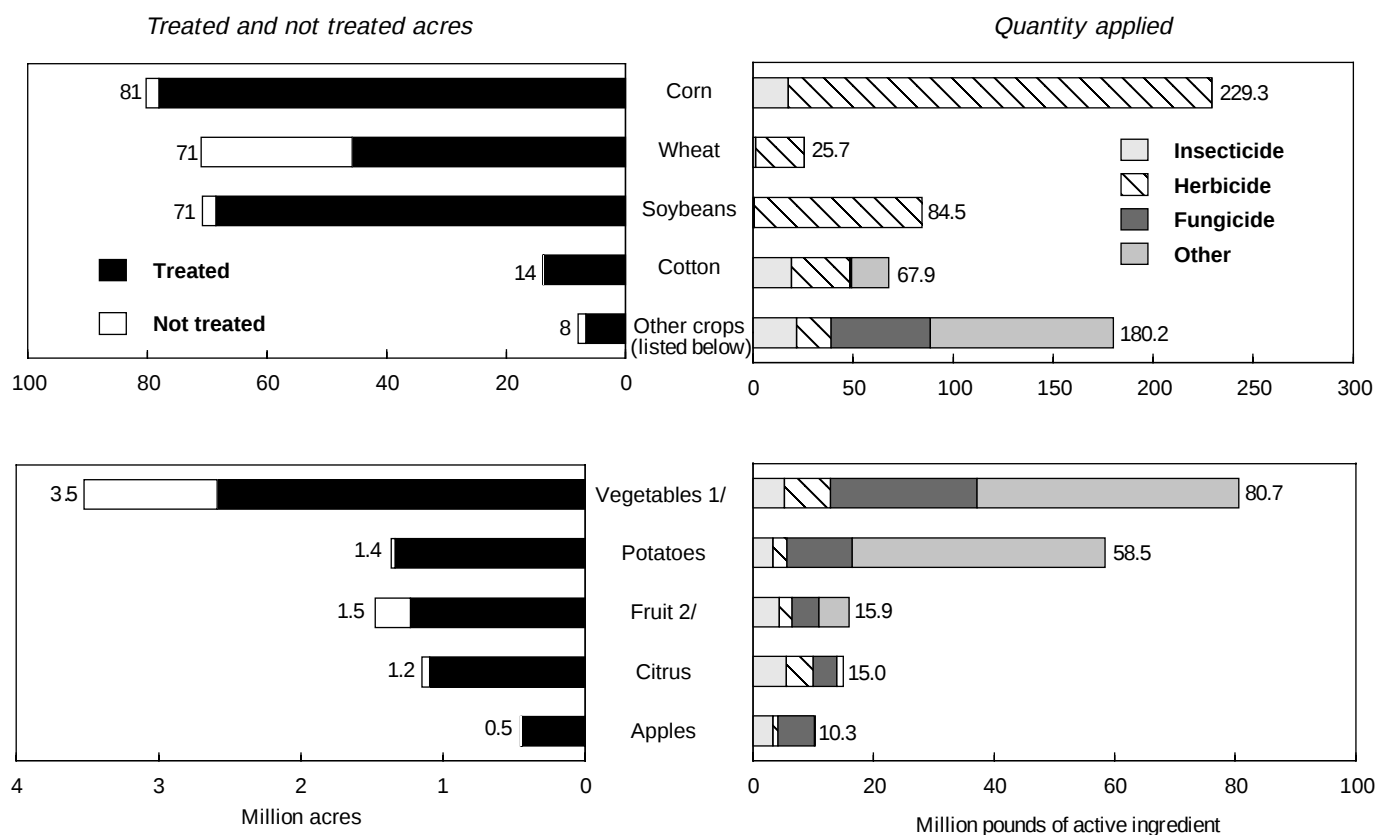
Sources: Lin, Padgett, Bull, Delvo, Shank, and Taylor, 1995; USDA, NASS and ERS, 1994, 1995d, 1996c, and 1996d.

Corn Received Largest Quantities of Pesticides

Most crops included in the USDA surveys received some pesticide treatments, but the seasonal rate of application and types of pesticides applied differed among crops (fig. 3A2). Corn had the largest crop acreage in 1997 with 81 million acres planted and exceeded all other surveyed crops in terms of quantity of pesticides applied and acreage treated. Nearly all corn acres were treated with some pesticides, and herbicides accounted for most of the use. Although wheat acreage is only slightly less than that of corn, significantly less pesticide was applied to wheat. Many winter wheat acres received no pesticide treatments, and the intensity of treatments on the treated acres was much less than for corn. Soybean acres were treated mostly for weeds and were the second largest users of herbicides. Cotton acreage was much smaller than that of corn, wheat, or soybeans, but the seasonal rate of aggregate applications was higher. Cotton was the largest user of insecticides and accounted for 32 percent of the total quantity of insecticides. Potatoes, with only 1.4 million acres planted in 1997, were the second largest users of pesticides among the surveyed crops. Nearly 75 percent of all potato pesticides were classified as “other pesticides”—mostly soil fumigants and vine killers. Most fruit acres received several treatments per year for insects and diseases, but because of their relatively small acreage and low application rates, fruit accounted for only 7 percent of the total pesticide use.

Figure 3A2

Largest quantities of pesticides used for corn production, 1997



1/ The constructed estimates represent 244 million acres. See appendix table B6 for specific crops and area. The pesticide use for vegetables is based on the 1994 use rates. The estimates for pesticide use for fruits are based on 1995 use rates, and the estimates for field crops are based on 1997 use rates.
2/ Includes fresh and processed vegetables and strawberries from the 1994 crop year.

Source: USDA, ERS and NASS, 1995a, 1996b, and 1998b.

Variation in Pesticide Application Rates Across Fields

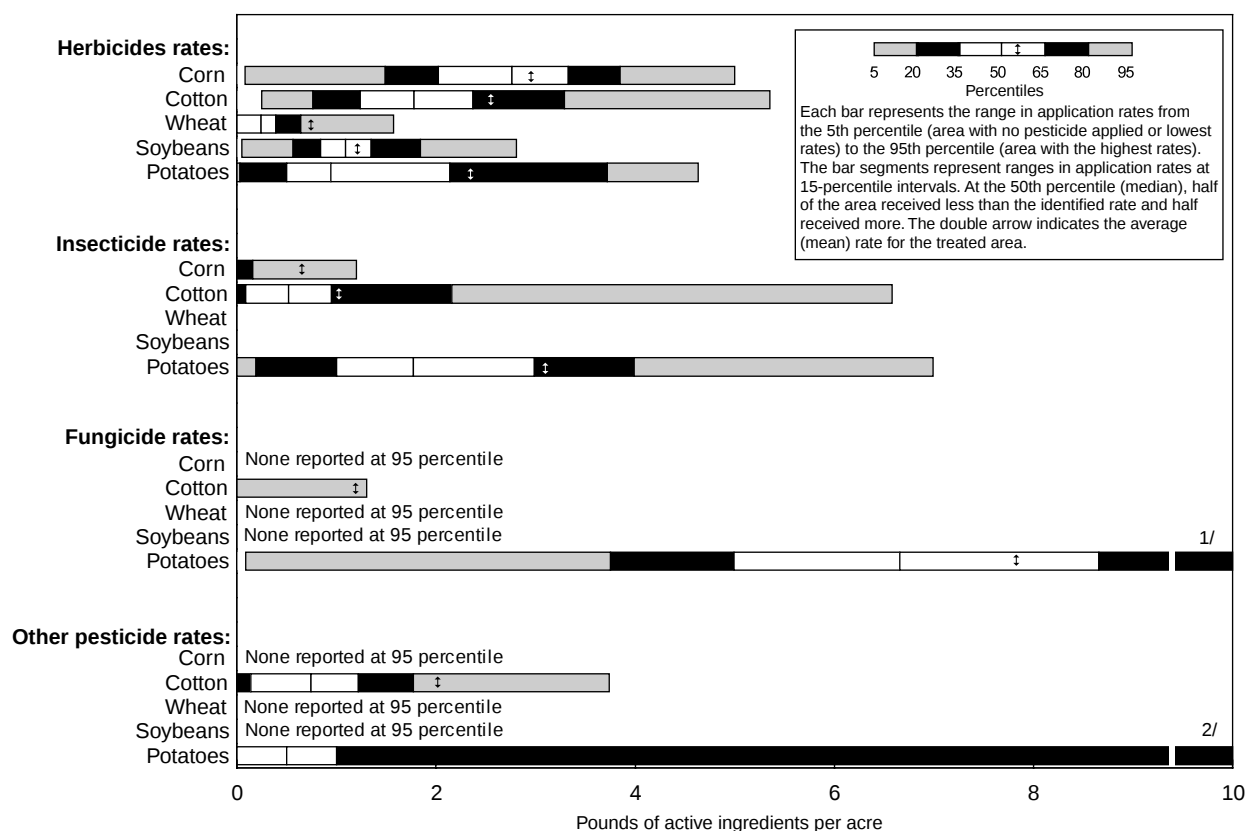
The intensity of pesticide applications varies widely not only between crops and pesticide types but also between fields of the same crop (fig. 3A3). Many factors contribute to differences in pesticide application rates between fields. The target pest species, infestation levels, weather, use of cultural practices, application methods and timing, and prices can all affect the selection and the amount of pesticide material applied [Lin, 1995]. Differences in the potency and persistence of ingredients are additional factors affecting the quantity applied. Some pesticide ingredients are applied at several pounds per acre, but alternative pesticides that provide similar kinds of pest control are applied at only a few ounces per acre. Some ingredients, especially insecticides and fungicides, require several treatments during the growing season because they soon lose their effectiveness when exposed to weather and other environmental forces. These factors and the length of the growing season can all affect the accumulated quantities applied and total number of acre-treatments.

The most intensively treated land can account for a disproportionately large share of pesticide use on any crop. For corn herbicides, the application rates ranged from zero at the 5th acreage percentile to 5 pounds per acre at the 95th acreage percentile. At the median (50th acreage percentile), half of the corn acreage received 2.8 pounds or more per acre while the other half received less than 2.8 pounds per acre.

Although the majority of potato acres received less than 2.5 pounds of herbicide or insecticide ingredients, some fields received higher rates of fungicide and other pesticide ingredients. Twenty percent (80th acreage percentile and higher) of the potatoes received at least 12 pounds of fungicides and at least 140 pounds of “other” pesticides. At the 95th acreage percentile, the rates exceeded 16 pounds for fungicides and 300 pounds for “other” pesticides. Treatments accounting for such high levels of use include several repeat application of fungicides, the use of sulfuric acid as a vine killer, or treatment with a soil fumigant. A single treatment with sulfuric acid or a soil fumigant can be at a rate of several hundred pounds per acre.

Figure 3A3

Pesticide application rates vary among fields, 1997



1/ This bar extends to 11 pounds per acre at the 80th acreage percentile and 17 pounds per acre at the 95th.

2/ This bar extends to 155 pounds at the 80th acreage percentile and over 400 pounds at the 95th, reflecting the use of sulfuric acid as a potato vine killer. The mean rate for other pesticides was 104 pounds per treated acre.

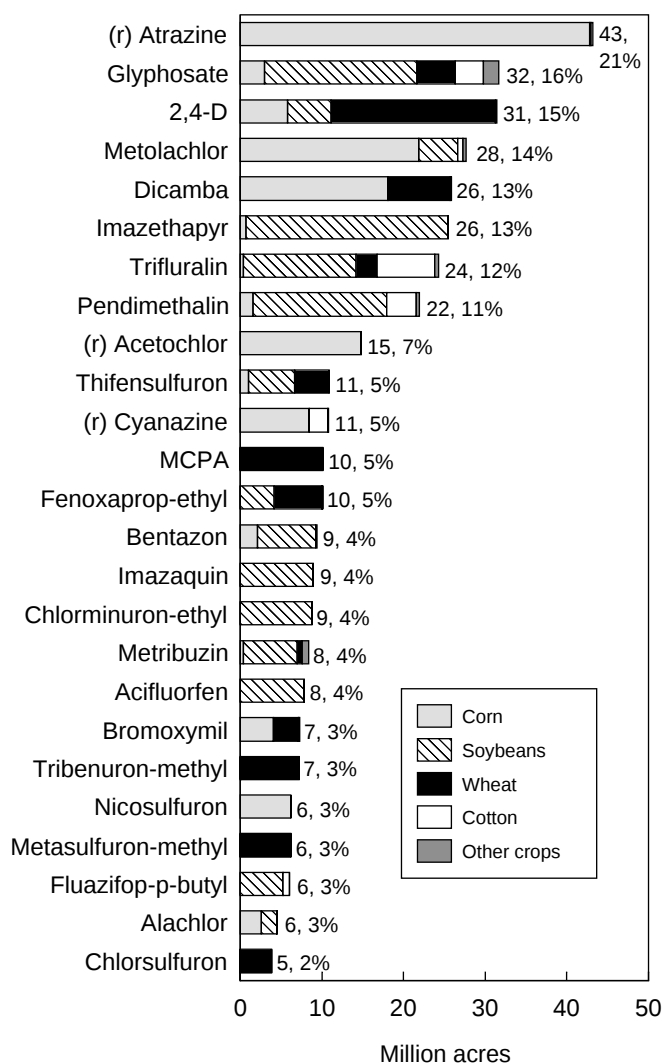
Source: USDA, ERS and NASS, 1996c.

Atrazine was the Leading Herbicide Ingredient

Although many herbicide ingredients are used in agriculture, a relative few account for most of the use (total pounds or acres treated, fig. 3A4a). Only 23 herbicide ingredients were applied to more than 5 million (3 percent) of the 188 million acres surveyed. Atrazine, 2,4-D, dicamba, and metolachlor were among the five leading herbicides, and all have been widely used for more than 30 years. These ingredients are applied both as a single ingredient or in combination with other ingredients to improve their efficacy and cost effectiveness. Atrazine is almost exclusively used on corn and grain sorghum, while dicamba and 2,4-D are also used on wheat and other crops. Glyphosate was the second most used herbicide in acres treated. It is frequently used on orchards and vineyards and widely used with no-till systems on corn, soybeans, and wheat. Imazethapyr, first registered for use in the late 1980's, is the leading ingredient used on soybeans. Trifluralin, another ingredient available 30 years ago, is the leading herbicide used on cotton and also is widely used on soybeans and vegetables. Three of the 25 leading herbicide ingredients are labeled as "restricted-use" pesticides—atrazine, cyanazine, and acetachlor. (All formulations of an ingredient, however, may not be labeled for restricted use). Restricted-use products are only to be applied by applicators who are trained and certified.

Figure 3A4a

Atrazine was the leading herbicide applied to the surveyed area, 1996-97 1/



1/ The letter "r" in the parentheses identifies ingredients that are restricted-use products. Not all formulations of the ingredient may be restricted. The first value at the end of each bar is the area treated, and the second value is the percent of total surveyed area receiving the ingredient.

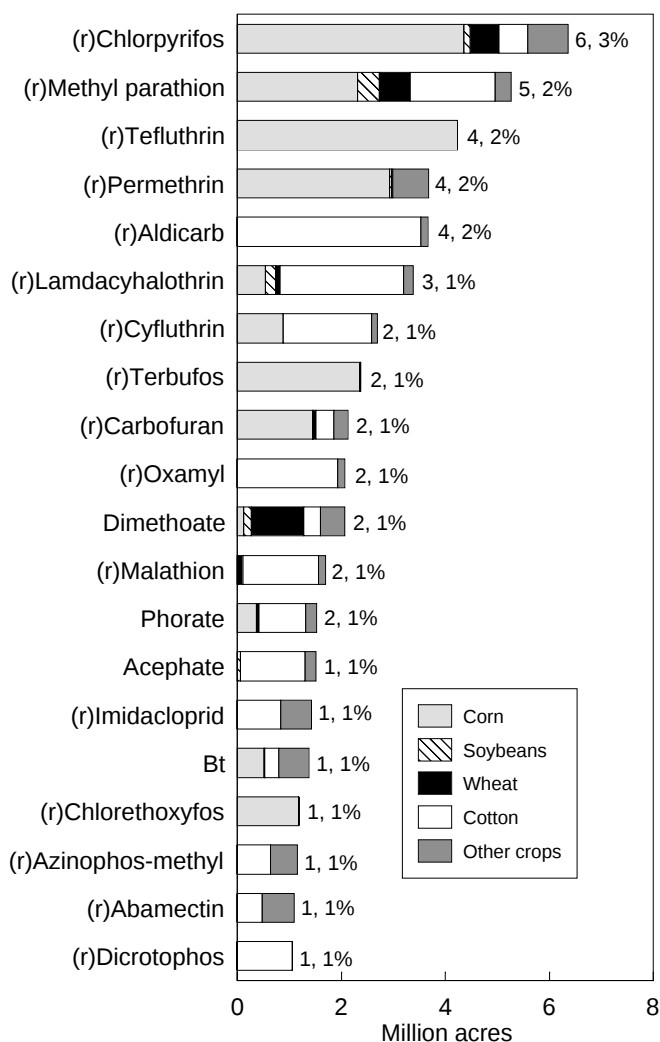
Sources: USDA, NASS and ERS, 1998a, 1998b, and 1997a.

Chlorpyrifos was the Leading Insecticide Ingredient

More than 60 different insecticide ingredients were reported used on the surveyed crops, but only a few accounted for most of the acres treated (fig. 3A4b). Only eight ingredients were applied to more than 2 million of the 188 million acres surveyed. Chlorpyrifos and methyl parathion, the two most widely used insecticidal ingredients, were applied to several different crops, with corn and cotton accounting for the largest treated area. Unlike herbicides, most of the leading insecticide ingredients are labeled as “restricted-use” pesticides and require application by licensed applicators. Chlorpyrifos and methyl parathion are among the organophosphate compounds which have been assigned top priority by the Environmental Protection Agency for tolerance re-assessment using the 1996 Food Quality Protection Act guidelines [EPA, 1998]. (See box, p.26, on the use of organophosphate pesticides.)

Figure 3A4b

Chlorpyrifos was the leading insecticide applied to surveyed area, 1996-97 1/



1/ Represents 188 million acres of field crops, fruits, and vegetables. See appendix table B.5.

The letter "r" in the parentheses identifies ingredients that are restricted-use products. Not all formulations of the ingredient may be restricted. The first value at the end of each bar is the area treated and the second value is the percent of total surveyed area receiving the ingredient.

Sources: USDA, NASS and ERS, 1998a, 1998b, and 1997a.

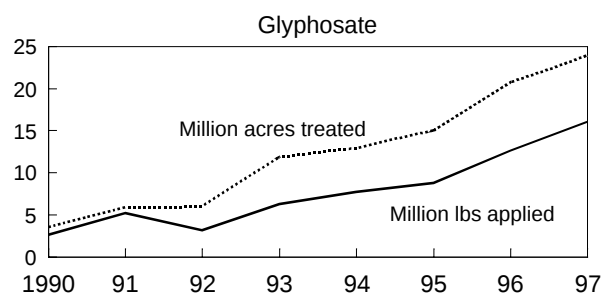
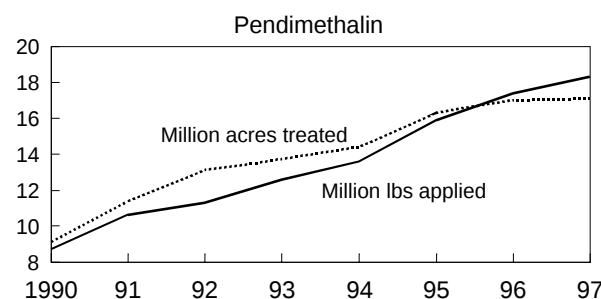
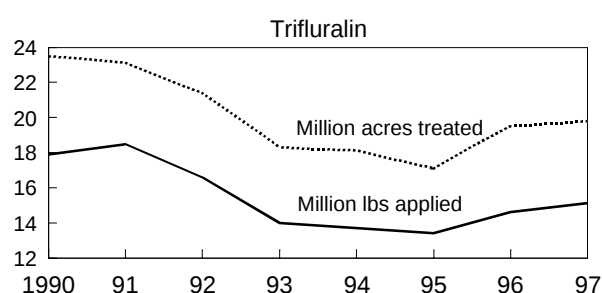
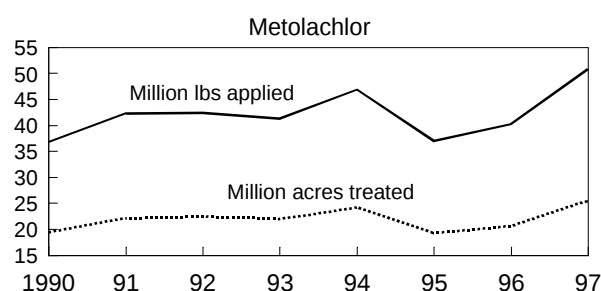
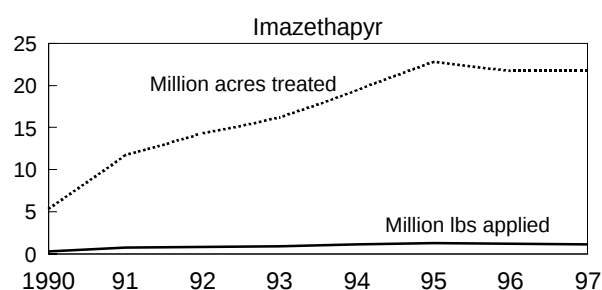
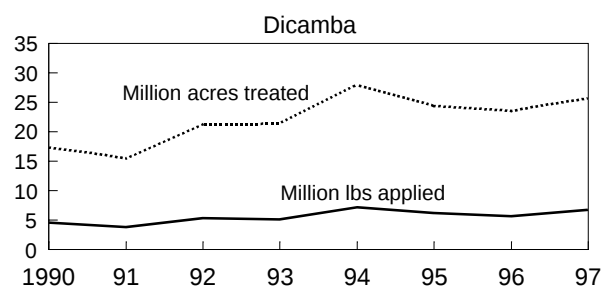
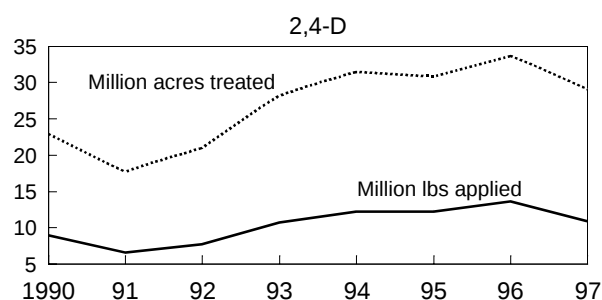
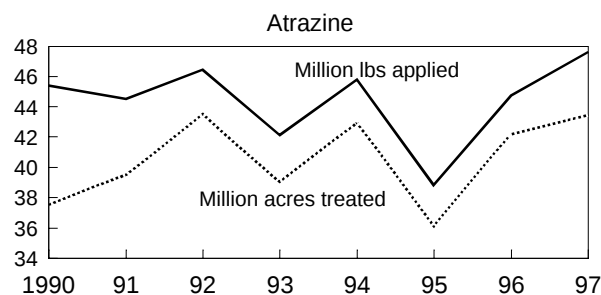
Change in Herbicide Ingredients and New Herbicides Adopted between 1990 and 1997

Because the combination of pesticide ingredients used is constantly changing with the adoption of newer products and abandonment of older products, the trend in aggregate use masks most changes in the use of individual ingredients (figs. 3A4c). The development and use of new ingredients

that are less toxic to humans and wildlife species, that quickly degrade to natural and safer compounds, and that are less likely to move into the atmosphere or water supplies can offer health and environmental benefits just as would any downward trend in aggregate quantity. Changes in the use of several leading herbicide ingredients are illustrated in this chart.

Figure 3A4c

Change in herbicide ingredients' use, 1990-97



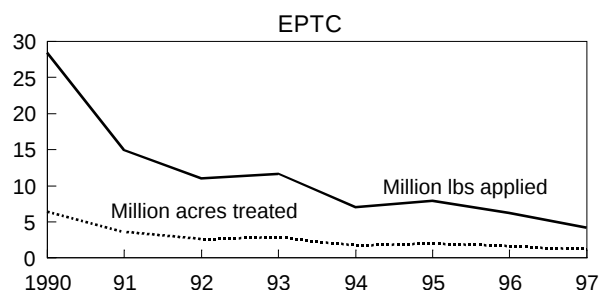
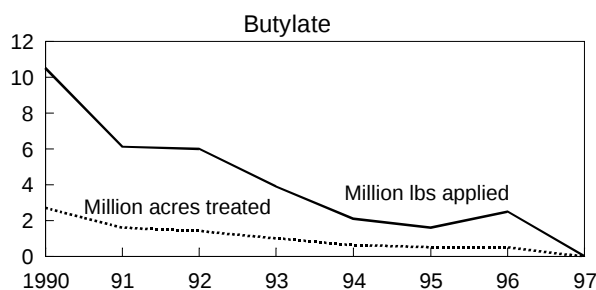
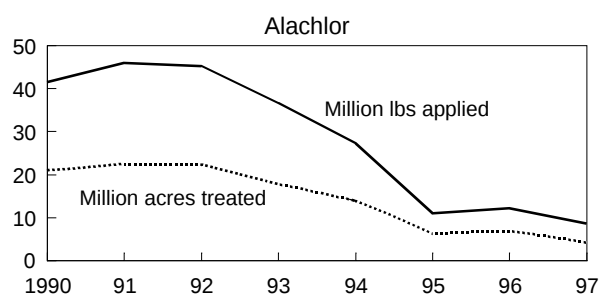
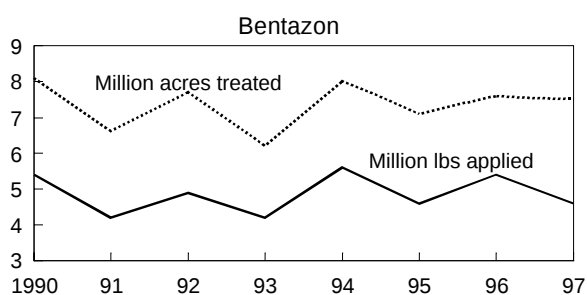
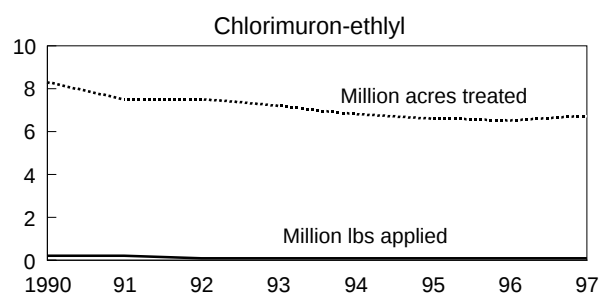
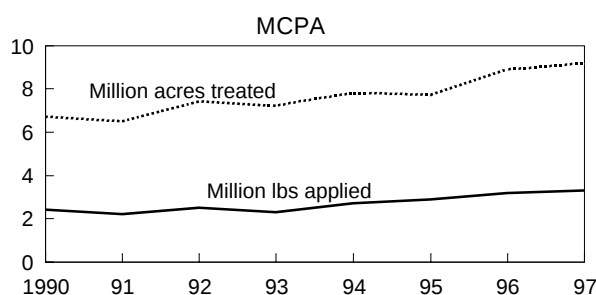
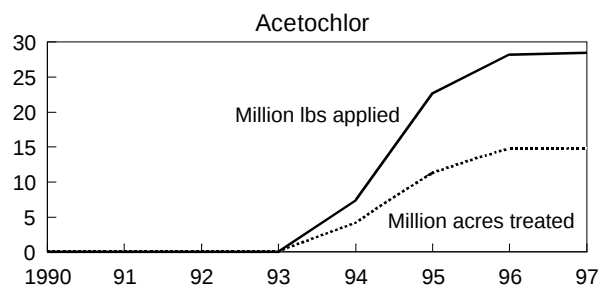
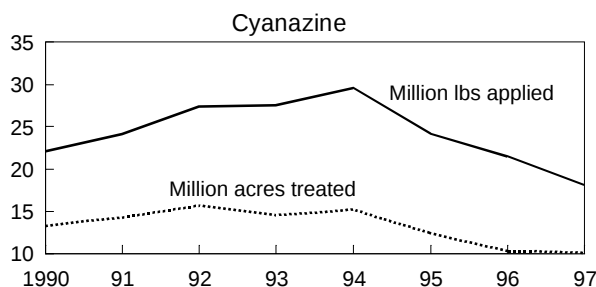
Source: USDA, NASS and ERS, 1996c and 1995c.

Acetochlor is a herbicide that was granted conditional registration by EPA in 1994 for use on corn. Its use climbed from 7 percent to 24 percent of the corn acreage between 1994 and 1997, while acreage treated with alachlor, a product that provides similar kinds of weed control on corn, dropped from 25 percent to 7 percent of the acreage. Acreage treated with glyphosate and imazethapyr more than quadrupled during the 5 years. Glyphosate use increased with the adoption of soybean seeds resistant to the herbi-

cide. Imazethapyr is a relatively new ingredient used for soybeans and apparently a cost-effective substitute for older ingredients, like trifluralin. The area treated with atrazine fluctuated between 64 and 69 percent of the planted corn acreage between 1990 and 1997 which is not significantly different from the 68 percent reported in a 1976 survey [Eichers, Andrienas, and Anderson, 1978]. While the share of acres treated with atrazine has been stable, total quantities have declined some from reductions in application rates.

Figure 3A4c--Continued

Change in herbicide ingredients' use, 1990-97



Source: USDA, NASS and ERS, 1996c and 1995c.

Organophosphate Pesticides are used in the Production of Many Agricultural Crops

The Food Quality Protection Act of 1996 [PL 104-170] stipulates that risk assessments for pesticide use consider the aggregate exposure from all sources, including food, drinking water, and household uses and that an extra tenfold safety margin be made for food items common in the diets of infants and children (apples, peaches, pears, potatoes, carrots, sweet corn, green beans, peas, and tomatoes). Organophosphate pesticides have been identified by the U.S. Environmental Protection Agency to be the first family of pesticides to be reviewed under the new guidelines [EPA, 1998]. Some current uses of organophosphate pesticides on crops could be prohibited under these new assessment procedures.

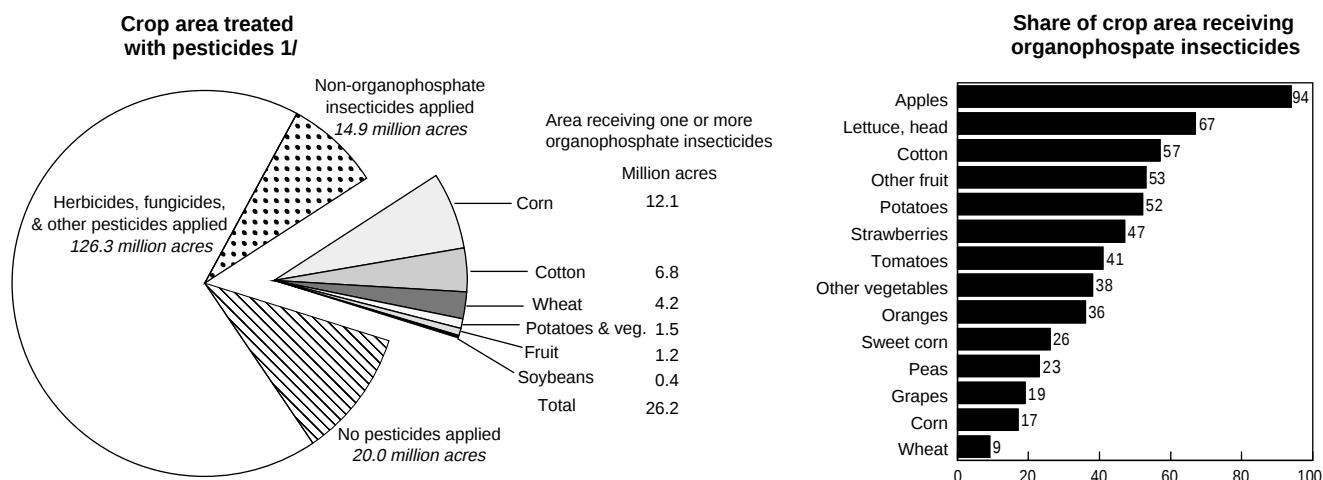
Organophosphate pesticides can affect the enzyme (acetylcholinesterase) which controls the nervous system. Organophosphate pesticides can be absorbed by inhalation, skin absorption, and ingestion, and certain organophosphates are prone to storage in fat tissues [EXTOXNET, web site]. The most common symptoms from overexposure are headaches, nausea, and dizziness, but they can cause sensory and behavior disturbances, lack of coordination, and depressed motor functions, and at high concentrations organophosphates can cause respiratory and pulmonary failure. The long-term effects of these chemicals, especially when the exposure is during early growth and developmental periods, are not fully known. Concern about those long-term effects is one reason for their re-assessment priority.

Farmers have used organophosphate pesticides for many years to reduce pest damages on many different crops. These pesticides can kill a broad spectrum of insect pests and have a longer persistence than some alternatives. A large share of the fruit and vegetable acreage is treated with organophosphate insecticides, but the major field crops of corn, cotton, and wheat account for most of the cropland area treated with these pesticides. Organophosphates were applied to over half the acreage of apples, peaches, pears, and potatoes, all of which are identified as most common in the diets of infants and children.

USDA's Agricultural Marketing Service collects data on pesticide residues in food, including fresh and processed fruits and vegetables [USDA, Agricultural Marketing Service, 1998]. In 1996, 4,856 fruit and vegetable samples were analyzed for residues of 78 different pesticide ingredients, including organophosphates that are most widely used in fruit and vegetable production. About 12 percent of the samples represented imported produce. Organophosphate pesticide residues were detected on many of the samples, but only three samples exceeded the established tolerance level for the commodity. Presumptive violations occurred on 90 samples where no tolerance has been set, but an organophosphate residue was detected.

Figure A

Organophosphate pesticides were applied to 14% of major field crops, potatoes, fruits, and vegetables, 1995-96



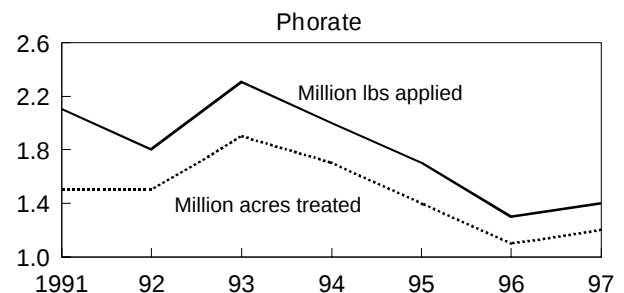
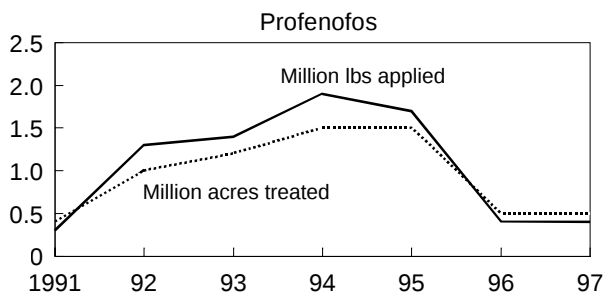
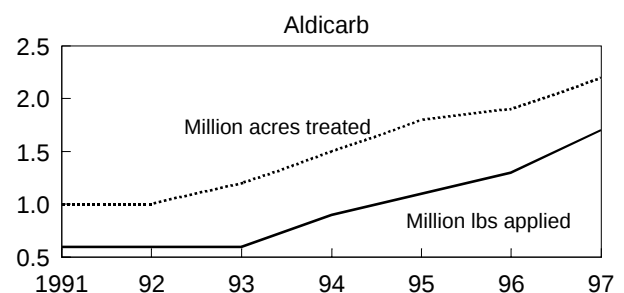
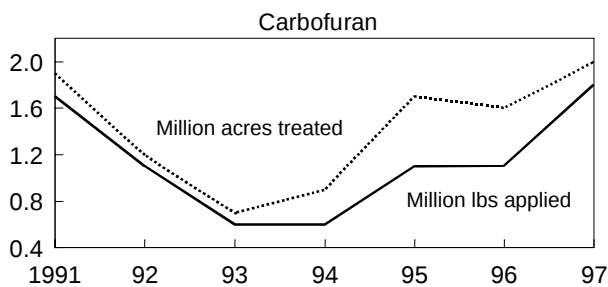
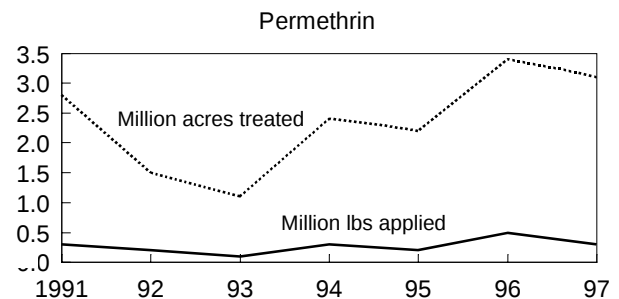
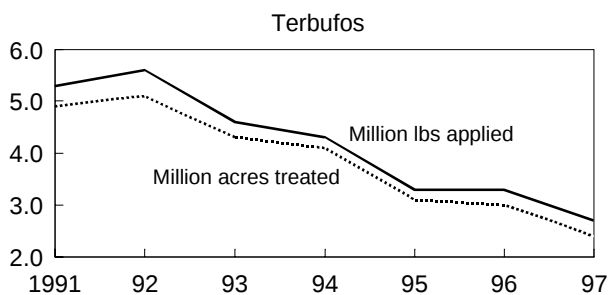
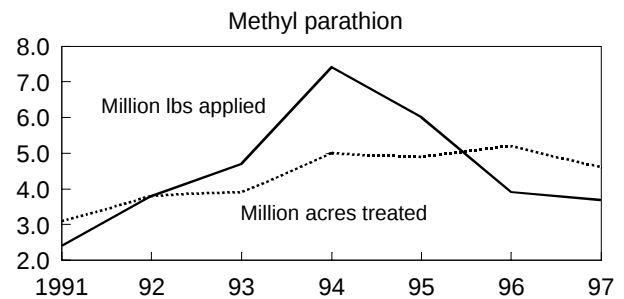
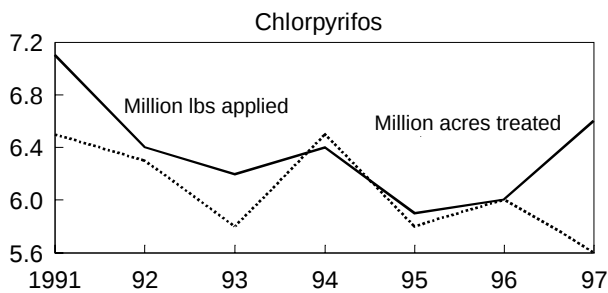
Change in Insecticide Ingredients, 1991-97

The use of some insecticide ingredients increased while others decreased or remained relatively unchanged between 1991 and 1997 (fig. 3A4d). Among the leading ingredients that decreased in use (chlorpyrifos, terbufos, and phorate)

were those most commonly used to treat corn pests while those that increased (methyl parathion and aldicarb) were widely used to treat cotton pests. The use of methyl parathion more than doubled between 1991 and 1997.

Figure 3A4d

Change in insecticide ingredients' use, 1991-97



Source: USDA, NASS and ERS, 1996c and 1995c.

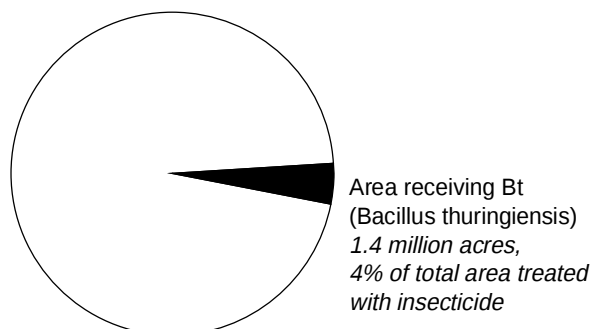
Bt (Bacillus Thuringiensis) Widely Applied on Vegetable Crops

Bacillus thuringiensis or Bt is a microbial pesticide that can kill certain insect pests (fig. 3A4e). It is the most widely used microbial pesticide and is used to treat Colorado potato beetle, cotton budworm, and several other insects on fruit and vegetable crops [Meister, 1996]. Because Bt is a natural bacterial organism, it offers several health and environmental safety advantages over synthetic pesticides, but may not be as cost effective as conventional insecticides. Bt was used on only 4 percent of the total surveyed crop acreage treated with an insecticide, but it was used on more than 25 percent of the acreage of several vegetables (cabbage, celery, cucumbers, eggplant, head lettuce, peppers, processed spinach, fresh market tomatoes, strawberries, and raspberries). Corn and cotton, however, account for most of the area treated with Bt. Besides the pesticide ingredient, bioengineered seeds with Bt have been developed and are now being marketed for cotton, corn, and potatoes.

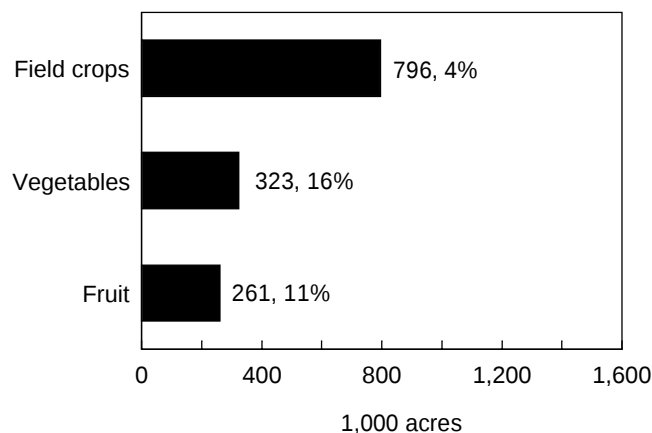
Figure 3A4e

Bt applied to 4 percent of area treated with insecticides, 1996-97 1/

Area treated with insecticides
other than Bt
35.0 million acres, 96%



Crops treated with Bt 2/



1/ Represents 36.4 million acres treated with an insecticide out of the 244 million acres that were represented by the surveys.

2/ The first value at the end of the bar is the area treated with Bt, and the second value is the percent of insecticide-treated area that was treated with Bt.

Sources: USDA, NASS and ERS, 1996b, 1997a, and 1997b.

Pesticide Use Trends by Pesticide Type: Total Quantities, Treated Area, Acre-Treatments, and Application Rates

The trends in pesticide use were quite different for each pesticide type (fig. 3A5). The change in intensity of pesticide use can be divided into three components: (1) share of area receiving any pesticide treatments, (2) number of ingredient treatments per treated acre (acre-treatments), and (3) application rate per acre-treatment. The total quantity of pesticide used over a full production season is the product of these three intensity measurements and planted acreage. Because planted acreage remained relatively stable for the major field crops between 1990 and 1997, most of the changes in pesticide use were the result of various changes in intensity.

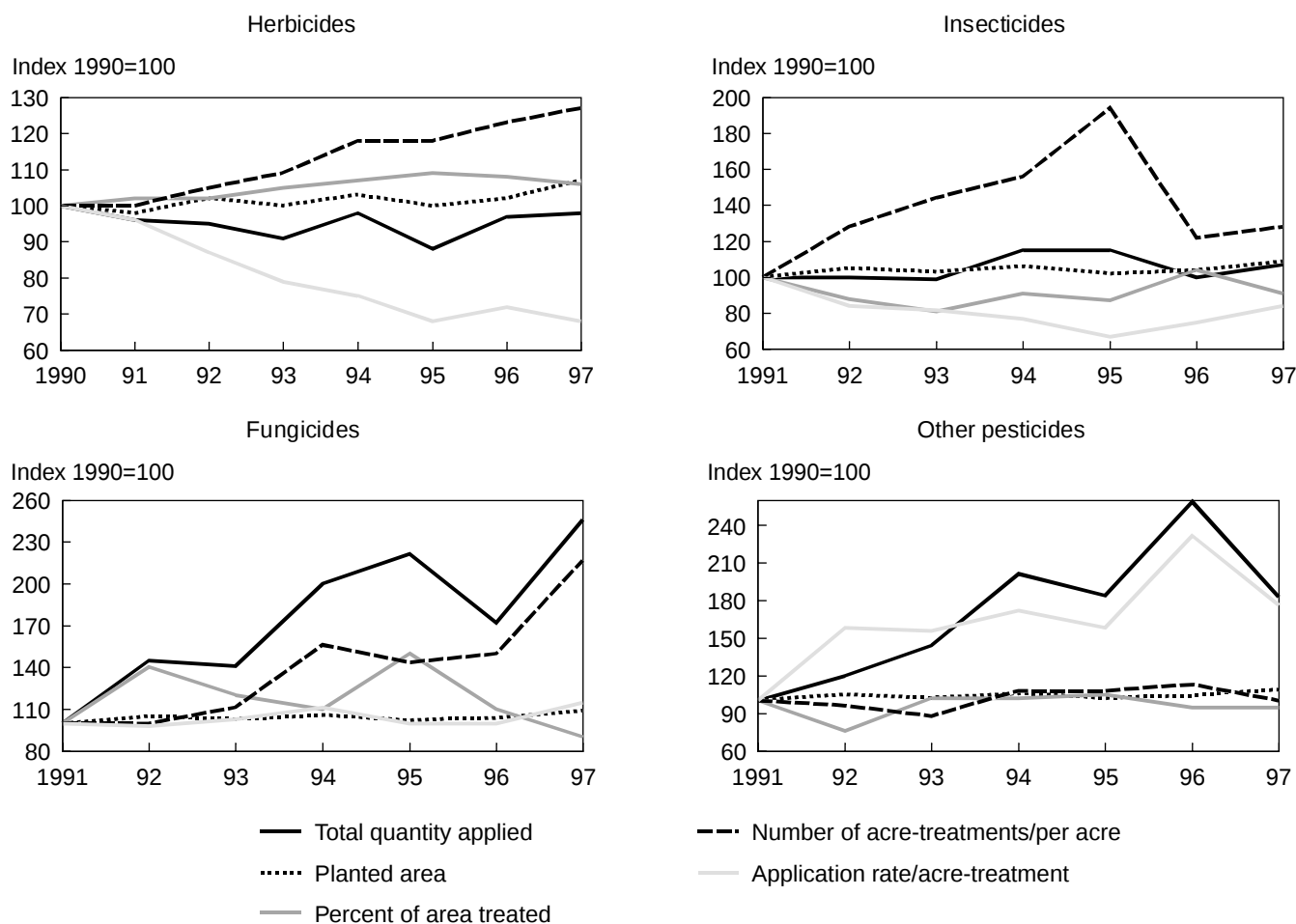
The share of acres treated gradually increased for herbicides and fungicides, but remained relatively unchanged for insecticides and other pesticides. The largest changes in the intensity of pesticide use occurred with the average number of acre-treatments and the application rates. For herbicides,

the number of acre-treatments per acre increased while the application rates decreased. The net result was a slight decline in total herbicide use between 1990 and 1997. These trends in herbicide use can partially be attributed to a shift to ingredients applied at ultra-low rates and the increased use of several narrow-spectrum ingredients rather than a single broad-spectrum ingredient.

The trends for insecticides were somewhat similar but the net result was a slight upward trend for the total quantities of insecticides. For fungicides, the change was from an increase in both the share of acres treated and the number of acre-treatments. Fungicide application rates per treatment did not change substantially. The large increase in the use of “other pesticide” types was largely a result of increased application rates. The increase in application rates between 1991 and 1997 primarily results from a shift to sulfuric acid to kill potato vines prior to harvest. When used, sulfuric acid is applied at several hundred pounds per acre and can substitute for other desiccants applied at only a few pounds or ounces per acre.

Figure 3A5

Pesticide use trends by pesticide type, 1990-97



Source: USDA, NASS and ERS, 1995c and 1996c.

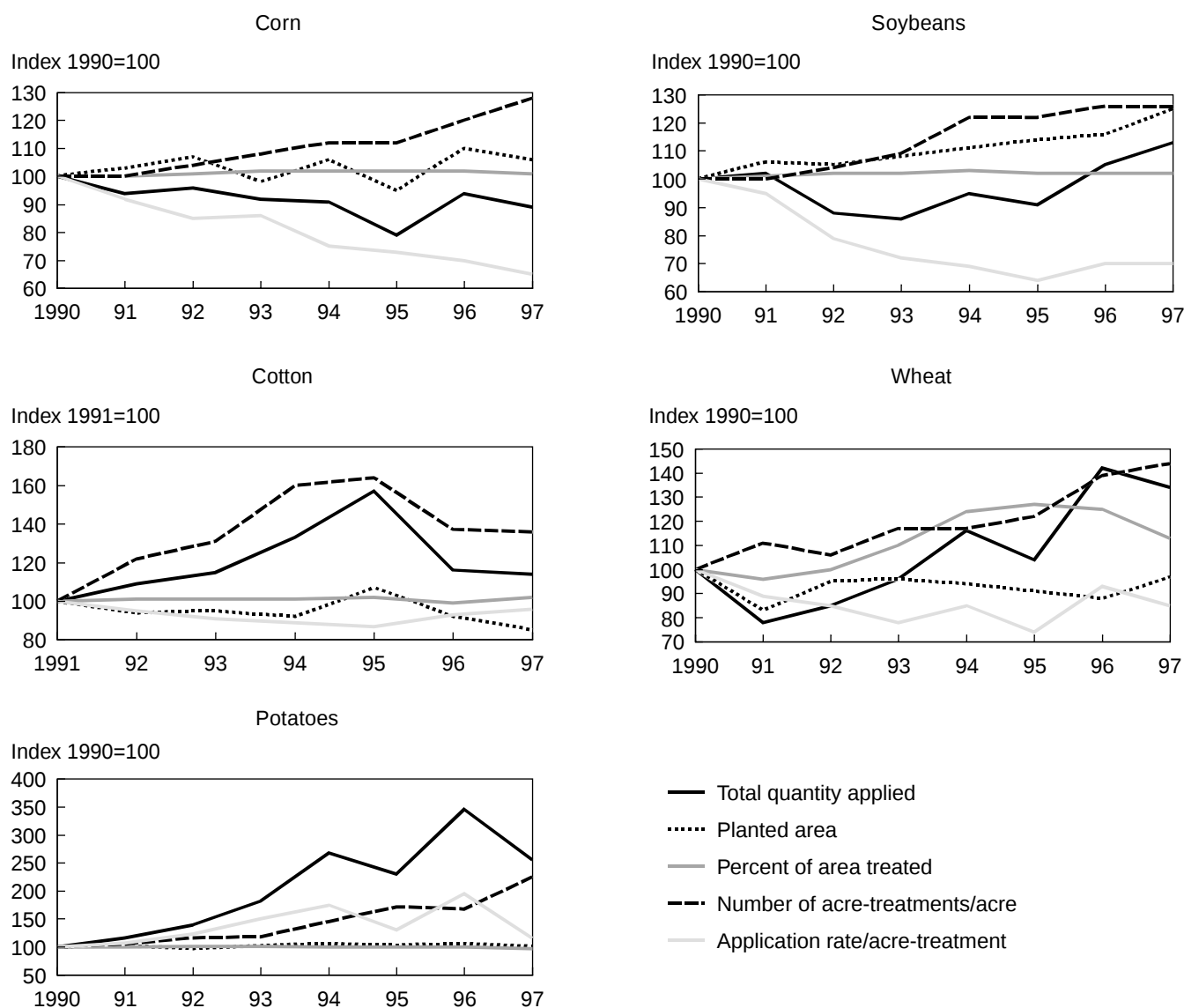
Pesticide Use Trends by Crop: Total Quantities, Treated Area, Acre-Treatments, and Application Rates

Changes in the intensity of pesticide use were also quite different among the surveyed crops (fig. 3A6). For corn and soybeans, the number of acre-treatments increased between 1990 and 1997, while the application rates decreased. Although slightly larger shares of both crops were treated, most of the increases in acre-treatments result from more acres treated with a combination of two or more ingredients rather than with a single ingredient. The decline in application rates came from the adoption of ultra-low application

rate ingredients and from reductions in the rates of some individual ingredients, e.g., atrazine on corn. The net result from these changes was a slight decline in the total quantity of pesticides applied to both corn and soybeans. For wheat, similar trends in acre-treatments and application rates occurred, but the share of acres treated with pesticides increased. Pesticide use on wheat increased from 59 percent of the planted area in 1990 to 75 percent in 1995, then dropped back to 66 percent in 1997. For cotton and potatoes, the changes were mostly increases in the number of acre-treatments on the treated area. For cotton, the increase was due to additional treatments for insect control; for potatoes, it was for disease control.

Figure 3A6

Pesticide use trends by crop, 1990-97



Source: USDA, NASS and ERS, 1995c and 1996c.

Primary Target Insects

Research to develop biological pest control products, pest eradication programs, and integrated pest management have the potential to reduce pesticide treatments for several specific pests (fig. 3B). Many of these products and programs have been directed toward specific insects that account for the major share of the total pesticide treatments. The boll weevil and bollworm together were the primary target species for about two-thirds of all insecticide acre-treatments applied to cotton in 1994. The boll weevil eradication program has succeeded in eliminating the pest on nearly 3 million acres in North and South Carolina, Georgia, Florida, Arizona, and California [APHIS, 1998].

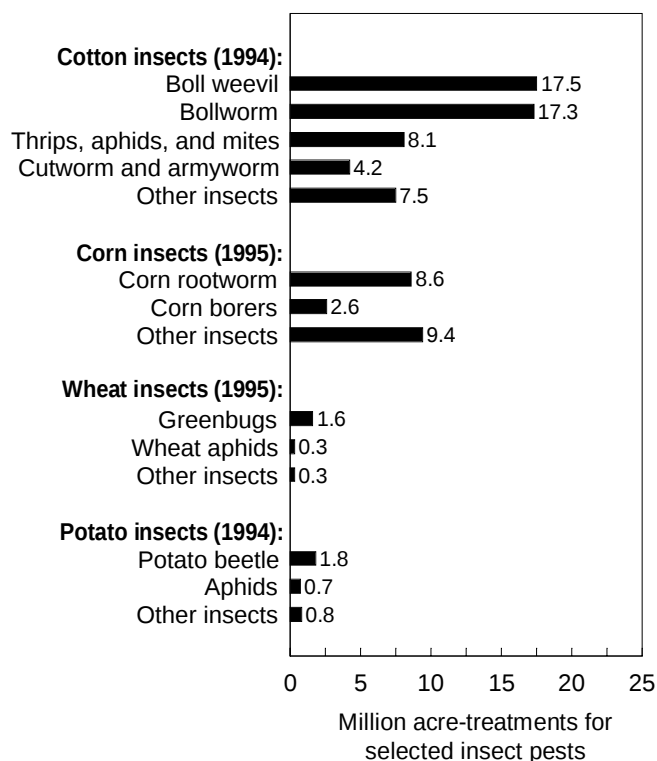
The emerging technology of Bt-transgenic seeds also holds a promise for reduced pesticide needs on corn, cotton, and possibly other crops. These transgenic crops produce a protein toxin in the plants that has been successful in controlling cotton bollworms, corn borers, and some other insect pests in these and other crops. Bollworms were the primary target species for 17.5 million (32 percent) insecticide acre-treatments on cotton in 1994, and the corn borer was the target pest for 2.6 million acre-treatments (13 percent) of all corn treatments in 1995. The Bt-transgenic corn and cotton seeds were first marketed for widespread use in 1996 and have the potential to reduce the amount of pesticide used for these target pests.

Most insecticide acre-treatments on corn are for corn rootworm control. Corn rootworm can usually be controlled by planting another crop in rotation with corn that does not serve as a host to the pest. Corn rootworm treatments are most common in the Plains regions and other areas where a nonhost crop is often less profitable than continuous corn. Corn rootworms have developed resistant species to several conventional insecticides in the past and since 1993 there is evidence that some rootworm species survive in corn-soybean rotations.

Most insecticide acre-treatments on wheat are for greenbugs and on potatoes for potato beetles. Both pests have developed biotypes resistant to several kinds of insecticide products prompting farmers to seek integrated pest management practices to reduce reliance on chemical control methods.

Figure 3B

Cotton boll weevil and bollworm and corn rootworm were primary target insects, 1994-95



Sources: USDA, NASS and ERS, 1995c.

Pest Monitoring Practices

Most definitions and applications of integrated pest management include pest-monitoring activities as a major element. Information about the presence and infestation levels of different pest species or beneficial organisms is essential for making sound economic decisions concerning the use of pest prevention or intervention practices. Treatment decisions that are based on economic decision rules or thresholds require specific measurements of pest infestation. An economic threshold, in general, is the pest infestation level at which the expected crop damages exceed the cost of treatment necessary to prevent those damages [Headly, 1972]. Economic thresholds have been developed for major insect pests using research that accounts for (1) the crop yield damage caused by pests at a known level of infestation, (2) the revenue loss from pest damage, and (3) the treatment costs. When this information is available, farmers can monitor pests in a field and apply the threshold pest number to decide whether a treatment is needed.

Even though scientifically developed thresholds are not available for all crop-pest situations, pest monitoring is still a valuable practice for making informed decisions. Some pests quickly reproduce to damaging infestation levels and just their presence can warrant preventive or intervention treatments. Knowledge of particular pest species, of changes in infestation levels, or of developmental stages also helps farmers select the appropriate pesticide ingredients, time of application, or treatment method. Monitoring for the purpose of making timely and appropriate treatments can prevent future spreading of the pest, development of pesticide-resistant species, or harm to beneficial organisms.

Professional Scouting Most Common on Cotton and Specialty Crops

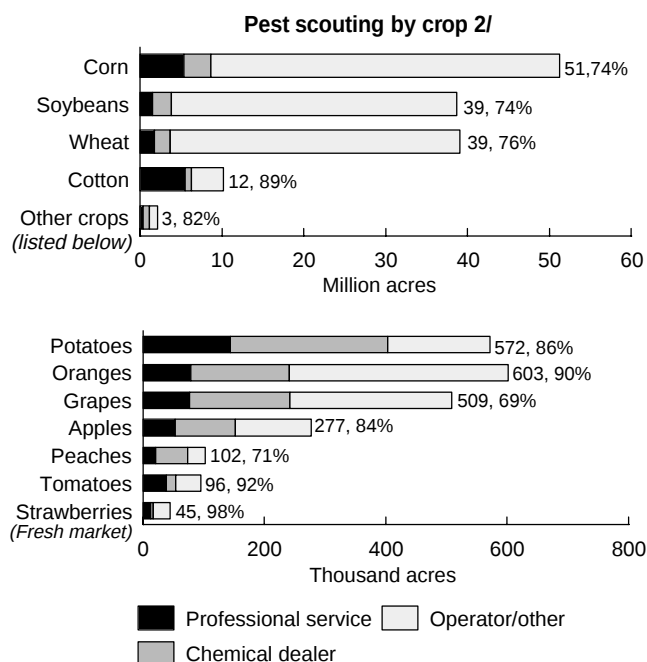
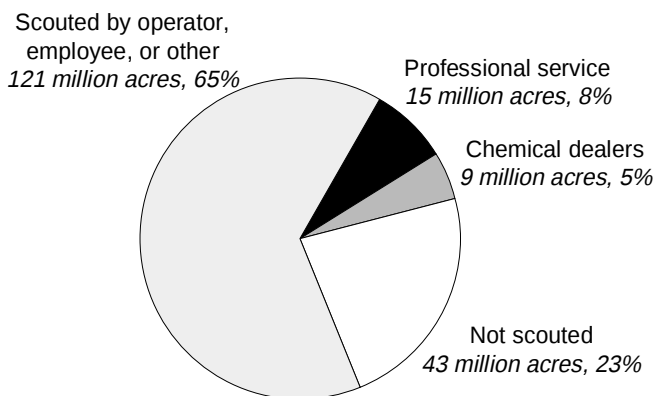
Scouting fields for insects, weeds, and diseases is a common form of pest monitoring (fig. 3C1). In general the process involves examining several small sections of a field or different plants to identify the presence of a pest species, to measure their population or infestation, or assess their developmental stage. The rigor by which the scouting process is applied can vary widely between regions, crops, and pest species. Some weed species can be monitored by rather casual observations while small insects, mites, or disease organisms require close examination or dissection of plant tissues.

USDA's Cropping Practices and Chemical Use Surveys in 1994 and 1995 collected general information about pest scouting on several crops [USDA, NASS and ERS, 1994; USDA, NASS and ERS, 1995c; USDA, NASS and ERS, 1995d]. Producers were asked if their fields were scouted for weeds, insects, or diseases and who did the scouting.

For most crops, either the operator, family member, or farm employee was most often reported as the person doing the

Figure 3C1

Professional scouting most common on cotton and specialty crops, 1994-95 1/



1/ Represents 188 million acres of surveyed crops.

2/ The first value at the end of each bar is the total acreage scouted and the second value is the percentage of crop area scouted.

Source: USDA, NASS and ERS, 1995c, 1995d, and 1994.

scouting. Approximately 8 percent of the surveyed crop area was scouted by a professional scouting service or crop consultant. An additional 8 percent was scouted by representatives of chemical dealers. Some scouting was also done by representatives of food processors or others.

Professional scouting services, crop consultants, representatives of chemical dealers and processors, or other professionals scouted over half of the cotton, potato, peach, and tomato acres.

Soil and Tissue Testing for the Presence of Pests Most Common on Specialty Crops

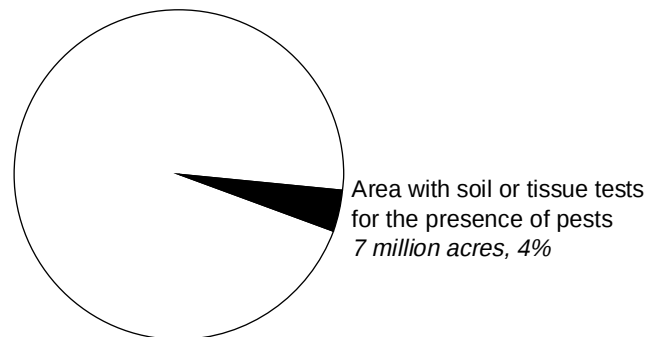
Soil and tissue testing are sometimes used to determine the presence or population of pests that cannot be effectively monitored by scouting or casual observations (fig. 3C2). Early detection and treatment during dormant or early developmental stages are often the most cost-effective way to treat several kinds of pests. Soil or tissue testing can detect the presence of egg masses, weed seeds, or other microorganisms, and the information can be used to determine if the pests are likely to cause economic losses if left uncontrolled.

Soil or tissue testing was applied to about 4 percent of the surveyed crop acres. While most of the tested acres were major field crops, the practice was used on a larger share of potatoes, vegetables, and fruit crops. Soil and tissue testing were reported on over half of the potato acres in the four surveyed States. Soil tests in soybeans are often for cyst nematodes while those for corn are for corn rootworm.

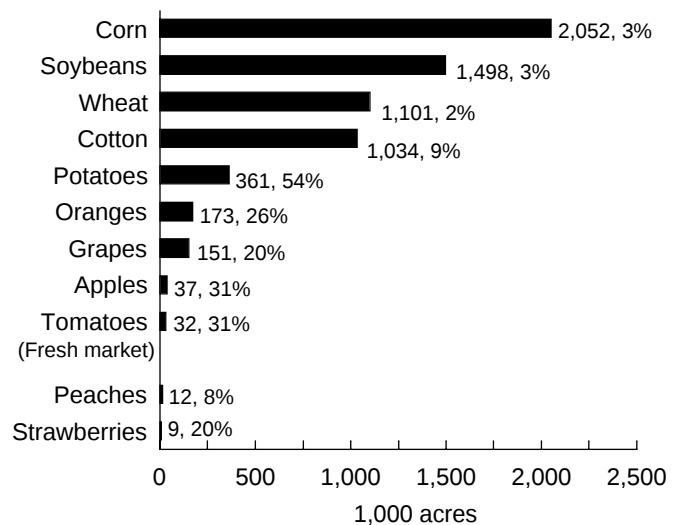
Figure 3C2

Soil and tissue testing for the presence of pests most common on specialty crops, 1994-95 1/

Area with no soil or tissue
tests for the presence of pests
181 million acres, 96%



Soil and tissue testing for the presence of pests, by crop 2/



1/ Represents 188 million acres of surveyed crops.

2/ The first value at the end of the bar is the acreage tested, and the second value is the percentage of crop area tested.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

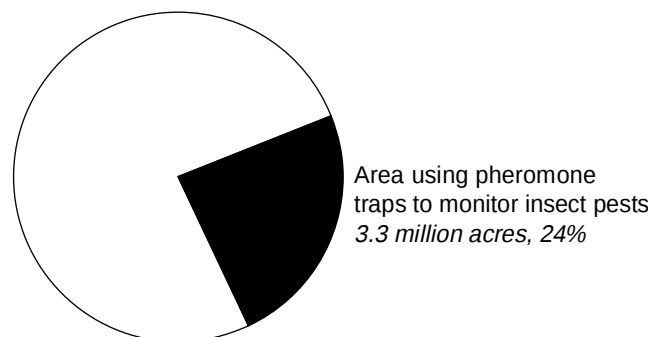
Monitoring Insect Pests with Pheromones

Pheromones are semio-chemicals (behavior-modifying chemicals) produced by pests and emitted to attract a mate (fig. 3C3). Pheromones have been synthetically produced for some insects and are used to lure specific insect pests into traps for the purpose of monitoring infestation levels and their developmental stages. Pheromones can also be used to control insect populations by disruption of mating. (See p. 39.) The number of insects found in traps over a period of time can be compared with thresholds to determine whether a treatment is needed. Also, the developmental stage of trapped insects is useful to determine appropriate timing of pest treatments. Such traps are widely used to monitor pests on cotton and in fruit orchards. Pheromone traps were reported to have been used on over two-thirds of the apple acres.

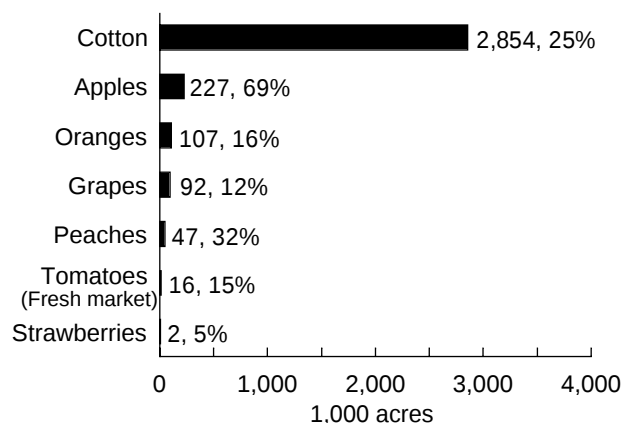
Figure 3C3

Monitoring insect pests with pheromones, 1994-95 1/

Area not using pheromone traps to monitor insect pests
10.3 million acres, 76%



Monitoring with pheromones by commodity 2/



1/ Represents 13.6 million acres of cotton, apples, oranges, grapes, peaches, tomatoes, and strawberries.

2/ The first value at the end of the bar is the acreage monitored, and the second value is the percentage of crop area monitored.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

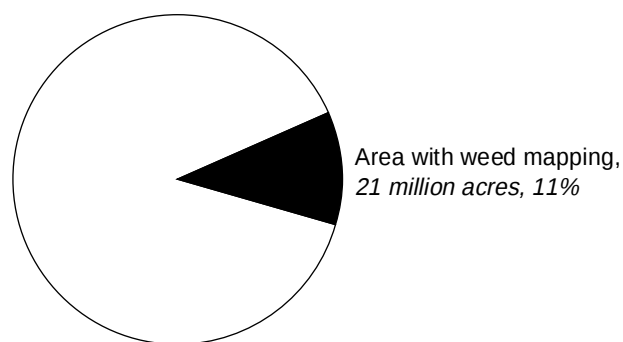
Weed Mapping to Aid Herbicide Treatment Decisions

The use of preemergence herbicides, which are applied early in the growing season to kill weeds as they germinate, is the most common form of weed treatment on field crops. Field mapping is a practice that identifies the location, species, and infestation of weeds in fields for the purpose of making decisions about future preventive treatments. Mapping weeds helps producers select appropriate herbicide ingredients and application rates and also helps detect the presence of any herbicide-resistant species. Precision farming, a technology that varies pesticide treatments according to changing field conditions, also requires mapping information to program equipment or to apply spot treatments within the field. The practice was reported on about 11 percent of the area (fig. 3C4).

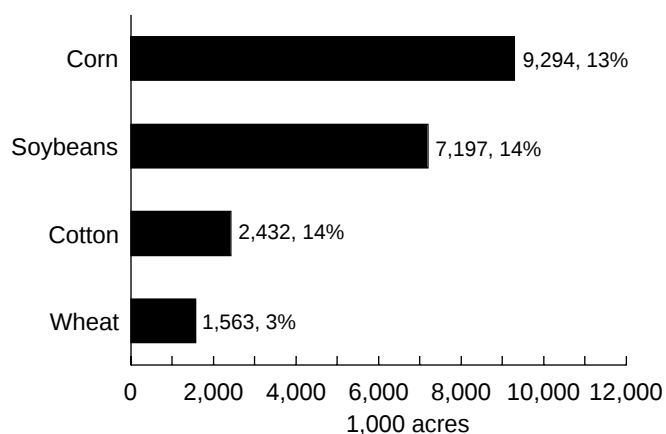
Figure 3C4

Weed mapping to aid herbicide treatment decisions, 1994-95 1/

Area with no weed mapping,
165 million acres, 89%



Weed mapping on field crops 2/



1/ Represents 186 million acres of corn, soybeans, wheat, and cotton.

2/ The first value at the end of each bar is the acreage mapped, and the second value is the percentage of crop area mapped.

Sources: USDA, NASS and ERS, 1995c.

Practices to Reduce Pest Infestations

Growers use several practices to reduce pest infestations and to eliminate or reduce the need for pesticides. They include several cultural and biological practices that are often components of integrated pest management.

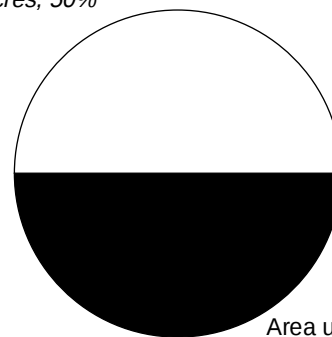
Planting Pest-Resistant Varieties or Rootstocks

Planting pest-resistant varieties of crops or using pest-resistant rootstock in fruit orchards is an available alternative to control certain crop diseases and pests (fig. 3D1). Plant breeding programs have been successful in developing more disease-resistant varieties of wheat, corn, cotton, potatoes, and apples. The cost to growers is generally less than costs associated with using pesticides. Resistant varieties were used on a large share of the wheat (54 percent) and peach (44 percent) acreage.

Figure 3D1

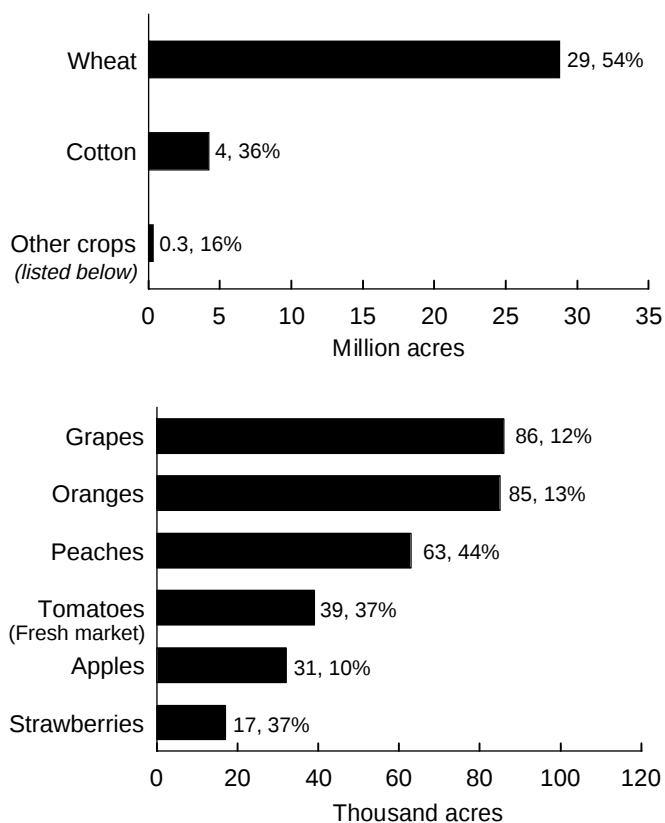
Planting pest-resistant varieties or rootstocks, 1994-95 1/

Area not using resistant varieties or rootstocks
33 million acres, 50%



Area using resistant varieties or rootstocks
33 million acres, 50%

Crops with resistant varieties or rootstocks 2/



1/ Represents 67 million acres of wheat, cotton, oranges, apples, grapes, peaches, tomatoes, and strawberries.

2/ The first value at the end of each bar is the acreage planted with pest-resistant varieties or rootstock, and the second value is the percentage of crop area with this characteristic.

Source: USDA, NASS and ERS, 1994, 1995c, and 1995d.

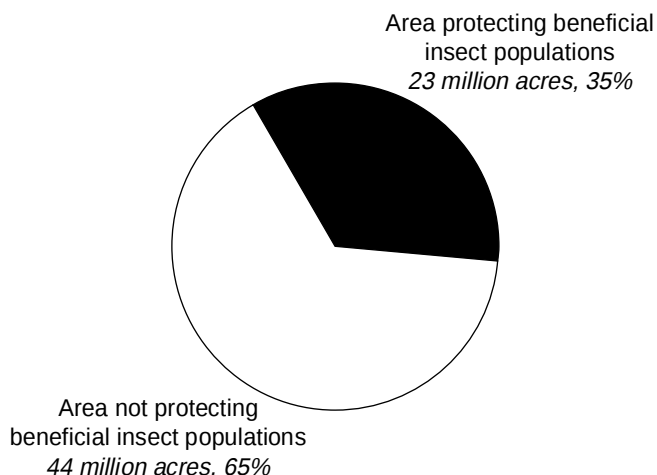
Protecting Beneficial Insect Populations

Beneficial insects are those that are natural predators of other pests. They may already be present in the crop fields or they may be purchased and released. Examples include lady beetles and green lacewings for treating fruit mites and naturally occurring parasites that are harmful to alfalfa weevils and cereal leaf beetles. This biological method provides successful control for some crop-pest situations and reduces the need for pesticide intervention.

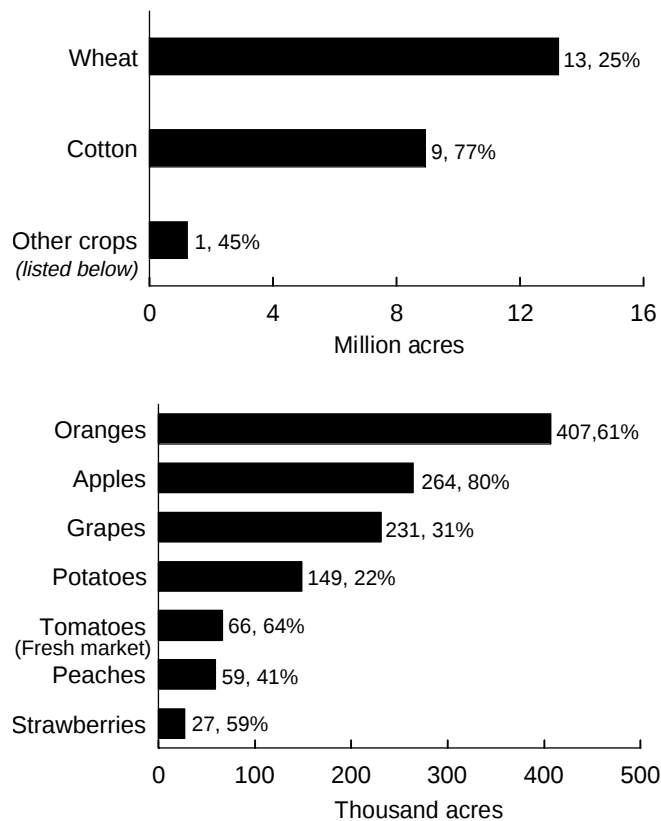
Beneficial insect populations were protected on approximately one-third of the surveyed acreage (fig. 3D2). Special precautions to protect beneficial insects were most common on commodities that have high use of insecticides—cotton, fruits, and vegetables.

Figure 3D2

Protecting beneficial insect populations, 1994-95 1/



Crops where beneficial insect populations were protected 2/



1/ Represents 67 million acres.

2/ The first value at the end of each bar is the acreage receiving protection, and the second value is the percentage of crop area receiving protection.

Source: USDA, NASS and ERS, 1994, 1995c, and 1995d.

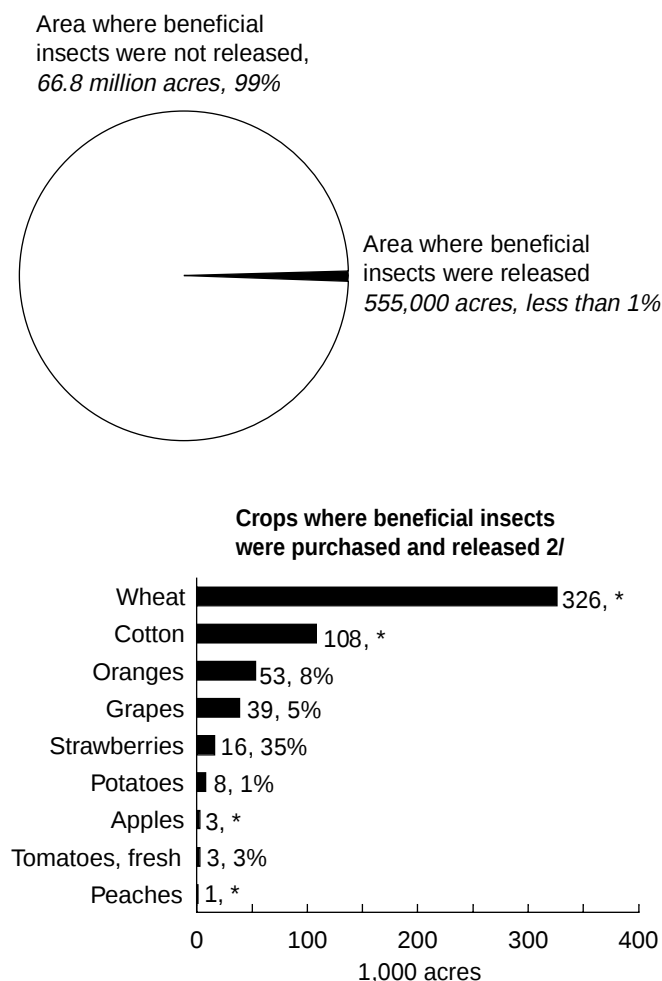
Purchasing and Releasing Beneficial Insects

When not naturally present, beneficial insects are sometimes purchased and released into crop fields for the purpose of suppressing pests and averting crop damage (fig. 3D3). For some crop-pest situations, beneficials can control pests without pesticide applications. When the level of infestation is too high, producers may first destroy pests with a pesticide and then introduce beneficials following the pesticide treatments to control subsequent generations.

Less than 1 percent of the surveyed crops were affected by the release of beneficial insects in the field or surrounding area. The practice was most common on strawberries.

Figure 3D3

Purchasing and releasing beneficial insects, 1994-95 1/



1/ Represents 67 million acres of surveyed crops.

2/ The first value at the end of each bar represents the acreage using beneficial insects and the second value is the percentage of crop area using them. An " * " indicates that beneficial insects were used on less than 1 percent of area.

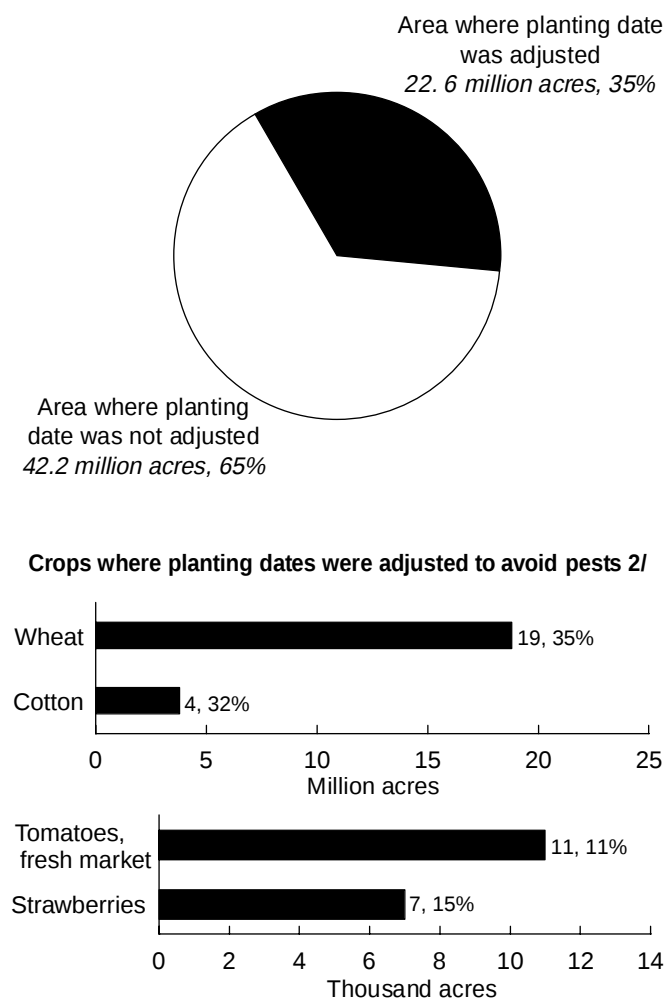
Sources: USDA, NASS and ERS, 1994, 1995c and 1995d.

Adjusting Planting Dates to Avoid Pests

Pest populations mature and reach peak concentrations at specific times. Adjusting planting dates can help avoid pest populations being in the fields at critical times to cause crop damage (fig. 3D4). A notable example is the Hessian-fly safe dates for planting winter wheat. Delaying wheat planting until after these "safe" dates assures less damage by insects than earlier plantings. Planting dates are also planned to avoid weather conditions that are conducive to plant diseases. Pest avoidance was considered in planting decisions on approximately one-third of the surveyed acres.

Figure 3D4

Adjusting planting dates to avoid pests, 1994-95 1/



1/ Represents 65 million acres.

2/ The first value at the end bar is the acreage where planting date was adjusted to avoid pests and the second value is the percentage of crop area for which the planting date was adjusted.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

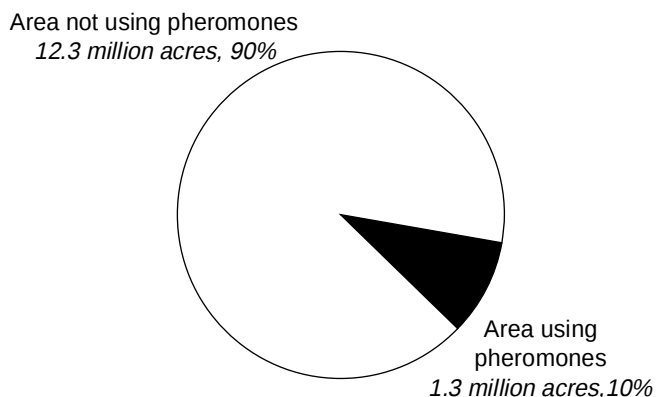
Controlling Insect Pests with Pheromones

Besides monitoring, pheromones are also used as a stimulus to disrupt the mating process, thus controlling and suppressing the pest population (fig. 3D5). Kits that slowly release the pheromone into the air are placed throughout crop fields. Usually males of the particular insect species are lured by the pheromone and few are able to find females and mate successfully. Synthetic pheromones continue to be developed for additional species and are now available for several common insect pests including pink bollworm, oriental fruit moth, and codling moth. Some benefits of using pheromones are long-term reduction in pest population for the treated areas, little or no mammalian toxicity, and compatibility with cultural practices and natural control agents.

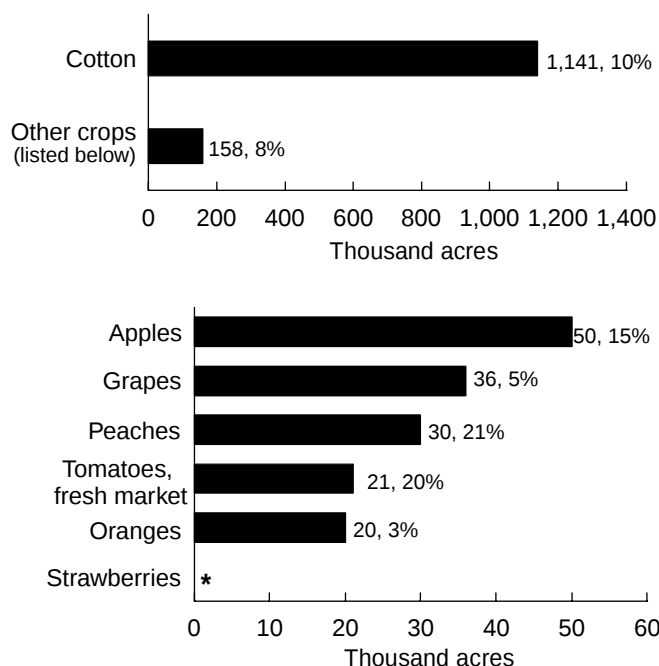
Pheromones were used for controlling pest populations on 10 percent of the surveyed area. Pheromones often cost more than insecticide treatments. Also, the treatment does not provide 100-percent control as some females are still able to mate successfully and others can migrate into surrounding areas to lay eggs.

Figure 3D5

Controlling insect pests with pheromones, 1994-95 1/



Crops where pheromones were used to control insects 2/



1/ Represents 13.6 million acres of cotton, fruits, and vegetables.

2/ The first value at the end of each bar is the acreage using pheromones, and the second value is the percentage of crop area using pheromones.

*=Less than 1 percent.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

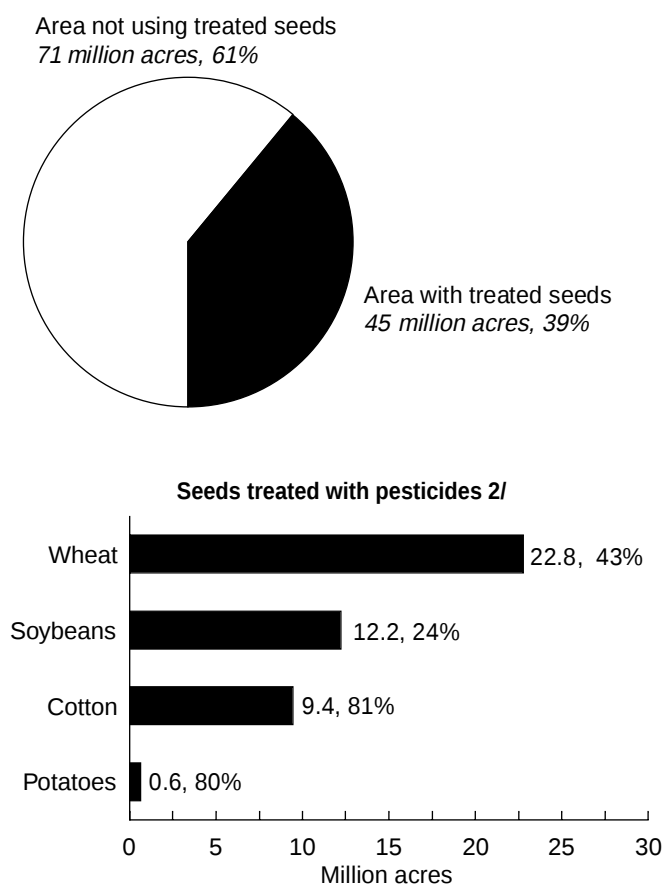
Treating Seeds with Pesticides

Treating seeds with pesticides protects the seeds from diseases or pests while in storage as well as preventing losses from pests after planting (fig. 3D6). Seed-borne diseases, like septoria seedling blight in wheat, can be avoided by seed treatments. Seed treatments or seed coating can also prevent damage from soil insects before the seed germinates.

For the major field crops surveyed—wheat, soybeans, cotton, and potatoes—39 percent of total acres used treated seeds. Most noted were cotton (81 percent) and potatoes (80 percent). Treated seedcorn was not included in the survey as nearly all hybrid seedcorn receives pesticide treatments.

Figure 3D6

Treating seeds with pesticides, 1995 1/



1/ Represents 116 million acres.

2/ The first value at the end of each bar is the acreage with seed treatments, and the second value is the percentage of crop area with seed treatments.

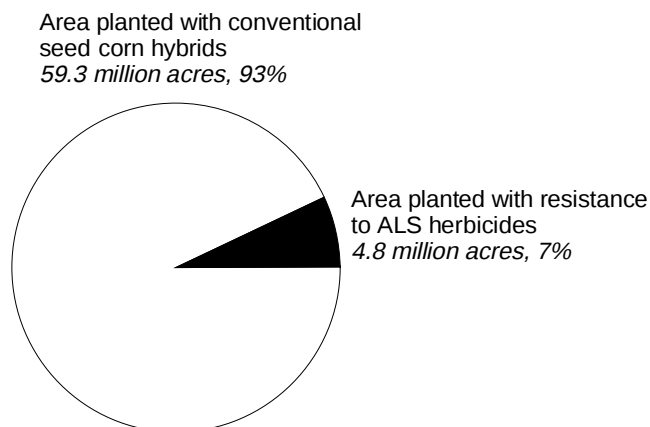
Sources: USDA, NASS and ERS, 1995c.

Planting Herbicide-Resistant Seedcorn

Recently, seeds have been developed that allow treatment with herbicides that previously damaged the crop (fig. 3D7). Specifically, seedcorn is now marketed with resistance or tolerance to imidazoline herbicides. Imidazoline herbicides inhibit the synthesis of certain amino acids as the mode of action (ALS inhibitors) and can be alternated with herbicides, such as triazines, that have a different mode of action to reduce the development of resistant weed species. Also, the broader choice of herbicides offers greater flexibility for controlling difficult weed species. For no-till systems that may eliminate the need for soil-incorporated herbicides, the new seeds offer a post-emergence treatment for grassy weeds. Soybeans are also being developed and marketed that are resistant to additional herbicides, including glyphosate (sold as Roundup Ready).

Figure 3D7

Corn planted with resistance to ALS-inhibitor herbicides, 1995



Sources: USDA, NASS and ERS, 1995c.

Alternating Pesticides to Slow Development of Resistant Species

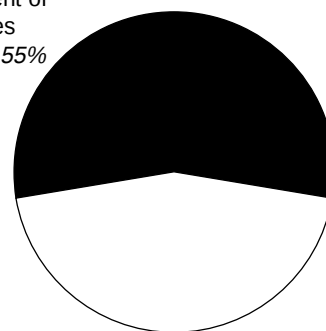
Pest populations can develop resistance to a particular pesticide or pesticide family over time. A few individuals from a pest population can inherit genetic characteristics that withstand the pesticide. These surviving species are the genetic pool for future generations, which are also likely to have the resistant trait. Repeated applications with the same pesticide can result in a population dominated by resistant species that require alternative means of control. Resistance has been identified as a problem in treating many crop pests, but has been most notable for insect pests of cotton and potatoes. Accounting for yield losses, alternative treatments, and environmental damages, pesticide-resistance costs have been estimated at more than \$1 billion (Meister, 1995).

Rotating pesticides from year to year is a practice that slows the development of resistant strains of insects or weeds (fig. 3D8). Approximately half of the surveyed acres were treated by alternating pesticides for the purpose of slowing resistance. Of the field crops surveyed, potatoes and soybeans were the crops that most used this practice. Of the fruit and vegetable crops, apples, fresh tomatoes, and strawberries were highest users.

Figure 3D8

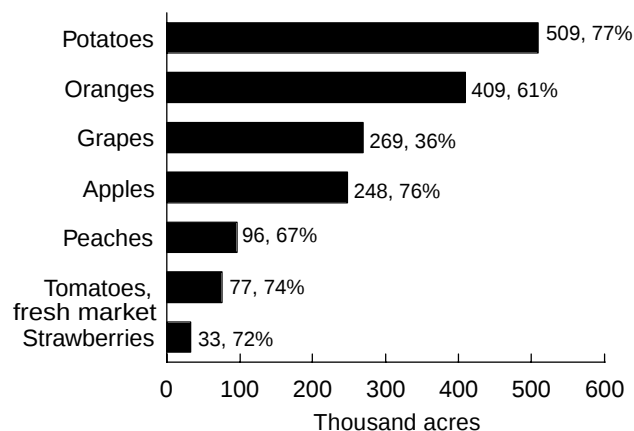
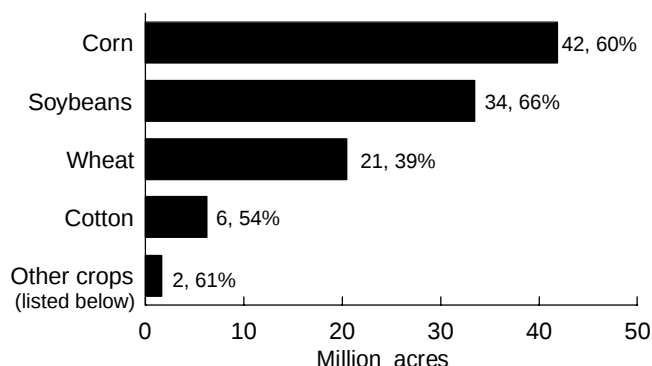
Alternating pesticides to slow development of resistant species, 1994-95 1/

Area alternating pesticides to slow development of resistant species
104 million acres, 55%



Area where same pesticide ingredients are consistently used for pest control
84 million acres, 45%

Crops for which pheromones were used to control insects 2/



1/ Represents 188 million acres of surveyed crops.

2/ The first value at the end of each bar is the acreage on which pesticides were alternated, and the second value is the percentage of crop area on which pesticides were alternated.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

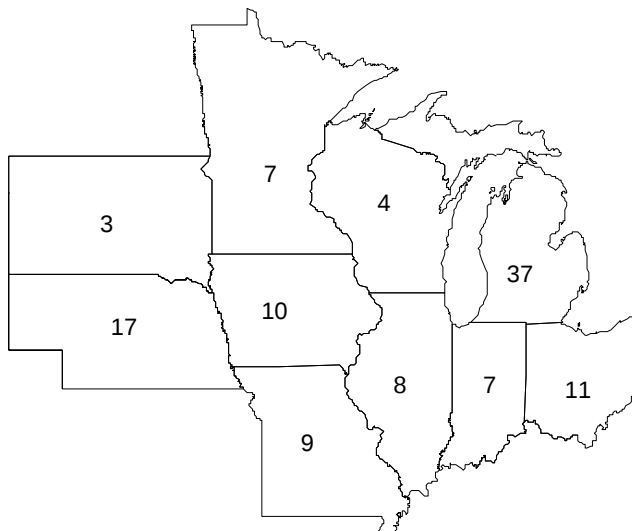
Triazine-Resistant Weeds in Corn, 1996

Repeated applications of triazine herbicides (atrazine, simazine, cyanazine, metribuzin, and others) can result in weeds resistant to the chemical. Weeds that are resistant to triazine herbicides are among the more common resistant biotypes found in corn fields. In 1996, farmers in major production States reported the presence of some triazine-resistant weeds on 10 percent of their planted corn area. The share of area with triazine-resistant weeds ranged from 3 percent in South Dakota to 37 percent in Michigan (fig. 3D8a). Some of the practices used by farmers to retard the development of resistance to triazines or other herbicides include alternating herbicides with different modes of action, crop rotations, and field cultivations.

Figure 3D8a

Triazine-resistant weeds in corn acreage, 1996

Percentage of planted corn area with triazine-resistant weeds



Sources: USDA, NASS and ERS, 1996c.

Pesticide Application Decision Factors

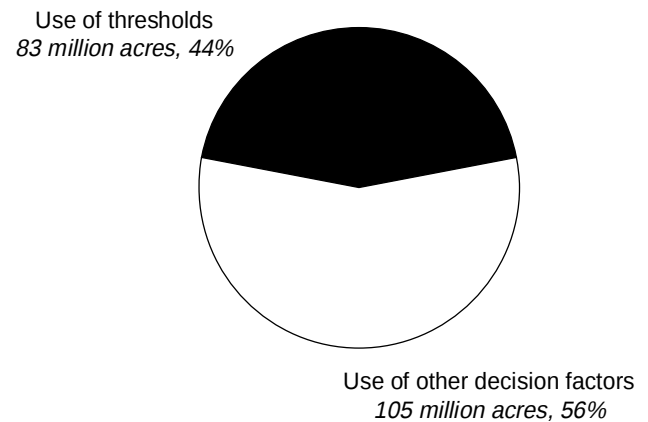
Several factors are used by growers to determine whether or not to apply pesticides. Economic thresholds, contract requirements, preventive schedules, previous infestation levels, and information sources such as agricultural magazines and journals are examples. The surveys asked farmers about the decision strategy used to determine whether or not to apply a pesticide.

Use of Thresholds as a Decision Factor to Apply Insecticides

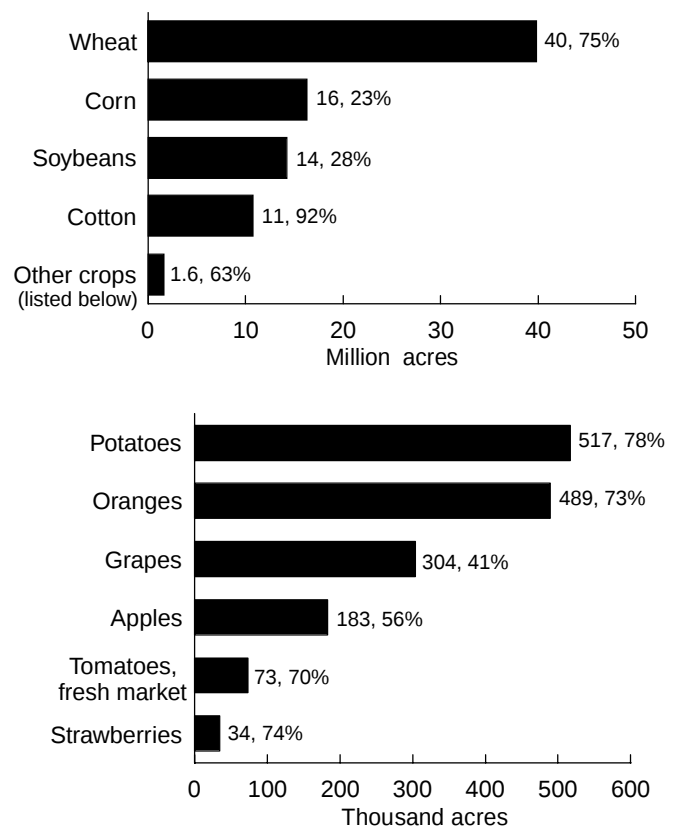
Growers use different methods to determine when pest infestations reach or are expected to reach levels that require treatment (fig. 3E1). Some use professional scouts to measure the infestation in their fields and apply pesticides only when the infestation reaches the threshold as prescribed by the Extension Service or other research-based sources. Farm operators or their employees may also do the scouting and similarly apply research-based thresholds. Analytically derived thresholds are not available for all crop-pest combinations or may not apply to all situations. Based on their own experience and knowledge, farmers may have their own “experience-based” thresholds that help them decide whether or not to apply pesticides. The surveys asked farmers if their decision strategy was based on threshold levels, either provided by an outside source or determined by the farm operator. Most insecticide treatments for cotton, wheat, and specialty crops were based on some threshold concept. Thresholds were less widely used for corn insecticides. Insecticide treatments on corn are often for soil insect pests that are difficult to monitor, and decisions are often based on previous problems and crop sequence.

Figure 3E1

Use of economic thresholds as a decision factor to apply insecticides, 1994-95 1/



Crops for which economic thresholds were used as a decision factor to apply insecticides 2/



1/ Represents 188 million acres of surveyed crops.

2/ The first value at the end of each bar is the acreage on which economic thresholds were applied, and the second value is the percentage of crop area on which they were applied.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

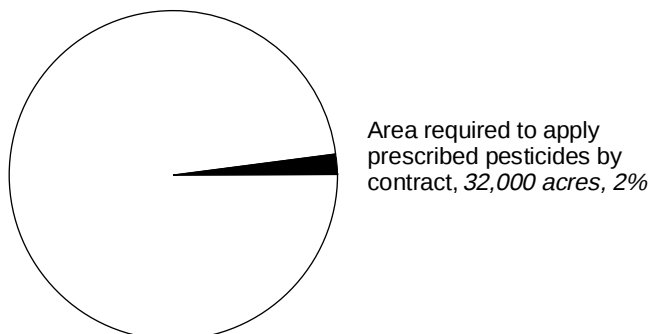
Sale Contracts That Require Treatments with Prescribed Pesticides

To maintain consistent product quality or for food safety reasons, some buyers restrict or prescribe the use of certain kinds of pesticides (fig. 3E2). Such buyers may include, among others, processors of infant foods, distributors of certified organic produce, or processors and retailers who use environmental labels. Processors who desire a uniform product quality or appearance may also stipulate the type and timing of pesticide treatments.

Figure 3E2

Sale contracts that required treatment with prescribed pesticides, 1995 1/

Area for which prescribed pesticides were not a contract requirement, 1.7 million acres, 98%



1/ Represents 1.74 million acres of oranges, apples, and grapes.

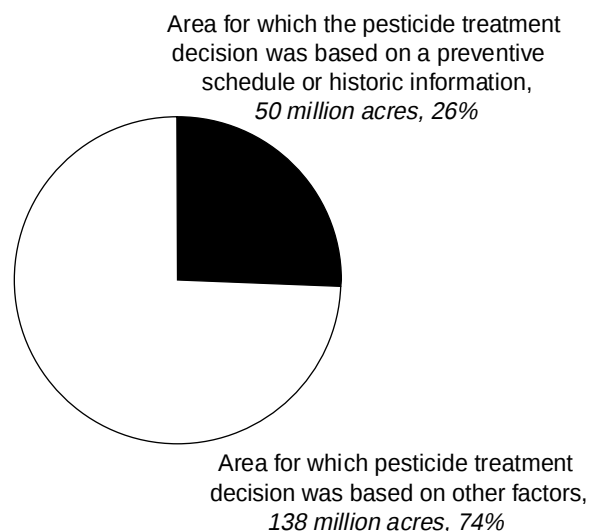
Sources: USDA, NASS and ERS, 1995d.

Use of Preventive Schedules or Historic Information for Pesticide Application Decisions

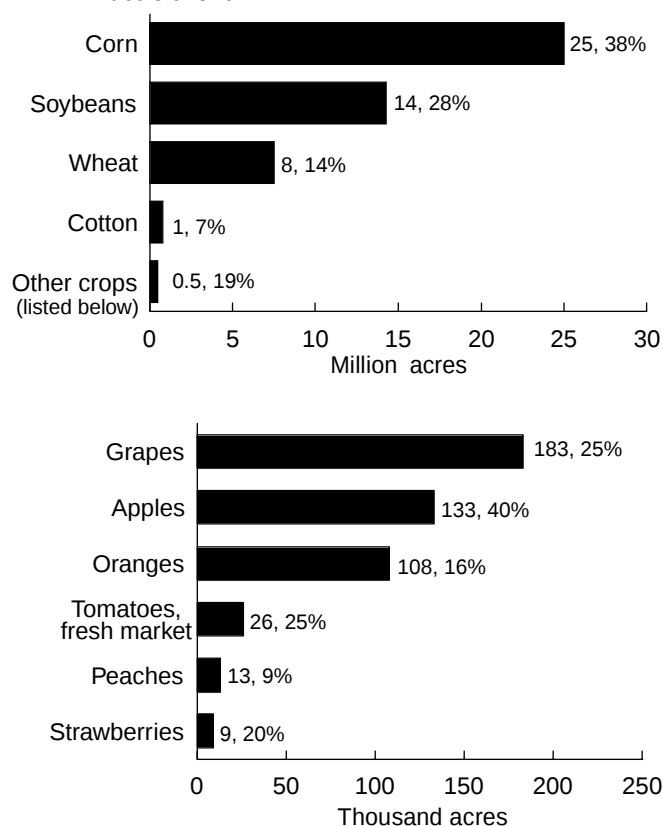
Producers who do not scout or use thresholds to make their decisions about whether treatments are necessary often rely on preventive schedules and historic information about the pest (fig. 3E3). Where pest infestations vary widely between years, the use of such preventive schedules can result in unnecessary treatments when threshold levels do not occur. Regularly scheduled pesticide applications were most common on apples—40 percent of area—where large economic damages can occur with very low infestations of pests that affect fruit quality.

Figure 3E3

Use of preventive schedule and historic information for pesticide application decisions, 1994-95 1/



Crops for which preventive schedules and historic information were used to make pesticide application decisions 2/



1/ Represents 188 million acres of surveyed crops.

2/ The first value at the end of each bar is the acreage on which preventive schedules were used, and the second value is the percentage of crop area using preventive schedules to make pesticide application decisions.

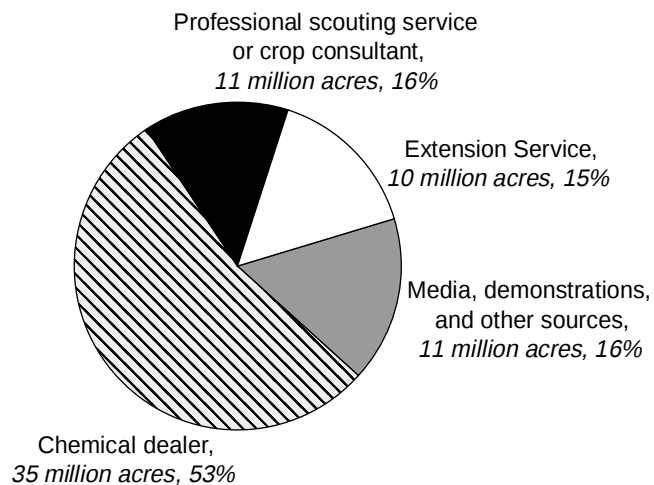
Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

Information Sources for Making Pest Management Decisions

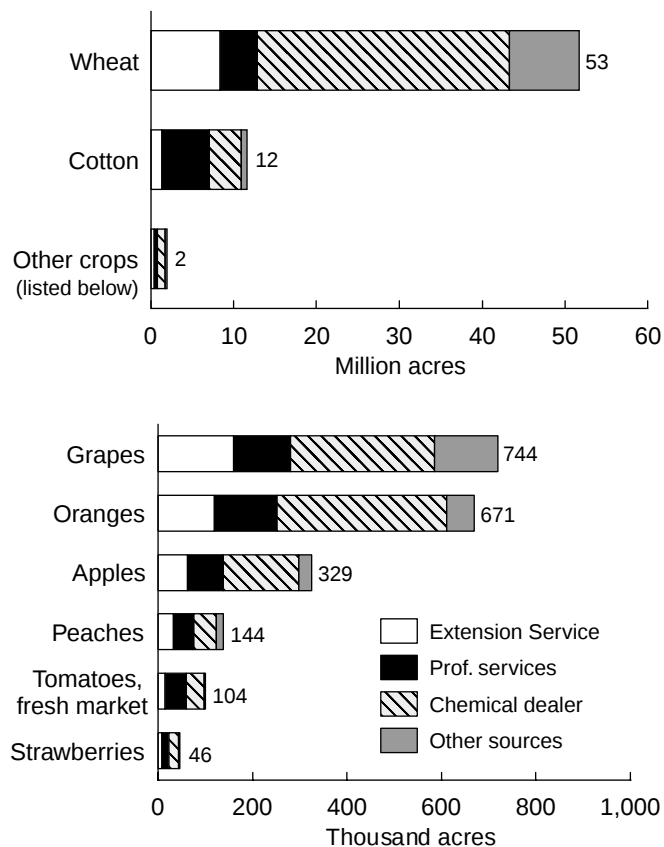
Growers obtain pest control information from a variety of sources including extension advisors, extension publications, chemical dealers, and scouting services (fig. 3E4). The source of producers' pest management information, as well as its currency and accuracy, can be important in implementing new pest management policies. Providers of professional pest management information, such as paid crop consultants, may recommend treatment options that have an established record for effectiveness, while chemical dealers may desire to expand sales of their newer or more profitable product lines.

Figure 3E4

Information sources for making pest management decisions, 1994-95 1/



Information sources for making pest management decisions, by crop 2/



1/ Represents 67 million acres of surveyed crops.

2/ The value at the end of each bar is the crop acreage relying on different information sources for pest management decisions.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

Pesticide Application Methods

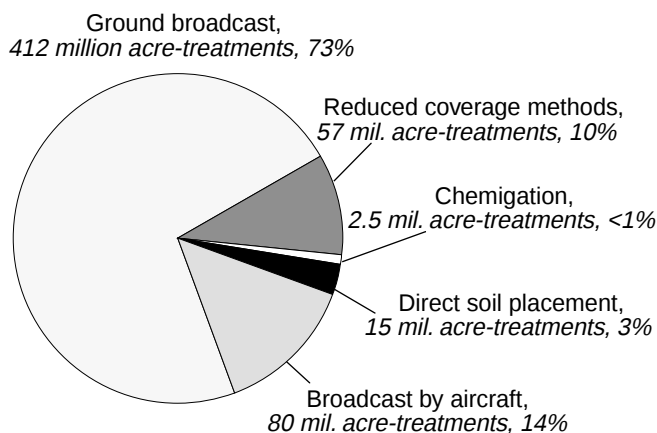
Different pesticide application practices can affect the treatment efficacy, reduce the quantity of pesticide applied, or have different potential health and environmental risks (fig. 3F1). Alternative treatment methods require different kinds of equipment and have different labor and equipment costs. To reduce risks, Federal and State laws, regulations, and permit systems dictate many safety precautions to be used when applying pesticides, as well as for storing, transporting, and disposing of unused pesticide materials. Additional safety precautions include restricting entry to the fields for a number of days following applications, forbidding applications within a certain number of days before harvest, specifying maximum application rates, requiring protective clothing, respirators, and special equipment, and specifying the crop development stages when applications can be made. Although these safety standards eliminate most risk to health and the environment, the quantity of material applied and the risk can vary by method of application.

Application methods can affect the amount of pesticide that moves off cropland either by atmospheric drift, leaching, or runoff. Pesticide applications made by aircraft or ground equipment that creates a mist, fog, or dust require special precautions to prevent drift by wind to nontarget areas or to prevent skin contact and inhalation. Pesticides incorporated or placed directly into the soil have a greater probability of leaching to ground water, while those applied to the surface are subject to both runoff and leaching. Pesticides applied to foliage have risk of atmospheric loss as well as risk to the health of applicators or farmworkers who enter the field following applications. Reduced coverage practices are sometimes used in lieu of full broadcast coverage and they usually require a smaller quantity of pesticide materials.

USDA surveys have estimated that ground broadcast applications were the most widely used means of applying all types of pesticides to crops. Nearly three-fourths of all pesticide acre-treatments on the surveyed fruits, vegetables, and field crops used this application method. Another 14 percent of the acre-treatments were broadcast by aircraft. While many broadcast pesticides must be incorporated into the soil to be effective, only a small share of the quantity of pesticides were applied directly to or injected into the soil. Application practices that provided less than 100 percent soil or canopy coverage accounted for about 10 percent of the total acre-treatments. Applying pesticides through irrigation systems (chemigation) is another broadcast method but it accounted for a very small share of the total acre-treatments.

Figure 3F1

Pesticide application methods, 1994-95 1/



1/ Represents 188 million acres of surveyed crops, of which 165 million received at least one pesticide acre-treatment.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

Reduced-Coverage Application Methods

Spot treatments, band application, and alternate-row spraying can reduce pesticide use and costs and still control certain pests (fig. 3F2). Spot treatment, which selectively treats small infested areas in a field, is effective when the pests are concentrated in a particular section of a field or when pests can be treated before spreading or migrating throughout a field. Another form of spot treatment is the selective treatment of each target pest, such as with a wick-type applicator used for shattercane or other tall weeds in soybeans.

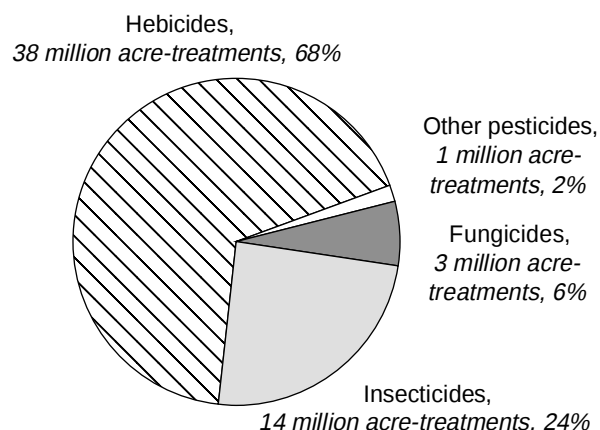
Banding pesticide application over the rows and not treating the middle of the rows is another reduced coverage practice that can reduce the quantity of pesticide applied. Banded herbicide applications are sometimes used to control weeds between plants within rows, then mechanical cultivations are used to control the weeds between the rows. Banded treatments are also used for certain soil insects that attack planted seeds or plant roots. Alternate-row spraying is a practice sometimes used in orchards. With this practice only one side of the fruit trees is sprayed with each treatment, with the opposite side sprayed with the following treatment. Some pesticide material will drift and provide partial protection to the opposite side of the tree until it receives a full treatment at the next application.

About 10 percent of all pesticide acre-treatments are one of the above types of reduced-coverage practices. Corn, cotton, and soybeans accounted for most of the acre-treatments using these practices, but the reduced-coverage practices accounted for only a small share of the total acre-treatments on these crops (corn, 12 percent; soybeans, 7 percent; cotton, 15 percent). In contrast, most pesticide treatments on fresh market tomatoes (86 percent) and strawberries (66 percent) were a reduced-coverage practice. Alternate-row spraying or other reduced-coverage practices accounted for more than 20 percent of the acre-treatments on apples and peaches. Reduced-coverage applications on field crops were chiefly of herbicides, while reduced-coverage applications on fruits and vegetables were most commonly insecticides and fungicides.

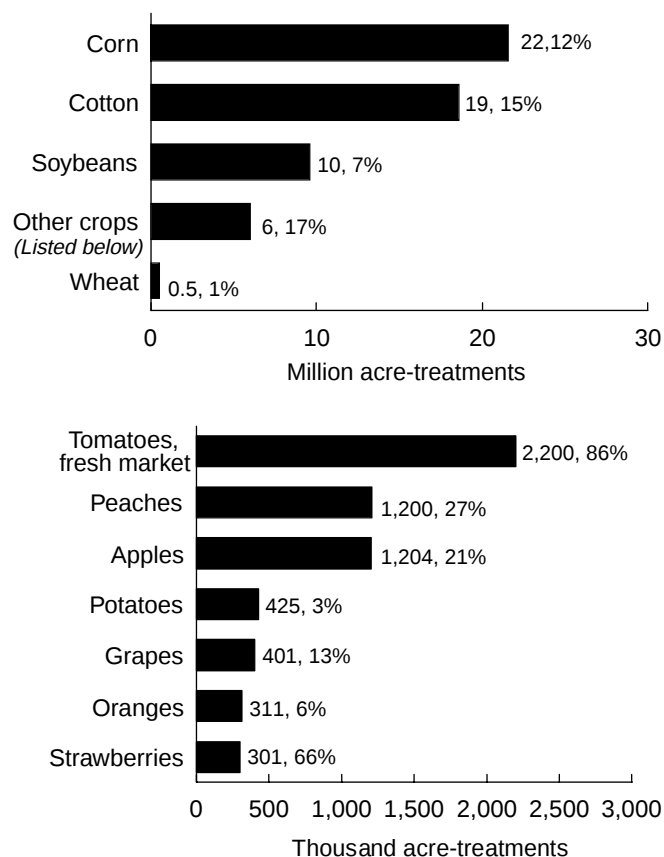
Figure 3F2

Reduced-coverage application methods (band applications, spot treatments, and alternate row spraying, 1994-95 1/)

Pesticide types applied using reduced-coverage methods



Reduced-coverage applications methods by crop 2/



1/ Represents 56 million acre-treatments using a reduced-coverage application method.

2/ The first value at the end of each bar is the number of acre-treatments, and the second value is the percentage of the total crop acre-treatments.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

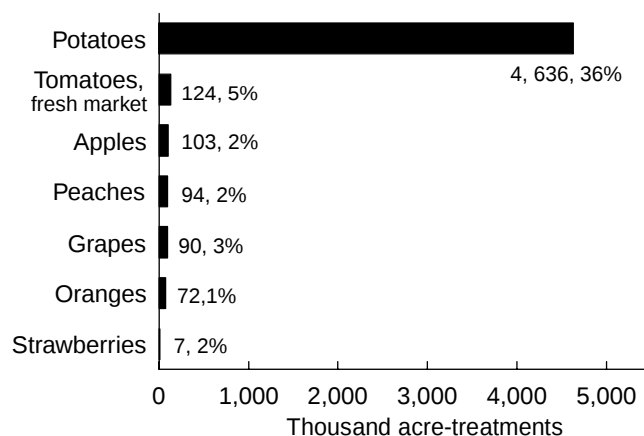
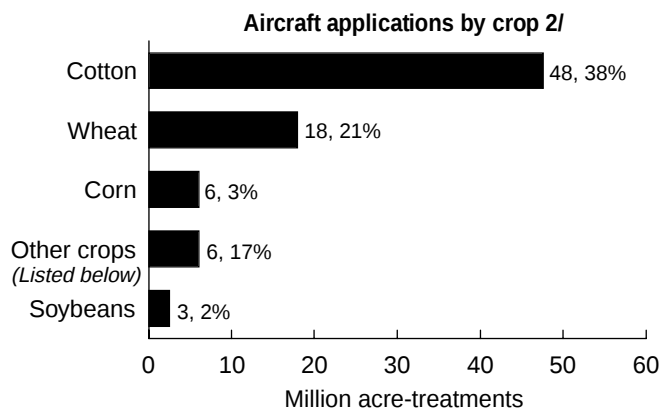
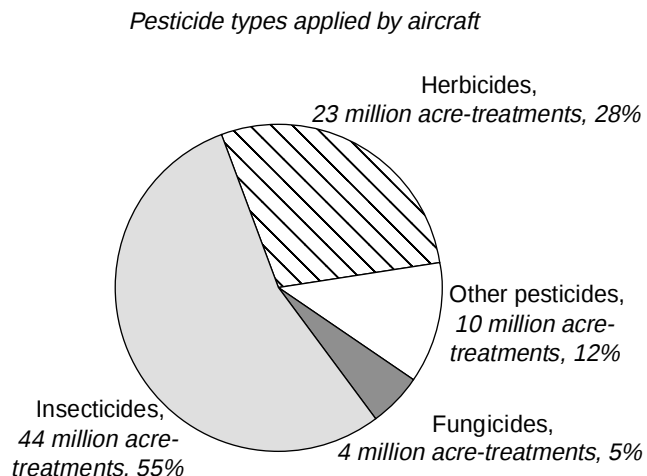
Pesticide Applications by Aircraft

Potential drift or “chemical trespass” is most likely when pesticides are applied as a fine mist, fog, or dust and applied in the presence of wind (fig. 3F3). Pesticides applied by either aircraft or ground broadcast methods can drift to nontarget sites with wind gusts or thermal inversions during and shortly following the application. Some pesticide materials will even continue to volatilize into the atmosphere for several days after application. While wind, particle size, spray pressure, and equipment calibration are important factors and require safety precautions, some application equipment and methods are better at targeting and preventing drift than others.

Pesticide applications made by aircraft usually are less precisely targeted than ground application equipment. Aircraft are often used to apply pesticides when crops reach a growth stage such that ground equipment would harm the crop or when soils are too wet to support ground equipment. Pesticide applications by aircraft were most common on cotton and wheat. About 38 percent of the cotton and 21 percent of the wheat pesticide acre-treatments were applied by aircraft. For cotton, these applications were mostly for insect control, while for wheat they were for weeds.

Figure 3F3

Pesticide applications made by aircraft, 1994-95 1/



1/ Represents 80 million acre-treatments applied by aircraft.

2/ The first value at the end of each bar is the number of acre-treatments applied by aircraft, and the second value is the percentage of total crop acre-treatments applied by aircraft.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

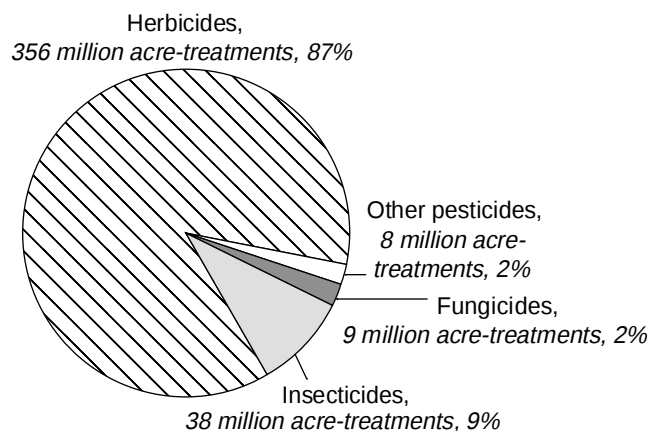
Ground Broadcast Applications

Whether applied to the plant canopy or to the soil surface, the use of ground broadcast equipment accounted for most pesticide applications (fig. 3F4). Ground broadcast applications accounted for 87 percent of the herbicide acre-treatments, but less than half of the acre-treatments of all other pesticide classes (insecticides, 9 percent; fungicides, 2 percent; other pesticides, 2 percent). More than 75 percent of all pesticide acre-treatments on wheat, soybeans, corn, and surveyed fruit used a ground broadcast application method, compared with less than 50 percent of cotton and vegetable acre-treatments.

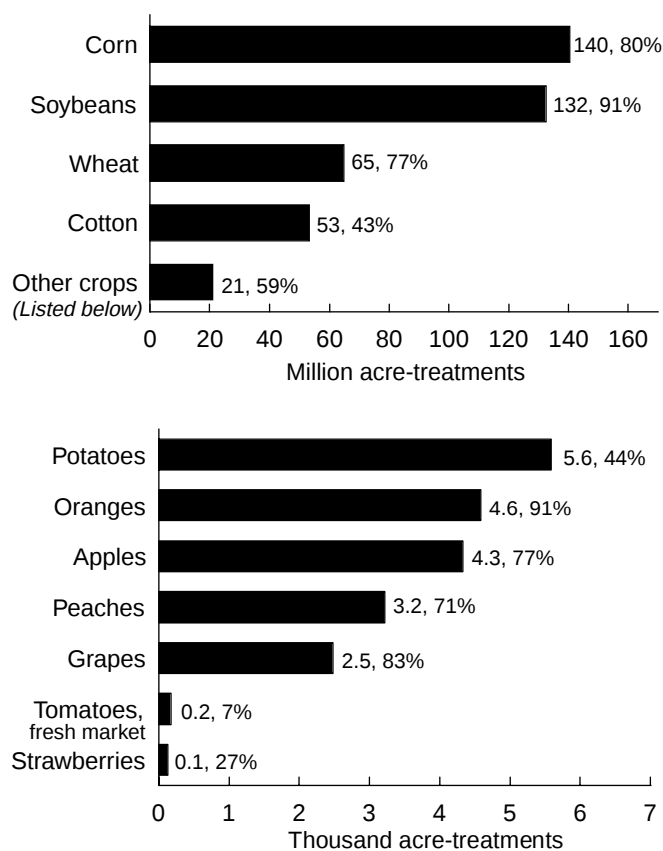
Figure 3F4

Pesticide applications made by ground broadcast methods, 1994-95 1/

Pesticide types applied by ground broadcast



Ground broadcast applications by crop 2/



1/ Represents 412 million acre-treatments made with ground equipment to either the plant foliage or the soil surface.

2/ The first value at the end of each bar is the number of acre-treatments applied by ground broadcast methods, and the second value is the percentage of crop acre-treatments applied by ground methods.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

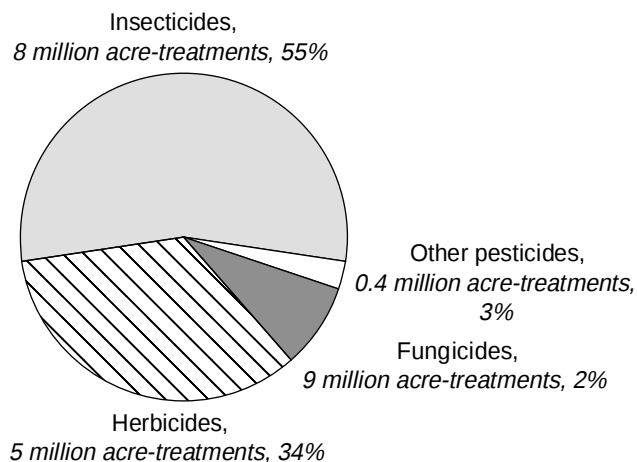
Direct Soil Placement Methods

Ground application equipment that applies the pesticide materials directly into the soil by injection or into a furrow made by a planter or tillage equipment can have some safety advantages over surface application methods (fig. 3F5). There is less risk of direct contact by humans or wildlife when the pesticide is placed in the soil, and the soil cover can reduce potential losses to the atmosphere or runoff from precipitation. Some States even exempt direct soil placement methods from obtaining spray permits when applying certain pesticide materials. A common use of direct soil placement is the treatment for corn rootworm in corn and several soil insects in cotton. Soil fumigation for strawberries, fresh market tomatoes, potatoes, and some other crops is another use of the practice, but accounts for a relatively small share of the total acres using direct soil placement methods.

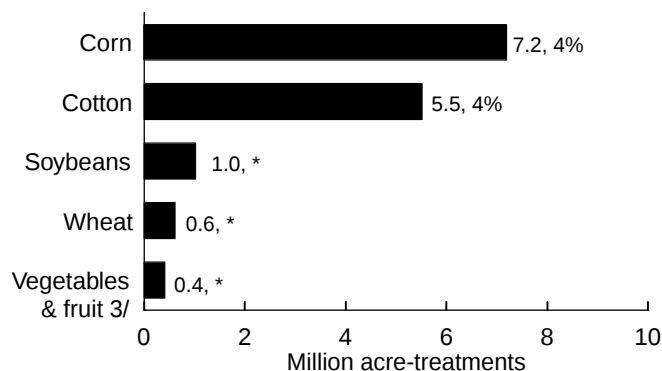
Figure 3F5

Pesticides applied by direct soil placement methods, 1994-95 1/

Pesticide types applied by direct soil placement methods



Crops treated by direct application methods 2/



1/ Represents 14.7 million acre-treatments of pesticides applied directly into the soil.

2/ The first value at the end of the bar is the number of pesticide acre-treatments applied by direct soil placement, and the second value is the percentage of total pesticide acre-treatments that used this application method. An "*" indicates that less than 1 percent used this method.

3/ Includes potatoes, tomatoes, lettuce, strawberries, apples, grapes, peaches, and oranges in surveyed States.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.

Irrigated Area and Chemigation

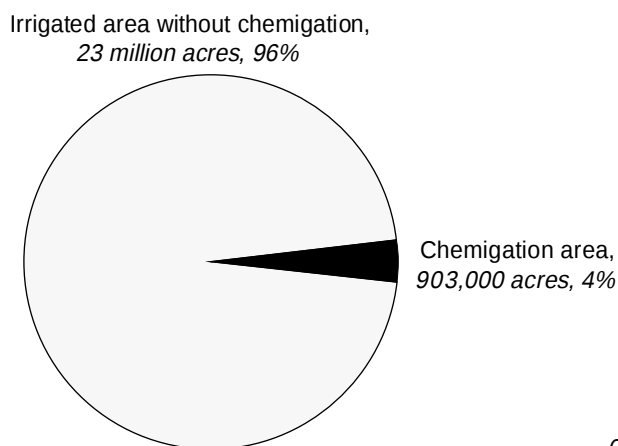
Some pesticide materials are applied through sprinkler and drip irrigation systems—a practice called chemigation (fig. 3F6). While a practical and cost-saving application technology for some pesticides, it requires special precautions to prevent water contamination from runoff, leaching, or back-siphoning into wells.

Chemigation was not a widely used practice for applying pesticides to any of the surveyed crops, except for potatoes. Approximately 80 percent of the potatoes were irrigated, and chemigation was used to apply some pesticides on about 40 percent of the irrigated acres (32 percent of total acres). On the potato area treated by chemigation, an average of five different pesticide applications, mostly fungicides, were made during the growing season.

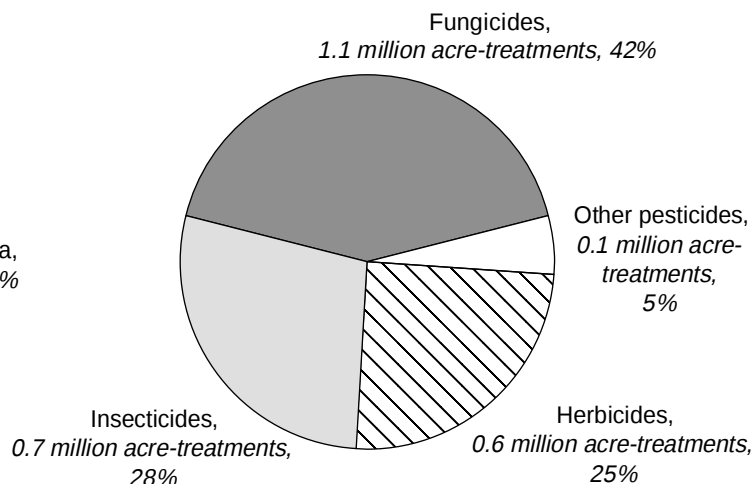
Figure 3F6

Irrigated area and chemigation, 1993-94

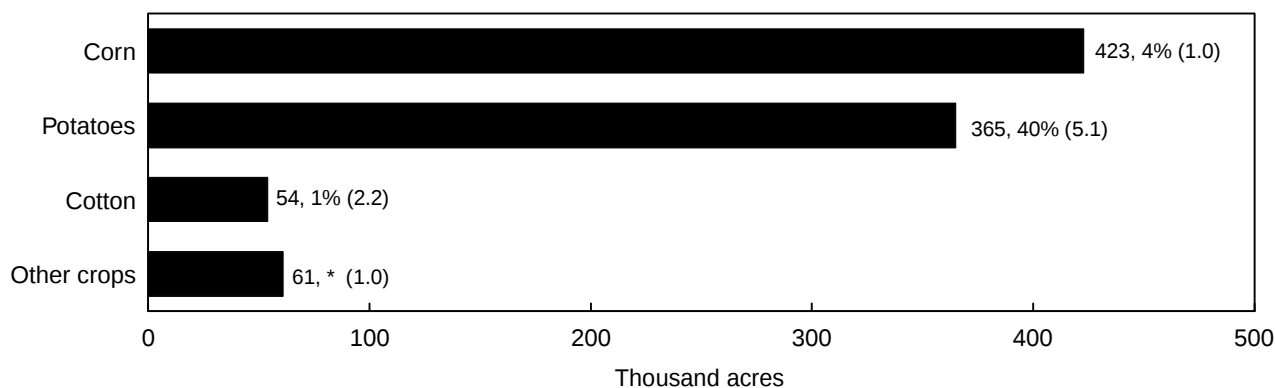
Irrigated area treated by chemigation



Pesticide types applied by chemigation 1/



Crop area treated and average number of chemigation treatments 2/



1/ Chemigation is the application of pesticides through an irrigation system. Represents 861,000 surveyed acres of irrigated corn, soybeans, cotton, potatoes, apples, oranges, and grapes and applied pesticides by chemigation.

2/ The first value at the end of each bar is the number of acres treated by chemigation; the second value is the percentage of irrigated area treated by chemigation; and the third value is the average number of chemigation acre-treatments applied during the year. An "*" indicates that less than 1 percent used this method.

Sources: USDA, NASS and ERS, 1994, 1995c, and 1995d.