3.2 Pesticides

Pesticide use in agriculture more than doubled during 1964-82, as cropland acreage increased, the proportion of acres treated with pesticides rose, and application rates per treated acre went up. Since 1982, agricultural pesticide use has trended slightly downward, mainly due to the decline in cropland acreage. The adoption of integrated pest management practices, coupled with the availability of new pesticides with lower application rates, can further reduce agricultural reliance on pesticides and the associated health and environmental risks.

Pesticides contribute to increased productivity in agriculture, but their use is also associated with potential human health, wildlife, and environmental risks. The Clinton administration has proposed a reduced use/risk policy, and the USDA's goal is to have 75 percent of U.S. crop acreage under Integrated Pest Management (IPM) by the year 2000.

This module reports trends in the quantity of pesticides used and the distribution of total use among major crops, chemical types, and active ingredients. Field crops account for the bulk of pesticide use in U.S. agriculture, and therefore management practices that influence pesticide use in these crops are reported. Indicators of the environmental risks associated with pesticide use are found in module 2.2.

This module also reports indicators of food safety (the first time such indicators have been reported), based on residue data collected for 10 fresh fruit and vegetable crops. Although fruits and vegetables account for a small portion of total pesticide use, these crops use more pesticides per acre than do field crops.

Pesticide Use, 1964-92

The USDA pesticide use surveys provide quantity data for eight benchmark years (1964, 1966, 1971, 1976, 1982, 1990, 1991, and 1992). Because not all crops have been surveyed in recent years, the discussion here is limited to those crops with consistent information over time (see box, "USDA Pesticide Use Surveys"). The crops include corn, cotton, soybeans, wheat, rice, grain sorghum, peanuts, fall potatoes, other vegetables, citrus, and apples.

Pesticide use on the selected crops grew from 233 million pounds in 1964 to 612 million pounds in 1982 (table 3.2.1). This increase can be attributed to three factors: larger cropland acreage, greater proportion of acres treated with pesticides, and higher application rates per treated acre. Since 1982, annual pesticide

Table 3.2.1—Pesticide use on selected U.S. crops by pesticide type, 1964-92

Item	1964	1966	1971	1976	1982	1990	1991	1992
				1,000 pounds of active ingredients				
Herbicides	54,884	87,351	198,949	368,422	464,596	376,367	368,268	388,175
Insecticides	128,167	121,717	137,808	135,920	84,793	56,621	51,053	57,855
Fungicides	21,715	21,660	30,906	29,546	27,519	31,641	33,112	37,358
Other pesticides	27,983	24,233	31,565	31,072	35,417	68,971	80,893	90,519
Total	232,750	254,961	399,228	564,960	612,325	533,600	533,346	573,907
				1,000 planted acres				
Area represented	193,923	194,216	213,930	255,101	275,997	242,218	240,484	248,385
Total cropland used for crops	335,000	332,000	340,000	369,000	383,000	341,000	337,000	343,000
				Pounds active ingredient per planted acre				
Herbicides	0.283	0.450	0.930	1.444	1.683	1.554	1.531	1.562
Insecticides	0.661	0.627	0.644	0.533	0.307	0.234	0.212	0.233
Fungicides	0.112	0.112	0.144	0.116	0.100	0.131	0.138	0.150
Other pesticides	0.144	0.125	0.148	0.122	0.128	0.285	0.336	0.364
Total	1.200	1.313	1.866	2.215	2.219	2.203	2.218	2.310

Source: Lin and others, 1994.

Glossary—Pesticides

Pests: Insects, diseases, and weeds or uncultivated plants that naturally exist in the environment. Agricultural pests cause damages to crops, resulting in reductions in yield, crop quality, or both.

Integrated Pest Management (IPM): "The optimization of pest control in an economically and ecologically sound manner, accomplished by the coordinated use of multiple tactics to assure stable crop production and to maintain pest damage below the economic injury level while minimizing hazards to humans, plants, and the environment." *Pest Management Strategies: Volume I*, Office of Technology Assessment (1979).

"A pest control strategy based on the determination of an economic threshold that indicates when a pest population is approaching the level at which control measures are necessary to prevent a decline in net returns. In practice, IPM is an ecologically based strategy that relies on natural mortality factors, such as natural enemies, weather, crop management, and seeks control tactics that disrupt these factors as little as possible." *Alternative Agriculture*, National Academy of Sciences (1989).

Pest scouting: The inspection of a field for pests (insects, weeds, or pathogens). A basic component of IPM programs, scouting is used to determine whether pest populations have reached levels that warrant intervention for control and to help determine the appropriate method of control.

Economic thresholds: Levels of pest population that, if left untreated, would result in losses in revenue that exceed treatment costs. The use of economic thresholds in making pesticide treatment decisions requires information on pest infestation levels from scouting.

Field mapping: Drawing a map indicating the location in the field where specific weed species are present so they can be treated.

Banded pesticide application: Applying pesticides over, or next to, each row of plants in a field. Banding herbicides often requires cultivation to control weeds in the row middles.

Broadcast pesticide application: Applying pesticides over the entire surface area of the field.

Preemergence herbicide: Herbicides that are applied before weeds emerge. Preemergence herbicides have been the foundation of row crop weed control for the past 30 years.

Postemergence herbicides: Herbicides that are applied after weeds emerge. Postemergence herbicides are considered more environmentally sound than preemergence herbicides because they have little or no soil residual activity.

Spot treatment: Pesticides are applied only to the area ("hot" spot) of a field where pest problems occur.

Crop rotations: The planting of different crops in the same field over a period of years.

Foliar pesticide application: Applying the pesticide to the foliage of the plant.

Chemigation: Applying the pesticide through an irrigation system.

Directed spray: Directing the pesticide spray at the base of the plant under the leaf canopy.

Infurrow: Placing the pesticide in the seed furrow at planting time.

USDA Pesticide Use Surveys

Surveys, 1964-82

Between 1964 and 1982, five national surveys were conducted (1964, 1966, 1971, 1976, and 1982) to estimate regional pesticide use by farmers and ranchers. The first three surveys obtained total farm use of pesticides and provided estimates of acreage, quantities, and expenditures for all crop uses. The 1976 and 1982 surveys excluded fruit and vegetable producers and some States, but still represented about 85 percent of U.S. cropland.

Crop-specific surveys were conducted during the 1977-80 period for citrus (1977), deciduous fruits (1978), cotton (1979), vegetables (1979), fall potatoes (1979), grapes (1979), corn, soybeans, and sorghum (1980). These surveys provided State-level estimates (regional for deciduous fruits) on each pesticide active ingredient (a.i.) applied to the crop.

Cropping Practices Surveys

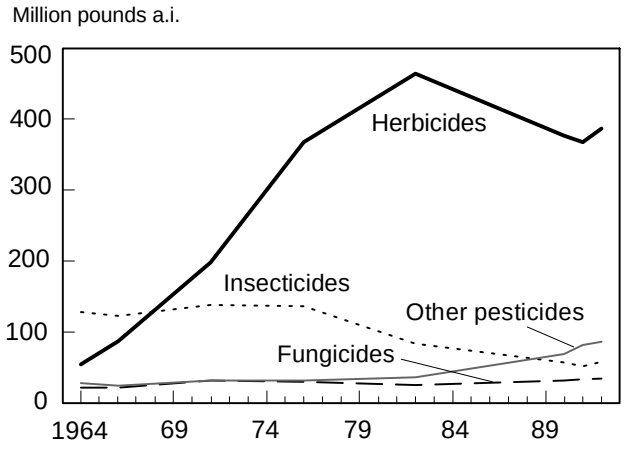
Since 1986, the Cropping Practices Surveys (CPS) for corn, cotton, soybeans, and wheat have collected information on pesticide use. These annual surveys cover the major producing States for each crop and account for 80 percent or more of the U.S. acreage for these crops. Fall potatoes and rice were added to the CPS in 1988. The pesticide information obtained between 1986 and 1989 included only acres treated with individual pesticide products but no information on quantities applied. Since 1990, additional funds were appropriated under the Water Quality Initiative to collect data on both acres treated and application rates per acre for each pesticide. These surveys provide reliable estimates of pesticide use at the State level. Because of prority data needs and available survey funds, the number of crops and States have varied from year to year. The crops and States surveyed for pesticide use since 1990 include:

- Corn: IL, IN, IA, MI, MN, MO, NE, OH, SD, and WI. Data some years for GA, KS, KY, NC, PA, SC, and TX
- Soybeans: Northern: IL, IN, IA, MN, MO, NE, and OH. Some data for KS and SD; Southern, 1988-92: AR, GA, KY, LA, MS, NC, and TN
- Upland cotton: AR, AZ, CA, LA, MS, and TX
- Winter wheat CO, IL, KS, MO, MT, NE, OH, OK, TX, and WA. AR and SD in 1990; AR, ID, IN, OR, and SD in 1991-92; and ID, OR, and SD in 1993.
- Spring wheat: MN, MT, ND, and SD
- Durum wheat: ND
- Fall potatoes: CO, ID, ME, MI, MN, ND, NY, OR, PA, WA, and WI.

Pesticide Data Program Surveys

The USDA's Pesticide Data Program (PDP), funded under the 1989 President's Food Safety Initiative, has an objective of improving the pesticide data base by establishing pesticide residue monitoring activities and by expanding pesticide use surveys. Fruits and vegetables are the primary target of the PDP, with alternate year surveys to cover most vegetables in one year (starting in 1990) and fruits the following year (starting in 1991). The 1990 vegetable survey was limited to four States and the 1991 fruit survey excluded California. The surveys conducted in 1992 (vegetables) and 1993 (fruits and nuts) cover most commercial production in the United States.

Figure 3.2.1
Pesticide use on selected crops, 1964-92[1]



[1]Includes corn, cotton, soybeans, wheat, sorghum, peanuts, rice, potatoes, other vegetables, citrus, and apples.
Source: Lin and others, 1994.

use has declined. After reaching its peak in 1980-82, cropland planted to the selected crops declined and contributed to the reduction in pesticide use.

The pesticide application rate per planted acre indicates the intensity of pesticide use over time. The rate increased substantially between 1964 and 1976. Since 1976, the rate has remained relatively stable at about 2.2 pounds of active ingredients per acre.

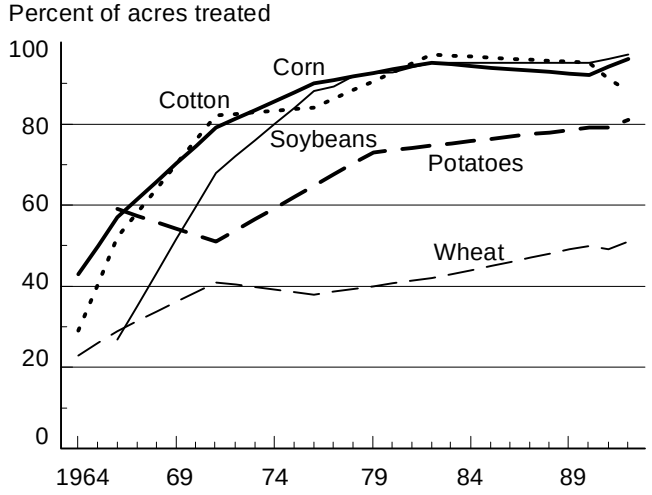
During the 1960's, pesticide use was dominated by insecticides, accounting for about half of all pesticides used on the crops considered in this analysis.

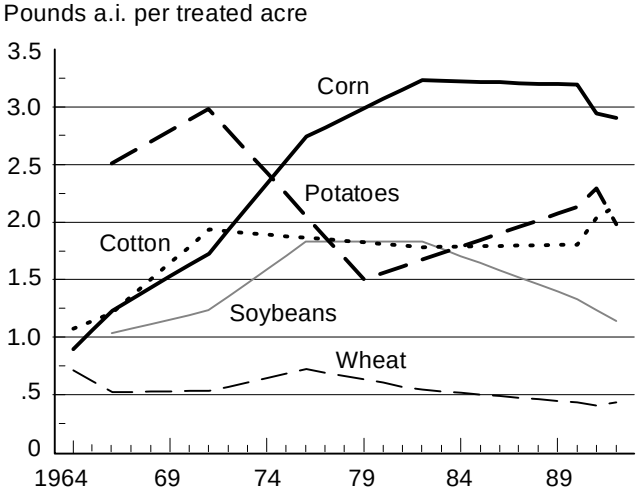
Insecticide use has declined from about 136 million pounds in 1976 to under 60 million pounds (10 percent of total pesticide use) in recent years. The decrease in insecticide use came mainly from cotton production, where organochlorines (DDT and toxaphene) were banned and replaced by pyrethroids, which are applied at much lower rates. Also, the success of the boll weevil eradication program and adoption of integrated pest management on cotton and other crops contributed to the decrease in insecticide use.

The widespread adoption and use of herbicides, especially on corn and soybeans, accounted for much of the increase in pesticide use during the 1960's and early 1970's (fig. 3.2.1). Total herbicide use increased from about 55 million pounds in 1964 to 465 million pounds in 1982, accounting for over three-fourths of total pesticides. Herbicide use then declined to 368-388 million pounds in the early 1990's. The decline in herbicide use coincided with a decline of about 25 million planted acres; average herbicide use per planted acre has declined only slightly since 1982.

Fungicides and other pesticides accounted for about one-fifth of all pesticides used on the selected crops. Because of the lack of comprehensive survey data, the "trend" estimates for fungicides and other pesticides should be interpreted with care. The use of fungicides was most common on peanuts, fall potatoes, other vegetables, citrus, and apples. About 35 million pounds of total fungicides (94 percent) were applied to these crops in 1992. The use of other

Figure 3.2.2
Herbicide use on major field crops, 1964-92





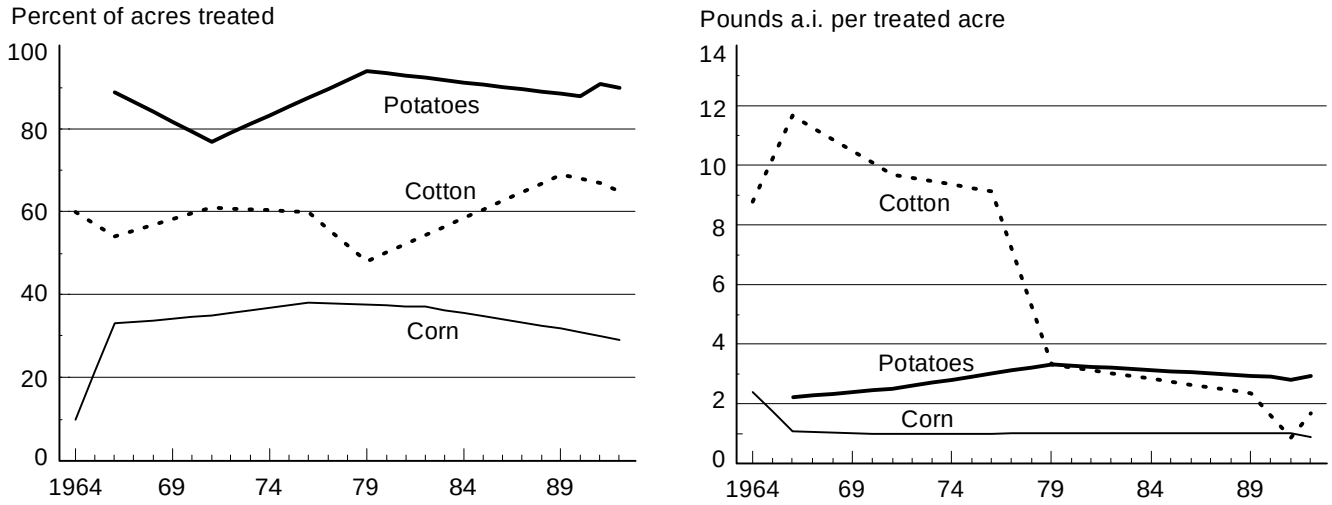
Source: Lin and others, 1994.

Table 3.2.2—Estimated quantity of pesticide active ingredient applied to selected U.S. crops, 1964-92[1]

Commodities	1964	1966	1971	1976	1982	1990	1991	1992
				1,000 pounds of herbicides				
Corn	25,476	45,970	101,060	207,061	243,409	217,500	210,200	224,403
Cotton	4,628	6,526	19,610	18,312	20,748	21,114	26,032	25,871
Wheat	9,178	8,247	11,622	21,879	19,524	16,641	13,561	17,398
Sorghum	1,966	4,031	11,538	15,719	15,738	13,485	14,156	16,995
Rice	2,559	2,819	7,985	8,507	14,089	16,139	16,092	17,665
Soybeans	4,208	10,409	36,519	81,063	133,240	74,400	69,931	67,529
Peanuts	2,894	2,899	4,374	3,366	4,929	4,070	4,510	3,738
Potatoes	1,296	2,220	2,178	1,765	1,636	2,361	2,547	2,152
Other vegetables	2,195	3,488	3,361	5,419	4,344	4,632	4,496	5,486
Citrus	207	353	546	4,756	6,289	5,639	6,331	6,289
Apples	278	389	156	575	649	386	411	649
Total herbicides	54,884	87,351	198,949	368,422	464,596	376,367	368,268	388,175
				1,000 pounds of insecticides				
Corn	15,668	23,629	25,531	31,979	30,102	23,200	23,036	20,870
Cotton	78,022	64,900	73,357	64,139	19,201	13,583	8,159	15,365
Wheat	891	876	1,712	7,236	2,853	970	208	1,153
Sorghum	788	767	5,729	4,604	2,559	1,085	1,140	1,368
Rice	284	312	946	508	565	161	309	178
Soybeans	4,997	3,217	5,621	7,866	11,621	0	445	360
Peanuts	5,518	5,529	5,993	2,439	1,035	1,726	1,913	1,585
Potatoes	1,456	2,972	2,770	3,261	3,775	3,591	3,597	3,514
Other vegetables	8,290	8,163	8,269	5,671	4,465	4,437	4,261	5,141
Citrus	1,425	2,858	3,049	4,604	5,305	3,976	4,145	4,420
Apples	10,828	8,494	4,831	3,613	3,313	3,891	3,841	3,901
Total insecticides	128,167	121,717	137,808	135,920	84,793	56,621	51,053	57,855
				1,000 pounds of fungicides				
Corn	0	0	0	20	69	0	0	0
Cotton	171	376	220	49	200	988	701	788
Wheat	0	0	0	862	1,088	172	73	1,155
Sorghum	0	0	0	0	0	0	0	0
Rice	0	0	0	0	80	194	426	388
Soybeans	0	0	0	176	71	0	0	85
Peanuts	1,106	1,108	4,431	6,834	4,740	7,321	8,114	6,725
Potatoes	3,229	3,531	4,124	4,168	4,031	2,808	3,172	3,616
Other vegetables	4,530	4,093	5,667	5,051	6,692	12,173	12,527	16,186
Citrus	4,929	4,056	9,257	5,897	4,881	3,357	3,750	4,000
Apples	7,750	8,496	7,207	6,489	5,667	4,629	4,349	4,416
Total fungicides	21,715	21,660	30,906	29,546	27,519	31,641	33,112	37,358
				1,000 pounds of other pesticides				
Corn	76	546	443	483	130	0	0	0
Cotton	12,431	14,207	18,696	12,682	9,347	15,188	15,457	15,841
Wheat	0	47	245	0	0	0	0	0
Sorghum	0	40	0	266	44	0	0	0
Rice	0	0	0	0	17	0	0	109
Soybeans	0	49	52	2,030	2,430	0	0	0
Peanuts	6,990	7,005	471	1,188	1,627	2,364	2,620	2,197
Potatoes	91	10	6,397	8,575	15,188	35,069	45,626	49,671
Other vegetables	5,819	569	3,433	5,060	6,206	16,286	17,174	22,685
Citrus	1,539	681	1,280	214	7	14	15	16
Apples	1,037	1,079	548	574	421	49	0	0
Total other pesticides	27,983	24,233	31,565	31,072	35,417	68,971	80,893	90,519
				1,000 pounds of all pesticides				
Corn	41,220	70,145	127,034	239,543	273,710	240,700	233,235	245,272
Cotton	95,252	86,009	111,883	95,182	49,497	50,873	50,349	57,865
Wheat	10,069	9,170	13,579	29,977	23,465	17,782	13,842	19,706
Sorghum	2,754	4,838	17,267	20,589	18,341	14,570	15,296	18,362
Rice	2,843	3,131	8,931	9,015	14,751	16,494	16,827	18,340
Soybeans	9,205	13,675	42,192	91,135	147,362	74,400	70,376	67,974
Peanuts	16,509	16,541	15,268	13,827	12,331	15,482	17,158	14,245
Potatoes	6,072	8,733	15,469	17,769	24,630	43,830	54,942	58,953
Other vegetables	20,834	16,313	20,731	21,201	21,707	37,528	38,459	49,498
Citrus	8,100	7,948	14,132	15,472	16,482	12,986	14,241	14,725
Apples	19,893	18,458	12,742	11,251	10,050	8,955	8,601	8,966
Total all pesticides	232,750	254,961	399,228	564,960	612,325	533,600	533,326	573,907

[1] Estimates are for the total U.S. acreage of the selected crops. Columns may not add due to rounding. Source: Lin and others, 1994.

Figure 3.2.3
Insecticide use on major field crops, 1964-92



Source: Lin and others, 1994.

pesticides (soil fumigants, growth regulators, and harvest aids) was most common in the production of peanuts, fall potatoes, and other vegetables, amounting to 75 million pounds (82 percent of the total) in 1992.

Pesticide Use on Major Crops

Corn occupies the largest acreage of U.S. crops and far exceeds any other commodity in pesticide use. In 1992, 79 million acres of cropland were planted with corn, compared with 4.6 million acres of vegetables, and 1.4 million acres of citrus and apples. On a per-acre basis, corn is an intensive pesticide user among field crops, but is less pesticide-intensive than many fruit and vegetable crops. Corn received 245 million pounds of pesticides in 1992, accounting for 43 percent of total pesticides (table 3.2.2). In 1992, herbicides and insecticides were applied at 2.83 and 0.26 pounds per planted acre of corn (figs. 3.2.2 and 3.2.3). Corn acreage accounted for 32 percent of the crop acres, but used 58 percent of all herbicides and 37 percent of all insecticides. Herbicides accounted for 91 percent of all pesticides applied on corn.

Soybeans were the second largest user of pesticides, receiving about 68 million pounds in 1992. Soybeans accounted for about one-fourth of the crop acreage and used about 12 percent of the pesticides. Most soybean acreage received herbicides, but only about 1.1 pounds per planted acre. Limited use is made of pesticides other than herbicides.

Wheat has the second largest acreage, but was the least pesticide-intensive crop; many wheat acres (45 percent) received no pesticide treatments. Wheat accounted for 29 percent of the total acreage, but only about 3.5 percent of the pesticides used in 1992. The 17 million pounds of herbicides applied in 1992 accounted for 88 percent of all pesticides used on wheat.

Cotton, with 13 million planted acres and nearly 58 million pounds of pesticides applied in 1992, accounted for 5 percent of total acreage and about 10 percent of all pesticides applied to the crops included in this analysis. Almost all cotton acres are treated with pesticides, with an average application rate of over 4 pounds per planted acre. About 45 percent of the pesticides used on cotton were herbicides, 27 percent insecticides, and 27 percent other pesticides.

Rice received the most intensive use of herbicides, with 5.6 pounds per planted acre. Herbicides applied to rice accounted for less than 5 percent of total herbicide use, because of its small acreage. Peanuts require intensive fungicide use, accounting for 20 percent of fungicides applied to all crops in 1992.

Vegetables, including potatoes, represented less than 2 percent of the acreage in 1992 but received 19 percent (108 million pounds) of the pesticides. These crops accounted for 15 percent of the insecticides, 53 percent of the fungicides, and 80 percent of other pesticides (soil fumigants, growth regulators, and harvesting aids) used in 1992. Like vegetables, citrus and apples received a relatively large share of

Table 3.2.3—Herbicide active ingredients used on field crops, major producing States, 1990-93[1]

Active ingredient	1990	1991	1992	1993
		1,000 pounds		
2,4-D	9,414	7,234	8,576	11,616
Alachlor	46,227	50,009	50,291	40,217
Atrazine	50,257	52,060	54,939	49,553
Butylate	10,377	8,478	8,117	5,441
Cyanazine	23,232	24,862	28,518	28,095
EPTC	27,059	15,547	11,523	12,132
Metolachlor	39,055	47,040	47,929	46,438
Pendimethalin	7,603	12,379	14,319	14,688
Trifluralin	21,854	22,682	20,758	16,529

[1]Includes 17 corn; 6 upland cotton; 11 fall potato; 16 soybean; 12 winter wheat in 1990, 15 in 1991 and 1992, and 13 in 1993; 4 spring wheat; and 1 durum wheat State. For names of States, see box, "USDA Pesticide Use Surveys."

Source: USDA, ERS, Cropping Practices Survey data.

pesticides. Citrus and apples accounted for less than 1 percent of the total acres but received 4 percent of the pesticides. The 8 million pounds of fungicides applied to citrus and apples in 1992 accounted for 23 percent of all fungicides.

Major Active Ingredients Used on Field Crops

The quantities of major herbicide and insecticide active ingredients (a.i.) used on field crops are summarized in tables 3.2.3 and 3.2.4. Crops covered are corn, upland cotton, fall potatoes, soybeans, winter wheat, spring wheat, and durum wheat grown in major producing States for multiple years in the 1990's (see box, "USDA Pesticide Use Surveys"). The major producing States represent about 88 percent of the U.S. planted acreage for these crops, ranging from 80 percent for upland cotton to 94 percent for fall potatoes (crop acres represented are shown in tables 3.2.6-3.2.9). The quantity of a.i. used in any year is influenced by the planted acreage, the proportion of a.i.-treated acres, and the application rate per acre.

Herbicides

Nine major herbicide a.i. account for about 85 percent of the total herbicide a.i. used on field crops in the major producing States (table 3.2.3). Atrazine was the most heavily used a.i., accounting for 18 percent of total herbicide a.i. in 1993. Atrazine is used extensively in corn production. It was applied to 69 percent of the corn acreage at a rate of 1.09 pounds per acre in 1993. In 1982, atrazine was applied to 60 percent of total U.S. corn acreage at a rate of 1.46 pounds per acre. So the proportion of corn area treated with atrazine has increased but the application rate has decreased as farmers have switched to banded applications and reduced the rate for broadcast applications (see Glossary, p. 87).

Alachlor, used primarily in corn and soybean production, accounted for 15 percent of herbicide a.i. use in 1993. Alachlor was used on about 25 percent of the corn acreage in the 1990's, compared with 33 percent in 1982. In soybean production, alachlor use has declined from 25 percent of the planted acreage in 1982 to 8 percent in 1993. New herbicide products have entered the soybean market in recent years. On both corn and soybeans, alachlor is applied at about 2 pounds per acre.

Metolachlor accounted for 17 percent of herbicide a.i. in 1993, and is used in corn, upland cotton, fall potato, and soybean production. The application rate for metolachlor is 1.7-1.9 pounds per acre for corn, fall potatoes, and soybeans. For upland cotton, the rate is 0.85-1.00 pound per acre because banded applications are used.

Cyanazine has been used on 15-20 percent of the corn and upland cotton acreage in the 1990's. It is applied at a rate of 1.8-2.0 pounds per acre (broadcast) in corn production and 0.8-1.0 pound (banded) in upland cotton production.

Trifluralin is used on about 60 percent of upland cotton acreage, 25-35 percent of soybean acreage, 20-33 percent of durum wheat acreage, and 5 percent of fall potato and spring wheat acreage. Trifluralin is applied at 0.6-0.9 pound per acre on upland cotton,

soybeans, and fall potatoes. In spring and durum wheat production, it is applied at 0.4 pound per acre. The lower rate for wheat is due to crop tolerance.

2,4-D is used on 40-60 percent of spring and durum wheat acreage, 15-20 percent of winter wheat acreage, and 10 percent of corn acreage. In 1992, it was registered as a preplant application for no-till soybeans and was used on 1 percent of the acreage, but by 1993 had grown to 7 percent. The application rate ranges from 0.3 to 0.5 pound per acre.

Pendimethalin is used on 15-20 percent of upland cotton, fall potato, and soybean acreage at about 0.9 pound per acre. Butylate is used on about 3 percent of corn acreage, down from 19 percent in 1982. It is applied at 4.0-4.4 pounds per acre. EPTC was used on 4 percent of corn acreage in 1993, down from 9 percent in 1990; however, it was used on 25-30 percent of fall potato acreage during the same period. EPTC is applied at 4.4 pounds per acre in corn production and 3.4 pounds in fall potato production.

Insecticides

Six major insecticide a.i. accounted for 73 percent of total insecticide a.i. in 1993 for corn, upland cotton, fall potatoes, and soybeans in the major producing States (table 3.2.4). Chlorpyrifos was the most heavily used insecticide, accounting for 21-24 percent of the insecticide total. Chlorpyrifos was used on about 8 percent of corn acreage and 5-10 percent of upland cotton acreage. In corn production, it is used at 1.1 pounds per acre and is applied banded at planting. In cotton, it is applied 2-3 times per season as a foliar application at 0.5-0.6 pound per acre per treatment. Terbufos accounted for 18 percent of insecticide use in 1993; it was used on 8 percent of the corn acreage banded at planting at a rate of 1.1 pounds per acre.

Carbofuran, fonofos, and phorate are banded at planting on 1-3 percent of corn acreage at a rate of 1.0-1.2 pounds per acre. In fall potato production, carbofuran is applied to 15 percent of the acreage 1.5 times per season at 0.5-0.6 pound per acre per treatment as a foliar application. Fonofos is applied to 2 percent and phorate to 30 percent of the fall potato acreage. They are banded at planting at a rate of 2.6-3.0 pounds per acre.

Methyl parathion was applied to 14 percent of upland cotton acreage in 1991, 23 percent in 1992, and 28 percent in 1993. Applications per season increased from 2.1 in 1991 to 3.7 in 1993 at a rate of 0.5 pound per acre per treatment. Boll weevil populations increased dramatically during 1991-93 because of a succession of mild winters. However, the harsh winter of 1993-94 should have reduced overwintering populations and thus the need for as many methyl parathion treatments in 1994.

Table 3.2.4—Insecticide active ingredients used on field crops, major producing States, 1991-93[1]

Active ingredient	1991	1992	1993
		1,000 pounds	
Carbofuran	2,386	1,791	1,255
Chlorpyrifos	7,434	6,689	6,615
Fonofos	2,932	2,165	1,940
Methyl parathion	2,552	3,798	5,046
Phorate	2,618	2,068	2,582
Terbufos	5,986	6,309	5,561

[1]Includes 17 corn, 6 upland cotton, 11 fall potato, and 16 soybean States. Data are not compiled for 1990 due to missing information on upland cotton. For names of States, see box, "USDA Pesticide Use Surveys."

Source: USDA, ERS, Cropping Practices Survey data.

Pesticide Prices

The decline in planted acreage in the mid-1980's dampened pesticide demand, so prices remained stable or declined between 1985 and 1987. The expiration of patents for alachlor and trifluralin in the early 1980's resulted in further price competition. Since the mid-1980's, pesticide prices have trended upward (table 3.2.5). Recent prices for methyl parathion (used extensively for boll weevil control in cotton production) have been volatile. In 1989, spring trappings indicated the possibility of heavy boll weevil pressure. Growers stocked up on methyl parathion, tightening supplies and increasing the price by 31 percent. Manufacturers responded with higher production and when the boll weevil threat did not materialize, inventory carryover into the 1990 season resulted in a 24-percent drop in price. The mild winter of 1990-91 indicated an upsurge in boll weevil pressure and again tight supplies resulted in a substantial price increase. A similar situation existed in 1992 and 1993.

Pesticide Application Practices in Field Crop Production

Information on pesticide application practices is an essential component of the pesticide data base for evaluating alternative policies for reducing

agricultural pesticide use. For example, herbicide application timing and method greatly influence herbicide use.

Corn

About 95 percent of the corn acreage in the 10 major producing States was treated with herbicides in the 1990's (table 3.2.6). Treatments averaged about 1.4 per season. After-planting-only applications increased from 29 percent of treated acres in 1990 to 37 percent in 1993. This indicates that farmers are waiting to identify the extent and intensity of weed problems before making a herbicide application. Broadcast applications with ground equipment accounted for 80 percent of the acre-treatments.

Insecticides were applied to 30 percent of the corn acreage with an average of 1 treatment per season. Corn rootworm larvae, the most prevalent pest in corn production, are generally treated at planting, by infurrow or banded applications by the farmer.

Table 3.2.5—April farm pesticide prices, 1985-94[1]

Pesticides	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
					Dollars per pound active ingredient					
Herbicides:										
Alachlor	5.15	5.10	4.84	5.10	5.40	5.70	6.15	6.35	6.45	6.48
Atrazine	2.04	2.14	2.20	2.28	2.70	2.93	3.25	3.48	3.60	3.76
Butylate	3.13	3.10	3.04	3.10	3.10	3.13	3.34	3.10	2.88	2.99
Cyanazine	4.55	4.55	4.62	4.78	5.03	5.43	5.65	5.83	5.95	6.55
Metolachlor	6.09	6.05	6.03	6.21	6.61	6.94	7.49	7.69	7.79	7.85
Trifluralin	6.43	6.25	6.30	6.45	6.60	6.70	7.50	8.00	8.08	8.13
2,4-D	2.38	2.26	2.44	2.53	2.60	2.71	2.83	2.93	3.20	3.38
Insecticides:										
Carbaryl	3.84	3.91	3.90	4.06	4.07	4.36	4.44	4.95	5.36	5.41
Carbofuran	10.29	10.27	9.57	9.36	9.51	9.77	10.39	10.84	12.20	12.80
Chlorpyrifos	8.23	8.30	8.25	8.50	9.05	9.65	10.65	11.30	12.03	12.10
Fonofos	8.85	8.82	8.70	8.83	8.96	9.26	10.30	10.20	0.75	10.85
Methyl parathion[2]	2.75	2.74	2.82	2.94	3.85	2.94	4.15	4.74	5.34	5.66
Phorate	6.57	6.54	6.59	6.68	6.85	7.25	7.78	8.06	8.80	9.15
Pyrethroids[3]	54.40	51.20	48.80	48.08	48.08	50.00	61.25	62.50	64.17	63.75
Terbufos	9.80	9.79	9.79	9.88	10.13	10.52	11.28	11.28	11.87	12.40
					Annual percent change					
Herbicides:										
Alachlor	n/a	-1.0	-5.1	5.4	5.9	5.6	7.9	3.3	1.6	0.5
Atrazine	n/a	4.9	2.8	3.6	18.4	8.5	10.9	7.1	3.4	4.4
Butylate	n/a	-1.0	-1.9	2.0	0.0	1.0	6.7	-7.2	-7.1	3.8
Cyanazine	n/a	0.0	1.5	3.5	5.2	8.0	4.1	3.2	2.1	10.1
Metolachlor	n/a	-0.7	-0.3	3.0	6.4	5.0	7.9	2.7	1.3	0.8
Trifluralin	n/a	-2.8	0.8	2.4	2.3	1.5	11.9	6.7	1.0	0.6
2,4-D	n/a	-5.0	8.0	3.7	2.8	4.2	4.4	3.5	9.2	5.6
Insecticides:										
Carbaryl	n/a	1.8	-0.3	4.1	0.2	7.1	1.8	11.5	8.3	0.9
Carbofuran	n/a	-0.2	-6.8	-2.2	1.6	2.7	6.3	4.3	12.5	4.9
Chlorpyrifos	n/a	0.9	-0.6	3.0	6.5	6.6	10.4	6.1	6.5	0.6
Fonofos	n/a	-0.3	-1.4	1.5	1.5	3.3	11.2	-1.0	5.4	0.9
Methyl parathion	n/a	-0.4	2.9	4.3	31.0	-23.6	41.2	14.2	12.7	6.0
Phorate	n/a	-0.5	0.8	1.4	2.5	5.8	7.3	3.6	9.2	4.0
Pyrethroids	n/a	-5.9	-4.7	-1.5	0.0	4.0	22.5	2.0	2.7	-0.7
Terbufos	n/a	-0.1	0.0	0.9	2.5	3.8	7.2	0.0	5.2	4.5

n/a = Not applicable.

[1]USDA, NASS, farm supply dealers annual survey.

[2]Fred Cooke, Mississippi Agricultural Experiment Station.

[3]Average of fenvalerate and permethrin prices.

Table 3.2.6—Pesticide use in corn and upland cotton production, major producing States, 1990-93[1]

Item	1990	1991	1992	1993	1990	1991	1992	1993
	Corn				*Upland cotton*			
1,000 acres planted	58,800	60,350	62,850	57,350	9,730	10,860	10,200	10,360
Herbicides:								
Percent of acres treated	94.7	95.4	96.9	97.6	93.9	91.9	88.7	91.5
Percent with--[2]								
1 treatment	59.1	62.3	57.2	60.4	47.7	41.9	38.9	36.9
2 treatments	32.0	31.0	36.0	32.8	23.0	25.9	19.7	24.3
3 treatments[3]	3.5	2.1	3.7	4.4	6.5	8.3	10.4	10.8
4 treatments					8.3	5.1	6.8	8.2
5 treatments					4.8	5.0	6.0	5.5
6 or more					3.6	5.7	6.8	5.8
Average acre-treatments	1.42	1.37	1.45	1.43	2.07	2.23	2.41	2.40
Percent by--[2]								
Farmers only	60.8	56.8	58.7	54.0	78.4	77.9	76.6	73.5
Custom applicators only	26.3	31.7	28.6	33.9	11.4	6.4	5.6	10.8
Both	7.6	6.9	9.0	8.9	4.1	7.5	6.5	7.2
Percent applied--[2]								
Before planting only	24.3	24.3	20.5	22.4	41.1	33.2	31.0	29.1
At planting only	13.5	13.0	11.5	11.4	4.5	5.9	5.1	4.6
After planting only	29.0	34.1	36.4	36.8	5.0	5.2	7.4	8.9
Before/at only	1.5	1.0	0.8	0.5	12.1	12.8	12.7	11.4
Before/after only	19.2	16.7	19.1	18.4	11.2	14.6	9.4	12.0
At/after only	6.8	6.3	7.9	6.7	4.7	5.6	8.3	7.7
Before/at/after	0.4	0.1	0.2	0.5	15.4	14.7	14.7	17.7
1,000 acre-treatments	78,838	78,850	88,292	80,016	18,906	22,305	21,783	22,764
Percent by--[4]								
Ground broadcast	77.9	79.7	78.3	79.2	59.8	57.7	54.2	50.9
Aerial broadcast	1.4	1.6	1.4	2.0	4.6	4.3	3.5	6.4
Infurrow	1.6	1.1	0.7	1.2	0.9	2.4	3.0	2.2
Chemigation	nr	nr	0.3	nr	nr	nr	0.7	nr
Banded in row	10.6	11.3	12.2	11.4	27.3	28.4	28.1	28.5
Directed spray	8.5	6.3	7.1	6.2	7.2	7.2	10.5	11.8
Insecticides:								
Percent of acres treated	32.3	30.4	28.7	28.2	NA	66.3	64.6	64.8
Percent with--[2]								
1 treatment	29.6	27.3	26.6	26.9	NA	24.0	16.7	13.1
2 treatments	2.5	2.4	1.8	1.2	NA	12.4	9.8	12.6
3 treatments[3]	0.2	0.7	0.3	0.1	NA	9.6	8.7	6.5
4 treatment					NA	5.5	7.5	6.5
5 treatments					NA	5.1	3.0	2.9
6 or more					NA	9.6	18.9	91.1
Average acre-treatments	1.09	1.13	1.09	1.05	NA	3.08	4.51	4.88
Percent by--[2]								
Farmers only	27.7	24.7	24.5	22.8	NA	31.4	24.1	26.0
Custom applicators only	2.8	3.6	3.4	3.3	NA	23.4	18.4	18.9
Both	1.5	1.8	0.7	nr	NA	11.5	19.1	19.9
Percent applied--[2]								
Before planting only	1.4	1.0	1.3	1.1	NA	1.2	0.6	0.1
At planting only	24.4	21.7	21.2	21.3	NA	4.1	3.9	5.5
After planting only	4.4	5.6	4.9	5.2	NA	53.3	51.2	48.3
Before/at only	nr	0.1	nr	nr	NA	nr	nr	nr
Before/after only	0.1	0.1	nr	nr	NA	1.0	1.5	0.9
At/after only	2.0	1.8	1.1	0.4	NA	6.5	7.4	9.9
Before/at/after	nr	nr	nr	nr	NA	0.2	nr	nr
1,000 acre-treatments	20,711	20,702	19,587	16,985	NA	22,136	29,731	32,745
Percent by--[4]								
Ground broadcast	16.1	14.4	11.1	14.3	NA	28.7	24.8	24.5
Aerial broadcast	6.1	9.2	7.6	6.7	NA	42.1	45.5	43.6
Infurrow	26.8	27.8	24.7	24.9	NA	4.7	3.1	6.9
Chemigation	1.0	1.3	1.5	0.5	NA	nr	1.5	0.1
Banded in row	48.7	45.8	54.2	52.5	NA	13.9	14.0	15.7
Directed spray	1.3	1.5	0.9	1.0	NA	10.6	12.4	9.3

NA = not available. nr = none reported.

[1]Includes 17 corn and 6 upland cotton States. For names of States, see box, "USDA Pesticide Use Surveys."

[2]Column sum equals percent of acres treated.

[3]Three or more treatments for corn.

[4]Column sum equals 100 percent.

Source: USDA, ERS,Cropping Practices Survey data.

Table 3.2.7—Herbicide use in soybean production, major producing States, 1990-93[1]

Item	1990	1991	1992	1993	1990	1991	1992	1993
	Northern soybeans				*Southern soybeans*			
1,000 acres planted	36,400	38,850	38,150	39,000	11,850	10,800	10,480	10,900
Percent of acres treated	96.5	96.7	98.4	97.8	92.9	92.5	94.8	94.8
Percent with--[2]								
1 treatment	56.1	57.2	55.6	50.9	48.9	49.8	45.2	39.4
2 treatments	35.2	35.1	38.7	40.2	34.7	35.0	35.6	37.7
3 treatments	4.8	3.9	3.6	5.5	7.7	6.2	11.5	12.2
4 or more	0.4	0.5	0.5	1.2	1.6	1.6	2.5	5.4
Average acre-treatments	1.48	1.46	1.48	1.56	1.60	1.57	1.71	1.83
Percent by--[2]								
Farmers only	62.4	60.3	59.1	52.5	80.9	78.2	76.5	79.3
Custom applicators only	26.8	29.8	31.4	33.4	8.8	9.8	12.7	9.6
Both	7.2	6.6	7.2	7.3	3.2	4.3	4.7	5.5
Percent applied--[2]								
Before planting only	32.2	29.8	28.9	22.4	24.2	27.5	26.4	18.2
At planting only	10.2	7.2	5.4	4.1	11.6	10.5	10.0	8.4
After planting only	19.0	26.2	27.8	29.9	23.2	18.7	18.9	22.9
Before/at only	2.4	1.4	1.1	0.8	3.9	2.5	3.0	1.8
Before/after only	29.6	28.6	32.0	33.3	19.2	22.5	25.9	29.3
At/after only	2.8	3.4	1.9	1.6	9.2	7.3	7.1	10.0
Before/at/after	0.2	0.1	0.4	0.3	1.7	3.4	2.5	3.7
1,000 acre-treatments	51,872	54,885	55,660	59,684	11,850	15,659	17,005	18,932
Percent by--								
Ground broadcast	79.6	84.5	84.8	85.5	73.5	78.1	76.2	72.3
Aerial broadcast	1.5	1.8	1.5	3.0	5.3	6.6	5.8	5.2
Infurrow	0.7	0.5	0.5	0.4	0.5	1.5	1.0	0.5
Chemigation	nr	nr	nr	nr	nr	nr	0.2	nr
Banded in row	8.8	8.8	7.8	6.3	14.8	10.0	10.7	12.8
Directed spray	9.4	4.4	5.4	4.7	5.9	3.7	6.0	9.2

nr = none reported.

[1] For names of States, see box, "USDA Pesticide Use Surveys."

[2] Column sum equals percent of acres treated. May not add exactly due to rounding.

[3] Column sum equals 100 percent.

Source: USDA, ERS, Cropping Practices Survey data.

Cutworms and European corn borers are also problem insects. If farmers detect cutworms in a field before planting, they will treat with a broadcast application; otherwise, they will scout and treat cutworms if seedling corn is damaged. European corn borers occur later in the season and are treated with broadcast ground or aerial applications.

Upland Cotton

About 90 percent of the upland cotton acreage in the 6 major producing States was treated with herbicides an average of 2.0-2.4 times per season (table 3.2.6). However, treatment frequency ranges from 3 to 5 per season in the Delta States to around 1.5 per season in Texas, Arizona, and California. Cotton farmers generally make a broadcast application before or after planting with a preemergence herbicide and apply a different preemergence material as a band application at planting. This broadens the spectrum of control and provides a weed-free environment for the slow growing cotton plant.

Insecticide applications were made to about 65 percent of the cotton acreage in 1991-93. The average number of treatments per year ranged from 3 in 1991 to 5 in 1993. The major cotton insect pests are the boll weevil, tobacco budworm, and cotton bollworm. The past few mild winters (excluding 1993-94) resulted in an explosion of boll weevils in the Delta States. Boll weevils need to be controlled when the cotton begins to square, while budworms and bollworms occur later in the season. A large proportion of the insecticide applications are aerial broadcast by custom applicators.

Table 3.2.8—Herbicide use in wheat production, major producing States, 1990-93[1]

Item	1990	1991	1992	1993	1990	1991	1992	1993
	Winter wheat				*Durum wheat*			
1,000 acres planted	38,900	31,000	33,990	35,500	3,100	3,000	2,200	1,950
Percent of acres treated	33.8	26.0	30.9	40.5	90.1	93.7	93.4	90.7
Percent with--[2]								
1 treatment	31.4	24.1	28.1	37.0	51.9	49.2	62.3	66.9
2 treatments	2.3	1.8	2.7	2.8	35.9	41.4	27.9	20.3
3 or more	0.1	0.2	0.1	0.7	2.3	3.1	3.3	3.4
Average acre-treatments	1.08	1.08	1.09	1.11	1.45	1.51	1.37	1.33
Percent by--[2]								
Farmers only	14.0	12.1	12.1	14.5	86.3	80.5	82.0	75.4
Custom applicators only	19.8	13.7	18.5	25.2	1.5	7.8	6.6	13.6
Both	0.1	0.2	0.4	0.3	2.3	5.5	4.9	1.7
Percent applied--[2]								
Before planting only	2.6	1.5	1.4	2.3	2.3	3.1	4.9	5.1
At planting only	0.4	0.2	0.3	0.6	nr	nr	nr	0.8
After planting only	30.0	23.1	28.5	36.4	56.5	57.8	60.7	66.1
Before/at only	nr	nr	nr	0.1	nr	nr	nr	nr
Before/after only	0.7	1.2	0.7	1.0	31.3	32.8	27.0	18.6
At/after only	0.1	nr	nr	0.1	nr	nr	0.8	nr
Before/at/after	0.1	nr	nr	nr	nr	nr	nr	nr
1,000 acre-treatments	14,158	8,739	11,485	15,892	4,047	4,242	2,813	2,347
Percent by--[3]								
Ground broadcast	82.8	80.7	74.7	70.0	96.2	93.8	92.8	95.4
Aerial broadcast	27.2	18.3	24.8	28.8	2.1	6.3	5.8	4.6
Infurrow	nr	1.0	0.5	0.7	nr	nr	1.3	nr
Chemigation	nr	nr	nr	0.4	nr	nr	nr	nr
Banded in row	nr	nr	nr	nr	nr	nr	nr	nr
Directed spray	nr	nr	nr	nr	1.7	nr	nr	nr
	Spring wheat							
1,000 acres planted	15,800	13,500	17,350	16,950				
Percent of acres treated	90.6	92.0	87.8	93.5				
Percent with--[2]								
1 treatment	74.2	75.3	74.1	75.9				
2 treatments	14.5	16.0	12.9	15.8				
3 or more	1.9	0.7	0.8	1.8				
Average acre-treatments	1.21	1.19	1.17	1.21				
Percent by--[2]								
Farmers only	72.7	69.7	70.8	73.8				
Custom applicators only	16.1	21.2	15.2	16.8				
Both	1.7	1.1	1.4	2.4				
Percent applied--[2]								
Before planting only	1.0	2.2	2.9	2.9				
At planting only	nr	0.6	2.7	0.5				
After planting only	81.9	82.5	76.5	80.5				
Before/at only	nr	nr	0.7	0.2				
Before/after only	6.9	6.7	4.2	8.7				
At/after only	0.7	nr	0.4	nr				
Before/at/after	nr	nr	nr	nr				
1,000 acre-treatments	17,264	14,760	17,741	19,124				
Percent by--[3]								
Ground broadcast	87.7	85.0	87.3	81.1				
Areial broadcast	12.3	14.5	12.1	16.8				
Infurrow	nr	0.5	0.2	1.4				
Chemigation	nr	nr	nr	0.8				
Banded in row	nr	nr	0.4	nr				
Directed spray	nr	nr	nr	nr				

nr = none reported.

[1] Includes 11 winter wheat States (CO, IL, KS, MO, MT, NE OH, OK, SD, TX, and WA); 4 spring wheat (MN, MT, ND, and SD); and 1 durum wheat (ND).

[2] Column sum equals percent of acres treated.

[3] Column sum equals 100 percent.

Source: USDA, ERS, Cropping Practices Survey data.

Table 3.2.9—Pesticide use in fall potato production, major producing States, 1990-93[1]

Item	1990	1991	1992	1993	1990	1991	1992	1993
1,000 acres planted	1,087	1,123	1,064	1,114	1,087	1,123	1,064	1,114
	Herbicides				*Fungicides*			
Percent of acres treated	81.4	80.7	81.7	82.2	69.0	68.8	72.8	77.0
Percent by--[2]								
1 treatment	58.9	56.6	59.4	59.0	29.5	28.6	19.3	21.0
2 treatments	19.5	19.8	17.1	19.0	17.6	12.0	16.0	13.2
3 treatments[3]	2.9	4.3	5.1	4.2	5.3	7.1	14.0	10.9
4 treatments	2.8	5.7	4.5	8.9				
5 or more	13.8	15.4	19.0	23.0				
Average acre-treatments	1.32	1.36	1.35	1.35	2.94	3.13	3.51	3.80
Percent by--[2]								
Farmers only	64.5	57.1	61.6	55.7	40.5	35.5	37.2	33.3
Custom applicators only	15.5	19.8	17.3	23.2	24.4	27.3	27.6	33.2
Both	1.4	3.9	2.5	3.0	4.1	6.0	7.8	10.1
Percent applied--[2]								
Before planting only	10.7	7.7	13.1	12.9	0.2	nr	0.4	0.7
At planting only	4.6	2.2	0.9	1.9	0.3	0.3	0.2	0.5
After planting only	59.8	62.0	63.0	60.5	68.0	68.2	70.9	74.3
Before/at only	0.5	1.6	0.2	0.3	nr	nr	nr	nr
Before/after only	5.5	6.4	3.9	5.3	0.1	0.2	0.4	0.7
At/after only	0.2	0.8	0.4	0.9	0.3	nr	0.8	0.5
Before/at/after	nr	nr	nr	0.1	nr	nr	nr	nr
1,000 acre-treatments	1,163	1,232	1,170	1,233	2,206	2,420	2,714	3,259
Percent by--[4]								
Ground broadcast	50.8	50.2	56.8	48.4	22.4	28.7	33.6	26.4
Aerial broadcast	9.3	14.5	8.8	13.8	37.5	42.4	39.2	43.1
Infurrow	2.1	1.0	0.4	1.6	nr	nr	nr	0.1
Chemigation	19.5	20.0	23.5	22.0	19.5	16.9	17.5	17.5
Banded in row	2.7	3.2	3.0	1.4	4.9	2.3	3.6	2.6
Directed spray	15.6	11.2	7.4	12.9	15.6	9.6	6.1	10.3
	Insecticides							
Percent of acres treated	88.1	91.8	90.0	88.4				
Percent with--[2]								
1 treatment	38.7	38.0	37.7	39.5				
2 treatments	25.9	27.2	22.4	22.4				
3 treatments	13.5	13.4	13.6	13.0				
4 treatments	6.1	7.8	8.0	6.2				
5 or more	3.9	5.4	8.3	7.3				
Average acre-treatments	2.04	2.17	2.27	2.22				
Percent by--[2]								
Farmers only	57.2	51.0	52.3	44.9				
Custom applicators only	15.2	23.0	21.3	28.3				
Both	15.7	17.0	15.7	14.9				
Percent applied--[2]								
Before planting only	4.2	1.2	1.6	3.4				
At planting only	13.0	11.4	11.7	11.6				
After planting only	51.6	57.0	59.0	57.3				
Before/at only	0.4	0.3	0.5	0.3				
Before/after only	4.1	3.2	3.4	3.6				
At/after only	14.3	18.5	13.1	12.4				
Before/at/after	0.6	0.2	0.3	0.4				
1,000 acre-treatments	1,950	2,231	2,172	2,184				
Percent by--[4]								
Ground broadcast	24.4	26.6	33.5	29.8				
Aerial broadcast	23.9	32.5	28.9	32.3				
Infurrow	12.6	9.1	8.1	10.0				
Chemigation	10.4	8.8	9.6	6.8				
Banded in row	16.8	17.0	14.9	13.1				
Directed spray	11.9	6.0	5.1	8.0				

nr = none reported.

[1] Includes 11 States. For names of States, see box, "USDA Pesticide Use Surveys."

[2] Column sum equals percent of acres treated.

[3] Three or more treatments for fungicides.

[4] Column sum equals 100 percent.

Source: USDA, ERS, Cropping Practices Survey data.

Soybeans

Herbicide data for soybeans are divided into the northern and southern producing regions. Because of differences in growing conditions and weed problems, herbicide use and the number of applications vary between regions. Soybeans in the northern region were treated with herbicides an average of 1.5 times per season (table 3.2.7). Before-planting-only applications declined 10 percentage points from 1990 to 1993, while after-planting-only applications rose 11 percentage points. This demonstrates that more farmers are waiting to see what weed problems develop before applying a herbicide. In the southern producing region, soybean acreage was treated with herbicides an average of 1.6-1.8 times per season. The biggest gain during the 4-year period was a 10-percentage-point jump in before/after planting applications. In recent years, several new herbicides have been introduced that are particularly effective on weeds in the southern region.

Wheat

Spring and durum wheat producers in the Northern Plains generally treat 90-94 percent of their acreage with herbicides (table 3.2.8). This percentage is substantially higher than for winter wheat (25-40 percent) because the spring seedbed preparation provides a good medium for both crop and weed seed germination; consequently, herbicides are needed and used more. In spring wheat production, 1.2 herbicide treatments are made per season after planting as broadcast applications applied by the farmer. On average, 1.3-1.5 treatments are made by durum wheat growers. In the durum wheat-producing area of North Dakota, wild oats and green foxtail (pigeongrass) are serious problems controlled with after-planting soil-incorporated herbicides. However, these herbicides do not control broadleaf weeds, which germinate later in the season. In winter wheat production, herbicide use is influenced by the extent of winterkill because it thins stands, and invading weeds need to be controlled to prevent additional yield losses. On average, 1.1 treatments are made per year after planting as a broadcast application with ground equipment.

Fall Potatoes

Fall potatoes are grown across the northern United States, from Maine to Washington. Growers treat about 80 percent of the fall potato acreage annually with herbicides (table 3.2.9). However, in Minnesota and North Dakota, only 40-50 percent of the acreage is treated. Growers generally make one broadcast treatment per season after the crop has been planted. About 20 percent of the herbicide treatments are applied through irrigation systems. Metribuzin, the most commonly used herbicide, requires moisture for activation. It is frequently applied through irrigation systems in the Pacific Northwest.

About 90 percent of the fall potato acreage is treated with insecticides. Colorado potato beetles, aphids, and leafhoppers are the major insect problems. On average, slightly over two insecticide treatments were made per year, with most applied after planting as broadcast applications (aerial or ground). However, about 25 percent of the acreage received an application at planting of a systemic insecticide for flea beetle and early-season Colorado potato beetle control.

Fungicides are applied to 70-80 percent of the fall potato acreage. The proportion of acreage treated with fungicides was highest in the humid Eastern States and lowest in the more arid Western States. The average number of treatments increased from 2.9 in 1990 to 3.8 in 1993. Summers in 1992 and 1993 were cool and damp, which is conducive to disease development.

Pest and Pesticide Management Practices in Corn, Soybean, and Fall Potato Production

The growing conditions that influence pest populations are crop- and location-specific, such that integrated pest management (IPM, see Glossary, p. 87) programs also differ by crop and location. IPM programs have been introduced as a more profitable and efficient approach to pest control than conventional chemical methods. Many studies have shown that pesticide use decreases with IPM. Therefore, IPM has been looked upon as a vehicle to reduce agricultural reliance on pesticides. Promotion of IPM is one of the Clinton administration's goals listed in the pesticide/food safety reform legislation proposed in April 1994. Data collected from the 1993 Cropping Practices Survey for corn, soybean, and fall potato production in selected States are summarized in this section (see ERS *Agricultural Outlook*, May 1994, for the use of IPM on fruits, nuts, vegetables, and field crops).

Pest Scouting

Pest scouting is a common practice in corn, soybean, and especially fall potato production (table 3.2.10). Pest scouting was conducted on two-thirds of the surveyed corn and soybean acres, and 85 percent of fall potato acres, most often by the farmer (including operator, family members, or employees). Chemical

dealers were the major off-farm providers of scouting services, especially in fall potato production in the Pacific Northwest where they scouted more than half of the acres.

Table 3.2.10—Pesticide decisionmaking in corn, soybean, and fall potato production, major producing States, 1993[1]

Item	Corn	Soybeans	Fall potatoes
	------ *Percent of acres* ------		
Scouting for weeds, insects, or diseases	64.52	69.16	85.22
Number of scouting sources[2]	1.15	1.17	2.12
Source of scouting--[3]			
Farmer	57.13	64.94	76.95
Extension	0.44	1.21	6.09
Dealer	8.82	11.62	52.49
Consultant	7.04	2.70	21.63
Processor (fieldman)	0.23	0.08	23.51
Other	0.45	0.12	0.34
Economic thresholds used with scouting information:			
Herbicides--			
Used	52.98	59.43	71.10
Not used	11.54	9.74	15.92
Insecticides--[4]			
Used	29.26	NA	77.64
Not used	35.25	NA	9.37
Fungicides--			
Used	NA	NA	70.68
Not used	NA	NA	16.34
Soil test for:			
All pests	2.25	0.39	na
Nematodes	NA	NA	50.61
Insects	NA	NA	18.10
Diseases	NA	NA	21.59
Crop rotation to control:[5]			
Weeds	51.59	66.60	75.20
Insects	51.91	NA	66.30
Diseases	NA	NA	79.77
Nematodes	NA	NA	60.55

NA = not available.

[1] Includes 10 corn States (IL, IN, IA, MI, MN, MO, NE, OH, SD, and WI); 8 soybean (AR, IL, IN, IA, MN, MO, NE, and OH); and 4 fall potato (ID, ME, OR, and WA).

[2] There are six possible scouting sources. Farmers reported each scouting source used.

[3] The sum within scouting sources exceeds the percent of acres scouted because an acre can be scouted by more than one source.

[4] The use of economic thresholds for corn insecticides is low because many farmers rotate corn with another crop to alleviate corn rootworm problems.

[5] Excludes fields where the same crop was planted in the preceding year.

Source: USDA, ERS, 1993 Cropping Practices Survey data.

Crop consultants assisted farmers in pest scouting on about 7 percent of corn acres, 3 percent of soybean acres, and 22 percent of fall potato acres. The use of crop consultants in scouting corn pests was most prevalent in Nebraska (30 percent of acres). Crop consultants also advise farmers in making pesticide use decisions, charging a per-acre fee averaging $3-$5 for corn and soybeans, and over $9 for fall potatoes.

Economic Thresholds

Economic thresholds (see Glossary) can be used to determine if a pesticide application is warranted economically. The use of economic thresholds, however, does not necessarily reduce pesticide use. Farmers need to scout their fields and then compare pest counts with economic thresholds to determine whether a pesticide treatment should be made. Economic thresholds were used most frequently to decide pesticide applications in fall potato production.

Crop Rotation

Many corn farmers rotate crops to alleviate rootworm problems, and hence do not scout for insects or use economic thresholds. In the 10 surveyed States, 65 percent of corn acres were planted with a different crop the previous year and only 11 percent of these acres were treated with insecticides. When corn was planted continuously, the percentage of acres treated increased to 45 and 60 percent for 2- and 3-year corn. Clearly, crop rotation is the most effective means for reducing insecticide use on corn. In the surveyed fall potato States, 66 percent of the acres were under crop rotation for insect control.

Farmers who operated half of corn and over half of soybean and fall potato acres employed crop rotation for weed control. Fall potato growers who operated 80 and 61 percent of fall potato acres employed crop rotation to control diseases and nematodes.

Application Timing

Herbicides can be applied before or after weeds emerge (pre- or postemergence). Soil-applied, preemergence herbicides have been the foundation of row crop weed control for the past 30 years. Postemergence herbicides are considered more environmentally sound than preemergence herbicides because they have little or no soil residual activity. Postemergence programs also facilitate the use of scouting and economic thresholds and allow reduced-rate applications for smaller weeds. The

application rates for postemergence-only treatments average one-fourth to one-half lower than preemergence rates for corn, soybeans, and fall potatoes (table 3.2.11). Preemergence-only herbicides were applied to almost twice the acreage (45-55 percent) as postemergence-only herbicides (17-20 percent) on corn and fall potatoes.

Farmers who apply preemergence herbicides generally base their decision on previous weed problems. Field mapping can facilitate spot treatments (see Glossary). Among the acres receiving preemergence-only herbicides, over 15 percent of corn, soybean, and fall potato acres were mapped for their weed problems. These percentages are higher among those acres receiving both pre- and postemergence herbicides.

The use of postemergence herbicides allows farmers to determine herbicide use according to observed weed species and infestation levels (that is scouting and comparing weed counts with economic thresholds). Farmers can apply postemergence herbicides at low rates when weeds are small. This practice was used on more than half of corn and soybean acres and 71 percent of fall potato acres that received postemergence-only herbicides.

Application Method

Herbicides are generally applied as banded or broadcast treatments. Banded rates averaged 1.85, 0.86, and 1.17 pounds per treated acre for corn, soybeans, and fall potatoes, compared with broadcast rates of 3.10, 1.08, and 2.21 pounds. Most herbicides (84-97 percent) were applied as broadcast-only treatments. While banding herbicides saves material costs over broadcast, banding often requires mechanical cultivation to control weeds in the row middles. A recent study suggests that mechanical cultivation for weed control could be more expensive than herbicide control in some locations (Lin and others, 1993).

Herbicide use varies greatly by application timing and method. Postemergence banded herbicide treatments are effective in reducing herbicide use. Banded rates for fungicides applied to fall potatoes were also found to be lower than broadcast rates. However, insecticide use may not be reduced through changes in timing and method. Some insecticides are applied during planting to prevent pests, such as rootworm in corn production or wireworms and nematodes in fall potato production, from feeding on the plant roots. These insecticides are generally applied at higher rates than those insecticides that are broadcast after planting.

Table 3.2.11—Herbicide application timing and method in corn, soybean, and fall potato production, major producing States, 1993[1]

Item	Unit	Corn	Soy-beans	Fall potatoes
Application timing:[2]				
Preemergence only--				
Area treated	%	44.87	30.60	54.60
Rate per acre	lbs	3.11	1.31	2.24
Previous problem	%	90.03	90.78	92.25
Field mapping	%	16.27	18.09	14.81
Postemergence only--				
Area treated	%	20.03	31.84	16.52
Rate per acre	lbs	2.17	0.62	1.09
Weed species present	%	87.51	91.87	79.76
Infestation level	%	72.98	70.02	80.19
Used reduced rate	%	55.88	56.10	71.35
Pre- and postemergence--				
Area treated	%	35.09	37.56	28.88
Rate per acre	lbs	3.14	1.33	2.78
Previous problem	%	89.18	92.02	82.01
Field mapping	%	25.54	29.35	25.17
Weed species present	%	90.10	94.30	90.66
Infestation level	%	75.74	83.53	74.39
Used reduced rate	%	59.89	59.88	80.28
Application method:[2]				
Banding only--[3]				
Area treated	%	10.16	4.48	1.67
Rate per acre	lbs	1.85	0.86	1.17
Broadcast only--[3]				
Area treated	%	84.12	89.15	96.66
Rate per acre	lbs	3.10	1.08	2.21
Banding and broadcast--				
Area treated	%	5.72	6.37	1.67
Rate per acre	lbs	2.48	1.26	3.00
Row cultivation to control weeds:				
Area cultivated[4]	%	52.30	37.88	89.14
Times cultivated	no.	1.23	1.47	1.60
Weed spot treatments[4]	%	2.39	3.01	nr
Rotating pesticides to slow resistance to:[2]				
Herbicides	%	52.34	54.81	61.33
Insecticides	%	50.47	NA	71.94
Fungicides	%	NA	NA	68.96

NA = not available.

nr = none reported.

[1] For States included, see footnote 1, table 3.2.10.

[2] Percentages are of treated acres.

[3] Banding includes infurrow and banded in/over row. Broadcast includes ground and aerial broadcast, chemigation, and directed spray.

[4] Percentages are of planted acres.

Source: USDA, ERS, 1993 Cropping Practices Survey data.

Row Cultivation and Spot Treatment

Many farmers cultivate their fields to control weeds. In 1993, 52, 38, and 89 percent of corn, soybean, and fall potato acres in the surveyed States were cultivated for weed control. On average, these three crops were cultivated slightly more than once per season. Spot treatment is a herbicide-saving practice that can be used before or after weeds emerge. This practice is rarely used, averaging only 2 and 3 percent of corn and soybeans acres and not reported in fall potato production.

Rotating Pesticides

Resistance to pesticides can develop if the same pesticide is used repeatedly on a particular pest. In many cases, farmers can rotate pesticides to control the same pest in order to slow resistance. Pesticides were rotated on over half of corn, soybean, and fall potato acres.

Pesticide Residues and Food Safety

Pesticide residue measurements contribute to our understanding of the safety of the food supply. The U.S. Environmental Protection Agency (EPA), for example, uses residue estimates in its pesticide risk assessments, which contribute to the regulation of pesticides. Also, to reduce risk from pesticides, residue estimates can be used to identify priorities for development of alternative pest control practices. To examine chronic dietary risks from pesticide residues, the average residue and a pesticide residue dietary intake indicator are estimated for each of the 50 pesticides on 10 fresh fruits and vegetables monitored under the 1992 Agricultural Marketing Service Pesticide Data Program (AMS PDP).

In addition, the Food and Drug Administration (FDA) Total Diet Study measures total dietary intake of pesticide residues, but does not have information about the sources of residues. The FDA also measures residues on commodities directly through the Regulatory Monitoring Program, which is focused on enforcing tolerances.

During 1992, the AMS PDP measured residues on samples of fresh fruits and vegetables, including apples, bananas, celery, green beans, grapefruit, grapes, lettuce, oranges, peaches, and potatoes. Samples included both imported and domestic commodities. Commodities were included in PDP based on their level of consumption. These commodities were screened for 14 fungicides, 6 herbicides, and 30 insecticides.

The samples were drawn from terminal markets and wholesale distribution centers in six States: California, Florida, Michigan, New York, Texas, and

Table 3.2.12—Rankings of residue detection frequency, average residues, and average residue as a percent of tolerance by pesticide and crop, 1992

Percent of samples with residues			Average residue[1]			Average residue as a percent of tolerance[2]		
Pesticide	Crop	%	Pesticide	Crop	ppm[3]	Pesticide	Crop	%
Thiabendazole	Oranges	63.8	Chlorpropham	Potatoes	0.835	Benomyl[4]	Bananas	12.0
Chlorpropham	Potatoes	59.3	Iprodione	Peaches	0.424	Thiabendazole	Bananas	8.9
Thiabendazole	Apples	56.5	Dichloran	Peaches	0.390	Imazalil[4]	Bananas	7.4
Iprodione	Peaches	54.4	Thiabendazole	Apples	0.351	Chlorpyrifos	Peaches	5.7
Thiabendazole	Grapefruit	54.0	Diphenylamine	Apples	0.256	Ethoprop[4]	Bananas	4.8
Dicloran	Peaches	46.7	Thiabendazole	Oranges	0.165	Acephate	Green beans	4.4
Permethrin	Celery	38.6	Acephate	Green beans	0.131	Methamidophos	Green beans	4.0
Chlorothalonil	Celery	32.3	Iprodione	Grapes	0.087	Thiabendazole	Apples	3.5
Azinphos-methyl	Apples	31.4	Captan	Grapes	0.082	Diphenylamine	Apples	2.6
Diphenylamine	Apples	30.5	Chlorothalonil	Celery	0.080	Myclobutanil	Grapes	2.3

[1] Residue averages are estimated following EPA guidelines, imputing values for residues too small to detect or measure precisely. These averages differ from the "Mean of Residues Found" reported by AMS, which are averages of the residue measurements for samples with residues above the limit of quantification. The average residue calculated from the whole sample is more appropriate in estimating the average long-term dietary intake of pesticide residues.

[2] Legal tolerances are published in the Code of Federal Regulations, title 40, part 180, July 1992.

[3] Parts per million.

[4] Based on a small number of detections.

Source: USDA, AMS, 1994.

Table 3.2.13—Fraction of negligible risk intake and major sources of intake from 10 fruits and vegetables, 1992

Pesticide	U.S. average	1-year-old	Major contributors to intake of 1-year-olds (percent of residue intake)
	Negligible risk = 1.00		
Nonthreshold pesticides:[1]			
DDE	0.38	1.19	Potatoes (59)
Propargite[2]	0.29	1.10	Peaches (100)
Captan	0.18	1.06	Grapes (47)
Benomyl	0.10	0.65	Apples (70)
DDT	0.20	0.54	Potatoes (56)
Threshold pesticides:[1]			
Methamidophos	0.16	0.59	Green beans (87)
Thiabendazole	0.08	0.38	Apples (72)
Dimethoate	0.06	0.31	Apples (45)
Azinphos-methyl	0.03	0.19	Apples (89)
Ethion	0.03	0.19	Apples (92)

[1] See text, p. 104, for definitions of nonthreshold and threshold.

[2] Based on a limited sample.

Source: USDA, ERS estimates.

Washington. These States were selected because they cover a large portion (about 40 percent) of the Nation's population, thereby ensuring that the data give a good estimate of the prevalence of the 50 pesticides in a portion of the food supply. Testing laboratories treated samples as consumers would: washing, peeling, and coring samples as appropriate before measuring residues. Because the PDP samples a small set of commodities and only a portion of the registered pesticides, PDP does not give an exhaustive view of the extent of dietary exposure to pesticides. However, the selected pesticides in PDP are important to examine, since many are believed to cause human health risks, and some are suspected carcinogens.

When commodities are screened for pesticides, a residue may (1) not be detected, (2) be detected but too small to measure accurately, or (3) be detected and measured. If a residue is measured, it may exceed or be below tolerance. AMS PDP shows higher detection rates than the commodity-specific data from the FDA Regulatory Monitoring Program because AMS uses more sensitive laboratory techniques than the FDA does in its comparable program. The percentage of AMS sample residues that exceed legal tolerances is similar to the level measured by FDA (approximately 1 percent).

Pesticide Residue Detections

The three independent rankings in table 3.2.12 are very different, indicating that some pesticide residues are frequently detected, but at low levels. Also, even the larger average residues may be small relative to the legal tolerance. The differences among the rankings show that detection frequency bears little relation to human health consequences of dietary exposure to pesticides.

Among the 5,750 samples screened, 61.2 percent were found to contain detectable residues. Only five pesticide/commodity combinations showed more than half the samples with positive findings (table 3.2.12). All five were the result of post-harvest pesticide uses. For bananas, grapefruit, and oranges, 98, 90, and 88 percent of the residue detections came from post-harvest pesticide uses. The majority of preharvest pesticides tested in the PDP did not leave detectable residues.

Only 23 pesticide/commodity combinations out of nearly 500 show average residues greater than 1 percent of tolerances. The 10 pesticide/commodity combinations with the highest averages and averages relative to legal tolerances are presented in table 3.2.12. The largest average residue relative to the tolerance is for benomyl on bananas at 12 percent (0.024 parts per million). Only 2 of the 10 most frequently detected

pesticides (thiabendazole on apples and diphenylamine on apples) appear among the 10 highest residues and the 10 highest percentages of tolerance. The other 8 most frequently detected pesticides range from 2.1 to 0.5 percent of tolerance.

Fraction of Negligible Risk Intake: A Residue Indicator

Efficient reduction of risk from pesticide intake requires a ranking of pesticide dietary risks. To create this ranking, average residue estimates are combined with food consumption data (1987-88 Nationwide Food Consumption Survey by USDA's Human Nutrition Information Service) to estimate pesticide intake, and this is compared with commonly used definitions of negligible risk. Consumption of fresh commodities and processed products are aggregated into total consumption of raw product equivalent using the Diet System Software by Technical Assessment Systems, Incorporated.

To assess risks from dietary exposure, pesticide intake estimates are divided by negligible-risk intake levels to provide the Fraction of Negligible Risk Intake (FNRI). The chronic risks examined here are classified as threshold or nonthreshold risks.

Threshold pesticides are those for which very low levels of exposure (up to the threshold quantity) cause no ill effect. Nonthreshold pesticides are those for which there is no positive exposure level that is risk-free. The pesticides classified as nonthreshold are possible or probable carcinogens. Threshold health effects include tissue damage and neurochemical changes. Some possible carcinogens, such as dimethoate, are evaluated by EPA for threshold health effects.

For nonthreshold pesticides, negligible risk is defined as the level of pesticide intake that would lead to a 70-year lifetime risk of 1 cancer case per million. For children, risk is calculated over a 1-year period rather than a 70-year lifetime and negligible risk is defined as a risk of 14 cases per billion. For threshold health effects, the negligible risk level is the Reference Dose determined by EPA. The Reference Dose is generally 100 times lower than the maximum dose that has no health effects on experimental animals. An FNRI greater than 1.0 is above negligible risk and an FNRI equal to or less than 1.0 is considered negligible risk.

Of the 50 pesticides, 8 carry nonthreshold risks and have been evaluated by EPA for their oncogenic potency. The remaining 42 are evaluated for their threshold health risks. Table 3.2.13 gives the FNRI estimates for the top 5 threshold and nonthreshold pesticides. These data show that dietary residue intake is far below the negligible-risk intake level for the average U.S. consumer based on a 70-year lifetime of intake.

The highest FNRI for a nonthreshold pesticide is 0.38 for DDE (a degradation product of DDT), or 38 percent of the negligible-risk intake level. This level demonstrates the persistence in the environment of DDT (and its degradation products), which has not been used since 1972.

The FNRI estimates for propargite must be considered provisional as results were derived from a relatively small sample on a single commodity. In 1993, AMS testing for propargite included seven commodities; more complete information will soon be available.

Among threshold pesticides, the highest FNRI is for methamidophos, at 0.16. Of the remaining threshold pesticides, 9 have intakes between 1 and 8 percent of the negligible-risk intake level, and the remaining 32 have intakes under 1 percent of the negligible risk intake level.

Most consumer subpopulations defined by race, income, region, and age have similar exposure to residues. FNRI estimates are shown for 1-year-olds; this age group has the highest FNRI for many pesticides. One-year-old children (12-24 months old) have intake levels greater than the negligible-risk intake levels for DDE, propargite, and captan. While no other pesticides exceed the negligible-risk intake level for 1-year-olds, 2 other nonthreshold pesticides have an estimated FNRI of greater than 0.50 for 10 fruits and vegetables. The highest FNRI for a threshold pesticide is for methamidophos (0.59).

The FNRI's for children are higher than for adults. Dietary residue intake for young children is much higher than adult intake for some pesticides because children's consumption is more specialized than adult consumption and because children consume more food per pound of body weight.

Examination of FNRI estimates for 1-year-olds reveals that, among 10 commodities, potatoes account for the majority of DDE residue intake. Grapes and apples are the major contributors to captan risk for 1-year-olds. Green beans account for virtually all of the dietary intake of methamidophos from these 10 commodities.

These estimates of pesticide residue intake levels from 10 fruits and vegetables are generally higher than residue intake levels estimated by the FDA Total Diet Study for the whole diet. FNRI estimates are based on the conservative assumption that processed foods carry residues identical to fresh produce. In many cases, residues are reduced during processing. Also, FDA assumes that residues too small to accurately measure are exactly zero. FNRI estimates assign a small positive value for samples with no detected residues or detected residues too small to measure, following EPA practices in risk assessment.

Only a few FNRI estimates exceed 1, and among those, the estimated risks are arguably negligible. However, these estimates apply to only 10 commodities, or 56 percent of fruit and vegetable consumption. FNRI estimates for the total diet would be higher. These estimates are useful for distinguishing among major and minor sources of risk from dietary exposure to pesticides, and for identifying research priorities for reducing pesticide use, such as IPM.

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Pesticide Record Keeping

Section 1491 of the Food, Agriculture, Conservation, and Trade Act (FACTA) of 1990 requires all certified pesticide applicators to keep records of their use of Federal restricted-use pesticides. A certified private applicator is anyone certified by the Environmental Protection Agency or the State to use or supervise the use of a restricted-use pesticide in the production of any agricultural commodity. This requirement became effective May 10, 1993. Private certified applicators are required to provide access to restricted-use pesticide record information to authorized representatives of USDA and the lead State agency for pesticide recordkeeping. In addition, licensed health care professionals may have access to pesticide record information if they determine the information is necessary to provide medical treatment to an individual who may have been exposed to a restricted-use pesticide.

Required information:

Within 30 days after applying a restricted-use pesticide, a private applicator must make a written record of:

(1) the product brand name and its EPA registration number; (2) the total quantity of formulated product used; (3) acres, linear feet, bushels, cubic feet, number of animals, etc. treated; (4) the crop, commodity, stored product, or site to which the pesticide was applied; and (5) the location of the application (legal property description, maps, or written descriptions of application site).

Records must be maintained for 2 years from the date of the pesticide application.