Chapter 1

EVOLUTION OF WEED CONTROL IN COTTON

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Cotton, from the beginning of its production in colonial times to the present, is one of the culturally most complex crops grown in the United States. The physiology of the cotton plant and the historical importance both sociologically, economically and politically to the development of specific United States regions has to be understood as the importance of weeds and their control in this major United States crop is discussed. Due to its unique growth and development, the cotton plant is greatly influenced by weeds, resulting in a $300 million crop loss per year.

The purpose of this chapter is to provide a summary of the remaining chapters of this book and to list some of the important areas that need additional research. Leading scientists concerned with the control of weeds and cultural practices in cotton have provided detailed information about cotton production from a historical basis through the present with projections into the future. This is coupled with a parallel in the weed control practices. Questions such as why they occurred, how they developed, and what can be expected for the future will be examined.

From the beginning, cotton, which was used to provide domestic textile needs, developed into one of the four major agricultural commodities in the United States. Events in England dealing with the industrial revolution revolutionized mechanization of the textile processing industry and, thereby, generated a tremendous demand for cotton. In the United States vast areas of land, primarily in the southern part of the United States, were well suited for cotton production. However, cotton production did not gain economic significance until a major development occurred: Eli Whitney's cotton gin. For years after the Civil War, a gigantic cotton monoculture existed in the South, which was largely dependent on manual labor in an extensive form of agriculture.

For almost a hundred years cotton was grown without having a major insect pest problem. In 1892 the cotton boll weevil invaded the United States and forced major changes in the cotton culture and greatly contributed to cotton acreage movement from the south and southeastern part of the United States towards the western areas. Technological innovations in the development of mechanical cotton harvesting and selective cotton herbicides allowed near complete mechanization of cotton culture.

The four major geographic areas of the United States in which cotton is produced vary considerably in their environmental and soil conditions. These four areas include: Southeast states of Alabama, Florida, Georgia, North Carolina and South Carolina; Mid-South states of Arkansas, Louisiana, Mississippi, Tennessee and Missouri; Southwest states including Texas, Oklahoma and New Mexico and the West including Arizona and California. Weed problems which occur in each of these geographic areas vary greatly due to the wide range of environmental, soil and cultural conditions.

As cotton production has evolved in the United States over the past 200 years, weed control technology has changed greatly. Up until the mid-1990s, cotton production and control of weeds involved a very intensive labor requirement both by humans and animals. Hand hoeing was the principal method of weed control and is still utilized today.

The first major advancement that changed weed control technology included mechanical technology which involved the row-crop tractor, the steel plow, and in-crop cultivation to mechanically till the crop and remove weeds. Many ingenious mechanical developments occurred during this era. Biological weed control was recognized during the mid-1940s with the use of geese in Mid-South and western states. Considerable effort is still being devoted to development of additional biological control mechanisms, mostly fungi. The development of the agricultural chemical industry began in the 1940s with initial development of herbicides. This initiated a dramatic new technology for weed control in cotton production in the United States which continues today as the major method of weed control. Hand hoeing as well as mechanical tillage for weed control continue to be utilized, but today these practices supplement the use of herbicides.

As weed science technology evolves and develops, scientists strive to understand more about how weeds interfere with cotton production through their competition for available resources including water, nutrients and light. The degree of competition is a function of the weed species composition of the population as well as the weed population density and duration. In addition, competition for these resources is regulated by their availability. The level of cultural and environmental conditions such as temperature, rainfall, cultural practices, row spacings and cotton cultivar influence competition. The consequence of competition, which is of major concern, is crop yield loss and lower lint quality, usually as a result of fewer, less mature bolls per plant in weed infested areas. Allelopathy is another component of interference which may also be important although limited evidence for this phenomenon can be documented in actual field production.

Allelopathy is the effect one plant has on other plants caused by chemical compounds given off by roots or decaying plant material. Production losses associated with weed interference may occur at harvest or with other management operations.

One of the major shortcomings of existing weed control technology is our inability to predict both cotton yield and quality losses from low populations of a few hundred to a few thousand weeds per acre for many individual weed species. Even more important, the effect of combinations of two, three, four or more species is unknown when they occur together in relatively low populations. In other words, what is the critical minimum of individual weeds or combinations of weeds that will permit us to say that neither yield nor lint quality will be affected by the presence of the weed or that weed seed production will be so low that the resulting weeds next year will not affect cost of production. This type of research is complex, time-consuming and costly. It is not likely that answers to these questions will be provided within the next decade even though this information is needed now to insure maximum profit in production.

Certainly the bottom line to any producer's interest is the cost associated with weeds and their control. It is an accepted fact that weeds indeed cause severe cotton losses and efforts have been made in recent times to document the actual losses by weeds in cotton. Losses have been as much as $300-500 million dollars a year in cotton production in the United States.

These economic considerations also have to include the cost of weed control programs associated with the cotton production. These costs have been documented in chapters within this book, specifically outlining the cost of various operations, herbicides used and the losses that are expected in cotton yield and quality. Weed scientists are providing actual loss figures per individual weed species. Weed science is a young discipline, and as scientists have time to develop the threshold levels of loss, then more precise weed control decisions can be made.

In order to utilize the most effective and most economical weed control practice, it is most critical that weeds are correctly identified in respective geographic areas. Included in this book is a taxonomic key and color photographs that can be used to identify many of the cotton weed pests in the United States. Weeds that were problems 20 years ago in many instances are not the weed problems that are of concern today. As better herbicides have been developed for specific weeds, new or different weeds have taken their place. It is a continuing battle for weed scientists to solve the new weed problems as they emerge. These changing weed populations may be influenced by many things including the continuous use of a respective herbicide, the continuous cotton monoculture, changing cultural practices, changing geographic areas, etc. Cotton producers know that if crop rotations and rotations of herbicides can be utilized in a farming program, the changing weed population can be minimized thus allowing better management of cotton production. However, as other cultural technologies evolve such as conservation tillage, again, dramatic changes in weed populations occur. It is a never ending battle to continually understand the growth patterns, the physiology of the weeds and to find mechanisms to control weeds in cotton.

The use of some 60 herbicides and/or herbicide combinations currently provide the main attack on weeds in cotton production. The use of herbicides began primarily in the early 1950s with development of chemicals such as diuron (Karmex® and Diurex®). Today a very high percentage of all cotton is being treated with a preplant incorporated, preemergence, postemergence directed, postemergence spot-sprayed or a postemergence over-the-top herbicide application.

The use of herbicides to adequately control weeds in cotton was not an overnight success when usage began in the 1950s. Practically none of the producers were trained to apply herbicides correctly and most were afraid that "those chemicals" might injure their cotton. This initial reluctance was justified in 1952 and 1953 when thousands of acres of cotton were killed after dinoseb (Premerge®) was applied preemergence. It is almost certain that this unfortunate experience delayed widespread acceptance of herbicides by farmers for several years. Prior to 1960, less than 10 percent of the total cotton acreage received herbicide treatment, but then by the mid-1960s use increased at such an accelerated rate that by 1970 essentially most cotton acreage received some type of herbicide treatment. The impetus behind this rapidly expanded use was more selective and effective herbicides such as trifluralin (Treflan®) and DSMA/MSMA. Also, the mass exodus of farm workers, who had provided the hand labor for hoeing weeds in cotton, continued to move from rural to urban settings. These factors were combined with a new generation of farm managers who were better trained and realized the need to use new weed control technology. Many of these new managers were veterans of World War II who obtained their education on the GI Bill after the war, began farming with their parents, and then took over the family farming operation after a few years of experience. All of these factors combined in the 1960s to provide an unprecedented increased use of herbicides in cotton production.

The trends in use patterns are discussed for specific cotton herbicides over time. The amount of herbicide use in cotton probably will remain constant over the next decade although there are significant new herbicides being developed that could find their niches in today's cotton market. Without the availability of current herbicides, it would not be unusual for hand labor weed control costs to run as high as $300 per acre. Obviously this would be prohibitive in terms of cotton production. The herbicides used in United States cotton production are primarily applied by farmers themselves, although the use of custom application has increased considerably in recent years. In some parts of the West more custom application is done than in areas of the Southeast and Mid-South.

As respective herbicides are used in cotton, a need exists to understand many things about them, including why and how they work or may not work in certain instances. This permits us to use herbicides more efficiently. This book spends considerable time on respective families of herbicide chemistry used in cotton production. The actual chemistry of each one of these herbicides plays a major role in its performance, persistence and activity in the soil, activity in plants, ability to penetrate or translocate in a plant and ability to control a specific weed species.

Linked with understanding the chemistry of respective herbicide families is the knowledge of their respective mode of action on specific weeds and on the cotton plant. An understanding of the herbicide mode of action is not only needed to aid in control of specific weeds but also to help design better, more specific herbicides for future use. There is no general mode of action of all cotton herbicides; each family of chemicals reacts differently. A herbicide may be targeting the germination process of the seed, or the root growth and development, or they may act by needing sunlight or the process of photosynthesis to be active. New herbicides being developed are even more specific in their mode of action—even down to a specific enzymatic reaction within the plant being sensitive to the herbicide.

Because a great percentage of cotton herbicides are soil applied with mechanical incorporation prior to planting or to the soil surface after planting, it is critical to have an understanding of the influence of soil on performance of respective herbicides. With cotton being planted across a large geographic area in the United States, many different types of soils are involved, from very sandy to clay, from essentially no organic matter ranging up to three percent. The percentage of sand, silt, clay and organic matter plays a critical role in soil applied herbicide performance. These factors influence the ability of the weed to absorb the herbicide from the soil as well as influence the length of time in which the herbicide remains in the soil before it is degradated. These factors also play a major role in determining the use rates of most herbicides.

Coupled with the actual soil properties, an understanding of how water in the soil and air affects herbicide performance is essential. Other things such as the volatility of the chemical, and whether it is subject to sunlight degradation are of vital importance to herbicidal activity. For instance, the dinitroaniline herbicide trifluralin (Treflan®) will not perform in most areas of the United States if it is simply sprayed and left undisturbed on the soil surface. It must be mechanically incorporated because of its high inherent volatility. When trifluralin (Treflan®) is trapped in the soil and protected against sunlight degradation, it becomes a vital herbicide. Without that simple mechanical incorporation, it would never have been a commercial herbicide. Factors such as the pH of the soil may also play a major role in herbicide performance. All of these factors and their interactions with herbicides are discussed in detail.

Another critical consideration in herbicide performance is application technology. A very interesting chapter on application technology is included which describes sprayer calibration, nozzles, pump types, and the mechanisms of herbicides application from a historical basis through present time and with projections into the future. Today as only ounces per acre of a herbicide are applied, application technology must be very precise. Significant advances have been made in this technology in recent years, but as conscientious farmers and scientists we must do a better job of accurately applying herbicides to the desired target.

As environmental constraints on application of chemicals become stricter, it is imperative that a better job of calibration and application be done. This chapter points out the interesting ingenuity of both farmers and scientists in their quest for ways of applying herbicides. When Roundup® (glyphosate) was developed, it was phytotoxic to cotton and too expensive when applied broadcast on a per acre basis. New ways were devised to apply the herbicide using recycling sprayers, wiper devices and spot sprayers which allowed selectivity and economic application of this herbicide on millions of acres of land. The ingenuity of applying chemicals is a very interesting psychological development in agriculture.

Even though a number of innovative herbicide application techniques have been developed for use in cotton, the technology of herbicide application was developed with little financial or moral support from industry, government, or academia. For example, in 1982, there were only 2.5 scientific years being devoted in agricultural engineering to weed science research in the United States and only a smaller portion of this would have been devoted to cotton. A number of recent conferences on pesticide application have acknowledged the need for greatly expanded research on application technology and have defined several steps that need to be taken to accomplish this, including: (a) defining obstacles that inhibit the development of improved application technology; (b) establishing research priorities that will respond to current problems; (c) developing plans for the establishment and funding of research centers of excellence; and (d) examining mechanisms for fostering interdisciplinary research activities within and between industry, government and academia.

The use of herbicides may cause problems from a crop injury standpoint. One of the chapters discusses in detail the respective injury problems associated from the different families of herbicides that are used in cotton and also describes some of the residual or carryover effects of herbicides from preceding crops as they might affect cotton production. In many cotton production areas, herbicides are used in other crops or pastures that are inherently very phytotoxic to cotton. The physical and/or volatility drift problems onto adjacent cotton fields have caused serious problems in the past. A discussion about these types of injury problems and symptoms is also included. This chapter also points out the need for a greater understanding of how herbicides behave from their chemistry standpoint, from their persistence in the soil and from their physiology and mode of actions. We must be able to insure that a cotton plant will not be injured when we use a chemical for the control of weeds within the crop or on adjacent areas.

Who develops new herbicides and identifies their potential use in cotton?

There are several groups of people that need to be identified as the key players in bringing forth weed control technology that is utilized today. The agricultural chemical industry has seen the need from an economic standpoint to develop and produce herbicides that will fit into the cotton market in the United States and around the world. They play a major role in bearing the cost of development of these chemicals as well as maintaining large research forces in laboratories and in field locations across the United States. Their marketing divisions deliver these products and provide technical assistance to the farmers.

Working with industry are two research groups: the USDA, ARS and state agricultural experiment stations and universities. These organizations conduct many research experiments in specific geographic locations throughout the United States each year. Their understanding of local areas can add valuable expertise as they work with industry to develop the herbicides that are needed for a geographic region. The extension service in each state has had and continues to play a vital role in the development and recommendations of herbicides. Agricultural consultants which bridge the gap between research and extension and the individual growers are emerging as important players in this team effort. Certainly, the farmer is the primary individual in this circle. By taking the herbicide and utilizing the best expertise and technology that other groups have developed, he can improve the profitability of his own farming operation.

Today we have other groups that serve as integral components of the weed control process; regulatory agencies of the Environmental Protection Agency and state regulatory groups. Many challenges in the regulation of herbicides and other agricultural chemicals will face us. But working hand-in-hand with these people and by providing the essential expertise, we can make this process successful. The development of herbicides has certainly been a teamwork effort, however, it is one that is not well understood by many people. Credit must be given to all facets of the industry for doing a magnificent job in the development of excellent herbicides for use in United States cotton production.

In looking to the future of weed control in cotton, we must consider evolving new cultural technology such as conservation tillage or limited tillage. In many parts of the Cotton Belt, research is underway that will provide the knowledge to produce cotton with little or no tillage. In order to make this technology work, effective economical weed control is absolutely essential.

Conservation tillage practices are being encouraged in many areas due to provisions of the 1985 and 1990 Farm Bills such as conservation compliance issues which will demand that farmers produce crops in a conservation tillage manner on erodible soils. As experience is gained in this technology, it is known that the weed populations change dramatically, and previously latent weeds become problems. There are excellent opportunities for the development of new herbicides and cultural technology for conservation tillage.

The future brings much optimism both in conventional and reduced tillage systems of cotton production. The future of weed control technology whether it is herbicidal, biological, mechanical, or some other mechanism that we don't understand at this time is very exciting. We know that the agricultural industry continues to develop many new experimental compounds that have potential for use in cotton. An example today is a new herbicide that will control cocklebur when applied postemergence over the top of cotton. The possibility of genetic manipulation of a cotton plant to provide resistance to either existing or new herbicides is very exciting. The possibility of biological control mechanisms that are emerging which can perhaps control very specific weed pests without the use of chemicals is also very exciting from an environmental standpoint. Indeed, we are facing increasing levels of regulation from the Environmental Protection Agency and from laws such as the Endangered Species Act. As a group of farmers, scientists and industry personnel, efforts must be coordinated to develop better methods of weed control in the future which will allow us to protect our environment and the individual user, while doing the very best job possible in controlling weeds.

Major advances in weed control technology during the past 40 years have provided many successful weed control options for United States production. It must be recognized that continued weed control research in high priority areas is essential. Through several surveys the following priority weed research areas have been identified:

1. Develop better herbicides and biological weed control mechanisms for current and evolving cotton production systems.
2. Identify, understand and develop naturally occurring allelopathic compounds.
3. Develop new and improved herbicide application technology.
4. Understand and manage environmental aspects such as surface and groundwater contaminants.
5. Develop weed/cotton competition and interference data.
6. Develop cotton herbicide resistance through genetics, biotechnology and chemical antidotes.
7. Develop models which describe weed growth and development and herbicide mobility and persistence.
8. Develop technology to regulate weed seed germination.
9. Develop formulation technology to control mobility of herbicides in soils.

As editors of this book, Weeds of Cotton, we hope that you find the remaining chapters extremely helpful in providing technology at whatever your level of use. The authors have done an outstanding job of presenting existing technology from a historical perspective through the future that could be used in the cotton industry in the United States.