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Pest Management in U.S. Agriculture

Jorge Fernandez-Cornejo
Sharon Jans

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Abstract

The report describes the use of pest management practices, including integrated pest management (IPM), for major field crops and selected fruits and vegetables. The data came chiefly from the 1996 Agricultural Resource Management Study (ARMS) developed by USDA. Because different pest classes may dominate among different crops and regions, requiring different pest management techniques to control them, the extent of adoption of pest management practices varies widely. For example, insects are a major pest class in cotton production, while minor for soybeans. As insect management has a wider variety of nonchemical techniques than weed control, cotton growers are expected to be further ahead on the IPM continuum than soybean producers.

Keywords: Pest management, IPM, pesticides, green technologies, field crops, fruits and vegetables.

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Summary

During the last 40 years U.S. farmers have achieved unparalleled increases in land productivity due, in part, to pesticides. But pesticides have come under scrutiny for their potential hazard to human health and the environment. While USDA, land-grant universities, and the private sector have helped develop Integrated Pest Management (IPM) techniques, many institutions have played an active role in encouraging IPM adoption. They include USDA, other government agencies, land-grant universities, agricultural extension services, private consultants, consumer groups, and environmental organizations.

IPM programs address at least one of the following goals: to improve farmers' profitability, to minimize the risk of pesticide use to human health and the environment, and to reduce pest resistance to pesticides. Because IPM has multiple objectives, opinions vary as to which of these should be emphasized. Moreover, the relative importance among the goals of IPM may be shifting (and will likely to continue to shift depending on local need) from the early emphasis on farm-level profitability to the current emphasis on reduction of pesticide use, a goal more in line with the public's desire to reduce risks associated with pesticide use.

Just as pests are specific to particular crops and locations, IPM programs are specific to the crop and region for which they are designed. Because the development of IPM programs has not been uniform across pest classes (insects, plant pathogens, weeds), crops, and regions, it is difficult to provide a general measure of IPM use. There have been encouraging advances in methodology in recent years, but a complete, practical, and accepted method to measure overall IPM adoption is not yet available. For this reason, this report does not provide results on the overall measure of IPM use. This report includes survey results on the extent of adoption of individual pest management practices or techniques for major field crops and selected fruits and vegetables by crop and region. The report also summarizes the major issues and discusses unresolved questions related to the development of pest management strategies, including Integrated Pest Management, in U.S. agriculture and provides detailed information on primary target pests by State and crop, and pesticide use by crop and active ingredient.

The data for field crops, including corn, soybeans, cotton, potatoes, and wheat were obtained from the 1996 Agricultural Resource Management Study (ARMS) conducted by USDA. Data for selected fruits and vegetables came from USDA's Chemical Use surveys and include apples, grapes, peaches, oranges, tomatoes, and strawberries.

Among the pest management practices, scouting was used extensively by most farmers: 72 to 94 percent of the field crop acreage (depending on the crop) was scouted for weeds and 59 to 98 percent was scouted for insects. Cultural techniques were the leading pest management practices for field crops and crop rotation was the top cultural practice used to control weed and insect pests. Mechanical cultivation for weed control was also a major cultural tool used by growers of row crops.

Weeds are the biggest problem for most field crops and, consequently, more herbicide is used on U.S. farms than insecticide and fungicide. The leading herbicide users are corn

and soybean producers, while the main users of insecticides and fungicides are cotton and potato growers, respectively.

Among growers of fruits and vegetables, scouting for pests ranged from 71 percent of the peach-planted acreage to 98 percent for strawberries, with an overall average of about 80 percent. Pheromones for both control and monitoring were more often used on fruit and vegetable acreages relative to field crops. Pest-resistant varieties were also used at relatively high rates for tomatoes (37 percent), strawberries (37 percent), and peaches (44 percent). A common pest management practice among growers of fruits and vegetables was alternating pesticides to reduce pest resistance. Its use ranged from 36 percent for grape acreage to 75 percent for apples. Growers considered beneficial insects in selecting pesticides on 80 percent of the apple acres.

Cotton and potato producers make more use of IPM practices than do producers of other field crops. Comparison across crops and regions is complex, however, because different pest classes may dominate among different crops and regions, calling for different pest management techniques to control them. For example, insects are a major pest class in cotton production, while minimal for soybeans. Thus, adoption of insect management techniques is more widespread among cotton producers than among soybean producers. Furthermore, since insect management has a wider variety of (nonchemical) control measures than does weed control, cotton growers are likely to have a higher overall measure of IPM adoption than soybean producers. On the other hand, weed control is very important for soybeans and corn. As a consequence, and given the large corn and soybean acreages, future progress in IPM adoption will depend upon weed management efforts.

Pest Management in U.S. Agriculture

Jorge Fernandez-Cornejo and Sharon Jans

Introduction

Pesticides, along with fertilizers and new hybrid seeds, have enabled American farmers to achieve unparalleled increases in land productivity over the last 40 years (Fahnestock). Despite pesticides' positive effects, as evidenced by the willingness of U.S. farmers to spend $8.5 billion on pesticides in 1996 (USDA, 1998a), their potential hazard to human health and the environment is of concern (Cooper and Loomis, Hallberg, Mott, Harper and Zilberman). The discovery of Alar residues on Northwest apples, residues of banned pesticides (EBD and DBCP) in Florida groundwater, and detection of many pesticides in the ground and surface water in several States have heightened this public concern (Huang et al.)

Many of the techniques or practices collectively referred to as Integrated Pest Management (IPM) were designed to address some of the health and environmental concerns of pesticide use and the problem of pest resistance to pesticides. In general terms, IPM has been defined as "a management approach that encourages natural control of pest populations by anticipating pest problems and preventing pests from reaching economically damaging levels. All appropriate techniques are used such as enhancing natural enemies, planting pest-resistant crops, adapting cultural management, and using pesticides judiciously" (USDA, 1993b).

In 1993, the U.S. Department of Agriculture (USDA), the Food and Drug Administration (FDA), and the Environmental Protection Agency (EPA) pledged to work together to reduce pesticide use and associated health and environmental risks, and set the goal of "developing and implementing IPM programs for 75 percent of the total crop acreage" by the year 2000 (Browner et al.). Information is critical to designing policies to help achieve that goal. First, the baseline conditions need to be understood: which pest management practices are being used, on which crops, and in which regions. Then policies can be targeted to the circumstances that most warrant attention. The second critical use for information is to identify the factors that affect the decision to adopt preferred practices or techniques. Some barriers to adoption can be overcome through demonstration, education, or additional research, while others might be reduced with only a financial incentive. Effective policy design is based on both types of information — status reports and adoption analyses.

While USDA, land-grant universities, and the private sector have helped develop IPM techniques, many institutions have played an active role in encouraging IPM adoption. They include USDA, other government agencies, land-grant universities, agricultural extension services, private consultants, consumer groups, and environmental organizations. Since 1993, several activities have been undertaken to assess the use of pest management techniques and to encourage the use of alternative techniques when appropriate. A 1994 report examined the extent of IPM use (Vandeman et al.). Although the report faced difficulties related to the measurement of IPM and data comparability, it presented the first estimates regarding the extent of IPM use based on nationwide survey data. USDA and the private sector initiated an effort to develop a measure of IPM adoption acceptable to the stakeholders (USDA, 1997b). In addition, USDA launched a series of new surveys to improve the data-gathering process. The Agricultural Resource Management Study (ARMS) surveys are designed to link the resources used in agricultural production to technologies (including pest management practices) and farm financial/economic conditions. The ARMS survey data can be used to assess the use of pest management practices and to link that use with yields, other management techniques, and chemical use for selected field crops. Similar surveys are conducted for selected fruits and vegetables in alternate years. The strength of these survey data is that they allow the determination of the important factors influencing the adoption of particular practices. Although they were not designed to characterize U.S. production as a whole, these surveys do provide information on the extent of adoption of pest management for most major crops.[1] The first ARMS survey was conducted between June 1996 and April 1997.

This report's main objective is to present recent survey results on the extent of adoption of pest management practices by growers of major field crops (based on the 1996 ARMS) and selected fruits and vegetables. Other reports will follow as the results of more recent ARMS surveys become available and as some of the definitional issues become more settled. In addition, the results of the empirical analysis of the factors influencing the adoption of pest management practices will be published separately.

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[1]USDA's National Agricultural Statistics Service (NASS) Fall Area Survey also gives aggregate information for particular pest management practices on selected crops (USDA, 1998b).

Pests and Pest Management

In general, the term "pest" can be simply defined as any organism detrimental to humans (Glass, p. 43). From the agricultural viewpoint, pests "are organisms that diminish the value of resources in which man is interested" (NRC, 1975, p. 27) as they "interfere with the production and utilization of crops and livestock" used for food and fiber. The term "pest" applies to all noxious and damaging organisms, including insects, mites, nematodes, plant pathogens, weeds, and vertebrates (OTA, 1979, Vol. I, p. 14).

From an economic viewpoint, an agricultural pest is an "animal or plant whose population density exceeds some unacceptable threshold level, resulting in economic damage" (Horn, 1988). There are approximately 600 species of insects and 1800 species of weeds considered pests in agriculture (USDA, 1997c, p. 181), but only a few of those are considered significant to U.S. agriculture. According to the ARMS 1996 survey, weeds are by far the most important pests in U.S. agriculture in terms of the share of pesticide treatments used to control them. For corn, 83 percent of all pesticide acre-treatments (number of acres treated times the number of pesticide treatments) were aimed at controlling weeds; for soybeans, it was nearly 100 percent, and for wheat around 90 percent (table 1). Only for potatoes and cotton, among major crops, do other pest classes surpass weeds in control efforts. Pathogens account for 56 percent of all potato pesticide acre-treatments, while insects account for 45 percent of all cotton pesticide acre-treatments. More detailed survey results on primary target pests by State and crop are shown in Appendix I.

Pest management involves a set of techniques to reduce pest populations or prevent their detrimental effect (Glass, p. 43). Technically, the term "pest management" has had various interpretations by researchers, but the underlying philosophy is that "pests should be managed, not eradicated" (Cate and Hinkle) and that pests are inevitable components of an agricultural system (Zalom et al., 1992). Pest management techniques can be broadly classified into chemical, cultural, and biological.

Chemical controls usually involve the immediate and temporary decimation of localized pest populations using chemical pesticides. The term "chemical pesticide" includes a large number of different products used to repel, debilitate, or kill pests. Thousands of formulations (commercial forms in which the pesticide is sold) are used, with different mixtures of active ingredients and inert materials. Hundreds of chemical products are used as active ingredients, and each has a different spectrum of pest control, a different potency, and a different impact on human health and the environment (Fernandez-Cornejo and Jans, 1995). From 1991-96 several of the major active ingredients experienced large changes in usage, and the most heavily used active ingredients were in the herbicide class (table 2). Appendix III provides detailed information on chemical pesticides used for major field crops by State and active ingredient.

Most pesticides in U.S. agriculture are applied on very few crops and, consequently, any effort in overall pesticide reduction is likely to focus on these crops. In 1995, four crops — corn, soybeans, cotton, and wheat — accounted for more than 85 percent of the herbicides used, and two crops (corn and cotton) accounted for nearly 65 percent of the insecticides used (table 3).[2] Potatoes and other vegetables used 75 percent of the fungicides and other pesticides.

[2]Per acre pesticide expenditures vary widely, increasing with the value of the crop. For example, wheat farmers annually spent less than $6 per acre on pesticides in 1991 while corn or soybean growers spent about $22 per acre, cotton farmers spent $48 per acre, and peanut growers spent $88 per acre. Per acre pesticide expenditures by producers of high-value commodities such as fruits and vegetables were much higher—more than $800 per acre for tomatoes and approaching $1,600 per acre for strawberries (Fernandez-Cornejo, Jans, and Smith).

Table 1— Pesticide treatments distributed by primary target pests, field crops, 1996

Weeds are the biggest pest in terms of share of pesticide treatments for most field crops

Item	Corn	Soybeans	Cotton	Fall potatoes	Winter wheat	Spring wheat	Durum wheat
				Percent of acre-treatments			
Insects and other arthropods	16	0	45	20	12	2	1
Aphids	*	0	2	4	7	1	0
Beetles, weevils or wireworms							
Corn rootworm - adult	3	0	0	0	0	0	0
Corn rootworm - larvae	7	0	*	0	0	0	0
Other[1]	1	**	20	14	**	0	0
Cutworms or armyworms	2	*	2	0	2	0	0
Moths or caterpillars:							
Pink bollworm	**	0	4	0	0	0	0
Tobacco budworm	0	**	3	0	0	0	0
Other[2]	3	**	4	1	0	0	0
True bugs[3]	*	*	4	1	2	0	0
Whitefly, mealybugs or leaf hoppers	0	0	1	**	0	0	0
Grasshoppers or crickets	**	**	**	0	*	0	**
Mites	*	0	2	*	1	0	0
Flies or maggots	0	0	**	0	0	1	1
Thrips	**	0	3	**	**	0	0
Pathogens[4]	0	0	2	56	1	2	1
Nematodes	0	0	1	2	0	0	0
Fungus diseases	0	**	1	49	1	2	1
Virus diseases	0	0	**	5	*	0	0
Weeds	83	100	38	16	87	97	99
Annual grasses:							
Foxtail	21	19	*	*	1	7	5
Other annual grasses	17	22	7	1	7	14	15
Perennial grasses:							
Shattercane	1	1	**	0	1	0	0
Johnsongrass	2	4	4	0	1	0	0
Quack grass	1	1	**	*	**	1	*
Other perennial grasses	4	6	4	1	2	8	1
Perennial broadleafs	9	8	4	3	20	13	21
Annual broadleafs	28	40	19	11	55	54	57
Others[5]	*	**	18	10	*	0	0

[1] Includes other beetles, weevils, or wireworms.

[2] Includes other moths or caterpillars such as loopers, leafminer, leaf perforator, leafworm, corn borer, webworm, and leafrollers.

[3] True bugs include fleahoppers, lygus bugs, stink bugs, chinch bugs, and tarnish plant bugs.

[4] Survey excludes treated seed and seed treatments for seedling diseases.

[5] Treatments of desiccants, defoilants, and growth regulators.

* Less than 0.5 percent. ** Less than 0.1 percent.

Source: National Agricultural Statistics Service and Economic Research Service, 1996 Agricultural Resource Management Study.

Table 2—Major pesticides used, by active ingredient, field crops, 1991-96[1]

Because weeds are the biggest pest, herbicides are used in the largest amounts

Name	Class	Family	Pesticide use	
			1991	1996
			Million pounds	
Atrazine	Herbicide	Triazine	44.4	53.6
Metolachlor	Herbicide	Acetamide	42.5	46.1
Cyanazine	Herbicide	Triazine	24.1	22.9
Acetochlor	Herbicide	Acetamide	0.0	29.9
Trifuralin	Herbicide	Dinitroaniline	18.4	16.3
Pendimethalin	Herbicide	Dinitroaniline	10.6	18.6
2,4-D	Herbicide	Phenoxy	6.8	13.9
Alachlor	Herbicide	Acetamide	46.0	15.2
Glyphosate	Herbicide	Phosphinic acid	3.0	12.9
Chlorpyriphos	Insecticide	Organophosphate	7.1	6.5
EPTC	Herbicide	Carbamate	15.2	6.3
Dicamba	Herbicide	Benzoic	3.8	6.3
Terbufos	Insecticide	Organophosphate	5.3	4.5
Methyl-parathion	Insecticide	Organophosphate	2.4	4.1

[1] Major field crops included in 1991: corn (10 States), soybeans (8 States), cotton (6 States), winter wheat (11 States), spring and durum wheat (4 States), and fall potatoes (11 States) (USDA, 1997c, p. 120, 122). Included in 1996: corn (16 States), soybeans (12 States), cotton (7 States), winter wheat (10 States), spring and durum wheat (4 States), and fall potatoes (5 States) (1997c, p. 120) (USDA, 1997d, p. 1). These States represent about 80 percent of these crops' acreage.
Source: USDA, 1997c, p. 120, 122; USDA, 1997d.

Table 3—Pesticide use for major U.S. crops, 1995 (million pounds of active ingredient)

The largest amounts of herbicides are used for corn and soybean production, while more insecticides and fungicides are used for cotton and potatoes respectively

Crop	Herbicides		Insecticides		Fungicides and other	
	Million lbs.	*Percent*	*Million lbs.*	*Percent*	*Million lbs.*	*Percent*
Field crops						
Corn	186.3	51.9	15.0	20.6	0.0	0.0
Cotton	32.9	9.2	30.0	41.2	20.7	11.3
Soybeans	68.1	19.0	0.5	0.7	0.0	0.0
Wheat	20.1	5.6	0.9	1.2	0.5	0.3
Potatoes	2.9	0.8	3.1	4.3	80.9	44.5
Other field crops[1]	34.9	9.7	3.3	4.5	9.6	5.3
Other crops						
Vegetables (excluding potatoes)	6.1	1.1	5.6	7.7	55.1	30.3
Fruits	7.4	1.5	14.5	19.9	15.0	8.3
Total	358.7	100.0*	72.9	100.0*	181.8	100.0*

*Percentages may not add up to 100 due to rounding.
[1] Sorghum, peanuts, and rice.
Source: USDA, 1997c, p. 119.

Several techniques have been developed to improve the efficiency of chemical pesticides. ***Scouting*** involves monitoring pest populations by regular and systematic sampling of the fields to determine the presence and severity of pest infestation levels, and to determine when an economic threshold (see below) is reached (Vandeman et al.). Scouting may also involve monitoring beneficial organisms, which help control pests without harming the crops. The scout may use several techniques, including visual rating of pest severity and the use of traps or collecting devices to concentrate pest samples (VCES, p. 19).[3]

An ***economic threshold*** refers to the pest population density below which pests are tolerated. When the threshold is reached or exceeded "control measures should be taken to prevent an increasing population from reaching the economic injury level," (EIL) defined as the lowest pest population density that will cause net economic losses (Stern et al.) The EIL is the pest population density at which the cost of incremental damage just equals the cost of controlling that damage (Headley, 1972a). Economic thresholds are difficult to determine and are not constant because they depend on individual farmer's pest problems, stage of crop growth, and economic expectations (NCR, 1989, pp. 176-77).[4] Moreover, economic thresholds have not been used as extensively for managing pathogens as they have for insects due to the lack of monitoring techniques.[5] Information on threshold levels for weeds is far from complete, but there is an increasing level of research being carried out on major weeds species or complexes of two or more species (El-Zik and Frisbie, p. 37).

Farmers can also use a number of ***cultural practices*** to make the environment less favorable to pests. The most common of these include crop rotation, tillage, plant density, timing of harvest, and water management (USDA, 1997c). Other techniques considered in this category include the use of trap crops, field sanitation to destroy or utilize crop refuse, mulching, and the use of pest-free seeds and seeding methods (USDA, 1997c).

Biological methods include controls such as predators (e.g., wasps, lacewings, lady beetles), parasites, pathogens (including bacteria, fungi, and virus), competitors, and antagonistic microorganisms (Hokkanen, p. 185), all of which are believed to pose little health and environmental effects (NRC, 1995). Other biological techniques involve the use of biological pesticides, or biopesticides, including bacteria, viruses, and fungi. Among biopesticides, the most successful so far is the soil bacterium *Bacillus thuringiensis* (Bt).[6]

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[3]Monitoring methods also include soil testing for pests (nematodes, for example), the use of pheromone odors and visual stimuli to attract target pests to traps, and the recording of environmental data (e.g., temperature and rainfall) associated with the development of some pests.

[4]For these reasons, the majority of the economic thresholds found in extension publications, as well as in verbal recommendations, are not based on calculated economic injury levels but rather are based on the practitioner's experience and are often called subjective or nominal thresholds (Pedigo).

[5]However, empirical thresholds based on observations and experience have been used successfully in many disease-managing programs (El-Zik and Frisbie, p. 37). In addition, computer models and other forecast methods based on weather conditions and other environmental factors are used to predict whether or not disease is likely to occur in an important manner.

[6]Another important technique sometimes considered among biological techniques includes the use of pest-resistant plant varieties and rootstock. Host plant resistance to pests enables the plant to avoid, tolerate, or recover from the effects of pests that would cause a greater damage to other genotypes of the same species under similar conditions (El-Zik and Frisbie, p. 46).

Integrated Pest Management

What the term "integrated" adds to the concept of pest management has been articulated by Zalom et al.: "all appropriate methods from multiple scientific disciplines are combined into a systematic approach for optimizing pest control." There are a large number of conceptual definitions of IPM (Bawjda and Kogan developed a compendium with nearly 70 definitions). Most definitions include using natural or ecologically sound principles or techniques, preventing pests from reaching the economically damaging levels, and using multiple tactics, including cultural, biological, and chemical.

The Objectives of IPM

While there is general agreement about the multiple objectives of IPM, how people rank these objectives varies with their background, interests, and local needs. Thus, growers, researchers, input producers, environmental activists, and the public may have different legitimate viewpoints on the relative importance of a particular objective. For example, a large sample of U.S. farmers ranked the most important IPM goals as follows: first, improved pest control; second, increased crop yield and quality; third, increased returns; fourth, protection of personal and public health; and fifth, reduced environmental damage (VCES, p. 77). Extension personnel working in the implementation of IPM programs ranked IPM goals as follows: first, reduced costs; second, reduced risk of output loss; third, reduced chemical use; fourth, improved environment; and fifth, improved onfarm health and safety (VCES, p. 51).

Recent focus group sessions among agricultural suppliers (including basic agrichemical manufacturers and retail input supply businesses) and independent crop and pest management consultants in Pennsylvania (Rajotte et al., p. 32) ranked the selling points for their IPM services as follows:

- For agricultural suppliers, the most important goal was profitability, followed by increased options based on increased information, reliability and company reputation, and environmental safety.

- For consultants, the most important selling points were increased options and benefits followed by profitability, reduced chemical use, and reliability.

Moreover, the relative importance among the goals of IPM may be shifting (and will likely continue to shift depending on local need) from the early emphasis on farm-level profitability to the current emphasis on reduction of pesticide use, a goal more in line with the public's desire to reduce risks associated with pesticide use. The public, Steffey observed, currently is focusing on the use of pesticides. Thus, Staffey believes, the success or failure of IPM programs will usually be measured by "a change in the amount of pesticide use."

While there are differences about IPM goals among the different economic agents, most IPM programs address at least one of the following goals: (i) to improve farmers' profitability, (ii) to minimize the risk of pesticide use to human health and the environment, and (iii) to minimize pest resistance to pesticides.

Measuring IPM Adoption

Just as pests are specific to particular crops and locations, IPM programs are specific to the crop and region for which they are designed. Because the development of IPM programs has not been uniform across pest classes (insects, plant pathogens, weeds), crops, and regions, it is difficult to provide a general measure of IPM use.

A measure of IPM use needs to be related to objectives established by the groups involved in the program. The measure also should allow analysts, with a reasonable amount of survey data, to ascertain the progress in farmers' adoption of IPM. Also, while the measure is defined locally, its aggregation to State and national levels should be tractable.

Finally, because IPM components may vary with the crop, region, time, and other factors, a measure of IPM use should be dynamic and flexible.

Most earlier studies of IPM used scouting as the basis for their operational definition of IPM (Burrows; McNamara et al.; VCES, pp. 55-56). The 1987 National Evaluation of Extension IPM programs used an economically derived decision rule in its operational definition of IPM, and considered three levels of adoption: nonadoption, low adoption, and high adoption (Napit et al.). Similarly, the National Research Council (NRC) reported the extent of IPM adoption in major crops by defining IPM to "include all acres where basic scouting and economic thresholds are reportedly used" (NRC, 1989, p. 178). The use of scouting and economic thresholds, or other equivalent intervention criteria, are considered basic elements of IPM and should, therefore, be included in any measure of IPM use. As Pedigo observed: "without question, pest population assessment and decision making are among the most basic elements of any integrated pest management (IPM) program. In fact, these activities characterize state of the art approaches in pest technology and differentiate IPM from other strategies."

Most economic studies did not specify the type(s) of pest(s) (insects, diseases, weeds) managed or controlled. While there is merit in using a general definition of IPM, additional understanding, particularly regarding the effects of IPM, is obtained by further classifying IPM into three groups: insect IPM, disease IPM, and weed IPM. USDA's report on the extent of IPM adoption provides separate measures of IPM for insects, diseases, and weeds. In addition, three levels of IPM adoption are defined: low-level IPM—if the farmer used both scouting for pests and economic thresholds in making pesticide treatment decisions; medium level—one or two additional IPM practices are used; and high level—three or more additional practices are used (Vandeman et al.). Fernandez-Cornejo (1996, 1998) and Fernandez-Cornejo and Jans (1996), in their studies of the impact of IPM, defined IPM to manage insects (diseases) as follows: a farmer is said to have adopted IPM to manage insects (diseases) if the farmer reports having used both scouting for insects (diseases) and economic thresholds in making insecticide (fungicide) treatment decisions; and the farmer reports having used one or more additional insect (disease) management practices among those commonly considered to be IPM techniques.

The World Wildlife Fund (with the help of a consultant) developed a complex method for measuring IPM adoption based on the ratio of preventive practice points to dose-adjusted acre-treatments. The preventive practices variable is the sum of "ecologically based practices that either reduce pest pressure, increase the number and role of beneficial organisms, or enhance a crop's ability to overcome a degree of pest pressure" (Hoppin; Benbrook and Groth).

Hollingsworth et al. (1992) developed a point system for Massachusetts in which each IPM practice is given a maximum number of points or weight.[7] This method, originally developed for apples, was later extended to eight other fruits and vegetables (Hollingsworth et al., 1995). In this system, higher weights are assigned to "practices considered essential to IPM." Growers gain points for each practice, up to the maximum, based on its level of completion. Growers who reach 70 percent of the total possible points are considered IPM practitioners. While the method improves upon previous subjective definitions of IPM, it is still subjective since the weights (maximum number of points assigned to each practice) are determined by expert judgment.

As Benbrook and Groth suggest, the point systems are a major improvement over "just count practices" systems, but they fail to take into account the levels of pest pressure and fail to "capture whether using IPM practices leads to significantly less pesticides than not using the practices."

In 1997, the National Potato Council (NPC) created a national protocol for potato IPM based on the results of advice from a team of industry representa-

[7]Earlier, Boutwell and Smith developed a weighting system to measure IPM adoption for cotton.

tives and researchers funded by an NPC-EPA Pesticide Environmental Stewardship Grant (National Potato Research and Education Foundation). The protocol involves a point system; but unlike Hollingsworth's system, the NPC system breaks up the IPM continuum into three levels. In addition, the NPC system has a correction for pest pressure.

Fernandez-Cornejo and Jans (1998) provided a method to develop a point system similar to that of Hollingsworth et al., except that the weights are calculated econometrically from the data, based on the contribution of each practice to IPM objectives. They illustrate the method by assuming that the main IPM objective is to reduce the use of chemical herbicides while maximizing farm profits. The model used to obtain the weights considers the simultaneous adoption of pest management practices and pesticide use decisions, corrects for self-selectivity (farmers are not assigned randomly to the two groups), and is consistent with farmers' optimization. The model can also control for pest pressure by incorporating proxies for infestation levels.

Coble proposed an approach that classifies pest management practices into four groups: prevention, avoidance, monitoring, and suppression of pest populations (PAMS). Coble proposed using a diversity index as an indicator of IPM resilience based on a concept that arose in the IPM Measurement Systems Workshop (held in Chicago on June 12-13, 1998, co-sponsored by the American Farmland Trust, EPA, and the World Wildlife Fund). An empirical measure for each PAMS component and the procedure to weight or combine them into an overall index are still to be developed.

There have been encouraging advances in methodology in recent years, but a complete, practical, and accepted method to measure overall IPM adoption is not yet available.[8] For this reason, this report does not provide results on the overall measure of IPM. This report includes survey results on the extent individual pest management practices or techniques have been used for major field crops and selected fruits and vegetables.

[8]Despite the measurement difficulties discussed here, as well as data comparability problems, some broad results have been obtained from IPM research regarding the factors of adoption and the impact of adoption on pesticide use, yields, and farm profits (Burrows; Fernandez-Cornejo, 1996, 1998; Greene and Cuperus; Hall; Harper et al.; McNamara et al.; Norton and Mullen; Mullen et al.; Wetzstein et al.; VCES). A summary and synthesis of this research will be presented in a later publication.

The Extent of Adoption of Pest Management Techniques or Practices

This section presents recent results regarding the extent of adoption of pest management techniques by growers of field crops and selected fruits and vegetables.

The Data

Most of ERS empirical research on pest management is based on a series of surveys carried out by the National Agricultural Statistics Service (NASS) of the USDA.[9] Data for field crops are obtained from the 1996 ARMS (Agricultural Resource Management Study) consolidated survey. This survey combines the former Cropping Practices Survey (CPS) and the Farm Costs and Returns Survey (FCRS) to link information on resource use to production technologies and financial data, and to improve data collection efficiency. The data collected include production practices, chemical input use, resource use, and costs of production, as well as production and resource data for corn, soybeans, cotton, potatoes, and wheat.[10] Corn was selected as the 1996 target crop, so additional production practices and financial data were collected for corn. Corn growers were surveyed in 16 States, soybean growers in 12 States, cotton producers in 8 States, fall potato growers in 3 States and the Red River Valley, winter wheat farmers in 11 States, spring wheat in 3 States, and durum wheat in only 1 State (USDA, 1997d). (Table 4 provides details of participating States.)

Data for fruits and vegetables were collected beginning in 1990 under the Pesticide Data Program (PDP) and the Water Quality Program, which were initiated as a response to public concern over health and environmental effects associated with chemicals used in agriculture (Vandeman et al.). Data used to report the extent of adoption of pest management practices for selected fruits and vegetables were collected in the 1993 Fruit Chemical Use Survey and its Economic Follow-On (apples, grapes, and oranges), the 1994 Vegetable Chemical Use Survey and its Economic Follow-On (tomatoes and strawberries), and the 1995 Fruit Chemical Use Survey and its Economic Follow-On (peaches) (USDA, 1994b, 1995b, 1996) (table 5).

The Extent of Adoption for Field Crop Producers

Tables 6-13 include the survey responses of field crop producers to questions regarding the adoption practices that aim at controlling one or more pest classes. They also include responses to questions about adoption practices that, while not considered pest management practices per se, are known to affect pest development and, consequently, pesticide use, such as the use of no tillage. The same information is distributed by crop and region and presented in Appendix II.

Given the detailed and technical nature of many of the questions asked in the pest management section of the ARMS survey, one should use care when comparing the results presented in this report with those of other surveys, as the answers may vary with the precise content of the question. To make clear the exact terms used in the survey, we present the questions included in the pest management section of the corn survey (Appendix IV). Soybeans, cotton, potato, and wheat growers answered a similar but somewhat smaller set of questions.

Scouting

The 1996 ARMS survey asked about scouting for three different classes of pest: weeds, insects, and diseases. Scouting for weeds ranged from 72 per-

[9]These surveys were based on probability samples drawn from NASS sampling frames. Stratified random sampling techniques were used. The surveys were carried out through on-site interviews conducted by trained and experienced enumerators.

[10]The 1996 ARMS survey was carried out between June 1996 and April 1997.

Table 4—Survey coverage for major field crops, ARMS 1996

Survey for field crops covered nearly 182 million acres in 32 States

State	Corn	Soybeans	Cotton	Fall potatoes	Winter wheat[1]	Spring wheat	Durum wheat
				Planted acreage, 1,000 acres			
Arizona	--	--	315	--	--	--	--
Arkansas	--	3550	1000	--	--	--	--
California	--	--	1000	--	--	--	--
Colorado	--	--	--	--	2200	--	--
Delaware	--	--	--	--	78	--	--
Georgia	--	--	1350	--	--	--	--
Idaho	--	--	--	410	860	--	--
Illinois	11000	9900	--	--	--	--	--
Indiana	5600	5400	--	--	--	--	--
Iowa	12700	9500	--	--	--	--	--
Kansas	2500	--	--	--	8800	--	--
Kentucky	1300	--	--	--	--	--	--
Louisiana	--	1100	890	--	--	--	--
Maine	--	--	--	78	--	--	--
Michigan	2650	--	--	--	--	--	--
Minnesota	7500	5950	--	--	--	2550	--
Mississippi	--	1800	1120	--	--	--	--
Missouri	2750	4100	--	--	--	--	--
Montana	--	--	--	--	1980	4200	--
Nebraska	8500	3050	--	--	2100	--	--
North Carolina	1000	--	--	--	--	--	--
North Dakota	--	--	--	--	--	9600	3000
Ohio	2900	4500	--	--	--	--	--
Oklahoma	--	--	--	--	4900	--	--
Oregon	--	--	--	--	850	--	--
Pennsylvania	1450	--	--	--	--	--	--
Red River Valley[2]	--	--	--	146	--	--	--
South Carolina	400	--	--	--	--	--	--
South Dakota	4000	--	--	--	1580	--	--
Tennessee	--	1200	540	--	--	--	--
Texas	2100	--	5700	--	2900	--	--
Washington	--	--	--	163	2350	--	--
Wisconsin	3900	920	--	--	--	--	--
Total	70250	50970	11915	797	28598	16350	3000
U.S. planted acreage included, percent	88	79	81	63	72	82	83

[1] Harvested acreage.

[2] Red River Valley includes the counties of Clay, Clearwater, Kittson, Mahnomen, Marshall, Norman, Pennington, Polk, Red Lake, Roseau and Wilkin in Minnesota; and Cass, Grand Forks, Pembina, Richland, Steele, Traill, and Walsh in North Dakota.

-- = States not surveyed for the given crop.

Source: USDA, 1997d.

cent of the acreage for cotton to 94 percent of the acreage for fall potatoes (figure 1, table 6). Corn and soybean farmers reported scouting for weeds on 78 and 79 percent of their acreage respectively.[11] Calculating a weighted average of all major field crops, scouting for weeds reached 80 percent in 1996. The major source of scouting for weeds was the farm operator or family member on about 45 percent or more of the planted acres. However, 19 percent of the cotton acres were scouted for weeds by a crop consultant or commercial scout.

Scouting for insects ranged from 59 percent of soybean acreage to 98 percent of fall potatoes, with 66 and 88 percent of the corn and cotton acreage also scouted (figure 1, table 6). On average, scouting for insects reached 67 percent among all field crops in 1996. The primary source of scouting for insects was the farm operator or family member for all field crops except cotton, for which 51 percent of the planted acres were scouted by crop consultants or commercial scouts. Diseases were scouted on more than half of the planted acres for field crops. While the figures for scouting for insects and diseases appear to be low for some of the field crops, notably corn and soybeans, insect pests and disease are not problems for certain crops in many of the States (Appendix II). This situation is reflected in the low percentage of corn and soybean acreage treated with insecticides and the low fungicide use on corn, soybeans, and cotton (Appendix III).

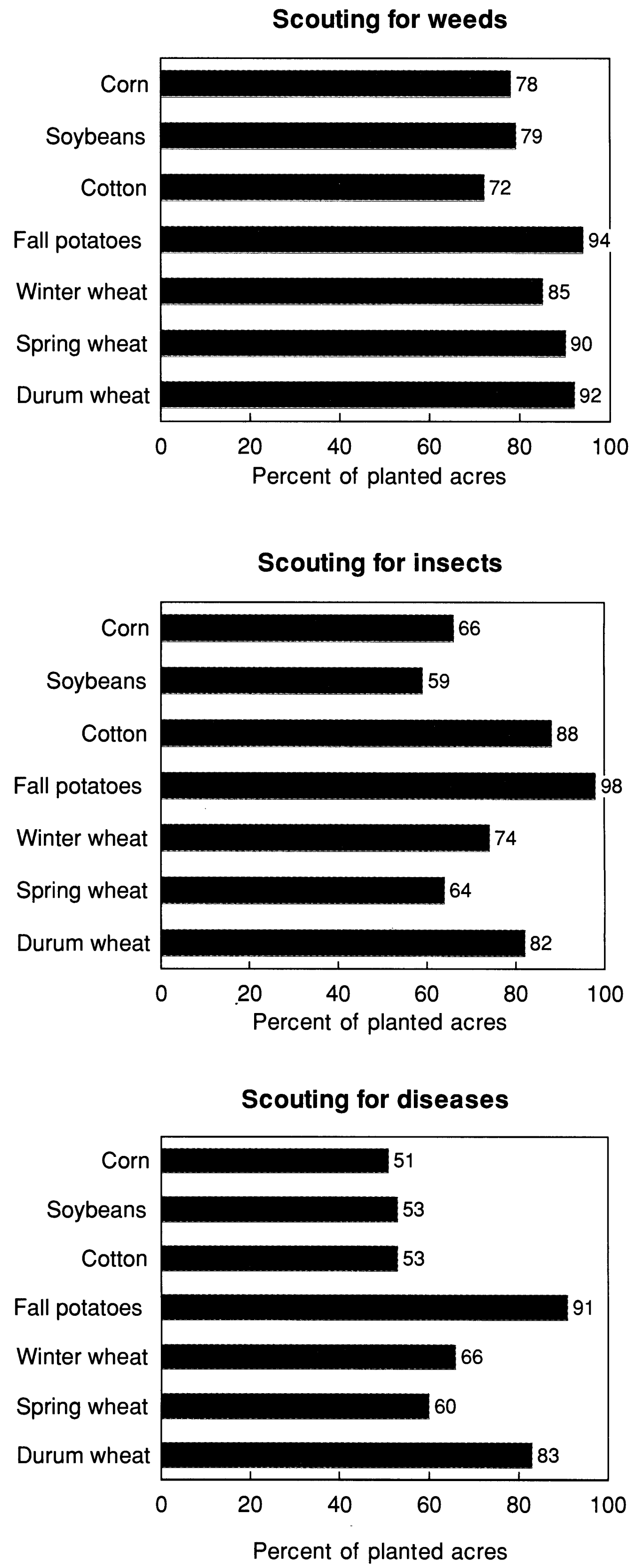
The ARMS survey also incorporated scouting by pest class with pest recordkeeping, either written or electronic. This pairing of practices represents a higher level of monitoring activity than just scouting. Across all crops, a lower percentage of farmers scouted and kept records on weeds compared with those who just scouted for weeds (table 6). The

(Text continues on p. 17)

Figure 1

Scouting field crops for pests, ARMS 1996

More than 50 percent of field crops are scouted for pests



[11] The proportion of farmers using scouting reported here differs from that reported for the Fall Area Survey (USDA, 1998b). Scouting results were lower in the Fall Area Survey apparently because this survey used different wording in the scouting question, adding the phrase "using a systematic method" (USDA, 1998b, p. 30).

Table 5—Survey coverage for selected fruits and vegetables

Survey covered more than 70 percent of the acreage for the selected fruits and vegetables

State	Apples	Grapes	Peaches	Oranges	Tomatoes[1]	Strawberries
			Planted acreage			
California	33300	651300	72600	181700	36500	23300
Florida	--	--	--	489200	47900	5800
Georgia	--	--	21000	--	4000	--
Michigan	54500	11200	5500	--	2800	2100
New Jersey	--	--	10800	--	4800	500
New York	52500	32500	1600	--	2700	2600
North Carolina	10900	--	--	--	1700	2500
Oregon	8300	4600	--	--	--	6300
Pennsylvania	2200	11000	6800	--	--	--
South Carolina	--	--	23000	--	--	--
Texas	--	--	--	--	3500	--
Washington	147000	32700	2500	--	--	1400
Wisconsin	--	--	--	--	--	1300
Total	328500	743300	143800	670900	103900	46800
U.S. acreage included, percent	71	98	83	98	76	95

-- = States not surveyed for the given crop.

[1] Fresh market tomatoes.

Source: Apples, grapes, and oranges: 1993 Fruit Chemical Use Survey (USDA, 1994b); tomatoes and strawberries: 1994 Vegetable Chemical Use Survey (USDA, 1995b); peaches: 1995 Fruit Chemical Use Survey (USDA, 1996).

Table 6—Scouting and source of scouting, field crops 1996

While the activity of scouting for weeds is important for all field crops, scouting for insects is more important for cotton and fall potatoes

Item	Corn	Soybeans	Cotton	Fall potatoes	Winter wheat	Spring wheat	Durum wheat
				Percent of planted acres			
Scouting for weeds	78	79	72	94	85	90	92
Source of scouting:							
Operator, partner, family member	59	68	46	59	73	77	91
Employee	2	1	3	7	*	*	0
Chemical dealer	8	6	4	17	6	9	0
Consultant or commercial scout	8	3	19	12	5	4	1
Scouting for insects	66	59	88	98	74	64	82
Source of scouting:							
Operator/family member	49	51	24	56	62	56	81
Employee	2	1	3	7	*	*	0
Chemical dealer	7	3	10	19	5	3	0
Consultant or commercial scout	8	3	51	15	6	4	1
Scouting for diseases	51	53	53	91	66	60	83
Scouted and kept written/electronic records to track the activity of:							
Broadleaf weeds	19	19	28	26	17	23	9
Grass weeds	19	19	28	26	15	17	5
Insects	‡	13	52	31	14	9	5

‡ See table 9 for corn insect pest management practices.

* Less than 0.5 percent. Source: NASS/ERS 1996 ARMS survey.

Figure 2

Herbicide application timing for field crops, ARMS 1996

Use of both pre- and postemergence herbicides is the most popular herbicide application timing for corn, soybeans, cotton, and fall potatoes

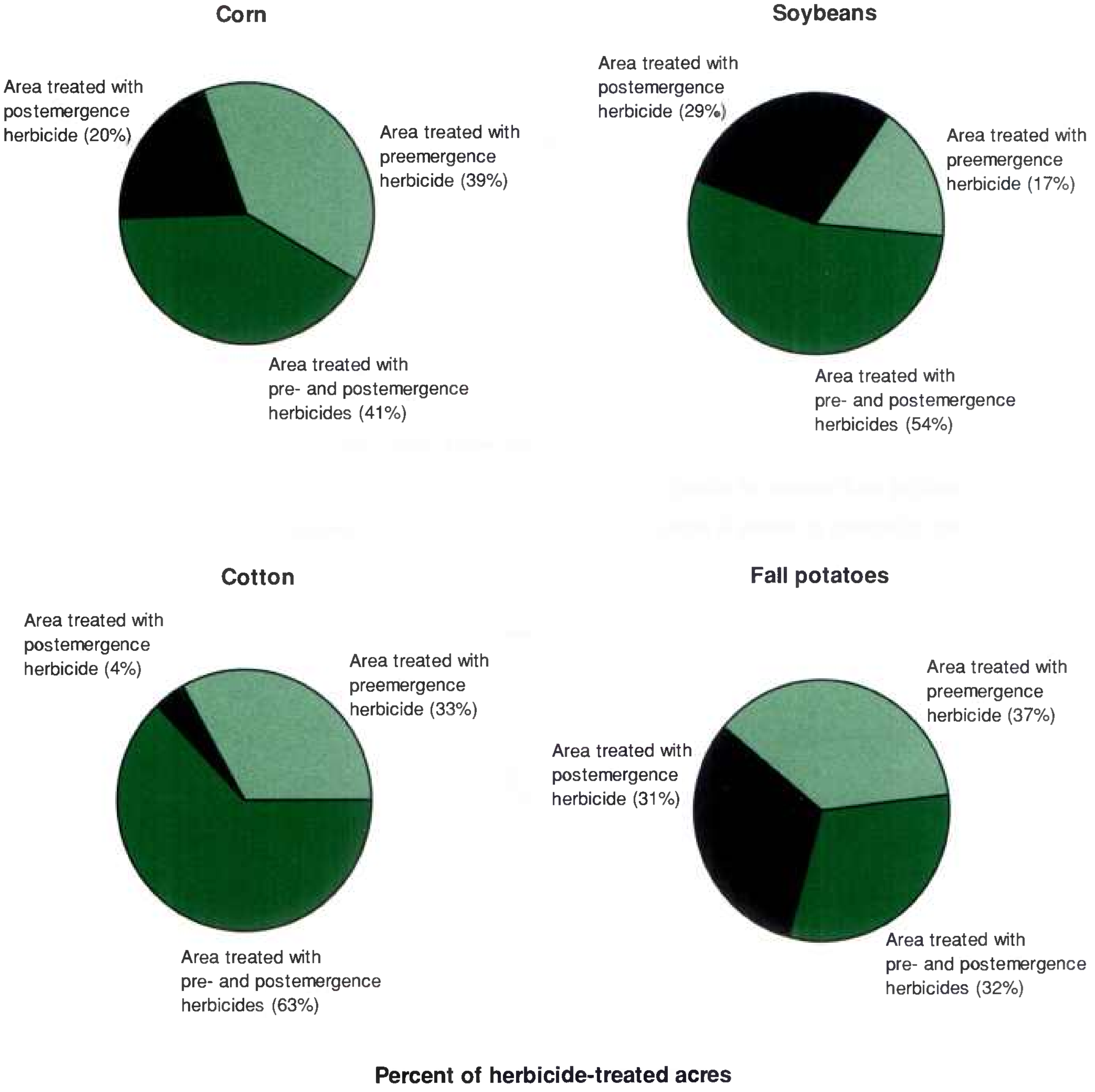


Figure 2

Herbicide application timing for field crops, ARMS 1996--Continued

Postemergence herbicide application is the most popular for wheat

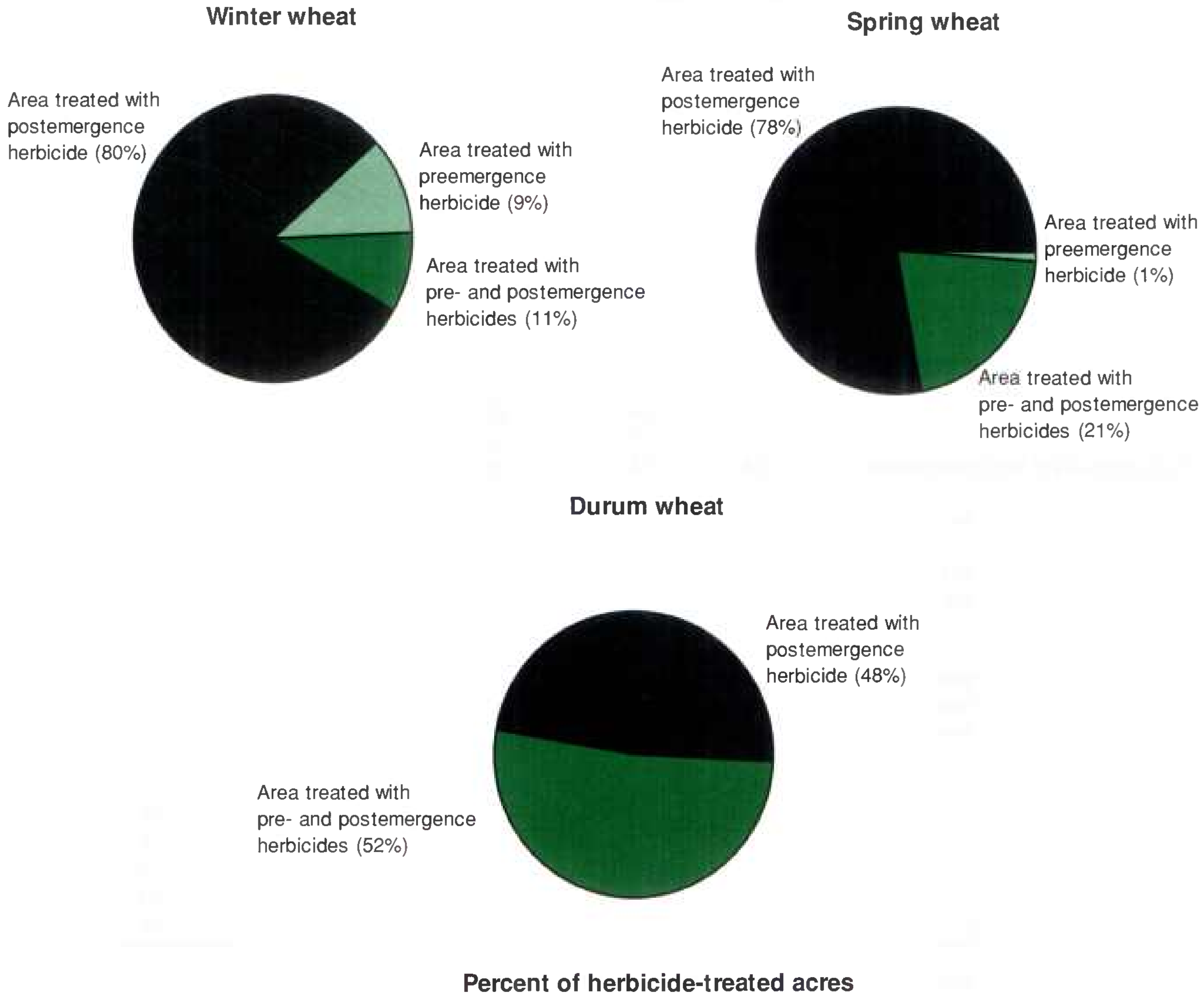


Table 7—Herbicide application timing, application decision criteria, and application methods, field crops, 1996

Among field crops, the application of preemergence herbicides versus postemergence herbicides or both is mixed. However, the majority of herbicides are applied using the broadcast method

Item	Corn	Soybeans	Cotton	Fall potatoes	Winter wheat	Spring wheat	Durum wheat
	Percent of herbicide-treated acres						
Preemergence only							
Area treated	39	17	33	37	9	1	*
Application decision criteria:							
Previous problem/routine	93	90	96	96	98	100	*
Field mapping	12	10	5	14	35	69	0
Computer decision model	1	*	*	1	0	0	0
Crop consultant recommendation	19	15	9	26	15	22	0
Postemergence only							
Area treated	20	29	4	31	80	78	48
Application decision criteria:							
Routine treatment	63	65	25	79	33	56	72
Type and density of weeds	52	64	80	43	77	63	87
Computer decision model	*	1	0	*	*	0	0
Crop consultant recommendation	24	14	6	37	21	12	9
Pre- and postemergence							
Area treated	41	54	63	32	11	21	52
Application decision criteria:							
Previous problem/routine	94	93	92	96	71	89	83
Field mapping	14	11	15	7	35	6	10
Routine treatment	64	63	60	82	71	53	72
Type and density of weeds	71	73	66	85	37	60	85
Computer decision model	1	1	*	1	0	0	0
Crop consultant recommendation	20	23	21	19	9	16	3
Application methods							
Broadcast[1]	85	88	45	46	86	84	55
In seed furrow[2]	1	*	2	20	*	2	3
In irrigation water	*	0	*	23	*	0	0
Banded[3]	9	5	38	*	1	0	0
Foliar or directed spray	6	7	15	11	14	14	42

[1] Broadcast includes ground with and without incorporation and aerial broadcast.
[2] Includes in seed furrow and chisel/injected or knifed in.
[3] Banded in or over row.
* Less than 0.5 percent.
Source: NASS/ERS 1996 ARMS survey.

same was true for scouting and recordkeeping for insects. In the case of cotton, however, growers on 52 percent of the acreage scouted and kept records. This is very close to the percentage of the cotton acreage scouted for insects by crop consultants or commercial scouts (51 percent of the planted acres).

Herbicide Application Timing, Decision Criteria, and Method of Application

As weeds are the most common pest problem for field crops (tables 1 and 2) and few alternatives to chemical treatments exist (Jordan), the 1996 ARMS survey collected detailed information on herbicide application timing, application decision criteria, and method of application. Herbicides can be applied before weeds emerge (preemergence), after weeds emerge (postemergence), or both pre- and postemergence. When only the acres that received herbicides were considered, the range of preemergence applications ran from 1 percent of spring wheat acreage to 39 percent of corn acreage. Postemergence applications of herbicides ran from 4 percent of cotton acres to 80 percent of winter wheat acres. For crops that received both pre- and postemergence applications of herbicides, the shares ranged from 11 percent for winter wheat to 63 percent for cotton (figure 2, table 7).

The survey data show that, except for wheat, most field crop acreage received preemergence herbicides. The application decision criteria used most often were based on weed problems in previous years. Other decision criteria for applying preemergence herbicides—such as field mapping, computer decision models, and recommendations from an independent crop consultant—were used less frequently, even though these techniques are considered more likely to result in lower herbicide applications. For example, the use of field mapping, a technique that pinpoints the location of weed problems in previous years and allows farmers to vary application rates accordingly, varied widely: where only preemergence herbicides were applied, the use of field mapping ranged from 5 percent of the acreage for cotton to 69 percent of the acreage for spring wheat (but only 1 percent of spring wheat herbicide-treated acres were treated with preemergence herbicides). Field mapping was also used on acres receiving both pre- and postemergence herbicides. Its use ranged from 6 percent for spring wheat acres to 35 percent for winter wheat.

When applying postemergence herbicides, farmers can treat weeds according to the species present and weed density level. Using the density of the weeds as a criterion for postemergence herbicide application has an advantage over routine treatment because it allows farmers to adjust application rates according to the size and density of the weeds. The density of weeds present was used as a decision criterion on 52 and 64 percent of the herbicide-treated acres for corn and soybeans, respectively.

Broadcast application was the most frequently used method of applying herbicides. For soybeans, 88 percent of the acres receiving herbicides received them via the broadcast method (table 7). For cotton, 45 percent of the acres receiving herbicides received them using the broadcast method, the lowest percentage of broadcast application for the surveyed crops. Banded application of herbicides, which uses less herbicide than the broadcast method, was used on far fewer acres—except for cotton—with 38 percent of the total acres receiving banded applications.

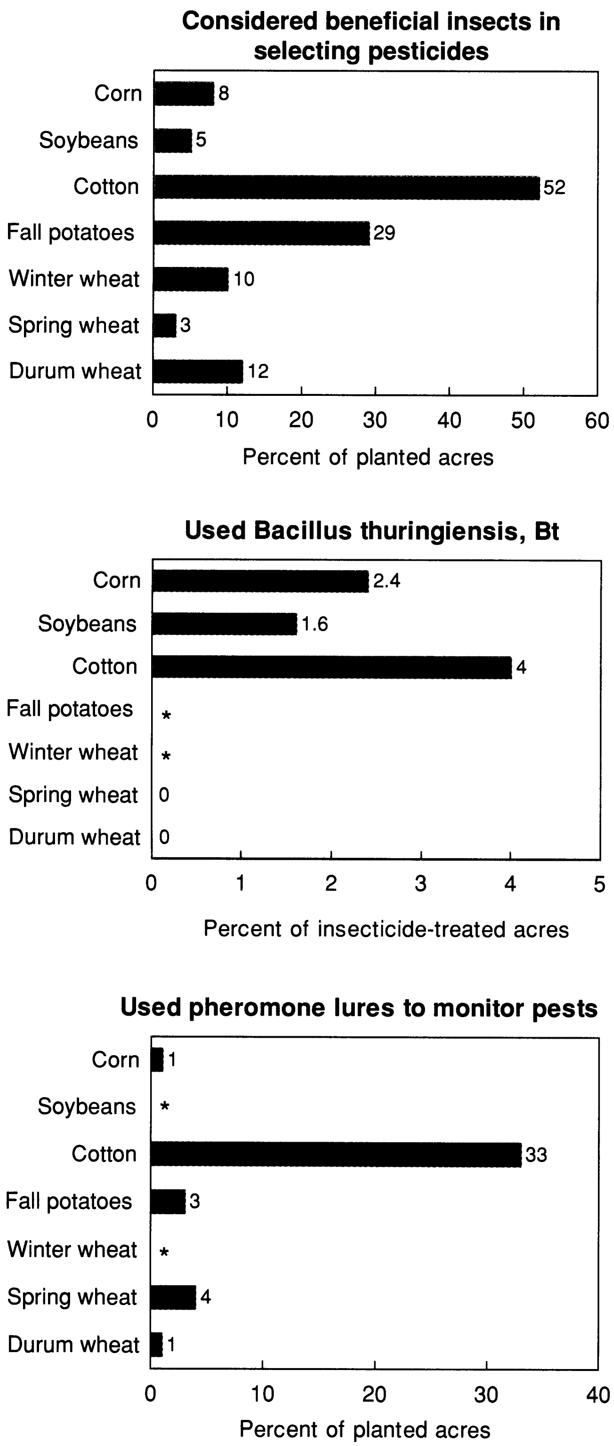
Other Pest Management Practices

Biological techniques of pest management include natural enemy/predator insects, pheromones for control, and Bt. Across all of the surveyed field crops, the technique of considering beneficial insects when selecting pesticides was more broadly used than any of the other biological practices, particularly for cotton, with 52 percent of the planted acres, and fall potatoes, with 29 percent of the planted acres (figure 3, table 8). Cotton growers are also the major users of most other biological practices: they used pheromone lures to control pests on 7 percent of their planted acres, foliar Bt on 4 percent of their insecticide-treated acres, and Bt varieties on 15 percent of the planted acres. However, soybean farmers were the largest users of herbicide-

(Text continues on p. 24)

Figure 3
Biological pest management practice for field crops, ARMS 1996

Considering beneficial insects when selecting pesticides is the most widely used biological pest management practice



*Less than 0.5 percent.

Figure 4
Cultural pest management practices, field crops, ARMS 1996

Crop rotations are used on more than a third of the planted acreage as a cultural pest management practice

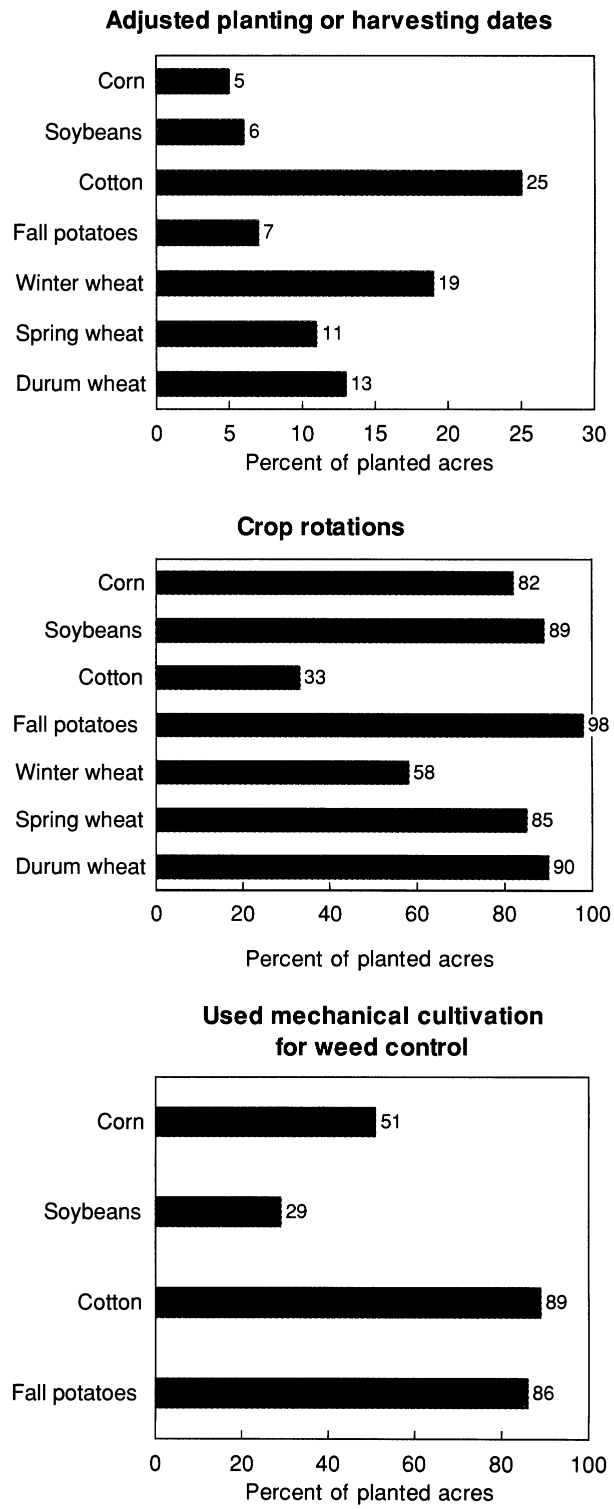


Table 8—Pest management practices, field crops, 1996

Cultural techniques are the leading pest management practice for field crops

Item	Corn	Soybeans	Cotton	Fall potatoes	Winter wheat	Spring wheat	Durum wheat
				Percent of planted acres			
Biological techniques							
Considered beneficial insects in selecting pesticides	8	5	52	29	10	4	12
Purchased and released beneficial insects	*	*	*	0	*	*	0
Used pheromone lures to control pests	na	*	7	2	*	1	0
Used Bacillus thuringiensis (Bt)[2]	2.4	1.6	4.1	*	*	0	0
Cultural techniques							
Adjusted planting or harvesting dates[3]	5	6	25	7	19	11	13
Used mechanical cultivation for weed control	51	29	89	86	na	na	na
Used a no till system	19	33	na	na	3	4	7
Crop rotations[4]							
Continuous[5]	18	11	67	2	42[11]	14	10
Rotation with other row crops[6]	54[8]	63[9]	15	2	2	2	0
Other[7]	28	26	18	96[10]	56[12]	83[13]	90[14]
Pesticide efficiency							
Alternated pesticides to control pest resistance	31	28	41	69	13	38	32
Monitoring							
Used pheromone lures to monitor pests[1]	1	*	33	3	*	4	1
Used soil biological testing to detect pests such as insects, diseases, or nematodes	2	3	9	46	2	0	0

1 For corn, pheromone lures were used to monitor black cutworm.

2 Percent of insecticide-treated acres for Bt.

3 Adjust planting dates only for corn.

4 Crop rotations include three years 1994, 1995, and 1996. Column crop heading indicates the crop planted in 1996.

5 The same crop was planted in 1994, 1995, and 1996.

6 A crop sequence, excluding continuous same crop, where only row crops (corn, soybeans, sorghum, cotton, and peanuts) were planted for three consecutive years.

7 Other excludes continuous same crop and rotation with row crops and includes fallow or idle.

8 49 percent of corn-planted acres were in rotation with soybeans.

9 56 percent of soybean-planted acres were in rotation with corn.

10 26 percent of potato-planted acres were fallow in 1994 and 1995, and 70 percent were in rotation with other crops or fallow in 1994 or 1995.

11 Continuous same crop for winter wheat were for two years 1995 and 1996, for winter wheat planted in fall 1994 and winter wheat planted in fall 1995.

12 40 percent of winter-wheat-planted acres were fallow in fall 1994 and had winter wheat planted in fall 1995.

13 23 percent of spring-wheat-planted acres were fallow in 1994 and had spring wheat in 1995, and 60 percent were in rotation with other crops or fallow in 1994 or 1995.

14 24 percent of durum-wheat-planted acres were fallow in 1994 and had durum wheat in 1995, and 66 percent were in rotation with other crops or fallow in 1994 or 1995.

na= not available or not applicable. * Less than 0.5 percent.

Source: NASS/ERS 1996 ARMS survey.

Table 9—Pest-resistant varieties used, field crops 1996

Bt cotton is the leading resistant variety used

Item	Corn	Soybeans	Cotton	Fall potatoes
	Percent of planted acres			
Herbicide-resistant hybrid/variety	3	7	id	na
Bt variety for insect resistance	1	na	15	1
Gray-leaf-spot-resistant variety	2	na	na	na
Potato-scab-resistant variety	na	na	na	1

na= not available or not applicable.
id= insufficient data for a statistically reliable estimate.
Source: NASS/ERS 1996 ARMS survey.

Table 10—Cultural management practices used by corn producers, 1996

Rotating crops is the leading cultural management practice used to control both weed and insect pests in corn

Item	To control		
	Weeds	Insects	Both
	Percent of planted acres		
Adjusted row spacing or plant density	5	*	2
Adjusted planting dates	1	1	2
Alternated pesticides to control pest resistance	15	2	12
Reduced pests from spreading by:			
Tilling/mowing field edges	13	2	17
Using water management practices	1	*	3
Cleaning harvest/tillage implements	12	1	11
Crop rotations[1]			
Continuous[2]	na	na	18
Rotation with other row crops[3]	na	na	54[5]
Other[4]	na	na	28

[1] Crop rotations include three years, 1994, 1995, and 1996, with corn planted in 1996.

[2] Corn planted in 1994, 1995, and 1996.

[3] A crop sequence, excluding continuous same crop, where only row crops (corn, soybeans, sorghum, cotton, and peanuts) were planted for three consecutive years.
[4] Other also includes fallow or idle.
[5] 49 percent were rotation with soybeans.
na= not available.
* Less than 0.5 percent.
Source: NASS/ERS 1996 ARMS survey.

Table 11—Monitoring and other pest management practices, corn, 1996

Scouting and keeping written records on insects are the most popular monitoring practices used for corn

Item	Corn
	Percent of planted acres
Monitoring	
Used soil biological testing to detect insects, diseases or nematodes	2
Scouted and kept written/electronic records on black cutworms	11
Scouted and kept written/electronic records on corn rootworms	14
Scouted and kept written/electronic records on European corn borers	18
Scouted and kept written/electronic records on spider mites	8
Scouted for adult corn rootworm beetles during 1995 season	14
Scouted for adult corn rootworm beetles during 1996 season	7
Used pheromone lures to monitor black cutworm	1
Used pre-plant grain traps to monitor wireworms	*
Submitted diseased plants to a lab for diagnosis	1
Other practices	
Considered beneficial insects in selecting and using pesticides	8
Removed weeds to prevent insect egg laying	10
Used seed treatments for seedling blight	12
Routinely used soil insecticide at planting to control corn rootworm	24
Weed resistance	
Weeds resistant to the triazine family of herbicides	11
Weeds resistant to ALS (sulphonylurea or imidazolinone families)	5
Biological practices	*Percent of insecticide-treated acres*
Purchased and released beneficial insects	*
Used Bacillus thuringiensis (Bt)	2.4

* Less than 0.5 percent.
Source: NASS/ERS 1996 ARMS survey.

Table 12 —Insecticide decision criteria for field crops, 1996

More than 50 percent of insecticide application decisions are based on the farmer's own determination of pest infestation levels

Insecticide decision criteria based on	Soybeans	Cotton	Fall potatoes	Winter wheat	Spring wheat	Durum wheat
			Percent of planted acres			
Scouting data and university or Extension guidelines for infestation thresholds	11	46	24	12	23	10
Standard practice or history of insect problems	30	22	55	20	29	23
Local information (other farmers, radio-TV, etc.) that the pest was or was not present	12	7	20	9	11	15
Operator's own determination of the pest infestation level	54	55	83	69	65	69

Source: NASS/ERS 1996 ARMS survey.

Table 13—Primary source of information for pest management, field crops, 1996

Farm supply or chemical dealers are the primary sources of information on pest management for major field crops except cotton

Item	Corn	Soybeans	Cotton	Fall potatoes	Winter wheat	Spring wheat	Durum wheat
				Percent of planted acres			
Extension advisors, commercial scouting service, and crop consultants	21	14	62	40	24	21	23
Farm supply/chemical dealer	69	74	22	54	42	52	58
Other growers and producer associations, newsletters or trade magazines	5	3	5	4	13	7	6
Media or other information sources (World Wide Web, DTN, etc.)	2	3	4	1	5	7	11
None	3	6	7	1	16	13	2

Source: NASS/ERS 1996 ARMS survey.

Table 14—Scouting for pests and source of scouting, selected fruits and vegetables, 1993-95

More than 70 percent of selected fruit and vegetable acres are scouted for pests

Item	Apples	Grapes	Peaches	Oranges	Tomatoes[1]	Strawberries
			Percent of planted acres			
Scouting for pests	84	68	71	90	92	98
Source of scouting						
Operator or employee	33	35	19	49	38	59
Chemical dealer	30	22	37	24	14	11
Professional service	16	10	15	12	38	26
Other	5	1	1	5	3	2
Decision strategies for pesticide applications						
Used pest thresholds	56	41	na	68	70	74
Routine or preventive schedule	41	25	na	16	25	19
Other or did not apply	3	34	na	11	5	7

na = not available.

[1] Fresh market tomatoes.

Source: Padgitt et al.

Table 15—Pest management practices, selected fruits and vegetables, 1993-95

Apple and tomato growers led the use of pest management practices among fruit and vegetable growers

Item	Apples	Grapes	Peaches	Oranges	Tomatoes[1]	Strawberries
	Percent of planted acres					
Biological						
Considered beneficial insects in selecting pesticides	80	31	41	61	64	59
Purchased/released beneficial insects	1	5	1	8	3	35
Used pheromone lures to monitor pests	69	12	32	16	15	5
Used pheromone lures to control pests	15	5	21	3	20	*
Planted resistant varieties or rootstock	10	12	44	13	37	37
Other						
Adjusted planting dates	na	na	na	na	11	15
Alternated pesticides to reduce pest resistance	75	36	67	61	73	72
Used soil and plant tissue testing	11	20	8	26	31	19

na= not available.

[1] Fresh market tomatoes.

* Less than 0.5 percent.

Source: Padgitt et al.

Table 16—Most often used source of information for pest control, selected fruits and vegetables, 1993-95

Extension advisors/professional scouters and chemical dealers are the two largest sources of pest control information used for selected fruits and vegetables

Item	Apples	Grapes	Peaches	Oranges	Tomatoes[1]	Strawberries
	Percent of planted acres					
Extension advisors and professional scouting service	42	38	55	37	57	52
Chemical dealer	49	43	34	54	37	41
Media or demonstration events	2	2	4	5	1	2
Other information sources	6	17	7	4	5	5

[1] Fresh market tomatoes.

Source: Padgitt et al.

tolerant varieties (table 9).[12]

Such cultural techniques as mechanical cultivation, adjusting planting/harvesting dates, no till, and crop rotations were used fairly extensively on all the field crops. For example, crop rotations were used on at least 82 percent of the planted acres for field crops except for cotton and winter wheat, where only 33 and 58 percent of the planted acres were in rotation, respectively (figure 4, table 8). Cotton growers used mechanical cultivation and adjusted planting or harvesting dates on 89 and 25 percent of the acres, respectively (table 8).

Controlling pest resistance by alternating pesticides, a technique used to increase pesticide efficiency, was used to a moderate degree by all growers and most extensively by fall potato and cotton growers, covering 69 and 41 percent of their planted acreage, respectively. This practice was used on 28 percent of the soybean-planted acres and 31 percent of corn-planted acres (table 8).

The survey also found 46 percent of the cotton-planted acres and 24 percent of the fall-potato-planted acres, both crops with major insect problems, received insecticide applications based on scouted data compared with university or extension infestation thresholds (table 12). On the other hand, soybeans and durum wheat, which have much less insect problems, used thresholds on only 10 percent of their acreages (table 12).

The farm supply or chemical dealer was the most important source of pest management information for most field crops, ranging from 42 percent for winter wheat acres to 74 percent for soybean acres (table 13). Cotton growers, however, used extension and crop consultants more often (62 percent) than farm supply or chemical dealers (22 percent). Crop consultants and extension advisors were also an important source of pest management information for potato producers.

The Extent of Adoption for Fruit and Vegetable Growers

Among growers of fruits and vegetables, scouting for pests ranged from 71 percent of the peach-planted acreage to 98 percent for strawberries, with an overall average of about 80 percent (table 14).[13] Farm operators or employees did most of the scouting, except for peaches and tomatoes. Chemical dealers were the main source of scouting for peaches, covering 37 percent of the planted acres. Professional scouting services reached 38 percent for tomatoes, matching the percentage of scouting carried out by the operator or employees. Pest thresholds were also extensively used, from 41 percent of the acres for grapes to 74 percent for strawberries.

Pheromones for both control and monitoring were more often used on fruit and vegetable acreage than on field crop acreages (table 15). Resistant varieties were also used at relatively high rates for tomatoes (37 percent), strawberries (37 percent), and peaches (44 percent). The most common pest management practice among growers of fruits and vegetables was alternating pesticides to reduce pest resistance. Its use ranged from 36 percent for grape acreage to 75 percent for apples. Growers considered beneficial insects in selecting pesticides on 80 percent of the apple-planted acres. Finally, the single most often used source of information for pest control was the chemical dealer for most selected fruits and vegetables; however, the combined use of professional scouting services and extension advisors often exceeded that of chemical dealers (table 16).

[12]The survey also included responses to a series of additional questions specific to corn (tables 8 and 9).

[13]In contrast to the ARMS survey, surveys for the selected fruits and vegetables considered all pests as a single group.

Concluding Comments

This report summarizes the major issues and unresolved questions related to the development of pest management strategies, including IPM, in U.S. agriculture. In addition, the report presents recent survey results regarding the extent of adoption of pest management practices by growers of major field crops and selected fruits and vegetables.[14]

There have been encouraging advances in methodology in recent years, but a complete, practical, and accepted method to measure overall IPM adoption is not yet available. Despite these measurement difficulties and data comparability problems, some progress has been made on IPM research regarding the factors influencing adoption and the impact of adoption. These issues will be discussed in a later publication as more recent data become available and as the measurement issues become more settled.

[14]The appendices contain more detailed information on primary target pests by State and crop, the extent of adoption of pest management practices by crop and region, and pesticide use by crop and active ingredient. The survey questionnaire is also included in Appendix IV.

The extent of adoption of pest management practices varies widely among field crops and regions. Cotton and potato producers are further ahead on the IPM continuum than producers of other crops. Comparison across crops and regions is complex, however, because different pest classes may dominate depending on crops and regions, calling for different pest management techniques to control them. For example, insects are a major pest class in cotton production, while minimal for soybeans (table 1). Thus, it is not surprising that adoption of insect management techniques is more widespread among cotton producers. As insect management has a wider variety of (nonchemical) techniques than weed control, it is also likely that cotton growers will have a higher overall measure of IPM adoption, which may have contributed to the decline in cotton pesticide use (Fernandez-Cornejo and Jans, 1995). On the other hand, weed control is very important for soybeans and corn. As a consequence, and given the large corn and soybean acreages, it is reasonable to conclude that important future progress in IPM adoption will depend upon weed management efforts.

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Appendix I—Tables of Pesticide Treatments by Major Target Pest, State, and Crop

Appendix table 1.1-Target pests - Corn 1996

Target pest		State								
		IL	IN	IA	KS	KY	MI	MN	MO	NE
10-Aphids	Pct[1]	0.4	--	--	--	--	--	--	--	--
727-Corn Rootworm (adults)	Pct	1.4	2.5	2.4	3.9	4.4	1.1	0.2	0.3	11.2
728-Corn Rootworm (larvae)	Pct	12.6	9.6	4.4	4.0	0.4	5.1	2.8	5.7	8.5
20-Other Beetles, Weevils, or Wireworms	Pct	0.5	0.5	0.2	2.4	--	--	0.4	5.0	1.1
30-Cutworms or Armyworms	Pct	1.9	4.9	0.3	0.8	4.6	0.1	--	4.1	1.5
40-Other Moths or Caterpillars	Pct	4.1	3.2	0.4	8.6	--	5.6	2.8	0.8	4.6
607-Foxtail	Pct	27.8	22.8	25.8	7.4	9.8	9.9	26.9	17.7	14.5
171-Other Annual Grasses	Pct	15.2	12.2	19.9	15.6	26.7	23.3	16.2	17.1	20.8
617-Shattercane	Pct	1.2	0.3	0.5	6.5	0.1	0.2	--	2.3	4.6
608- Johnsongrass	Pct	0.1	5.3	0.0	1.3	30.2	--	--	1.1	0.4
172-Other Perennial Grasses	Pct	1.9	4.5	3.0	0.8	4.6	7.0	2.7	3.1	2.3
173-Perennial Broadleafs	Pct	2.3	3.5	7.5	34.1	5.1	12.7	11.6	6.8	11.0
174-Annual Broadleafs	Pct	30.7	30.4	35.4	5.4	13.9	26.6	33.4	35.3	19.4
616-Quack Grass	Pct	--	0.3	0.2	0.1	--	8.3	3.0	--	--
50-True Bugs	Pct	--	--	--	0.1	--	--	--	0.2	--
90-Mites	Pct	--	--	--	5.3	--	--	--	--	0.1
180-Other (Defoliant, Desiccant, or Growth Regulator)	Pct	--	--	--	3.8	--	--	--	--	--
80-Grasshoppers or Crickets	Pct	--	--	--	--	0.0	--	--	--	0.0
177-Sedges	Pct	--	--	--	--	--	0.1	--	0.4	--
754-Pink Bollworm	Pct	--	--	--	--	--	--	--	--	
85-Thrips	Pct	--	--	--	--	--	--	--	--	--
Total	1,000 Acre-Treatments	25048	10751	26504	6012	3210	5530	16575	5528	19629

[1] Percent of acre-treatments.

Continued--

Appendix table 1.1—Target pests - Corn 1996 (continued)

Target pest		State							
		NC	OH	PA	SC	SD	TX	WI	Total
10-Aphids	Pct[1]	--	--	--	--	--	--	--	0.1
727-Corn Rootworm (adults)	Pct	0.2	3.1	0.9	4.8	0.6	1.5	5.9	3.1
728-Corn Rootworm (larvae)	Pct	6.5	4.8	10.5	1.1	1.2	8.7	12.1	7.1
20-Other Beetles Weevils, or Wireworms	Pct	4.9	0.5	--	2.3	--	2.7	--	0.8
30-Cutworms or Armyworms	Pct	1.5	3.3	3.3	4.2	3.6	6.7	--	1.8
40-Other Moths or Caterpillars	Pct	2.7	1.3	0.4	--	5.1	13.4	0.1	3.2
607-Foxtail	Pct	--	29.7	10.4	--	19.9	0.0	21.5	20.5
171-Other Annual Grasses	Pct	29.9	11.7	13.5	46.0	13.1	10.2	10.5	16.8
617-Shattercane	Pct	--	0.2	6.4	--	--	0.1	--	1.4
608-Johnsongrass	Pct	4.9	1.7	2.7	5.1	--	14.7	0.2	1.9
172-Other Perennial Grasses	Pct	8.5	2.9	13.9	11.7	8.8	0.3	7.8	3.9
173-Perennial Broadleafs	Pct	10.9	10.1	12.8	9.1	20.5	8.6	5.2	9.3
174-Annual Broadleafs	Pct	29.1	29.5	22.1	15.7	25.3	28.5	28.2	28.1
616-Quack Grass	Pct	--	1.3	2.8	--	1.1	--	8.4	1.4
50-True Bugs	Pct	0.9	--	--	--	--	1.9	--	0.1
90-Mites	Pct	--	--	--	--	--	2.9	--	0.3
180-Other (Defoliant. Desiccant, or Growth Regulator)	Pct	--	--	--	--	--	--	--	0.1
80-Grasshoppers or Crickets	Pct	--	--	--	--	0.6	--	--	0.0
177-Sedges	Pct	--	--	0.2	--	0.2	--	0.2	0.0
754-Pink Bollworm	Pct	0.0	--	--	--	--	--	--	0.0
85-Thrips	Pct	--	--	--	--	--	0.1	--	0.0
Total	1,000 Acre-Treatments	2114	6216	5063	745	8259	4900	8911	154995

[1] Percent of acre-treatments.

Appendix table 1.2—Target pests - Soybeans 1996

Target pest		State								
		IL	IN	IA	MN	MO	NE	OH	AR	LA
727-Corn Rootworm (adults)	Pct[1]	--	--	--	--	--	0.0	--	--	--
728-Corn Rootworm (larvae)	Pct	--	--	0.0	--	--	--	--	--	--
20-Other Beetles Weevils, or Wireworms	Pct	--	--	0.0	--	--	0.2	--	0.2	0.1
30-Cutworms or Armyworms	Pct	--	--	--	--	--	--	0.3	0.6	--
40-Other Moths or Caterpillars	Pct	--	--	0.1	--	--	--	--	--	0.4
607-Foxtail	Pct	26.6	17.1	19.7	18.5	24.3	20.7	23.3	0.5	0.0
171-Other Annual Grasses	Pct	24.6	18.5	24.8	20.4	17.0	10.8	9.5	46.2	19.6
617-Shattercane	Pct	0.2	2.3	0.1	--	1.3	4.4	0.5	--	--
608- Johnsongrass	Pct	0.1	8.1	0.0	0.0	5.0	0.0	0.8	14.6	14.5
172-Other Perennial Grasses	Pct	3.1	7.1	3.8	5.8	7.3	6.5	6.5	8.1	9.8
173-Perennial Broadleafs	Pct	5.6	8.8	9.6	7.6	4.9	8.1	11.5	4.9	5.1
174-Annual Broadleafs	Pct	39.7	37.5	41.9	45.4	39.8	49.2	42.0	24.4	32.6
616-Quack Grass	Pct	0.1	0.5	0.1	2.3	--	--	5.5	0.3	2.0
50-True Bugs	Pct	--	--	--	--	--	--	--	--	13.2
180-Other (Defoliant, Desiccant, or Growth Regulator)	Pct	--	--	--	--	--	--	--	--	--
80-Grasshoppers or Crickets	Pct	--	0.0	--	--	0.1	0.0	--	--	--
177-Sedges	Pct	--	--	--	0.0	0.4	--	--	0.2	0.7
757-Tobacco Budworm	Pct	--	--	--	--	--	--	--	--	1.0
110-Fungus Diseases	Pct	--	--	--	--	--	--	--	--	1.1
Total	1000 Acre-Treatments	24004	11939	21993	13529	8597	6726	11162	7329	2761

[1] Percent of acre-treatments.

Continued--

Appendix table 1.2 —Target pests - Soybeans 1996 (continued)

Target pest		State		
		MS	TN	Total
727-Corn Rootworm (adults)	Pct[1]	--	--	0.0
728-Corn Rootworm (larvae)	Pct	--	--	0.0
20-Other Beetles Weevils, or Wireworms	Pct	0.0	--	0.0
30-Cutworms or Armyworms	Pct	0.1	--	0.1
40-Other Moths or Caterpillars	Pct	0.4	--	0.0
607-Foxtail	Pct	--	--	18.5
171-Other Annual Grasses	Pct	23.0	27.4	21.9
617-Shattercane	Pct	--	--	0.7
608-Johnsongrass	Pct	6.1	24.7	3.5
172-Other Perennial Grasses	Pct	13.9	6.8	5.8
173-Perennial Broadleafs	Pct	8.9	3.0	7.6
174-Annual Broadleafs	Pct	44.9	37.8	40.3
616-Quack Grass	Pct	--	--	1.0
50-True Bugs	Pct	1.4	--	0.4
180-Other (Defoloiant, Desiccant, or Growth Regulator)	Pct	0.7	--	0.0
80-Grasshoppers or Crickets	Pct	--	0.2	0.0
177-Sedges	Pct	0.5	--	0.1
757-Tobacco Budworm	Pct	--	--	0.0
110-Fungus Diseases	Pct	0.1	0.1	0.0
Total	1,000 Acre-Treatments	4565	3084	115689

[1] Percent of acre-treatments.

Appendix table 1.3—Target pests - Cotton 1996

Target pest		State								
		TX	AR	LA	MS	TN	AZ	CA	GA	Total
10-Aphids	Pct[1]	3.4	0.2	1.4	0.5	0.0	--	8.4	0.2	2.0
728-Corn Rootworm (larvae)	Pct	--	0.5	2.0	--	--	--	--	0.0	0.4
20-Other Beetles Weevils, or Wireworms	Pct	26.6	32.6	27.3	16.2	20.4	--	0.6	0.3	19.7
30-Cutworms or Armyworms	Pct	0.5	1.4	4.1	0.8	--	0.1	1.8	2.7	1.5
40-Other Moths or Caterpillars	Pct	2.7	2.9	6.3	5.6	0.3 --	3.2	1.5	3.5	
607-Foxtail	Pct	0.1	--	--	0.1	--	--	0.0	0.0	0.1
171-Other Annual Grasses	Pct	2.0	4.8	3.5	10.1	12.7	1.7	8.3	18.5	6.8
617-Shattercane	Pct	--	--	0.2	--	--	--	--	--	0.0
608-Johnsongrass	Pct	4.9	4.9	4.9	2.9	4.7	0.8	0.8	0.1	3.6
172-Other Perennial Grasses	Pct	2.6	7.8	3.2	3.7	1.6	1.5	2.5	4.1	3.6
173-Perennial Broadleafs	Pct	5.5	2.2	3.1	2.6	2.5	6.2	0.8	5.0	3.6
174-Annual Broadleafs	Pct	23.3	17.5	12.3	17.2	29.5	6.3	9.5	30.0	19.0
616-Quack Grass	Pct	--	--	0.2	--	--	--	--	--	0.0
50-True Bugs	Pct	2.2	1.7	3.5	10.5	1.6	17.8	3.4	2.1	4.4
90-Mites	Pct	0.0	--	0.1	--	--	--	19.0	--	1.7
180-Other (Defoliant, Desiccant, or Growth Regulator)	Pct	16.6	14.0	9.9	18.2	23.4	17.8	39.7	18.6	18.2
80-Grasshoppers or Crickets	Pct	--	--	--	--	--	--	0.0	0.0	0.0
177-Sedges	Pct	0.1	--	0.3	0.1	0.8	0.2	0.2	0.8	0.2
754-Pink Bollworm	Pct	4.5	1.0	5.2	3.4	0.0	24.7	0.6	5.6	4.0
85-Thrips	Pct	3.3	2.4	1.4	4.3	0.9	--	0.8	6.2	2.9
757-Tobacco Budworm	Pct	1.5	1.4	6.9	3.3	--	--	--	4.2	2.6
110-Fungus Diseases	Pct	0.1	2.1	1.2	0.3	0.9	--	0.0	--	0.6
60-Whitefly, Mealybugs, or Leafhoppers	Pct	0.1	--	0.1	--	--	22.9	0.2	--	0.6
100-Nematodes	Pct	0.1	2.6	3.0	--	0.1	0.0	0.2	0.0	0.8
120-Virus Diseases	Pct 1/	--	--	0.2	--	0.0	--	--	--	0.0
95-Flies or Maggots	Pct	0.0	--	--	--	0.6	--	--	--	0.0
Total	1000 Acre-Treatments	25546	12329	13984	18095	4566	2459	8596	9004	94579

[1] Percent of acre-treatments.

Appendix table 1.4—Target pests - Winter wheat 1996

Target pest		State								
		KS	NE	SD	TX	CO	DE	ID	MT	OK
10-Aphids	Pct[1]	5.7	--	--	16.1	0.6	3.7	0.8	--	41.8
20-Other Beetles, Weevils, or Wireworms	Pct	--	--	--	--	--	14.8	--	--	--
30-Cutworms or Armyworms	Pct	0.6	--	--	20.4	--	--	--	--	--
607-Foxtail	Pct	0.8	--	6.0	--	--	--	--	--	.
171-Other Annual Grasses	Pct	2.4	12.5	7.9	1.2	19.8	--	19.7	9.0	0.3
617-Shattercane	Pct	--	--	--	--	--	--	--	--	
608-Johnsongrass	Pct	2.0	--	--	0.2	--	--	--	--	0.8
172-Other Perennial Grasses	Pct	2.1	13.6	--	1.7	1.2	25.9	--	--	1.7
173-PerennialBroadleafs	Pct	24.7	26.6	47.4	0.7	14.5	7.4	27.5	9.0	5.7
174-Annual Broadleafs	Pct	59.6	46.7	38.6	32.7	55.1	11.1	50.5	79.9	49.7
616-Quack Grass	Pct	--	--	--	--	--	--	0.8	--	.
50-True Bugs	Pct	--	--	--	23.9	--	--	--	--	.
90-Mites	Pct	2.1	--	--	2.0	8.7	--	--	--	--
180-Other (Defoliant, Desiccant, or Growth Regulator)	Pct	--	--	--	1.2	--	--	0.7	--	--
80-Grasshoppers or Crickets	Pct	--	0.5	0.1	--	--	--	--	1.4	--
85-Thrips	Pct	--	--	--	--	--	--	--	--	--
110-Fungus Diseases	Pct	--	--	--	--	--	37.0	--	0.7	--
120-Virus Diseases	Pct	--	--	--	--	--	--	--	--	--
Total	1000 Acre-Treatments	7535	1858	1919	2348	2782	27	1317	4824	3154

[1] Percent of acre-treatments

Continued--

Appendix table 1.4—Target pests - Winter wheat, 1996 (continued)

Target pest		State		
		OR	WA	Total
10-Aphids	Pct[1]	0.5	1.7	6.9
20-Other Beetles, Weevils, or Wireworms	Pct	--	--	0.0
30-Cutworms or Armyworms	Pct	--	--	1.6
607-Foxtail	Pct	0.6	2.6	1.0
171-Other Annual Annual	Pct	6.3	8.2	7.2
617-Shattercane	Pct	10.7	1.7	1.0
608-Johnsongrass	Pct	--	--	0.6
172-Other Perennial Grasses	Pct	0.6	3.0	2.1
173-Perennial Broadleafs	Pct	46.5	19.5	20.3
174-Annual Broadleafs	Pct	32.2	59.1	54.9
616-Quack Grass	Pct	--	--	0.0
50-True Bugs	Pct	--	--	1.7
90-Mites	Pct	--	--	1.4
180-Other (Defoliant,. Desiccant, or Growth Regulator)	Pct	--	--	0.1
80-Grasshoppers or Crickets	Pct	--	--	0.2
85-Thrips	Pct	0.1	--	0.0
110-Fungus Diseases	Pct	2.5	3.7	0.8
120-Virus Diseases	Pct	--	0.4	0.1
Total	1000 Acre-Treatments	2293	4347	32404

[1] Percent of acre-treatments.

Appendix table 1.5—Target pests - Durum wheat, North Dakota, 1996

Target pest		ND	Total
607-Foxtail	Pct[1]	5.0	5.0
171-Other Annual Grasses	Pct	15.2	15.2
172-Other Perennial Grasses	Pct	0.7	0.7
173-Perennial Broadleafs	Pct	21.1	21.1
174-Annual Broadleafs	Pct	56.5	56.5
616-Quack Grass	Pct	0.2	0.2
80-Grasshoppers or Crickets	Pct	0.0	0.0
110-Fungus Diseases	Pct	0.7	0.7
95-Flies or Maggots	Pct	0.6	0.6
Total	1000 Acre-Treatments	7370	7370

[1] Percent of acre-treatments.

Appendix table 1.6—Target pests - Spring wheat, 1996

Target pest		State			
		MN	MT	ND	Total
10-Aphids	Pct[1]	6.3	--	--	1.0
607-Foxtail	Pct	15.6	--	8.1	7.4
171-Other Annual Grasses	Pct	19.6	9.1	14.3	13.9
172-Other Perennial Grasses	Pct	4.0	8.0	8.6	7.8
173-Perennial Broadleafs	Pct	11.9	17.0	12.0	13.1
174-Annual Broadleafs	Pct	35.3	65.4	54.1	53.8
616-Quack Grass	Pct	0.4	0.6	0.7	0.6
110-Fungus Diseases	Pct	5.2	--	1.1	1.5
95-Flies or Maggots	Pct	1.7	--	1.2	1.0
Total	1000 Acre-Treatments	4578	6819	18473	29870

[1] Percent of acre-treatments.

Appendix table 1.7—Target pests - Potatoes, 1996

Target pest		State				
		ID	WA	ME	RR	Total
10-Aphids	Pct[1]	2.4	10.4	4.4	1.0	4.1
20-Other Beetles, Weevils, or Wireworms	Pct	14.2	13.3	4.4	17.0	13.6
40-Other Moths or or Caterpillars	Pct	0.7	1.2	--	0.7	0.7
607-Foxtail	Pct	0.0	--	--	0.3	0.1
171-Other Annual Grasses	Pct	1.1	2.5	0.3	1.0	1.3
172-Other Perennial Grasses	Pct	1.4	1.0	0.1	--	0.8
173-Perennial Broadleafs	Pct	5.0	3.4	0.1	0.1	2.7
174-Annual Broadleafs	Pct	18.0	7.8	5.4	5.0	10.6
616-Quack Grass	Pct	0.3	0.1	--	--	0.1
50-True Bugs	Pct	0.0	1.9	--	0.8	0.7
90-Mites	Pct	--	1.2	--	--	0.3
180-Other (Defoliant, Desiccant, or Growth Regulator)	Pct	8.4	6.4	12.4	12.9	9.6
85-Thrips	Pct	0.1	--	--	--	0.0
110-Fungus Diseases	Pct	45.6	46.6	71.9	44.3	48.7
60-Whitefly, Mealybugs, or Leafhoppers	Pct	--	--	--	0.1	0.0
100-Nematodes	Pct	2.1	3.4	0.9	--	1.7
120-Virus Diseases	Pct	0.8	0.8	--	16.8	5.0
Total	1000 Acre-Treatments	2129	1303	680	1502	5614

[1] Percent of acre-treatments.

Appendix II—Tables on Pest Management Practices by Crop and Region[1]

Appendix table 2.1—Corn: Scouting, source of scouting, and pest management practices, by region, 1996

Item	Region[2]			
	Northeast	North Central	South	All corn States
	Percent of planted acres			
Scouting for weeds	80	78	73	78
Source of scouting:				
Operator, partner, family member	57	60	54	59
Employee	1	2	1	2
Chemical dealer	17	8	8	8
Consultant or commercial scout	4	8	10	8
Scouting for insects	60	67	58	66
Source of scouting:				
Operator/family member	43	50	41	49
Employee	1	2	1	2
Chemical dealer	12	7	9	2
Consultant or commercial scout	4	9	6	8
Scouting for diseases	33	52	50	51
Scouted and kept written/electronic records to track the activity of:				
Broadleaf weeds	12	20	11	19
Grass weeds	10	19	12	19
Insects	‡	‡	‡	‡
Other monitoring				
Used pheromone lures to monitor pests[3]	0	1	*	1
Used soil biological testing to detect pests such as insects, diseases or nematodes	*	2	4	2
Biological techniques				
Considered beneficial insects in selecting pesticides	10	8	12	8
Purchased and released beneficial insects	0	*	0	*
Used pheromone lures to control pests	na	na	na	na
Used Bacillus thuringiensis (Bt)[4]	1	2.5	2.3	2.4
Cultural techniques				
Adjusted planting or harvesting dates[5]	2	5	7	5
Used mechanical cultivation for weed control	6	52	43	51
Used a no-till system	29	19	13	19
Crop rotations[6]—				
Continuous[7]	36	18	17	18
Rotation with other row crops[8]	20	55	40	54
Other[9]	44	27	43	28
Pesticide efficiency				
Alternated pesticides to control pest resistance	26	31	33	31
Planted acres (1,000 acres)	1450	64000	4800	70250

[1] Durum wheat was excluded from this appendix because the results in the text tables were for a single State.
[2] Regions: Northeast— PA; North Central— IL, IN, IA, KS, MI, MN, MO, NE, OH, SD, WI; South— KY, NC, SC, TX.
[3] For corn, pheromone lures were used to monitor black cutworm. [4] Percent of insecticide-treated acres for Bt. [5] Adjust planting dates only for corn. [6] Crop rotations include three years 1994, 1995, and 1996. [7] The same crop was planted in 1994, 1995, and 1996. [8] A crop sequence, excluding continuous same crop, where only row crops (corn, soybeans, sorghum, cotton, and peanuts) were planted for three consecutive years. [9] Other excludes continuous same crop and rotation with row crops and includes fallow or idle.
‡ See Appendix table 2.14 for corn insect pest management practices.
na= not available. * Less than 0.5 percent.

Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.2—Soybeans: Scouting, source of scouting, and pest management practices, by region, 1996

Item	Region[1]		
	North Central	South	All soybean States
	Percent of planted acres		
Scouting for weeds	80	76	79
Source of scouting:			
Operator, partner, family member	68	67	68
Employee	1	3	1
Chemical dealer	7	1	6
Consultant or commercial scout	3	4	3
Scouting for insects	58	69	59
Source of scouting:			
Operator/family member	50	59	51
Employee	1	3	1
Chemical dealer	4	1	3
Consultant or commercial scout	3	6	3
Scouting for diseases	52	59	53
Scouted and kept written/electronic records to track the activity of:			
Broadleaf weeds	19	18	19
Grass weeds	19	18	19
Insects	12	18	13
Other monitoring			
Used pheromone lures to monitor pests	*	1	*
Used soil biological testing to detect pests such as insects, diseases or nematodes	3	2	3
Biological techniques			
Considered beneficial insects in selecting pesticides	3	15	5
Purchased and released beneficial insects	*	*	*
Used pheromone lures to control pests	*	1	*
Used Bacillus thuringiensis (Bt)[2]	0	2.2	1.6
Cultural techniques			
Adjusted planting or harvesting dates	6	8	6
Used mechanical cultivation for weed control	28	34	29
Used a no-till system	35	21	33
Crop rotations[3]—			
Continuous[4]	5	43	11
Rotation with other row crops[5]	72	15	63
Other[6]	23	42	26
Pesticide efficiency			
Alternated pesticides to control pest resistance	30	20	28
Planted acres (1,000 acres)	42320	7650	50970

[1] Regions: North Central— IL, IN, IA, MN, MO, NE, OH, WI; South— AR, LA, MS, TN. [2] Percent of insecticide-treated acres for Bt. [3] Crop rotations include three years 1994, 1995, and 1996. [4] The same crop was planted in 1994, 1995, and 1996. [5] A crop sequence, excluding continuous same crop, where only row crops (corn, soybeans, sorghum, cotton, and peanuts) were planted for three consecutive years. [6] Other excludes continuous same crop and rotation with row crops and includes fallow or idle.

na= not available. * Less than 0.5 percent.

Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.3—Cotton: Scouting, source of scouting, and pest management practices, by region, 1996

Item	Region[1]		
	South	West	All cotton States
	Percent of planted acres		
Scouting for weeds	70	94	72
Source of scouting:			
Operator, partner, family member	48	32	46
Employee	1	14	3
Chemical dealer	1	26	4
Consultant or commercial scout	19	21	19
Scouting for insects	86	99	88
Source of scouting:			
Operator/family member	24	19	24
Employee	2	14	3
Chemical dealer	7	34	10
Consultant or commercial scout	54	32	51
Scouting for diseases	49	86	53
Scouted and kept written/electronic records to track the activity of:			
Broadleaf weeds	26	47	28
Grass weeds	26	47	28
Insects	49	73	52
Other monitoring			
Used pheromone lures to monitor pests	36	17	33
Used soil biological testing to detect pests such as insects, diseases, or nematodes	9	7	9
Biological techniques			
Considered beneficial insects in selecting pesticides	50	71	52
Purchased and released beneficial insects	*	1	*
Used pheromone lures to control pests	7	9	7
Used Bacillus thuringiensis (Bt)[2]	4.7	4	4.1
Cultural techniques			
Adjusted planting or harvesting dates	26	19	25
Used mechanical cultivation for weed control	88	98	89
Used a no-till system	na	na	na
Crop rotations[3]—			
Continuous[4]	69	44	67
Rotation with other row crops[5]	17	3	15
Other[6]	14	53	18
Pesticide efficiency			
Alternated pesticides to control pest resistance	37	70	41
Planted acres (1,000 acres)	10600	1315	11915

[1] Regions: South— AR, GA, LA, MS, TN, TX; West— AZ, CA. [2] Percent of insecticide-treated acres for Bt.
[3] Crop rotations include three years 1994, 1995, and 1996. [4] The same crop was planted in 1994, 1995, and 1996.
[5] A crop sequence, excluding continuous same crop, where only row crops (corn, soybeans, sorghum, cotton, and peanuts) were planted for three consecutive years.
[6] Other excludes continuous same crop and rotation with row crops and includes fallow or idle.
na= not available. * Less than 0.5 percent. Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.4—Fall potatoes: Scouting, source of scouting, and pest management practices, by region, 1996

Item	Region[1]			
	North-east	North Central	West	All fall potato States
	Percent of planted acres			
Scouting for weeds	100	88	95	94
Source of scouting:				
Operator, partner, family member	100	43	57	59
Employee	0	9	7	7
Chemical dealer	0	17	20	17
Consultant or commercial scout	0	20	12	12
Scouting for insects	100	97	98	98
Source of scouting:				
Operator/family member	100	50	52	56
Employee	*	9	8	7
Chemical dealer	0	17	23	19
Consultant or commercial scout	0	21	16	15
Scouting for diseases	41	97	97	91
Scouted and kept written/electronic records to track the activity of:				
Broadleaf weeds	68	19	23	26
Grass weeds	68	22	22	26
Insects	69	22	29	31
Other monitoring				
Used pheromone lures to monitor pests	4	*	3	3
Used soil biological testing to detect pests such as insects, diseases, or nematodes	2	4	62	46
Biological techniques				
Considered beneficial insects in selecting pesticides	6	23	34	29
Purchased and released beneficial insects	0	0	0	0
Used pheromone lures to control pests	2	0	2	2
Used Bacillus thuringiensis (Bt)[2]	*	0	*	*
Cultural techniques				
Adjusted planting or harvesting dates	*	3	9	7
Used mechanical cultivation for weed control	90	99	82	86
Used a no-till system	na	na	na	na
Crop rotations[3]—				
Continuous[4]	8	0	1	2
Rotation with other row crops[5]	3	1	2	2
Other[6]	89	99	97	96
Pesticide efficiency				
Alternated pesticides to control pest resistance	72	61	71	69
Planted acres (1,000 acres)	78	146	573	787

[1] Regions: Northeast— ME; North Central— Red River Valley, part of MN and ND; West— ID, WA

[2] Percent of insecticide-treated acres for Bt. [3] Crop rotations include three years 1994, 1995, and 1996.

[4] The same crop was planted in 1994, 1995, and 1996. [5] A crop sequence, excluding continuous same crop, where only row crops (corn, soybeans, sorghum, cotton, and peanuts) were planted for three consecutive years.

[6] Other excludes continuous same crop and rotation with row crops and includes fallow or idle.

na= not available. * Less than 0.5 percent. Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.5—Winter wheat: Scouting, source of scouting, and pest management practices, by region, 1996

Item	Region[1] North-east	North Central	South	West	All winter wheat States
	Percent of planted acres				
Scouting for weeds	86	75	89	95	85
Source of scouting:					
Operator, partner, family member	67	68	74	78	73
Employee	0	0	0	2	*
Chemical dealer	14	2	2	15	6
Consultant or commercial scout	5	4	12	1	5
Scouting for insects	97	62	85	80	74
Source of scouting:					
Operator/family member	74	57	68	64	62
Employee	0	0	*	1	*
Chemical dealer	18	1	3	14	5
Consultant or commercial scout	5	5	13	1	6
Scouting for diseases	83	62	66	71	66
Scouted and kept written/electronic records to track the activity of:					
Broadleaf weeds	10	17	22	14	17
Grass weeds	10	12	21	12	15
Insects	12	13	21	11	14
Other monitoring					
Used pheromone lures to monitor pests	*	0	0	*	*
Used soil biological testing to detect pests such as insects, diseases, or nematodes	2	0	1	5	2
Biological techniques					
Considered beneficial insects in selecting pesticides	6	10	9	12	10
Purchased and released beneficial insects	0	0	0	*	*
Used pheromone lures to control pests	*	0	0	*	*
Used Bacillus thuringiensis (Bt)[2]	0	0	0	1	*
Cultural techniques					
Adjusted planting or harvesting dates	8	22	6	25	19
Used mechanical cultivation for weed control	na	na	na	na	na
Used a no-till system	2	4	1	4	3
Crop rotations[3]—					
Continuous[4]	0	46	69	11	42
Rotation with other row crops[5]	9	2	3	*	2
Other[6]	91	52	28	89	56
Pesticide efficiency					
Alternated pesticides to control pest resistance	38	7	4	31	13
Planted acres (1,000 acres)	78	12480	7800	8240	28598

[1] Regions: Northeast— DE; North Central— KS, NE, SD; South— OK, TX; West— CO, ID, MT, OR, WA.
[2] Percent of insecticide-treated acres for Bt. [3] Crop rotations include three years 1994, 1995, and 1996.
[4] The same crop was planted in 1994, 1995, and 1996. [5] A crop sequence, excluding continuous same crop, where only row crops (corn, soybeans, sorghum, cotton, and peanuts) were planted for three consecutive years.
[6] Other excludes continuous same crop and rotation with row crops and includes fallow or idle.
na= not available. * Less than 0.5 percent. Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.6—Spring wheat: Scouting, source of scouting, and pest management practices, by region, 1996

Item	Region[1] North Central	West	All spring wheat States
	Percent of planted acres		
Scouting for weeds	87	98	90
Source of scouting:			
Operator, partner, family member	77	78	77
Employee	*	*	*
Chemical dealer	5	20	9
Consultant or commercial scout	6	0	4
Scouting for insects	63	67	64
Source of scouting:			
Operator/family member	52	67	56
Employee	*	*	*
Chemical dealer	5	0	3
Consultant or commercial scout	6	0	4
Scouting for diseases	59	65	60
Scouted and kept written/electronic records to track the activity of:			
Broadleaf weeds	18	37	23
Grass weeds	18	14	17
Insects	11	5	9
Other monitoring			
Used pheromone lures to monitor pests	5	0	4
Used soil biological testing to detect pests such as insects, diseases, or nematodes	0	0	0
Biological techniques			
Considered beneficial insects in selecting pesticides	4	3	4
Purchased and released beneficial insects	1	0	*
Used pheromone lures to control pests	2	0	1
Used Bacillus thuringiensis (Bt)[2]	0	0	0
Cultural techniques			
Adjusted planting or harvesting dates	9	19	11
Used mechanical cultivation for weed control	na	na	na
Used a no-till system	2	8	4
Crop rotations[3]—			
Continuous[4]	15	11	14
Rotation with other row crops[5]	3	0	2
Other[6]	82	89	83
Pesticide efficiency			
Alternated pesticides to control pest resistance	44	22	38
Planted acres (1,000 acres)	12150	4200	16350

[1] Regions: North Central— MN, ND; West— MT. [2] Percent of insecticide-treated acres for Bt.
[3] Crop rotations include three years 1994, 1995, and 1996. [4] The same crop was planted in 1994, 1995, and 1996. [5] A crop sequence, excluding continuous same crop, where only row crops (corn, soybeans, sorghum, cotton, and peanuts) were planted for three consecutive years.
[6] Other excludes continuous same crop and rotation with row crops and includes fallow or idle.
na= not available. * Less than 0.5 percent. Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.7—Corn: Herbicide application timing, application decision criteria, and application methods, by region, 1996

Item	Region[1]			
	North-east	North Central	South	All corn States
	Percent of herbicide-treated acres			
Preemergence only				
Area treated	43	37	55	39
Application decision criteria:				
Previous problem/routine	86	93	94	93
Field mapping	11	12	8	12
Computer decision model	0	1	0	1
Crop consultant recommendation	26	19	14	19
Postemergence only				
Area treated	20	20	13	20
Application decision criteria:				
Routine treatment	55	63	72	63
Type and density of weeds	28	53	19	52
Computer decision model	0	*	0	*
Crop consultant recommendation	31	24	36	24
Pre- and postemergence				
Area treated	37	42	30	41
Application decision criteria:				
Previous problem/routine	96	93	96	94
Field mapping	3	15	3	14
Routine treatment	93	63	79	64
Type and density of weeds	83	71	53	71
Computer decision model	0	1	0	1
Crop consultant recommendation	17	21	9	20
Application methods:				
Broadcast[2]	83	85	82	85
In seed furrow[3]	0	1	1	1
In irrigation water	0	*	0	*
Banded[4]	2	9	9	9
Foliar or directed spray	15	5	8	6

[1] Regions: Northeast— PA; North Central— IL, IN, IA, KS, MI, MN, MO, NE, OH, SD, WI; South— KY, NC, SC, TX.

[2] Broadcast includes ground with and without incorporation and aerial broadcast.

[3] Includes in seed furrow and chisel/injected or knifed in.

[4] Banded in or over row.

* Less than 0.5 percent.

Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.8—Soybeans: Herbicide application timing, application decision criteria, and application methods, by region, 1996

Item	Region[1]		
	North Central	South	All soybean States
	Percent of herbicide-treated acres		
Preemergence only			
Area treated	16	20	17
Application decision criteria:			
Previous problem/routine	89	96	90
Field mapping	11	3	10
Computer decision model	*	0	*
Crop consultant recommendation	17	4	15
Postemergence only			
Area treated	30	20	29
Application decision criteria:			
Routine treatment	68	44	65
Type and density of weeds	63	76	64
Computer decision model	1	0	1
Crop consultant recommendation	15	4	14
Pre- and postemergence			
Area treated	52	57	54
Application decision criteria:			
Previous problem/routine	93	92	93
Field mapping	12	7	11
Routine treatment	66	47	63
Type and density of weeds	74	65	73
Computer decision model	1	1	1
Crop consultant recommendation	25	11	23
Application methods:			
Broadcast[2]	89	83	88
In seed furrow[3]	*	*	*
In irrigation water	0	0	0
Banded[4]	3	12	5
Foliar or directed spray	8	4	7

[1] Regions: North Central— IL, IN, IA, MN, MO, NE, OH, WI; South— AR, LA, MS, TN.
[2] Broadcast includes ground with and without incorporation and aerial broadcast.
[3] Includes in seed furrow and chisel/injected or knifed in.
[4] Banded in or over row.
* Less than 0.5 percent.

Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.9—Cotton: Herbicide application timing, application decision criteria, and application methods, by region, 1996

Item	Region[1]		
	South	West	All cotton States
	Percent of herbicide-treated acres		
Preemergence only			
Area treated	31	48	33
Application decision criteria:			
Previous problem/routine	97	91	96
Field mapping	3	15	5
Computer decision model	*	*	*
Crop consultant recommendation	9	10	9
Postemergence only			
Area treated	3	1	4
Application decision criteria:			
Routine treatment	23	74	25
Type and density of weeds	80	82	80
Computer decision model	0	0	0
Crop consultant recommendation	6	0	6
Pre- and postemergence			
Area treated	64	48	63
Application decision criteria:			
Previous problem/routine	92	98	92
Field mapping	14	29	15
Routine treatment	60	53	60
Type and density of weeds	65	78	66
Computer decision model	*	1	*
Crop consultant recommendation	21	13	21
Application methods:			
Broadcast[2]	43	71	45
In seed furrow[3]	2	4	2
In irrigation water	*	*	*
Banded[4]	40	9	38
Foliar or directed spray	15	16	15

[1] Regions: South— AR, GA, LA, MS, TN, TX; West— AZ, CA.

[2] Broadcast includes ground with and without incorporation and aerial broadcast.

[3] Includes in seed furrow and chisel/injected or knifed in.

[4] Banded in or over row.

* Less than 0.5 percent.

Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.10—Fall potatoes: Herbicide application timing, application decision criteria, and application methods, by region, 1996

Item	Region[1]			
	North-east	North Central	West	All fall potato States
	Percent of herbicide-treated acres			
Preemergence only				
Area treated	12	23	42	37
Application decision criteria:				
Previous problem/routine	100	100	94	96
Field mapping	7	0	16	14
Computer decision model	0	0	1	1
Crop consultant recommendation	19	0	29	26
Postemergence only				
Area treated	65	59	20	31
Application decision criteria:				
Routine treatment	97	60	79	79
Type and density of weeds	6	55	56	43
Computer decision model	0	1	0	*
Crop consultant recommendation	*	79	37	37
Pre- and postemergence				
Area treated	19	5	37	32
Application decision criteria:				
Previous problem/routine	82	83	96	96
Field mapping	8	0	7	7
Routine treatment	85	34	83	82
Type and density of weeds	15	79	90	85
Computer decision model	0	0	2	1
Crop consultant recommendation	0	55	20	19
Application methods:				
Broadcast[2]	3	98	43	46
In seed furrow[3]	2	0	24	20
In irrigation water	0	0	28	23
Banded[4]	0	1	*	*
Foliar or directed spray	94	1	4	11

[1] Regions: Northeast— ME; North Central— Red River Valley, part of MN and ND; West— ID, WA

[2] Broadcast includes ground with and without incorporation and aerial broadcast.

[3] Includes in seed furrow and chisel/injected or knifed in.

[4] Banded in or over row.

* Less than 0.5 percent.

Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.11—Winter wheat: Herbicide application timing, application decision criteria, and application methods, by region, 1996

Item	Region[1]				
	North-east	North Central	South	West	All winter wheat States
	Percent of herbicide-treated acres				
Preemergence only					
Area treated	22	12	17	3	9
Application decision criteria:					
Previous problem/routine	100	99	94	100	98
Field mapping	23	26	60	20	35
Computer decision model	0	0	0	0	0
Crop consultant recommendation	23	12	6	43	15
Postemergence only					
Area treated	51	73	76	88	80
Application decision criteria:					
Routine treatment	58	22	100	47	33
Type and density of weeds	37	87	44	81	77
Computer decision model	0	0	0	*	*
Crop consultant recommendation	5	19	45	15	21
Pre- and postemergence					
Area treated	9	13	4	9	11
Application decision criteria:					
Previous problem/routine	100	80	31	66	71
Field mapping	0	63	0	6	35
Routine treatment	100	87	45	54	71
Type and density of weeds	0	20	47	57	37
Computer decision model	0	0	0	0	0
Crop consultant recommendation	0	13	0	7	9
Application methods:					
Broadcast[2]	72	86	75	88	86
In seed furrow[3]	0	0	0	*	*
In irrigation water	0	0	0	*	*
Banded[4]	0	2	0	0	1
Foliar or directed spray	28	12	25	11	13

[1] Regions: Northeast— DE; North Central— KS, NE, SD; South— OK, TX; West— CO, ID, MT, OR, WA.

[2] Broadcast includes ground with and without incorporation and aerial broadcast.

[3] Includes in seed furrow and chisel/injected or knifed in.

[4] Banded in or over row.

* Less than 0.5 percent.

Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.12—Spring wheat: Herbicide application timing, application decision criteria, and application methods, by region, 1996

Item	Region[1]		
	North Central	West	All spring wheat States
	Percent of herbicide-treated acres		
Preemergence only			
Area treated	*	2	1
Application decision criteria:			
Previous problem/routine	100	100	100
Field mapping	0	71	69
Computer decision model	0	0	0
Crop consultant recommendation	0	23	22
Postemergence only			
Area treated	78	75	78
Application decision criteria:			
Routine treatment	53	69	56
Type and density of weeds	65	54	63
Computer decision model	0	0	0
Crop consultant recommendation	14	7	12
Pre- and postemergence			
Area treated	20	23	21
Application decision criteria:			
Previous problem/routine	88	93	89
Field mapping	7	0	6
Routine treatment	50	52	53
Type and density of weeds	60	59	60
Computer decision model	0	0	0
Crop consultant recommendation	22	0	16
Application methods:			
Broadcast[2]	80	100	84
In seed furrow[3]	2	0	2
In irrigation water	0	0	0
Banded[4]	0	0	0
Foliar or directed spray	17	0	14

[1] Regions: North Central— MN, ND; West— MT.
[2] Broadcast includes ground with and without incorporation and aerial broadcast.
[3] Includes in seed furrow and chisel/injected or knifed in.
[4] Banded in or over row.
* Less than 0.5 percent.

Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.13—Pest-resistant varieties used by field crop and region, 1996

Item	Region[1]				
	North-east	North Central	South	West	All States
	Percent of planted acres				
Corn					
Herbicide-resistant hybrid/variety	id	2	11		3
Bt variety for insect resistance	1	1	1		1
Gray-leaf-spot-resistant variety	20	2	2		2
Planted acres (1,000 acres)	1450	64000	4800		70250
Number of observations	93	3589	259		3941
Soybeans					
Herbicide-resistant hybrid/variety		7	10		7
Planted acres (1,000 acres)		43320	7650		50970
Number of observations		2259	590		2849
Cotton					
Herbicide-resistant hybrid/variety			id	id	id
Bt variety for insect resistance			15	7	15
Planted acres (1,000 acres)			10600	1315	11915
Number of observations			936	213	1149
Fall Potatoes					
Bt variety for insect resistance	7	0		1	1
Potato-scab-resistant variety	1	1		1	1
Planted acres (1,000 acres)	78	146		573	787

[1] Regions: Northeast— DE, ME, PA; North Central— IL, IN, IA, KS, MI, MN, MO, ND, NE, OH, SD, WI; South— AR, GA, LA, MS, KY, NC, SC, OK, TN, TX; West— AZ, CA, CO, ID, MT, OR, WA.

id= insufficient data for a statistically reliable estimate.

Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.14—Monitoring and other pest management practices for corn by region, 1996

Item	Region[1]			
	North-east	North Central	South	All corn States
	Percent of planted acres			
Monitoring				
Used soil biological testing to detect insects, diseases, or nematodes	*	2	4	2
Scouted and kept written/electronic records on black cutworms	5	12	10	11
Scouted and kept written/electronic records on corn rootworms	9	15	10	14
Scouted and kept written/electronic records on European corn borers	7	19	8	18
Scouted and kept written/electronic records on spider mites	1	8	6	8
Scouted for adult corn rootworm beetles during 1995 season	11	14	16	14
Scouted for adult corn rootworm beetles during 1996 season	8	7	4	7
Used pheromone lures to monitor black cutworm	0	1	1	1
Used pre-plant grain traps to monitor wireworms	0	*	1	*
Submitted diseased plants to a lab for diagnosis	*	2	2	1
Other practices				
Considered beneficial insects in selecting and using pesticides	10	8	12	8
Removed weeds to prevent insect egg laying	22	9	11	10
Used seed treatments for seedling blight	19	11	25	12
Routinely used soil insecticide at planting to control corn rootworm	52	23	30	24
Weed resistance				
Weeds resistant to the triazine family of herbicides	40	10	16	11
Weeds resistant to ALS (sulphonylurea or imidazolinone families)	1	5	2	4
	Percent of insecticide-treated acres			
Biological practices				
Purchased and released beneficial insects	0	*	0	*
Used Bacillus thuringiensis (Bt)	0	2.5	2.3	2.4
Planted acres (1,000 acres)	1,450	6,4000	4,800	7,0250

[1] Regions: Northeast— PA; North Central— IL, IN, IA, KS, MI, MN, MO, NE, OH, SD, WI; South— KY, NC, SC, TX.
* Less than 0.5 percent.
Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.15—Primary source of pest management information for corn growers by region, 1996

Item	Region[1]			
	North-east	North Central	South	All corn States
	Percent of planted acres			
Extension advisors, and commercial scouting service, and crop consultants	40	22	22	21
Farm supply/chemical dealer	52	70	63	69
Other growers and producer associations, newsletters, or trade magazines	5	3	9	5
Media or other information sources (World Wide Web, DTN, etc.)	*	2	1	2
None	2	3	5	3
Planted acres (1,000 acres)	1450	64000	4800	70250

[1] Regions: Northeast— PA; North Central— IL, IN, IA, KS, MI, MN, MO, NE, OH, SD, WI; South— KY, NC, SC, TX.
* Less than 0.5 percent.
Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.16—Soybean: Insecticide decision criteria and primary source of pest management information, by region, 1996

Item	Region[1]		
	North Central	South	All soybean States
	Percent of planted acres		
Compared scouted data to university or Extension guidelines for infestation thresholds	10	15	11
Used standard practice or history of insect problems	32	20	30
Used local information (other farmers, radio TV, etc.) that the pest was or was not present	13	6	12
Used the operator's own determination of the pest infestation level	54	56	54
Pest management information sources:			
Extension advisors, and commercial scouting service, and crop consultants	12	28	14
Farm supply/chemical dealer	79	44	74
Other growers and producer associations, newsletters or trade magazines	3	2	3
Media or other information sources (World Wide Web, DTN, etc.)	2	7	3
None	4	19	6
Planted acres (1,000 acres)	42,320	7,650	50,970

[1] Regions: North Central— IL, IN, IA, MN, MO, NE, OH, WI; South— AR, LA, MS, TN.
Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.17—Cotton: Insecticide decision criteria and primary source of pest management information, by region, 1996

Item	Region[1]		
	South	West	All cotton States
	Percent of planted acres		
Compared scouted data to university or Extension guidelines for infestation thresholds	43	59	46
Used standard practice or history of insect problems	19	45	22
Used local information (other farmers, radio TV, etc.) that the pest was or was not present	6	15	7
Used the operator's own determination of the pest infestation level	56	44	55
Pest management information sources:			
Extension advisors, and commercial scouting service, and crop consultants	63	52	62
Farm supply/chemical dealer	20	40	22
Other growers and producer associations, newsletters or trade magazines	5	1	5
Media or other information sources (World Wide Web, DTN, etc.)	4	5	4
None	8	2	7
Planted acres (1,000 acres)	10,600	1,315	11,915

[1] Regions: South— AR, GA, LA, MS, TN, TX; West— AZ, CA.
Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.18—Fall potatoes: Insecticide decision criteria and primary source of pest management information, by region, 1996

Item	Region[1]			
	North-east	North Central	West	All fall potato States
	Percent of planted acres			
Compared scouted data to university or Extension guidelines for infestation thresholds	15	39	22	24
Used standard practice or history of insect problems	6	62	60	55
Used local information (other farmers, radio TV, etc.) that the pest was or was not present	3	29	19	20
Used the operator's own determination of the pest infestation level	87	82	83	83
Pest management information sources:				
Extension advisors, and commercial scouting service, and crop consultants	31	49	40	40
Farm supply/chemical dealer	67	35	57	54
Other growers and producer associations, newsletters or trade magazines	0	13	2	4
Media or other information sources (World Wide Web, DTN, etc.)	1	2	*	1
None	1	*	1	1
Planted acres (1,000 acres)	78	146	573	787

[1] Regions: Northeast— ME; North Central— Red River Valley, part of MN and ND; West— ID, WA
* Less than 0.5 percent.
Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.19—Winter wheat: Insecticide decision criteria and primary source of pest management information, by region, 1996

Item	Region[1] North-east	North Central	South	West	All winter wheat States
	Percent of planted acres				
Compared scouted data to university or Extension guidelines for infestation thresholds	14	14	6	15	12
Used standard practice or history of insect problems	7	24	8	26	20
Used local information (other farmers, radio TV, etc.) that the pest was or was not present	4	10	4	14	9
Used the operator's own determination of the pest infestation level	70	63	83	65	69
Pest management information sources:					
Extension advisors, and commercial scouting service, and crop consultants	19	27	20	20	24
Farm supply/chemical dealer	49	41	28	57	42
Other growers and producer associations-newsletters or trade magazines	2	12	26	6	13
Media or other information sources (World Wide Web, DTN, etc.)	1	5	6	3	5
None	29	15	20	14	16
Planted acres (1,000 acres)	78	12,480	7,800	8,240	28,598

[1] Regions: Northeast— DE; North Central— KS, NE, SD; South— OK, TX; West— CO, ID, MT, OR, WA.
Source: NASS/ERS 1996 ARMS survey.

Appendix table 2.20—-Spring wheat: Insecticide decision criteria and primary source of pest management information, by region, 1996

Item	Region[1]		
	North Central	West	All spring wheat States
	Percent of planted acres		
Compared scouted data to university or Extension guidelines for infestation thresholds	17	38	23
Used standard practice or history of insect problems	29	27	29
Used local information (other farmers, radio TV, etc.) that the pest was or was not present	11	9	11
Used the operator's own determination of the pest infestation level	63	71	65
Pest management information sources:			
Extension advisors, and commercial scouting service, and crop consultants	22	20	21
Farm supply/chemical dealer	52	55	52
Other growers and producer associations-newsletters or trade magazines	7	5	7
Media or other information sources (World Wide Web, DTN, etc.)	9	0	7
None	10	20	13
Planted acres (1,000 acres)	12,150	4,200	16,350

[1] Regions: North Central—MN, ND; West—MT.
Source: NASS/ERS 1996 ARMS survey.

Appendix III—Tables on Pesticide Use by Crop and Active Ingredient

Appendix table 3.1—Pesticide use by State, corn 1996

State	Planted acreage	Percent of acres treated and total applied							
		Herbicide		Insecticide[1]		Fungicide		Other chemical	
	1,000 acres	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*
Illinois	11,000	99	34,223	27	2,143				
Indiana	5,600	98	18,856	35	1,466				
Iowa	12,700	99	36,109	17	1,779				
Kansas	2,500	94	5,784	40	515				
Kentucky	1,300	99	4,159	24	43				
Mississippi	2,650	98	7,250	21	318				
Minnesota	7,500	97	17,819	13	614				
Missouri	2,750	98	7,547	27	492				
Nebraska	8,500	98	19,817	51	3,068				
North Carolina	1,000	97	2,565	37	376				
Ohio	2,900	100	10,029	28	591				
Pennsylvania	1,450	98	4,371	54	419				
South Carolina	400	98	1,017	26	84				
South Dakota	4,000	91	7,091	25	422				
Texas	2,100	91	2,770	74	712				
Wisconsin	3,900	93	7,570	37	1,176				
Total	70,250	97	186,977	30	14,218				

[1] Total applied excludes Bt's (Bacillus thuringiensis) because amounts of active ingredient are not comparable between products.

Source: USDA, 1997d.

Appendix table 3.2—Pesticide applications for States surveyed, corn 1996

Agricultural chemical	Area applied	Appli-cations	Rate per application	Rate per crop year	Total applied
	Percent	*Number*	*-Pounds per acre-*		*1,000 lbs*
Herbicides:					
2,4-D	11	1.0	0.39	0.40	3,237
Acetochlor	22	1.0	1.88	1.89	29,850
Alachlor	9	1.0	1.64	1.65	10,188
Atrazine	71	1.1	0.99	1.07	53,466
Bentazon	3	1.0	0.40	0.41	806
Bromoxynil	7	1.0	0.26	0.26	1,345
Butylate	1	1.0	4.63	4.63	2,475
Clopyralid	*	1.0	0.10	0.10	29
Cyanazine	13	1.0	2.20	2.28	20,795
Dicamba	25	1.0	0.32	0.32	5,545
Dimethenamid	6	1.0	1.04	1.05	4,110
EPTC	2	1.0	3.81	3.81	5,117
Flumetsulam	1	1.0	0.05	0.05	49
Glyphosate	4	1.0	0.68	0.71	2,200
Halosulfuron	2	1.0	0.04	0.04	46
Imazethapyr	1	1.0	0.05	0.05	20
Metolachlor	30	1.0	1.89	1.92	41,135
Metribuzin	1	1.0	0.10	0.10	38
Nicosulfuron	12	1.0	0.03	0.03	245
Paraquat	2	1.0	0.54	0.56	637
Pendimethalin	3	1.0	1.11	1.12	2,631
Primisulfuron	7	1.0	0.02	0.02	106
Propachlor	*	1.0	2.73	2.73	337
Prosulfuron	5	1.0	0.02	0.02	59
Rimsulfuron	1	1.0	0.01	0.01	6
Simazine	2	1.0	1.31	1.31	2,059
Thifensulfuron	1	1.0	0.005	0.005	3
Insecticides:					
Bifenthrin	1	1.0	0.05	0.05	45
Bt (Bacillus thur.)	1	1.0			
Carbofuran	1	1.0	0.94	0.94	727
Chlorpyrifos	8	1.0	1.04	1.05	5,877
Cyfluthrin	1	1.0	0.007	0.007	4
Dimethoate	*	1.0	0.46	0.46	127
Esfenvalerate	1	1.0	0.03	0.03	11
Fonofos	1	1.0	1.07	1.07	619
Lambdacyhalothrin	2	1.0	0.02	0.02	25
Methyl parathion	2	1.2	0.43	0.51	704
Permethrin	4	1.0	0.12	0.12	324
Phorate	1	1.0	1.11	1.11	636
Phostebupirim	1	1.0	0.13	0.13	72
Tefluthrin	5	1.0	0.09	0.09	321
Terbufos	6	1.0	1.09	1.09	4,516

* Area applied is less than 1 percent.

Source: USDA, 1997d.

Appendix table 3.3—Pesticide use by State, soybeans 1996

State	Planted acreage	Percent of acres treated and total applied							
		Herbicide		Insecticide		Fungicide		Other chemical	
	1,000 acres	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*
Arkansas[1]	3,550	92	4,491						
Illinois	9,900	97	10,670						
Indiana[1]	5,400	97	5,845						
Iowa[1]	9,500	99	10,821						
Louisiana[1]	1,100	94	1,645	32	161				
Minnesota	5,950	98	7,826						
Mississippi[1]	1,800	99	2,287						
Missouri[1]	4,100	98	5,373						
Nebraska[1]	3,050	99	3,459						
Ohio[1]	4,500	98	5,692						
Tennessee[1]	1,200	100	1,770						
Wisconsin[1]	920	99	750						
Total[1]	50,970	97	60,629	1	273				

[1] Insufficient reports to publish data for one or more of the pesticide classes.

Source: USDA, 1997d.

Appendix table 3.4—Pesticide applications, soybeans 1996

Agricultural chemical	Area applied	Appli-cations	Rate per application	Rate per crop year	Total applied
	Percent	*Number*	*-Pounds per acre-*		*1,000 lbs*
Herbicides:					
2,4-D	13	1.0	0.44	0.44	2,802
2,4-DB	*	1.0	0.11	0.11	24
Acifluorfen	11	1.0	0.23	0.24	1,346
Alachlor	5	1.0	2.17	2.17	5,036
Bentazon	11	1.1	0.72	0.80	4,562
Chlorimuron-ethyl	14	1.0	0.02	0.02	143
Clethodim	7	1.0	0.12	0.12	398
Clomazone	3	1.0	0.62	0.62	928
Dimethenamid	1	1.0	0.86	0.86	320
Ethalfluralin	1	1.0	0.59	0.59	215
Fenoxaprop	4	1.0	0.13	0.13	246
Fluazifop-P-butyl	7	1.0	0.09	0.09	342
Flumetsulam	2	1.0	0.06	0.06	54
Flumiclorac Pentyl	2	1.0	0.03	0.03	24
Fomesafen	5	1.0	0.28	0.28	716
Glyphosate	25	1.1	0.63	0.69	8,687
Imazaquin	15	1.0	0.09	0.09	688
Imazethapyr	43	1.0	0.06	0.06	1,229
Lactofen	8	1.0	0.08	0.08	355
Linuron	1	1.0	0.53	0.53	225
Metolachlor	5	1.0	1.78	1.78	4,221
Metribuzin	9	1.1	0.29	0.30	1,460
Paraquat	1	1.0	0.56	0.58	340
Pendimethalin	27	1.0	0.97	1.01	13,810
Quizalofop-ethyl	7	1.0	0.05	0.05	190
Sethoxydim	9	1.0	0.26	0.26	1,158
Thifensulfuron	10	1.0	0.003	0.003	15
Trifluralin	22	1.0	0.88	0.88	10,008
Insecticides:					
Methyl parathion	1	1.2	0.42	0.50	192

* Area applied is less than 1 percent.
Source: USDA, 1997d.

Appendix table 3.5—Pesticide use by State, upland cotton 1996

State	Planted acreage	Percent of acres treated and total applied							
		Herbicide		Insecticide[1]		Fungicide		Other chemical	
	1,000 acres	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*
Arizona	315	75	357	89	1,029		71	1,703	
Arkansas	1,000	99	2,750	93	1,303	28	157	91	1,206
California	1,000	90	1,856	97	2,031		95	5,180	
Georgia	1,350	100	4,079	73	633		48	1,234	
Louisiana	890	81	1,957	97	1,486	17	89	69	546
Mississippi	1,120	99	3,981	95	2,417	7	45	99	2,541
Tennessee	540	100	1,889	89	505	33	97	87	732
Texas	5,700	90	5,692	68	5,832		39	2,064	
Total	11,915	92	22,561	79	15,236	6	397	60	15,206

[1] Total applied excludes Bt's (Bacillus thuringiensis) because amounts of Bt active ingredient are not comparable between products.

Source: USDA, 1997d.

Appendix table 3.6—Pesticide applications, upland cotton 1996

Agricultural chemical	Area Applied	Appli-cations	Rate per application	Rate per crop year	Total applied
	Percent	*Number*	*Pounds per acre*		*1,000 lbs*
Herbicides:					
Clethodim	2	1.2	0.10	0.12	31
Clomazone	8	1.0	0.39	0.39	362
Cyanazine	20	1.2	0.76	0.89	2,106
DSMA	2	1.1	1.51	1.61	447
Diuron	16	1.1	0.51	0.56	1,091
Fluazifop-P-butyl	2	1.1	0.13	0.14	42
Fluometuron	39	1.2	0.58	0.72	3,304
Glyphosate	13	1.0	0.63	0.66	991
Lactofen	1	1.2	0.11	0.13	17
MSMA	24	1.5	0.90	1.34	3,819
Metolachlor	5	1.0	1.08	1.08	701
Norflurazon	13	1.1	0.57	0.61	934
Oxyfluorfen	3	1.0	0.26	0.26	82
Pendimethalin	22	1.1	0.71	0.76	2,010
Prometryn	16	1.1	0.51	0.58	1,133
Pyrithiobac-sodium	10	1.0	0.04	0.05	56
Quizalofop-ethyl	1	1.2	0.06	0.07	9
Sethoxydim	1	1.0	0.23	0.23	31
Trifluralin	57	1.0	0.74	0.76	5,233
Insecticides:					
Abamectin	5	1.1	0.007	0.008	5
Acephate	12	1.6	0.38	0.59	828
Aldicarb	21	1.0	0.62	0.63	1,596
Amitraz	2	1.4	0.18	0.26	58
Azinphos-methyl	6	1.9	0.23	0.44	315
Bifenthrin	1	1.0	0.06	0.06	5
Bt (Bacillus thur.)	3	2.2			
Buprofezin	*	1.0	0.35	0.35	17
Carbofuran	6	1.0	0.29	0.29	207
Chlorpyrifos	5	1.6	0.66	1.07	641
Cyfluthrin	11	2.0	0.03	0.06	82
Cypermethrin	9	1.7	0.07	0.12	132
Deltamethrin	1	1.6	0.003	0.005	1
Dicofol	4	1.1	1.01	1.09	470
Dicrotophos	11	1.3	0.25	0.33	433
Insecticides (cont.):					
Dimethoate	3	1.4	0.20	0.29	111
Disulfoton	5	1.0	0.71	0.71	441
Endosulfan	3	1.5	0.60	0.90	283
Esfenvalerate	7	1.4	0.03	0.05	36
Imidacloprid	7	1.3	0.04	0.05	38
Lambda-cyhalothrin	16	2.1	0.03	0.06	121
Malathion	17	2.3	0.89	2.07	4,310
Methomyl	2	1.4	0.36	0.49	127
Methyl parathion	19	3.2	0.36	1.16	2,560
Oxamyl	13	1.5	0.23	0.35	529
Permethrin	1	1.3	0.08	0.10	10
Phorate	4	1.0	0.77	0.77	392
Profenofos	5	1.6	0.46	0.75	413
Propargite	2	1.0	1.14	1.15	339
Pyriproxyfen	1	1.2	0.06	0.07	9
Thiodicarb	5	1.6	0.33	0.54	349
Tralomethrin	3	1.8	0.02	0.04	15
Zeta-cypermethrin	4	1.6	0.04	0.06	34
Fungicides:					
Etridiazole	2	1.0	0.16	0.17	39
Metalaxyl	3	1.0	0.09	0.09	26
PCNB	4	1.0	0.62	0.63	279
Other chemicals:					
Cacodylic acid	2	1.1	0.70	0.79	183
Dimethipin	1	1.0	0.27	0.27	36
Ethephon	32	1.1	1.03	1.11	4,208
Mepiquat chloride	17	1.8	0.02	0.03	64
Paraquat	17	1.1	0.28	0.32	655
Sodium chlorate	10	1.2	3.07	3.62	4,107
Thidiazuron	23	1.1	0.13	0.15	394
Tribufos	38	1.1	0.82	0.88	3,963

Source: USDA, 1997d.

Appendix table 3.7—Pesticide use by State, fall potatoes, 1996

State	Planted acreage	Area receiving and total applied							
		Herbicide		Insecticide		Fungicide		Other chemical	
	1,000 acres	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*
Idaho	410	90	1,131	73	649	85	1,089	39	30,529
Maine	78	98	49	90	46	100	737	98	580
Washington	163	93	322	94	485	85	986	72	12,064
Red River Valley[1]	146	64	75	97	190	100	1,117	64	696
Total	797	87	1,577	83	1,370	89	3,929	56	43,869

[1] Red River Valley includes the counties of Clay, Clearwater, Kittson, Mahnomen, Marshall, Norman, Pennington, Polk, Red Lake, Roseau, and Wilkin in Minnesota; and Cass, Grand Forks, Pembina, Richland, Steele, Traill, and Walsh in North Dakota.

Source: USDA, 1997d.

Appendix table 3.8—Pesticide applications, fall potatoes 1996

Agricultural chemical	Area applied	Appli-cations	Rate per application	Rate per crop year	Total applied
	Percent	*Number*	*-Pounds per acre-*		*1,000 lbs*
Herbicides:					
EPTC	37	1.0	3.78	3.91	1,156
Glyphosate	1	1.0	0.70	0.74	3
Linuron	2	1.0	0.68	0.68	8
Metolachlor	3	1.0	2.53	2.53	55
Metribuzin	64	1.0	0.45	0.45	229
Pendimethalin	18	1.0	0.68	0.68	99
Rimsulfuron	11	1.0	0.02	0.02	2
Sethoxydim	2	1.1	0.16	0.16	3
Trifluralin	6	1.0	0.43	0.43	20
Insecticides:					
Aldicarb	4	1.0	2.82	2.82	93
Azinphos-methyl	9	1.2	0.34	0.42	29
Carbaryl	2	1.1	0.99	1.09	19
Carbofuran	31	1.3	0.69	0.87	214
Dimethoate	1	1.2	0.47	0.56	6
Endosulfan	10	1.2	0.65	0.78	62
Esfenvalerate	7	1.1	0.03	0.04	2
Ethoprop	4	1.0	4.62	4.62	142
Fonofos	4	1.0	2.29	2.29	77
Imidacloprid	9	1.0	0.13	0.13	10
Methamidophos	29	1.4	0.86	1.19	272
Permethrin	7	1.7	0.12	0.20	11
Phorate	16	1.0	2.67	2.67	339
Propargite	3	1.1	1.74	1.84	46
Fungicides:					
Chlorothalonil	78	4.1	0.82	3.35	2,079
Copper ammonium	1	4.5	0.35	1.59	17
Copper hydroxide	13	1.7	0.80	1.36	140
Cymoxanil	1	1.7	0.12	0.20	2
Iprodione	7	1.1	1.00	1.07	57
Mancozeb	36	2.5	1.16	2.87	814
Maneb	9	3.5	1.00	3.54	251
Metalaxyl	26	1.6	0.18	0.28	58
Metiram	5	3.0	1.49	4.53	196
Propamocarb hydroch.	4	1.1	0.75	0.84	29
Sulfur	2	3.1	4.71	14.41	239
Triphenyltin hydrox.	8	2.3	0.15	0.35	22
Other chemicals:					
Dichloropropene	6	1.0	178.03	178.03	8,635
Diquat	33	1.6	0.30	0.47	124
Maleic hydrazide	6	1.0	1.98	1.98	93
Metam-sodium	11	1.0	116.19	119.09	10,888
Sulfuric acid	9	1.0	333.51	340.00	23,664

Source: USDA, 1997d.

Appendix table 3.9—Pesticide use by State, winter wheat 1996

State	Harvested acreage	Percent of acres treated and total applied							
		Herbicide		Insecticide[1]		Fungicide		Other chemical	
	1,000 acres	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*
Colorado	2,200	61	756	11	139				
Idaho	860	80	433						
Kansas	8,800	47	1,304	7	212				
Montana	1,980	93	1,385						
Nebraska	2,100	61	332						
Oklahoma	4,900	35	655	27	391				
Oregon	850	99	503			8	21		
South Dakota	1,580	65	390						
Texas	2,900	27	319	38	447				
Washington	2,350	96	1,304			8	43		
Total	28,520	56	7,381	12	1,214	1	101		

[1] Total applied excludes Bt's (Bacillus thuringiensis) because amounts of Bt active ingredient are not comparable between products.

Source: USDA, 1997d.

Appendix table 3.10—Pesticide applications, winter wheat 1996

Agricultural chemical	Area applied	Appli-cations	Rate per application	Rate per crop year	Total applied
	Percent	*Number*	*-Pounds per acre-*		*1,000 lbs*
Herbicides:					
2,4-D	33	1.0	0.43	0.45	4,262
Atrazine	1	1.0	0.68	0.68	157
Bromoxynil	7	1.0	0.24	0.24	477
Chlorsulfuron	8	1.0	0.01	0.01	24
Dicamba	9	1.1	0.08	0.09	233
Diclofop-methyl	0	1.0	0.94	0.94	45
Diuron	0	1.0	0.93	0.93	45
Glyphosate	7	1.1	0.37	0.42	856
Imazamethabenz	1	1.0	0.28	0.28	58
MCPA	9	1.0	0.31	0.31	778
Metribuzin	1	1.0	0.17	0.17	58
Metsulfuron-methyl	22	1.0	0.003	0.003	20
Thifensulfuron	4	1.0	0.01	0.01	13
Triallate	1	1.0	1.42	1.42	252
Triasulfuron	7	1.0	0.02	0.02	32
Tribenuron-methyl	5	1.0	0.006	0.006	9
Insecticides:					
Chlorpyrifos	1	1.0	0.43	0.43	65
Dimethoate	6	1.0	0.23	0.23	374
Methyl parathion	5	1.0	0.46	0.47	684
Fungicides:					
Propiconazole	1	1.0	0.16	0.16	36

Source: USDA, 1997d.

Appendix table 3.11—Pesticide use by State, durum and other spring wheat, 1996

State	Planted acreage	Area receiving and total applied							
		Herbicide		Insecticide		Fungicide		Other chemical	
	1,000 acres	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*	*Percent*	*1,000 lbs*
Durum									
North Dakota	3,000	98	2,087						
Spring									
Minnesota	2,550	96	1,547						
Montana	4,200	76	2,122						
North Dakota	9,600	92	6,170						
Total	16,350	88	9,839	3	216				

Source: USDA, 1997d.

Appendix table 3.12a—Pesticide applications, durum wheat, North Dakota, 1996

Herbicide	Area applied	Appli-cations	Rate per application	Rate per crop year	Total applied
	Percent	*Number*	*-Pounds per acre-*		*1,000 lbs*
2,4-D	71	1.0	0.36	0.36	772
Dicamba	43	1.1	0.07	0.08	100
MCPA	25	1.0	0.34	0.35	265
Triallate	14	1.0	0.94	0.94	394
Triasulfuron	12	1.0	0.02	0.02	7
Tribenuron-methyl	20	1.0	0.01	0.01	6
Trifluralin	40	1.0	0.34	0.34	410

Source: USDA, 1997d.

Appendix table 3.12b—Pesticide applications, other spring wheat 1996

Herbicide	Area applied	Appli-cations	Rate per application	Rate per crop year	Total applied
	Percent	*Number*	*-Pounds per acre-*		*1,000 lbs*
2,4-D	50	1.0	0.34	0.34	2,797
Bromoxynil	14	1.0	0.26	0.27	597
Dicamba	28	1.1	0.08	0.08	376
Fenoxaprop	17	1.0	0.07	0.07	196
Glyphosate	10	1.0	0.34	0.35	565
Imazamethabenz	6	1.0	0.36	0.36	333
MCPA	38	1.1	0.34	0.36	2,225
Metsulfuron-methyl	4	1.0	0.003	0.003	2
Thifensulfuron	14	1.0	0.009	0.01	22
Triallate	11	1.0	1.04	1.04	1,804
Triasulfuron	2	1.0	0.009	0.009	4
Tribenuron-methyl	22	1.1	0.006	0.006	22
Trifluralin	11	1.0	0.34	0.34	603

Source: USDA, 1997d.

Appendix IV—Pest Management Questions from the 1996 ARMS Survey - Corn

Section D - Field Characteristics

9. Was one of these pest resistant varieties of seed used in this field--
[*Show respondent Seed Variety Code List in Respondent Booklet. Choose one and enter code.*]

1	**an herbicide resistant hybrid or variety** (*such as Pioneer 3162R, Beck's 6868IRT*)**?**
2	**a Bt variety for insect resistance,** (*such as Nature Guard or Maximizer with Knockout*)**?**
3	**a gray leaf spot resistant variety?**
5	**none of these?**

. . . . **CODE** [ ]

Section F - Pesticide Applications

1. Were any herbicides, insecticides, fungicides or other chemicals used on this field for the 1996 corn crop?

   ☐ **YES** - [*Continue.*]   ☐ **NO** - [*Go to Section G.*] . . . .

2. What products were applied to this field?

3. Was this product bought in liquid or dry form?

4. Was this part of a tank mix?

5. When was this applied?

6. How much was applied per acre per application?

   OR

7. What was the total amount applied per application in this field?

8. *[Enter unit code.]*

9. How was this product applied?

[*Choose one and enter code.*]

- ☐ **1 Broadcast, ground without incorporation**
- ☐ **2 Broadcast, ground with incorporation**
- ☐ **3 Broadcast, by air**
- ☐ **4 In Seed Furrow**
- ☐ **5 In irrigation water**
- ☐ **6 Chisel/Injection or knifed in**
- ☐ **7 Banded in or Over Row**
- ☐ **8 Foliar or Directed spray**
- ☐ **9 Spot treatments**

CODE ....

10. How many acres in this field were treated with this product?

11. Were these applications made by--
    1. *Operator, Partner, Family member?*
    2. *Custom applicator?*
    3. *Employee/Other?*

12. What was the PRIMARY target pest for this application?

Section G - Pest Management Practices

1. Now I have some questions about your pest management decisions and practices used on this field for the 1996 corn crop. **By pests, we mean WEEDS, INSECTS and DISEASES.**

2. Let's begin with questions about scouting this field for pests.

1	2 **Was the corn field scouted for--** [*column 1*] **YES=1**	3 [*For rows with* **YES =1**, *ask--*] **Was most of the scouting for** [*column 1*] **done by--** 1 Operator, Partner or Family member? 2 an Employee? 3 Farm supply or Chemical dealer? 4 Crop consultant or Commercial scout? **CODE**
a. weeds		
b. insects		
c. diseases		

5. [*Ask only if field was SCOUTED (column 2 of item 2 is code 1); else go to item 6.*]
Were written or electronic records kept for this field to track the **activity or numbers** of--

a.	broadleaf weeds?	**YES = 1**	
b.	grass weeds?	**YES = 1**	
d.	black cutworms?	**YES = 1**	
e.	corn rootworms?	**YES = 1**	
f.	European corn borers?	**YES = 1**	
g.	spider mites?	**YES = 1**	

6. [*Ask only if HERBICIDES (pesticide codes 4000 - 4999) were entered in Section* **F**, *item 1 column 2; else go to item 11.*]
Did you apply herbicides to this field BEFORE weeds emerged?

☐ **YES** - [*Enter code 1 and continue.*] ☐ **NO** - [*Go to item 8.*] **CODE** ☐

7. Did you decide to use **pre-emergence** herbicides based on--

a. a routine treatment for weed problems experienced in previous years? . . . . **YES = 1** ☐

b. field mapping of previous weed problems? . . . . **YES = 1** ☐

c. a computerized decision model? . . . . **YES = 1** ☐

d. recommendations from an independent crop consultant? . . . . . . **YES = 1** ☐

8. Did you apply herbicides to this field AFTER weeds emerged?

☐ **YES** - [*Enter code 1 and continue.*] ☐ **NO** - [*Go to item*

9. Did you decide to use **post-emergence** herbicides based on--

a. a routine treatment? . . . . **YES = 1** ☐

b. type and/or density of weed(s) present? . . . . **YES = 1** ☐

c. a computerized decision model? . . . . **YES = 1** ☐

d. recommendations from an independent crop consultant? . . . . **YES = 1** ☐

10. Were any weeds on this field resistant to--

a. Atrazine, Aatrex, Bladex, Extrazine, Princep, Simazine or other **TRIAZINE** family herbicides? . . . . **YES = 1** ☐

b. Account, Beacon, Classic, Pinnacle, Pursuit, Septer or other **ALS** family herbicides? . . . . **YES = 1** ☐

11. Do you routinely use a soil insecticide at planting time to control corn rootworm on this field?

☐ **YES** - [*Enter code 1 and go to item 14.*] ☐ **NO** - [*Continue.*] . . . .

a. Did you scout this field for adult corn rootworm beetles during the 1995 growing season to determine the need for a soil insecticide at planting?

☐ **YES** - [*Enter code 1 and go to item 14.*] ☐ **NO** - [*Continue.*] . . . . .

b. Did you scout for adult corn rootworm beetles during the 1996 growing season to determine the need for a soil insecticide?

☐ **YES** - [*Enter code 1 and continue.*] ☐ **NO** - [*Continue.*]

14.

	1	2	3
	Did you--	➜ YES=1	[*If YES = 1 in column 2, ask--*] **Was your main reason for doing this to control--** **1 WEEDS 2 INSECTS 3 BOTH** CODE
a.	control pests on this field by adjusting row spacing or plant density?		
b.	reduce (or control) pests by adjusting planting dates on this field?		
c.	control pest resistance by alternating pesticides on this field from year to year? (*Use pesticides from different families.*)		
d.	keep pests from spreading into this field by using practices such as tilling, mowing, burning, and/or chopping of field edges, lanes or roadways?		
e.	control pests on this field by using water management practices, such as controlled drainage or irrigation scheduling? [***Exclude** chemigation.*]		
f.	reduce the spread of pests to or from this field by cleaning the harvesting and tillage implements?		

16. Did you--

			CODE
a.	have a biological soil analysis done on this field to detect the presence of soil pests, such as insects, diseases or nematodes?	YES = 1	
b.	consider beneficial insects in selecting and using pesticides on this field?	YES = 1	
c.	remove weeds in infested areas in this field to prevent insect egg laying?	YES = 1	
d.	use seed treatments for seedling blight control?	YES = 1	
e.	submit diseased plants from this field to a lab for diagnosis? .	YES = 1	

17. Did you--

a.	purchase and release beneficial insects in this field?	YES = 1	
b.	use pheromone lures in this field to monitor for black cutworm? [***Include** traps and bait sticks.*]	YES = 1	
c.	set and monitor pre-plant grain traps for wireworms?	YES = 1	

19. What was your primary outside source of information on pest management recommendations for the 1996 corn crop?
[*Ask the respondent to look at Pest Management Information Sources Code List in Respondent Booklet. Choose one and enter code.*]

PEST MANAGEMENT INFORMATION SOURCES CODE LIST

- ☐ 1 **Extension Advisor, Publications or Demonstrations** (County, Cooperative or University)
- ☐ 2 **Farm Supply or Chemical Dealer**
- ☐ 3 **Commercial Scouting Service**
- ☐ 4 **Crop Consultant or Pest Control Advisor**
- ☐ 5 **Other Growers or Producers**
- ☐ 6 **Producer Associations, Newsletters or Trade Magazines**
- ☐ 7 **Television or Radio Programs, Newspapers**
- ☐ 8 **Electronic Information Services** (*World Wide Web, DTN, etc.*)
- ☐ 9 **Other**
- ☐ 10 **None**

. . . . **CODE** [ ]

Section G - Pest Management Practices - for soybeans, cotton, fall potatoes, winter wheat, spring wheat, and durum wheat.

12. Did you decide **to apply OR not apply** insecticides to the soybean field based on--

a. scouting data compared to University or Extension guilelines for infestation thresholds? . . . . **YES = 1** [ ]

b. standard practices or history of insect problems? . . . . **YES = 1** [ ]

c. local information (*from other farmers, radio, TV, newsletters, etc.)* that the pest was or was not present? . . . . **YES = 1** [ ]

d. your (the operator's) own determination of the infestation level? . . . . **YES = 1** [ ]