

Chapter 28

ENVIRONMENTAL ISSUES

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INTRODUCTION

In the 1970s cotton growers made certain adjustments in their farming practices because of decisions handed down by the administrator of the United States Environmental Protection Agency (EPA). The most comprehensive adjustments were those associated with agricultural pest control operations. These adjustments eventually resulted in a decrease in the total amount of chlorinated hydrocarbon pesticides released into our environment. During the intervening years, agricultural regulators also implemented numerous agricultural worker and consumer safety protocols. However, as with most agricultural commodity producers, cotton growers continue to rely on pesticides to a greater or lesser extent depending on geographic location and current site-specific pest management practices. In addition, our current knowledge and research progress suggest that the present methods of cotton crop protection will continue to be based largely on synthetic organic pesticides through the remainder of the 20th Century. And, since the utilization of crop protection materials exposes both man and the environment to the hazards associated with pesticides, agriculture will remain under scrutiny as a non-point source of probable pesticide pollution.

The pesticide group of greatest concern with respect to worker safety is the organophosphates, but environmental concerns have shifted focus from the persistent chlorinated hydrocarbons to the soil-applied pesticides as potential groundwater contaminants. Current issues include the potential environmental and health impacts surrounding pesticide use patterns, groundwater protection, pest resistance and risk significance. These issues and some problems surrounding them will be discussed in this paper, but the issue of groundwater protection will be the first priority of federal and state authorities for the foreseeable future.

PESTICIDE USE PATTERNS

In the 14 major cotton-producing states, there are about a dozen arthropod pests that are of economic concern. Those that attack the squares and bolls are considered the most damaging, although leaf feeders can reduce yield if they destroy too much foliage. Seedling pests can make it necessary to replant parts of a field, while whiteflies and aphids are more apt to reduce lint grade than yields. Some pests such as the boll weevil, *Anthonomus grandis grandis* (Boheman), potentially are present in all the

cotton-producing states. A few pests are relatively new and/or are of concern to certain geographic areas, such as thrips, or in North Carolina, the European corn borer, *Ostrinia nubilalis* (Hübner) (King *et al.*, 1986). The choice of control material for these pests has included just about every major family of insecticides ever developed. Some of the first pest control attempts were with calcium arsenate. Later the chlorinated hydrocarbons were utilized, followed by organophosphates, carbamates, formamidines and now the pyrethroids. Bottrell and Adkisson (1977) have summarized the historical pesticide use patterns of insect pest control in cotton that may have created our present day environmental concerns.

Doutt and Smith (1971) describe the development in the late 1940s of a new philosophy towards pest control, that of expediency. Up until the 1940s, field observations of organismal interaction led to tremendous amounts of energy being directed towards biological and cultural control of crop pests. Then, in the late 1940s, synthetic organic pesticides became available. They proved effective on most all the pest insects. Suddenly, crop yields could be maximized through utilization of these synthetic organic pesticides. The new synthetics also created an opportunity for entomological crop protection specialization. By picking a pest and a crop and concentrating on insect control utilizing synthetic chemicals, commercial (private) insect/crop consultants quickly carved out an area of expertise in their jurisdictions. Entomologists designed calendar-based insecticidal pest control practices for crop yield maximization. Then, unexpected pest resistance and secondary pest control problems developed that had to be solved. From this era of expediency emerged new opportunities for pest control advancement through an understanding of insect pheromone biology and chemistry, pest resistance, pest management, agroecosystem modeling, insect behavior, pathology and physiology. Perhaps these advancements were ordained by the use and misuse of the first synthetic organic pesticides.

Now 50 years later, yield enhancement programs are being designed around the new broad spectrum pyrethroids. These "new" programs may eventually be negated by the same insecticide-resistant pest strains, secondary pest outbreaks, and environmental quality problems experienced earlier if correct judgment is not employed by growers, consultants and industry, communicating and working together.

REGISTRATION AND REGULATIONS

REGISTRATION

The registration process is the only effective way to regulate pesticide use patterns. At the national level, the Environmental Protection Agency (EPA) has built into the registration process three mechanisms that scrutinize pesticides for potential adverse health effects and for potential to reach groundwater. They are: (a) new chemical registration process; (b) reregistration or the registration standards process; and (c) the amendment to existing registrations process. In addition, the EPA can utilize the Ground Water Data Call-In option to determine which of the most used pesticides have the potential to reach groundwater under actual use conditions (Creeger, 1986). Many pre-1983 registered

products and public domain products need toxicity studies done before the re-review can begin. Some will need environmental fate data. Thus, the older chemicals will be required to meet the same scrutiny as new chemicals regarding chronic health effects and groundwater pollution. Whether or not a company chooses to provide the data necessary for reregistration most likely will depend on the market profitability of that product.

Insecticide and nematicide residues in the soil occur as a result of: (a) fall-out after crop spraying; (b) incorporation of plant residues in the soil; or by (c) direct treatment. The persistence of these chemical materials depends on their stability and biodegradability, all of which in turn are influenced by soil type, micro-organism populations, pesticide formulation and method of application. Not only does the grower have to consider these factors when planning a plant-back schedule but these same factors have to be considered by regulatory officials when evaluating the potential of a pesticide to reach groundwater.

Likewise, the effects of pesticides on non-target organisms are also an issue of regulatory and environmental concern. Any pesticidal effects to non-target organisms at field-applied rates will be governed by the stage of crop development, the climate, and the distribution and behavior of the non-target arthropod population itself. Generally, organophosphates are considered broad spectrum insecticides that are also toxic to mammals and birds. The pyrethroids, however, have a relatively low dermal toxicity to mammals and birds at field-applied rates, with birds being less sensitive to pyrethroids than mammals (Hill, 1985). Invertebrate organisms, such as the parasitic wasps and predacious mites, are acknowledged in very few regulations governing pesticide use compared to the honey bee. Honey bees are important pollinators of many high value crops, and commercial pollination and honey production are agricultural industries to be protected. Although pyrethroid toxicity to bees may be of little concern at field application rates (Hill, 1985), they should be considered comparable to the organophosphate compounds in impact on beneficial insects.

The regulatory concerns of pesticide impact on non-target organisms can be mitigated somewhat through application technique. A potential advance in the technology of precision application of pesticides is represented by controlled droplet application. Controlled droplet application offers the potential of reduced environmental contamination and better operator safety if fundamental questions on droplet transport and disposition are actively pursued (Bals, 1987). Full development of this technology deserves the cooperative implementation effort of both industry and government. Other aspects of pesticide use that can either create or mitigate regulatory concerns are: (a) proper management of insecticidal equipment, especially chemigation equipment; (b) accurate calibration; (c) correct mixing rate for proper pesticide concentration; (d) swath coverage so as to avoid water areas; (e) the use of qualified consultants to scout for field pests; and (f) the use of alternate classes of pesticides when feasible.

REGULATIONS

It has been suggested that, between resistance and escalating costs for pesticide development, registration and reregistration, insecticides are becoming an endangered

resource for cotton production (Frisbie, 1987). Despite thinking to the contrary, legislation and regulations are implemented because of a demonstrated need. A need for safe drinking water in California resulted in Proposition 65, the "Safe Drinking Water and Toxic Enforcement Act of 1986." Under this Act the Governor can declare any chemical as a health hazard if it is a carcinogen or reproductive toxicant. Among the first chemicals named in 1987 were aramite, dibromochloropropane (DBCP), ethylene oxide, arsenic, and arsenical compounds. Methyl bromide was added in 1993. Likewise when the air concentration of methyl parathion exceeded established thresholds for health effects, California identified it as a toxic air contaminant in 1993. In response to air quality concerns, California now prohibits the selling or use of weed oil in certain counties.

There was a demonstrated need for The Endangered Species Act of 1973. This Act was reauthorized in 1985 and requires all federal agencies to insure that their action will not jeopardize endangered or threatened animal or plant species and their habitats. Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the EPA must protect endangered and threatened species. The compliance date for cotton was February 1, 1988. EPA, however, has postponed implementation of the program due to suggestions from various sources. If and when the program is ever implemented, certain pesticides most likely will be restricted from use in areas where endangered species exist. Some of these pesticides which are used in cotton are paraquat, parathion, aldicarb (Temik®), azinphos-methyl (Guthion®), Cypermethrin (Ammo®), Cymbush®), Fenvalerate (Pydrin®), and profenofos (Curacron®). If the program is implemented, it is obvious that some cotton producers in all states will have to make land use adjustments.

ENVIRONMENTAL AND BIOLOGICAL RISKS

The issues of risk assessment, significance, and management are current topics in regulatory circles. From a public health standpoint, we possess the technology to maintain an environment virtually free of pest-transmitted diseases. Public health is maintained in part through the use of insecticides to reduce the incidence of malaria, yellow fever, encephalitis, and other arthropod-transmitted diseases. This same technology provides the food and fiber we all need for longer, more productive lives and now provides economic control of pests at levels of less than 10 parts per million of active ingredient per acre rather than pounds of active ingredient per acre.

Nevertheless, even as field application rates decrease, our ability to detect synthetic organic materials has increased at a rate faster than our scientific assessment of associated risk, its management, or the public's perception of risk. And as these refined analytical techniques revealed even smaller levels of pesticide residues in our food and environment, the health consequences of exposure were refocused in an attempt to explain chronic health concerns ranging from cancer to birth defects. Thus, the numbers characterizing trace contamination of our environment need a significant understanding for appropriate regulatory response and public perception. For example, there is uni-

form interest in groundwater protection, but considerable differences exist among parties in setting acceptable limits for detected chemicals in groundwater. Some will not accept any level or limit for chemicals in groundwater, while others recognize that naturally occurring water is not pure and that some limit to assure high quality is reasonable (Summer and Stevens, 1986). Some believe that, in order for the public ever to perceive the difference between the analytical finding and acute and chronic health significance, the government must establish numerical groundwater standards (Ehart *et al.*, 1986). EPA's Office of Drinking Water has set some Maximum Contamination Levels (MCLs) as established standards of what is safe water (Summer and Stevens, 1986). These MCLs function in the same way as food tolerances do. However, there is the question of public trust in government officials. Recent survey results reveal that 63 percent of those asked disagreed with the idea that if the government allows "small amounts of chemicals in water," the water is safe to drink (Ehart *et al.*, 1986). In an effort to address these concerns, a regulating agency's response to the public can make for curious circumstances. The California State Water Resources Board's list of "Criteria for Selection of Priority Chemicals" places public concern before chronic and acute human toxicity potential. The Board seems to react to public opinion before it initiates evaluation of potential human toxicity problems. The logic is if there is difficulty in establishing a cause-effect relationship between the detected chemical and long-term health effects, then responsible precautions should be taken since it is prudent to err on the side of caution (Cohen, 1986). Thus, there is a need to bridge the void between analytical detection and public perception by risk assessment and management.

Risk significance is an issue clouded by a lack of data on certain pesticides and poor communications between scientists, manufacturers and the media. When the issue of groundwater contamination is raised, the investigative focus by the media usually is on pesticides simply because it is assumed we have more data on them than on other classes of chemicals. Yet when a pesticide is discovered in groundwater at parts per million or parts per billion, there are no definite answers to questions about potential health effects. Now the investigation becomes clouded. Because data are lacking, a risk is perceived. Media and public focus immediately shift from the pesticide to the analytical finding (the mere presence of the chemical). Lacking evidence to the contrary, they assume that since these products are poisonous, even small amounts are undesirable in our ground or surface waters. Sometimes there is a great disservice to the public when media reports focus on the detection and gloss over the health effects associated with that detected level. At other times the public is misinformed when media, through ignorance, report the toxicology of a substance on study animals but fail to mention the existence of legally enforceable EPA standards and thereby imply that the water is unsafe to drink (Newby and Rouk, 1986). Thus, it is necessary that the quantitative estimates of risk made by the risk assessor be communicated in a way understandable to the risk manager, the regulatory decision makers, and the public (Colthern, 1986). Otherwise, when scientists are unable to assess the health significance of parts per million or billion, the public justifiably demands no-risk protection from their elected representatives. Because the public is not well informed on techni-

cal issues, an unknown health assessment provides a reaction rather than informed opinion. In response, laws are passed and regulations are written to mitigate future analytical findings in an attempt to restore the no-risk environment. This scenario reaffirms the belief that risk assessment is a scientific endeavor but that the decision of risk significance and risk management should be left to societal judgment (Smith, 1986).

GROUNDWATER PROTECTION

Concern about groundwater contamination from pesticides has resulted in use restrictions or regulations at both the federal and state levels. This turns out to be the least costly and most effective approach to alleviating groundwater pollution. The United States Environmental Protection Agency hopes to prevent future chemical contamination of groundwater resources by promoting state groundwater protection programs and by requiring more rigorous pesticide registration requirements, especially on the potential for leaching. Promulgating these regulations has been especially exasperating for lawmakers who have had to listen to evidence, testimony and opinion stating that less than one percent of the ground water is polluted, that this number will decrease in a couple of decades, and that groundwater moves so slowly that there is adequate time to achieve a management plan for the future (Cohen, 1986). Contrasting views state that we are just seeing the tip of the iceberg. They state that contamination may turn out to be greater than now realized, given the lag time for chemicals to reach groundwater from the expanded use of synthetic organic chemicals in manufacturing since 1940. Others are of the opinion that we cannot wait for health effects data to come in; the contaminants must be removed now (Cohen, 1986). Although there are nine existing federal ground water protection programs ranging from FIFRA's pesticide policy to the Nuclear Wastes Policy Act, consultants in Michigan believe that a state level policy approach for groundwater protection offers the greatest promise for immediate protection (Libby and Kovan, 1987). Local legislative responses have been in acts such as the Wisconsin Ground Water Law, and the birth defects and groundwater protection bills in California. The birth defects bill mandates review of all pesticide data for possible deficiencies regarding potential health effects, while the groundwater protection bill, known as the Pesticide Contamination Prevention Act prohibits or restricts pesticide use through the establishment of pesticide management zones for those pesticides with a high potential for leaching. Established in 1990 and identified by township, range and section, applied pesticides must meet specific numerical values for water solubility, hydrolysis, soil absorption and aerobic soil metabolism.

Groundwater contamination by pesticides is usually associated with spills, runoff, accidents and use patterns. Normally, pesticides are dissipated by photochemical, microbial or chemical degradation, or by leaching. Those herbicides, insecticides and nematicides susceptible to leaching are subject to regulation. Pesticides that remain in solution have the greatest chance of making it to groundwater compared to those that are less soluble or insoluble in water or that are retained by the soil. There are records of contamination of groundwater by illegal pesticide use, improper discharge of

unused pesticide mixtures or rinse water, and accidents, (Cohen, 1986), all of which are few in number.

Detections of herbicides and insecticides/nematicides in groundwater are about equal in those states that have surveyed for contamination. Aldicarb (Temik®) has been detected in groundwater in eleven states in addition to New York, California, Florida and Wisconsin (Cohen *et al.*, 1986). However, it has not been found in groundwater in association with cotton despite its extensive use in that crop (Leser, 1986; Cai *et al.*, 1993). The fact that it is soil-applied makes aldicarb's continued use questionable especially in areas with a perched water table and sandy soil. The short-lived pyrethroid insecticides have not been found in groundwater, although residues were found in fish and invertebrates (Bennett *et al.*, 1983). Documented adverse health effects associated with a specific contaminant acquired by drinking pesticide-contaminated groundwater are difficult to develop, although there are documented health risks associated with ingesting groundwater having excess leached nitrate from nitrogen fertilizer, sewage or feedlots (Kamrin, 1987).

Public health and environmental concerns will continue when new technology is utilized without adequate substantiating data on the potential long-term effects simply because experimentation in time and place is not adequate enough to be predictive (Bradley and Agnello, 1986). Creative mitigation solutions to groundwater pollution problems may involve fundamental land use patterns proposed by those unfamiliar with agricultural production issues. The authority and procedures (zoning laws) for directing the private use of land are in place and well established (Libby and Kovan, 1987). Only through group articulation can a reasonable approach compatible with current and developing agricultural practices and technology be reached on the issue of groundwater protection.

WORKER SAFETY

Organophosphate insecticides are popular crop protection chemicals because of their high efficacy and relatively low environmental persistence. There exists, however, the potential for adverse exposure to farm workers from handling farm chemical pesticides. Over thirty workers became ill in California in 1984 while applying organophosphates. Most of these illnesses are associated with dermal absorption resulting from spills or application mists (Meinders, 1985). Farm worker safety is addressed by the pesticide label, mandatory protective clothing, and required education and training programs stressing safe handling and application of pesticides. Other safety aspects include closed systems for mixing pesticides, and the actual posting in California fields of reentry times after application of specific pesticides.

The potential acute and chronic health effects that could result from pesticide residues on cotton are of concern. For example, field evaluations in California of the health safety of twelve chemicals (six organophosphate insecticides, three synthetic pyrethroid insecticides and three defoliants) found that the measured residues on bolls at harvest did not pose an inhalation hazard to cotton harvest workers (Maddy *et al.*,

1984). And the airborne levels of the harvest-aid paraquat declined rapidly both temporally and spatially, but residues on cotton plants at harvest were comparable to those downwind from a sprayed field (Seiber *et al.*, 1983).

The residual life of a pesticide is also influenced by the carrier. All of the tested pyrethroids and some of the organophosphates in a cottonseed oil carrier had their residual life greatly enhanced compared to those pesticides applied in an aqueous solution, thus indicating a need to evaluate worker reentry times when different carriers are used (Ware *et al.*, 1983). However, there is need for common understanding between researchers and regulatory officials regarding the actual versus potential exposure risks for farm workers. The EPA model for exposure assumes 100 percent absorption, but mixer-loader studies indicate that less than 10 percent of the "actual" exposure was absorbed (Nye, 1986).

The environmental, biological and economic complexity of production decisions is evident when the agricultural pest control practices incorporated in the field can be of worker health significance in the gin or the mill (cottonseed or textile). Several researchers have found relationships between insect infestation and aflatoxin contamination. Aflatoxin is a secondary metabolite of the common soil fungus *Aspergillus flavus*. Aflatoxin is sometimes found on lint and is considered to be an animal health risk and could be a human health risk (Maddy *et al.*, 1983). It has been observed that as the level of pink bollworm infestations increased, so did the mean amount of aflatoxin (Russell *et al.*, 1976 and Widstrom, 1979). It may be that insect injury to cotton locules (locs, locks) slows the rate of boll opening, thus maintaining higher moisture in the boll which is ideal for aflatoxin elaboration by the soil fungus.

In another study concerning worker safety, three different arsenical harvest-aids were analyzed in cotton lint and seed but were found not to be significantly above the pre-application levels after eight days (Mastradone and Woolsen, 1983). However, Columbus (1987) discovered a good correlation between defoliant left on lint and the amount of gin cleaning and drying — the less foreign matter in the lint, the lower the defoliant.

From these selected examples, it is evident that as long as chemicals are to be used for production agriculture, we can expect federal and state regulatory authorities to continue pesticide monitoring and to specify safety requirements for agricultural workers at all production levels. These safety concerns also should address the proper selection, handling and storage of protective clothing as outlined by Laughlin and Gold (1987), as well as protective devices, training sessions, medical monitoring where appropriate, and reentry requirements. For applicators and mixers/loaders, continued training and certification will be necessary as the EPA continues to assign restricted use labels to pesticides. Regulatory agencies have begun to enforce the requirements of the 1992 Federal Worker Protection Standard (Code of Federal Regulations, Title 40, Part 170) when pesticides with labeling that refers to the Worker Protection Standard are used. Any agricultural pesticide user and/or an employer of agricultural workers or pesticide handlers is required to provide to those employees information about exposure to pesticides, protections against exposures to pesticides, and ways to mitigate exposures to pesticides.

TOXICITY

Toxicity can be viewed as the inherent capacity of a compound to produce a harmful effect (Bohmont, 1981). The toxicity of a pesticide depends on the: (a) chemistry of the compound, (b) target or non-target organism, (c) method and duration of exposure, and (d) inherent ability of the target organism to metabolize the toxic compound into innocuous compounds before the pesticide can harm the target organism. Using standard test procedures, a relative measure of toxicity among pesticides has been established. Although there may be potential for injury to the skin or eyes from a compound, the most familiar measure of toxicity is the LD₅₀, or the acute oral lethal dose in milligrams, that kills 50 percent of the test animals. Since this number is based on the weight in kilograms of the test organism, a lower number means the compound is more toxic. The chlorinated hydrocarbon dicofol (Kelthane®) is generally considered less toxic (LD₅₀=809 mg/kg) than is the organophosphate monocrotophos (Azodrin®) whose LD₅₀ is 20mg/kg. Some newer pesticides are now subject to a data call-in for existing data gaps that would help to assess acute and chronic toxicity risks. Most are of the organophosphate group. Standard health studies to assess the potential of pyrethroids to cause cancer have shown that at very high dose levels of 3,000 to 6,000 ppm, the pyrethroid molecule does not have carcinogenic properties (Litchfield, 1985).

In order to use the more toxic pesticides, the potential hazard to agricultural workers has to be mitigated. Hazard is the combination of toxicity and exposure. Mitigation occurs through different pesticide formulations (granular vs. liquid or dilute vs. concentrate), application equipment (enclosed cabs and closed mixing systems), and applicator training and experience. Currently, organophosphates, carbamates and pyrethroids are the most commonly used insecticides on cotton. All of these pesticides overlap as to their relative toxicity or potential hazard to agricultural workers. Some pyrethroids [cypermethrin (Ammono®, Cymbush®), LD₅₀=251mg/kg] are more toxic than some organophosphates [acephate (Orthene®), LD₅₀=945mg/kg]. Thus, when handling concentrates, there would be no health safety advantage of a pyrethroid over an organophosphate as far as the mixer/loader is concerned. The safety advantage of the pyrethroids is evident to field applicators and workers since their normal application rates are less than 0.15 pounds active ingredient per acre. This safety is always compromised when, for instance, a pyrethroid/organophosphate mixture is recommended.

PEST RESISTANCE

Resistance problems historically have been solved by the discovery of pesticides with a new chemistry or with a new mode of action. Perhaps the current bollworm/tobacco budworm resistance phenomenon will be addressed through the development of a transgenic strain of cotton or genetically engineered pesticides based on pesticidal toxins (Micinski *et al.*, 1992 and Brumley, 1987). New compounds and techniques could offer new dimensions for cotton pest control, but thinking such as this places blind reliance on the ability of technology to bail us out of a predicament that could be avoided with correct thinking. We know that resistance development in

insects is a population phenomenon. It develops due to selection pressures, like pesticides, on the pre-existing genes that impart resistance. These genes occur in a population at a certain frequency and their expression is determined by both biological and operational factors. We have no control over the biological factors such as generation turnover, gene dominance and migration. But we can manipulate some of the operational factors such as the chemistry and persistence of pesticides (Graves, 1987). Resistance can be managed in each producing area with correct thinking and careful planning of an annual pest control strategy similar to that practiced for cotton production in Australia, Egypt and in some areas of the United States. (Denholm and Rowland, 1992). Resistance management strategies include pesticide selection, utilization of short-season cotton varieties, irrigation and fertilizer management, planting date, row spacing and plant growth regulators to remove immature bolls (Henneberry, 1987; Clower, 1987; Denholm and Rowland, 1992).

Resistance to pyrethroid insecticides in the United States was first detected in 1985 in Texas (Plapp and Campanhola, 1986). Before that, there was evidence of pyrethroid resistance by the diamondback moth, *Plutella xylostella* (L.), in Thailand and Malaysia, by the beet armyworm, *Spodoptera exigua* (Hübner), in South and Central America, and by a *Helicoverpa* species, in Australia. Today, researchers are monitoring resistance and suggesting ways to prolong the biological activity of the pyrethroids in general. Local area studies found that the economic advantages of early maturing varieties in the Rio Grande Valley of Texas were the potential reduction of pesticide use by over one million pounds and an increase in net returns (Sprott *et al.*, 1975). Short-season cotton requires less inputs for insect control (0-24 percent less) and can have higher yields (0-25 percent) than the longer seasoned varieties (Norman and Henneberry, 1987).

With potential resistance problems looming, it is alarming that statements have been made pronouncing reliance on pyrethroids for bollworm, *Helicoverpa zea* (Boddie)/tobacco budworm, *Heliothis virescens* (F.), control in the event that pest problems develop as the result of early-season insecticidal controls (Ratchford *et al.*, 1987). Pesticide selection and use rates should be considered in terms of potential effects both long range (resistance, environmental contamination) and short range (capabilities of the insecticides available) (Luttrell and Reed, 1986). Resistance management through thoughtful selection of pesticides appropriate for early-season pest control may avoid tobacco budworm problems. Clower (1987) has observed that use of pyrethroids early in the season triggers the resistance selection process, especially in Mid-South early fruiting cotton. Graves *et al.* (1991) documented seasonal changes in frequency of pyrethroid-resistant moths. This information combined with cultural practices may prolong the useful life of pyrethroids in cotton.

For early-season thrips management, varietal pubescence or delayed planting may be a consideration. Cotton producers in the high wheat producing Rolling Plains area in Texas adopted a uniform delayed planting date to combat boll weevil and may secondarily be controlling thrips because the thrips have dispersed by the time cotton is susceptible (Leser, 1986). Pesticide resistance in bollworm/tobacco budworm may be delayed by avoiding the temptation to apply pyrethroids during the early stages of crop

development. A reasonable pest management program of organophosphates and carbamates for early-season pest control and pyrethroids mid- to late-season may prolong the useful life of the pyrethroid insecticides.

Some thought as to this direction is coming from the Pyrethroid Efficacy Group (PEG), an organization whose purpose is to establish technical recommendations for pyrethroids and to extend the useful life of these insecticides. The United States contingency of this group met with manufacturers after resistance was confirmed in the tobacco budworm. With the exchange of pest control ideas, the pyrethroids can be a long and useful tool in cotton pest management. The success of resistance management will depend on a high level of cooperation within and between the agrichemical industry, production consultants and growers (Denholm and Roland, 1992) and with the realization that resistance management is just one other aspect of an integrated pest management philosophy. That there will always be a need for managed pesticide use is well illustrated by the recent appearance in several cotton producing states of the pesticide-resistant silverleaf whitefly, [*Bemisia argentifolii* (Bellows and Perring)], formerly recognized as strain B of the sweetpotato whitefly [*Bemisia tabaci* (Gennadius)].

SUMMARY

Preservation of the quality of our environment and natural resources, especially the quality of our surface and ground water, are important and sensitive issues today and always will be. Yet, on a worldwide basis, chemical pesticides will continue to be the primary tool against the threat of disease and famine well into the twenty-first century. Therefore, proper use of these tools will always be under the scrutiny of the public and regulatory officials. Knowing the health and environmental risks of these pesticides as well as their benefits mandates that common sense and correct thinking be practiced when using them. In order to insure continued safe use of these tools, there must be meaningful communication among the respective concerns of commodity producers, regulatory officials, industry and the public. The current environmental issues in cotton production are no different than they were thirty years ago. The chemical names have changed but the problems of environmental pollution, pest resistance problems, worker safety, residues and secondary pest outbreaks are still with us. Why, with such demanding pesticide use and registration regulations, are we still faced with thirty year old problems? Will they ever be resolved? They will probably never be completely resolved until science and technology show us how to produce agricultural commodities without the use of pesticides. And they will not be solved immediately because of our cultural heritage regarding the legal and administrative processes. These processes guarantee fairness to all through open hearings where government's role is to arbitrate among competing interests. Are more regulations to be expected then? Yes. Continued public demands for health safety and a quality environment will add more restrictions on pesticides used for commodity production and perhaps limit the total amount of pesticides applied. In fact, Pimentel (1993) reports that the results of a feasibility study

suggest a legislated 50 percent reduction in pesticide use would be possible without compromising crop yield or substantially increasing food costs. This restriction may seem utopian but through focused lobbying efforts by agenda-driven nescience groups, similar restrictions will be proposed for legislative action in all the agricultural producing states. But are more regulations really needed? Wartenberg (1988), in commenting on the aldicarb (Temik®) incident in New York, believes the existing power already allocated to various regulating agencies is sufficiently broad-based to address the problem. The pesticide registration and health agencies, both federal and state, already have the prerogative to demand additional data on compounds with questionable health properties or to restrict or ban pesticides likely to cause environmental contamination. Health authorities can close contaminated wells or conduct sampling programs or implement health studies. The only thing needed for efficient pesticide management is sufficient coordination among these regulatory agencies and coordinated input from commodity producers. The public, regulatory officials and growers will always be concerned for the quality of our environment and the implications pollution may have for our present and future living standards. "We don't inherit the land from our ancestors, we borrow it from our children" is wisdom and good philosophy from the old Pennsylvania Dutch farmers that can be shared by all agricultural commodity producers.