Chapter 14

# TEAMWORK IN THE DEVELOPMENT OF WEED MANAGEMENT PROGRAMS FOR COTTON FARMERS

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## INTRODUCTION

### HISTORICAL ASPECTS

Controlling weeds has been a part of "farming" since before historic recording. In America farmers rarely used chemical techniques prior to World War II. Non-chemical techniques used included the continuing present standards of cultivation, hand-weeding, crop rotation and perhaps use of weed-free seed. Most farmers learned these techniques from their parents or neighbors, but the national network (now global) of experts who share ideas was unheard of then. Successful farmers were often "artists" at farming, rather than users of scientific principles.

### RECENT COOPERATIVE EFFORTS

Because weed science has been one of the most recent components of crop protection to widely utilize chemistry in integrated weed management systems (Street, 1957; Miller, *et al.*, 1961; Miller *et al.*, 1962; Arle and Hamilton, 1963), the analysis of roles played by various collaborators is most revealing. The major emphasis with herbicide development has been pragmatic; that is, to control weeds more economically. As the recent regulatory focus has shifted from permitting development of efficient weed control systems to health risk assessment of pesticides, a reduction in candidate herbicides for registration by the United States Environmental Protection Agency (USEPA) has occurred. More academic weed scientists have shifted toward the elucidation of scientific principles that make up weed science, rather than just to develop weed management techniques.

During the past three decades—beginning with the introduction of the highly successful substituted-urea herbicides, such as diuron (Karmex®, etc.) and fluometuron (Cotoran®, etc.), and the triazines such as prometryn (Caparol®, etc.), simazine (Princep®, etc.), and atrazine (AAtrex®, etc.) to the present time when sethoxydim (Poast®) and fluazifop-P (Fusilade 2000®) have entered the marketplace—considerable cooperative effort has been a characteristic of these successes. Yet, considerable evolution of who is doing what has occurred. This is due largely to the widening circle of technology used in protecting crops from weeds.

One can easily identify the various cooperators who team up to make weed management programs work. The manufacturers (Figure 1) are primary, but the land-grant university staffs, the U.S. Department of Agriculture's Agricultural Research Service (ARS) and the State Extension Services all play key roles in researching and finding the best fit for a given candidate herbicide (Turner, 1981). Their work is greatly facilitated by cooperating dealers and distributors, consultants and the farmers who integrate new lower-cost technology into their operations. All of their effort, over several years, must be within the framework of regulatory laws and rules promulgated by federal, state and county agencies.

Early efforts might now be called "shot-gun" approaches to control. But with

Figure 1. Industry representatives such as Elanco have held annual diagnostic field days for consultants (1979).

the passage of a couple of decades, "weed management" is now regularly practiced. It utilizes an array of weed science principles and in-field experience. Much more research on weed science principles is needed along with systems to utilize these research findings. But much has been written on weed science and weed management, a percentage privately published. (See "Useful publications for weed management in cotton" in the Appendix at the end of this chapter.)

Since weeds—like other components of nature—are always dynamic, continued updating and "resetting of sails" is needed as we move toward our not totally known destination. Resistance to herbicides, as to insecticides and pathogens, is present in populations of weeds. Continued use of a given herbicide for a decade or more can shift the numbers in that population where many are resistant rather than one in a million or a billion (Day *et al.*, 1983). Therefore, continued effort is needed to stay ahead of Mother Nature's natural phenomenon of resistance.

As with other crop protection disciplines, the weed scientist's goal must not be to kill weeds, but to protect our crops efficiently so we can compete internationally. Thus the benefits from optimum quantities of quality food and fiber may be secured, with minimal downside effects.

Recently, it seems that the urban and political perspectives on the seriousness of trace findings of pesticides, using increasingly precise analytical technology, has resulted in new legislation with potential for great impact on what we have strived for the past three decades to accomplish. These laws may dismantle a large portion of our arduously obtained production systems (Ames *et al.*, 1983). Without major educational effort of the urban sector of our team, we will permit an undoing of most that we have accomplished in this young science. That effort may be coming into place in the 1990s (Archibald and Winter, 1989; Whelan, 1990).

## WHO DOES WEED RESEARCH

Since about 1.5 billion pounds of crop protection chemicals are sold annually in the United States, and about half are used on our cropland, a considerable staff of professionally trained personnel must be employed. About 65 percent of all pesticides are herbicides (Anonymous, 1987).

Access to Weed Science Society of America (WSSA) membership lists provides insight into the number who work on field crop weeds in cotton-growing states (Table 1). These data are not exact because not all weed science researchers are members.

The compilation shows that the manufacturing companies far out-number USDA, university department and extension personnel inputs. Of course, not all field crop researchers are doing research on cotton but the numbers give some insight into how many are doing research in the regions of cotton production. It provides little indication of how many extension personnel such as county agents, or distributors, dealers, independent consultants or applicators, are involved since these are not normally members of WSSA.

Table 1. Weed Science Society of America members in cotton-growing regions of the United States who are involved in field crops. (From Directory of North American Weed Scientists and WSSA Members World-Wide. Weed Science Society of America. July 1986. 173 pp.)

| State | Manufacturers | | USDA & Universities | | Extension services | |
|---|---|---|---|---|---|---|
| | Number | Time | Number | Time | Number | Time |
| | | (percent) | | (percent) | | (percent) |
| AZ | 5 | 57.4 | 0 | — | 2 | 100.0 |
| CA | 106 | 70.9 | 9 | 64.4 | 23 | 46.3 |
| FL | 18 | 66.7 | 9 | 86.7 | 0 | — |
| GA | 14 | 55.5 | 4 | 78.7 | 5 | 68.0 |
| KY | 4 | 93.8 | 2 | 100.0 | 0 | — |
| LA | 8 | 85.0 | 13 | 65.0 | 0 | — |
| MS | 27 | 66.9 | 20 | 72.3 | 3 | 80.0 |
| MO | 44 | 86.9 | 12 | 60.0 | 0 | — |
| NC | 36 | 70.3 | 9 | 71.1 | 0 | — |
| NV | 0 | — | 4 | 13.8 | 0 | — |
| OK | 2 | 62.5 | 10 | 57.0 | 1 | 40.0 |
| TN | 12 | 73.8 | 4 | 86.3 | 1 | 30.0 |
| TX | 24 | 57.5 | 25 | 72.8 | 4 | 48.8 |
| Totals | 300 | 71.3 | 121 | 68.7 | 39 | 54.1 |

Manufacturing personnel are mostly involved (300) in cotton-growing states: USDA/university department scientists are second (121); and, extension personnel are third (39). Data on pest control advisors and consultants were evaluated but not included; most apparently do not belong to WSSA.

Other sources of numbers of weed scientists involved were found. Parochetti (1982) reported that there were 281 people (121 Full-Time Equivalent [FTE] assignments) as extension weed specialists at land-grant universities in the United States. That compared to 145 plant pathologist and nematologist FTE's, and 258 entomologist FTE's. County agents and regulatory professions were not included. It would be interesting to know how many regulatory people are involved in pesticide regulation. The authors tried but were unsuccessful in determining those numbers.

Dunster (1982) reported that in the Western Society of Weed Science, 45 percent were public agency personnel and 55 percent were industry personnel. His survey of 26 industry colleagues, with 20 responses, showed the trends on who was doing what (Table 2).

Dunster's evaluation of his colleagues' perspectives on university involvement in field research suggested that industry was carrying an increasing percentage of the research load. Since 1982 most would agree, I believe, that industry is now

Table 2. Evaluation of public sector involvement in field research. (Evaluations by industry researchers. From Dunster 1982. Proc. West. Soc. Weed Sci. 35:109-112.)

| | |
|---|---|
| 1. The primary need or justification for public sector involvement is impartial evaluation of: | |
| a. Field Performance | 80% |
| b. Environmental factors | 40% |
| c. Other aspects | 20% |
| 2. The interest and ability of university programs to respond to pesticide registration needs has: | |
| a. Increased | 15% |
| b. Stabilized | 30% |
| c. Decreased | 55% |
| 3. Relative involvement of public sector personnel in field R & D activities has: | |
| a. Increased | 5% |
| b. Stabilized | 20% |
| c. Decreased | 75% |
| 4. Financial support of university programs by industry has: | |
| a. Increased | 70% |
| b. Stabilized | 20% |
| c. Decreased | 10% |

doing a much higher percentage of the many studies additionally required since then. Studies on residue testing, metabolism, persistence and groundwater must now be done in accordance with EPA's "Good Laboratory Practices" (GLP) manual. The GLP manual must be followed exactly or the results will not be accepted by EPA evaluators. Only researchers trained in the practices manual can do such research, precluding university involvement in many cases.

## THE EXPERIMENT STATION TEAM

America's agricultural experiment stations, both USDA and state, provide an environment for weed scientists to cooperate with other scientists on localized weed control problems in various farm commodities. In most states, new weed management practices are developed by university researchers. The principles of weed management can be researched by using well-controlled experiments—researched with or without the latest technical advances in cultivars, other pesticides, cultural practices, fertilizers, etc., to determine the contribution of each input.

Weeds always have been best managed by a variety of practices. For thousands of years mankind has used combinations of timely planting, tillage, mowing, rotation and environmental management in his struggle against weeds. "Integrated Weed Management" is a term used by weed scientists to emphasize that herbicides are only one component of a total system for managing weeds in crops. An integrated weed management program combines all forms of weed science technology into a coordinated strategy to obtain maximum benefits, including minimal costs and risks. In an integrated weed management program, managers recognize the problem, determine what kind of control is needed, and organize and employ the most cost-efficient strategy to minimize the effects of the weeds. Herbicides are considered a component used in conjunction with other methodologies, but they are essential for profitable cotton production (Dowler and Hauser, 1974, 1975). Herbicides are used on almost all cotton acreage in the United States (Whitwell *et al.*, 1985). (Also, see Chapter 3).

In the research and development of new weed management programs, experiment station scientists must understand why weed problems develop. Why do we continue to have such a problem with weeds when we have highly effective herbicides to supplement all the traditional methods?

Weed problems develop year after year because of our inability to cope with their great reproductive capacity, massive recycling potential, and sporadic germination and establishment patterns. Another factor is the ecological or botanical shift toward more tolerant and aggressive species due to reduced tillage and/ or repeated use of the same herbicide program. For example, continuous use of trifluralin (Treflan®, etc.) in cotton has decreased the population of annual grasses, but allowed increases in the population of nutsedges (*Cyperus* spp.) and annual broadleaf weeds. Continuous use of fluometuron (Cotoran®) has decreased the population of annual broadleafs, but has led to increases in annual grasses and nutsedges (Coble and Schrader, 1974; Dowler and Hauser, 1974, 1975). Therefore, growers use herbicide programs that are designed for broad-spectrum weed control. This helps to delay and reduce population shifts in continuously planted cotton (Dowler and Hauser, 1974).

In the early days of increasing herbicide usage, the dramatic results of many new herbicides shifted emphasis away from study of these ecological trends. But the current herbicide era has not cancelled the ecological principle concerning the spread of species to their limits of adaptation. The pernicious character of weeds is further enhanced by the development of resistance in specific weeds to herbicides (Bandeen *et al.*, 1982; Gressel *et al.*, 1982). Development of resistance has been documented in North and South Carolina cotton fields with a population of goosegrass (*Eleusine indica* L.) that is highly resistant to trifluralin (Treflan®, etc.) and other dinitroaniline herbicides (Mudge *et al.*, 1984; Slater, 1984). Common cocklebur (*Xanthium strumarium* L.) populations in South Carolina cotton fields show some plants highly resistant to DSMA and MSMA, the organic arsenical herbicides (Haigler *et al.*, 1986). These resistant populations must be managed as new and exotic pests in cotton. Past resistance problems have been managed by the use of herbicide mixtures, sequential treatments and the rotation of herbicides and crops. However, this has led to increases in production costs.

Effective weed management is only one of the many production practices required for a successful and profitable crop production system. It has been documented (Gaylor *et al.*, 1983) that various production practices, including those used to control pests, are not independent of each other . Therefore, many local variations have to be considered in fitting a new herbicide or a new farm tool into a specific cropping system. Scientists cannot go their separate ways; they must keep abreast of recent developments in other disciplines because progress in one area only can go forward along with progress in other areas. Past examples are mechanical harvesting, plant breeding and cultural practices. State and federal researchers have constantly looked for innovative ways to use herbicides in basic agricultural practices. For example, the concept of conservation tillage originated before 1970, but expanded research and more effective herbicide programs have led more and more farmers to adopt some form of reduced tillage in most crops. Higher energy costs and the need to reduce soil erosion also contributed to the acceptance of this practice.

Since the introduction of diuron (Karmex®, etc.) in the 1950s, refinements have permitted increasing sophistication in spray equipment. The importance of precise placement of herbicides (Figures 2 and 3) to obtain maximum efficiency on soils, in soils and on plants and the variables that affect placement has long been recognized (Dawson, 1963; Holstun, 1966; Klingman, 1964). Putting herbicides on target weeds or sites by application systems have been vastly improved. Post-directed sprays using selective oils permitted application to cotyledon-stage cotton in the 1950-1960 era. Later, with the introduction of diuron (Karmex®, etc.), fluometuron (Cotoran®, etc.) and other herbicides, "oiling shoes" permitted growers to be as precise as possible with post directed sprays (PDS). More recently, specialized application equipment such as the recirculating sprayer and various types of wiper applicators for glyphosate (Roundup®) application has enabled farmers to control tall growing weeds in crops that have escaped other control measures (Dale, 1978; McWhorter, 1970). In addition to being a new application technique, this equipment reduces drift, reduces the amount of herbicides used and the volume of water required. Chemigation, a technique for applying herbicides through center pivot or solid-set irrigation systems, is being adopted by farmers (Dowler *et al.*, 1982). Each method reduces application costs, improves the consistency of performance for some herbicides and is suited for the application of many soil-applied and foliar-applied herbicides in volumes of water as low as one gallon per acre (gpa) or as high as 27,000 gpa (one acre-inch).

Experiment station researchers also have contributed to the development of new uses for old products and procedures for proper use. In the early 1960s, soil-applied diuron was found effective as a post directed spray application for cotton

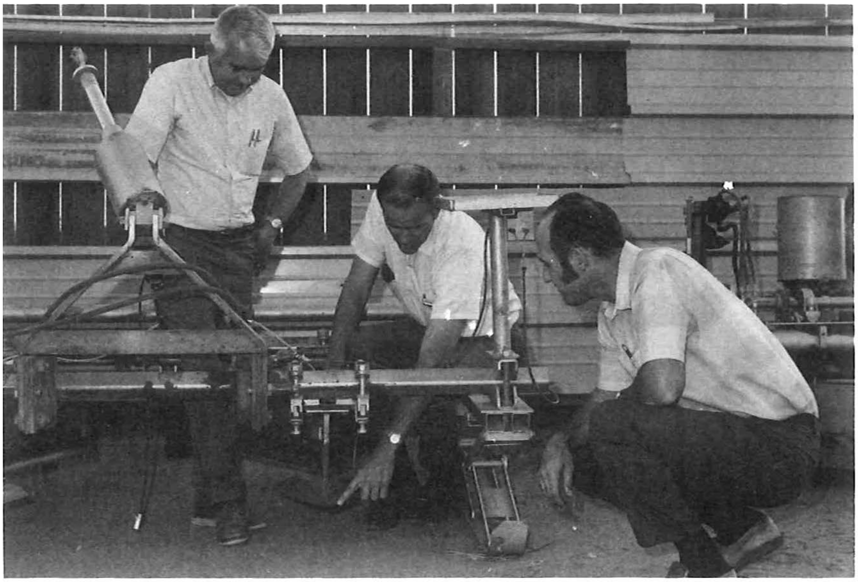

Figure 2. The Stoneville spray-blade was modified and tested at the USDA Cotton Research Station, Shafter, CA, in 1959 with Dr. Paul Keeley (left), Lyle Carter, Engineer (right), and Harold Kempen (center). Subsequent extension field testing with trifluralin was promising and growers used it for several seasons. But, if rainfall occurred immediately after planting, retardation was moderate. Currently, metham (Vapam®) is successfully bladed preplant on several California crops (1964).

when used with adjuvants (McWhorter, 1964). This discovery led to greater flexibility and efficiency with herbicide applications in other crops. Occasional delayed applications of the organic arsenical herbicides DSMA and MSMA by growers suggested yield reductions. Beltwide research showed that topical applications at advanced growth stages reduced cotton bloom, delayed maturity and increased the arsenic content in cottonseed (Baker *et al.*, 1969). These findings alerted farmers to the multiple dangers of late applications.

Experiment station researchers developed principles based on the effects of weeds on crops and the variables that influence weed competition (Figure 4). Many studies have shown the need for early-season weed control in cotton (Buchanan and Burns, 1970; Buchanan and McLaughlin, 1975; Higgins *et al.*, 1983; Patterson *et al.*, 1980; Rogers and Buchanan, 1976). While control for six to eight weeks after planting usually is adequate, factors such as soil type, soil fertility, geographical location, weather conditions, weed species and their population levels, crop varieties and row spacing can modify that period (Buchanan and Burns, 1971a, 1971b; Chandler and Meredith, 1983; Oliver *et al.*, 1981; Robinson, 1976; Rogers and Buchanan, 1976; Snipes *et al.*, 1983). Some early-

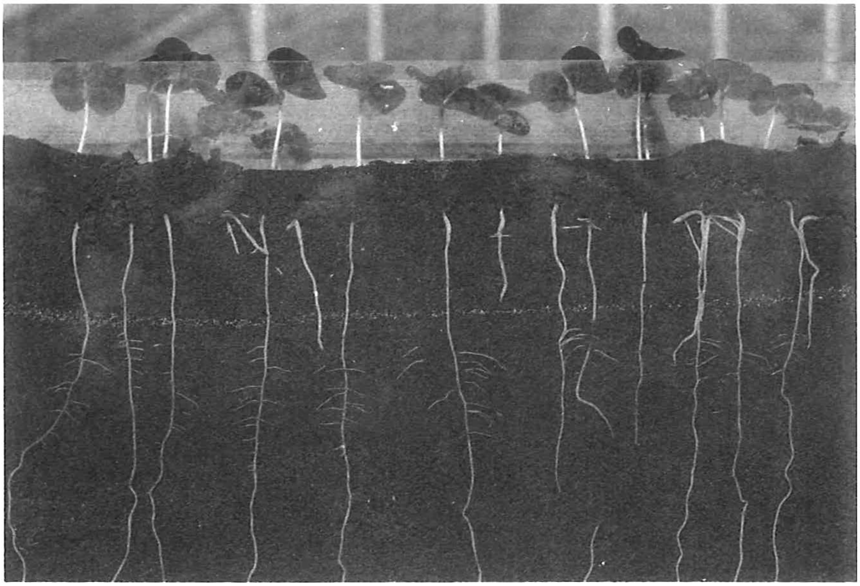

Figure 3. The classic glass box studies with dinitroanilines dramatized "root pruning" differences.

season weed interference will not significantly reduce yields if weeds are removed and the cotton is maintained weed-free for the remainder of the growing season (Buchanan and McGlaughlin, 1975); Higgins *et al.*, 1983; Keeley and Thullen, 1975; Patterson *et al.* 1980; Rogers and Buchanan, 1976). Results from these studies have helped in developing efficient weed management programs and is being incorporated into computer models which should help future growers.

Weed scientists continually work with geneticists and plant breeders in developing and releasing new cultivars to determine how they will respond to the herbicides generally used on the crop. Other cooperative research efforts continually are emerging to improve the efficiency of weed management.


Figure 4. A 1961 observation on irrigated cotton planted into moist soil showed that with no rainfall after planting, barnyardgrass survived on the primary root until post-plant irrigation. Adventitious roots then developed rapidly one, two and seven days later.

## EXTENSION'S ROLE IN WEED MANAGEMENT PROGRAMS

Extension was institutionalized by the Smith-Lever Act in 1914, which obligated cooperation between the USDA and land-grant colleges whose state legislatures accepted the provisions of the federal Act (Evans, 1938). It appropriated the money to set up county-based agents who would work with local farmers in setting up local demonstration programs. The Morrill Act in 1862 provided the "Land-grant" concept for state university experiment stations. In 1887 the Hatch Act provided cooperative federal grant-in-aid funding for agricultural research that each state land-grant university justified and undertook. The extension service mission was to "extend" that information to growers.

In the early years, extension was accomplished by schooled professionals who would then stay on the front end of the learning curve by working with innovative colleagues, farmers and others. Since then extension personnel continue to do that but often supplement the latest innovative practices with in-field adaptive research. Especially in weed control, extension weed specialists and county-based personnel usually have well-established programs aimed at developing weed science and weed management data which establishes new practices and verifies existing practices. This in-field research is widely sought after by innovative farmers so that they might profit from the latest technology.

Typically, extension personnel work with the most innovative growers who then introduce new, more economical farming practices into the community. After most growers utilize such practices, the savings from efficiencies are passed on to the consumers in the form of lower prices. For example, the price of cotton during the Civil War in 1864 was 95 cents per pound of lint. Other conditions, however, have greatly altered prices. After Eli Whitney invented the cotton gin in 1792, the price in 1802 was 14.7 cents a pound. In 1898 it dropped to six cents; in 1931 during the depression, it dropped to 6.3 cents; in 1945, the maximum price during World War II was 27 cents (Brown and Ware, 1958). Prices in 1986-87 ranged from 70-80 cents per pound. Efficiencies have not prevented price variations but certainly increases in prices are much less than increases for manufactured goods. More detail on prices appears in Chapter 2.

With the introduction of radio—and more recently other communication mediums such as television, video cassettes, fascimile machines and desk-top publishing—the information flow has markedly accelerated (Kempen, 1989). Concomitantly, new ideas from anywhere in the world can find an end-user in a given region. Regular conferences, brochures and books, computerized databases along with an increasingly mobile population of farmers result in extension employees being deluged with information. For this reason, more emphasis must be given to quality and less on quantity. That does not mean color or shiny paper, but well-composed grower manuals that are easily used or "user-friendly" computer databases.

Extension's capability at "keeping up" is increasingly at risk due to these new changes. Industry has massive databases which are not publicly accessible, but which enable them to research, develop and market their products. While extension can utilize public databases, it has greater difficulty focusing on getting all components together. Yet, its collective contribution, despite downside problems, is enormously important to our increasingly urbanized society.

In many other nations, extension has been non-existent, or linked to national research and regulatory agencies rather than to the land-grant research and teaching universities that we have in the United States. Some of them are attempting to charge for services rendered, but indications are that these systems will not be successful.[1]

In the United States, most universities now charge for extension publications and weed recommendation guides. Some are attempting to recover operational costs by additional means. Some are trying to have a greater urban focus (to accommodate urban voters). In California, extension specialists and farm advisors are doing most of the field research. Few experiment station researchers are available to do problem-solving field research. Those present must also teach

[1]Personal communication with Don Luvisi, Extension Advisor, while on sabbatical in Australia, 1988.

and do basic research for publication, their key to promotion. All these personnel management aspects impact on inputs into grower weed management programs. But because weed science is the latest of the crop protection sciences to gain recognition among university agricultural disciplines, it has been affected more than most other disciplines by these pressures. Grants-in-aid from crop commodity groups and from the chemical industry have helped in production-oriented weed management studies, but not significantly in basic weed science. Where extension specialists do considerable field research, they have often generated enough grants from industry and commodity groups to hire extra help (Figure 5). In California, the California Planting Cottonseed Distributors, a non-profit group, has funded weed and other research by cooperative extension farm advisors and department researchers for several decades.

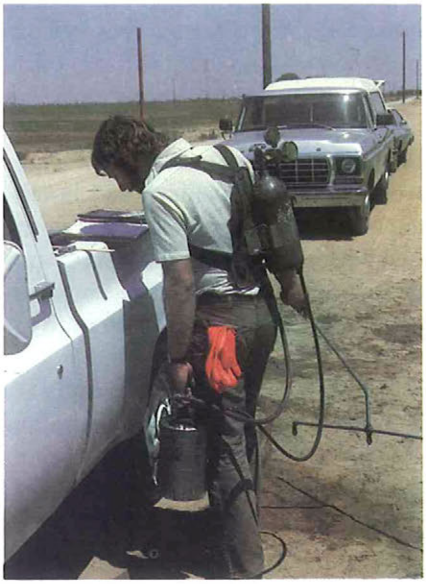

Figure 5. Grant funds from cotton marketing/research groups and manufacturers have enabled extra research assistants for conducting field experiments.

## HOW INDUSTRY WORKS WITH PUBLIC AGENCIES

Without a viable agricultural chemical industry, weed management as we know it today would not exist. Industry employees are the ones who invent the chemistry, evaluate it, develop it, sell it and then continuously monitor the results of their efforts. Without the successful sale of herbicides, they would not exist and the marvels of new herbicides such as glyphosate (Roundup®), fluazifop-P (Fusilade 2000®) and sethoxydim (Poast®) would not be commonplace in agriculture today. Millions of dollars would be spent on the arduous task of hand-weeding in the hot sun instead of such labors going into more useful exploits. Only those who grew up doing such tasks, know the dullness and drudgery of such work.

Weed scientists know the cost-effectiveness of products such as atrazine (AAtrex®, etc.), diuron (Karmex®, etc.) and trifluralin (Treflan®, etc.). Prices have not changed appreciably over decades despite continuing inflation of most industrial products. The value to mankind of the newer discoveries such as glyphosate (Roundup®), fluazifop-P (Fusilade 2000®) and nicosulfuron (Accent®), when they have no patent protection and generic introductions appear on the market, will be in the billions of dollars! (Figure 6) And the introduction of biotechnology products will permit development of herbicide-resistant crops which will permit use of low rates of some of these very low animal toxicity, environmentally suitable products on a wide array of crops. The value to mankind will be tremendous, not to mention the reduction in acreage needs devoted to food and fiber production for man's benefit. But, as with the pharmaceutical industry, advances in protecting crops with "farmaceuticals" will not come without profit to the innovators.

Nature's dynamic changes in the genetics of weeds, as with insects, has resulted in the selection of species now resistant to herbicides. A viable industry will stay ahead of this normally occurring reality-of-life on this planet. Otherwise, we will not be able to develop and produce the crop protection chemicals necessary to sustain agriculture in an efficient manner, one that will provide the increasing population of man with ample quantities of quality food and fiber.

Industry's role in the cooperative development of reliable weed management practices is obvious. Regulatory requirements before registration on about five crops cost as much as $25 million. But costs continue after registration due to continuing and new requirements. The successful manufacturer must be uniquely qualified in many areas to be able to cope with it all. And increasingly the manufacturer does it himself, providing partial or total renumeration to those who work with them on these lengthy projects. Whereas industry could fairly well judge where, when and how big their market was, in recent times environmental regulations may eliminate a market or a product. New laws may incur clean-up costs or litigation costs over alleged as well as real hazards. Industry employees must nurture a product from the cradle to the grave, monitoring its development and profitability all along the way.

Industry solicits inputs from academic researchers fairly early in the game, but they must obtain legal control of their products prior to release to the academics. Often larger companies will have done adequate field efficacy studies to obtain EPA and state registrations. But they highly value the inputs of experiment station and extension researchers, in part because of their independent status and their capability to compare with existing products in existing field practice. Also, university department and extension personnel must know the product prior to

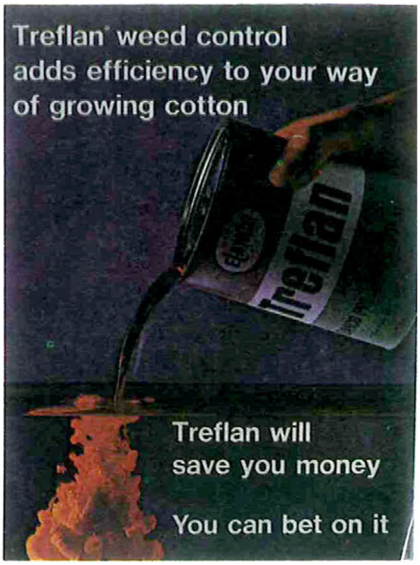


Figure 6. Trifluralin (Treflan®), one of our miracle cotton herbicides, now is sold under generic names at no greater cost per gallon than when registered in 1963.

its introduction so that they can assist growers in its integration with existing practices. Often, the public agency people aid considerably in grower acceptance if a herbicide indeed does work and is cost-effective. In generic markets, new product mixes called "pre-mixes" are introduced to "cannibalize" the market (in business jargon) to gain market share.

When a new proprietary product is introduced, a heavy burden falls on the manufacturer representatives. They have researched the product and know its advantages and disadvantages as well as anyone. They must educate the consultants, applicators and end-users as to how they might best utilize it. Litigation risk is greatest when products are introduced, so they must monitor it well in its early years to see that it is properly used, where further research is needed and where further education is needed. Product awareness is most important. Growers do not use new cost-effective technology without being aware of its existence. So sales efforts are needed, with incentives to distributors and dealers, so that all possible users are advised and aided. Actually, it is a massive effort, and many techniques are used to accomplish the job. Aiming at innovative growers, well-respected specialists and consultants, both directly and through media and promotional programs, they are able to ensure "saturation" of the area needing the effort. Marketing involves complex techniques these days and is a science in itself, which, with the aid of computers, permits reasonably exact analysis of the results from efforts made.

As with the consultants, time is usually the limiting factor in getting the job done well. The circle of technology in agriculture, as in other sciences, is enlarging. New products compete with older (and usually cheaper) ones but, because herbicides can be risky if not used correctly, servicing of older, less profitable products is necessary. Such reduced profit margins put more burden on the sales staff, their technical support team and the researchers themselves. Again, the race is to do research well, sell efficiently, keep up with competitor activity, assist and encourage academics and regulatory personnel so that they are not countering industry efforts and keep the image of the product healthy.

So, increasingly within industry, as with other groups, specialization is necessary. But to manage it all is also necessary. Largeness seemingly is becoming a necessity for all to "stay in the game," be they industry, government, consultants, sales organizations, the popular publications or farmers. Advocacy groups may not like it but they are probably most instrumental in causing this trend. Products registered on minor specialty crops or minor uses in major crops are lost because of lack of profitability. Fortunately, cotton is one of the major crops and efforts to develop new products for it are still major, but not for one weed such as "minor" nutsedge which only infests 10-20 percent of the cotton acreage. With 10 million acres of cotton, 10 percent is only one million. If growers chose to treat 50 percent of the acreage, only 500,000 acres would be treated. To get return on a $25 million development investment in four years after registration, that would need a return of $12.50 in profit per acre treated after all investment and marketing costs. With a 100 percent markup, that means growers would need to be convinced that $25 per acre was a good investment on their part.

Perhaps the biggest lack of cooperation in the entire "working together" concept is from the regulatory and urban sector. Since the regulatory sector operates at the will of politicians who tend to be responsive to the urban sector, it behooves the industry and its cooperators to maintain ties with that sector. We also must help the urban public to understand the upside as well as the downside of crop protection chemicals, and why herbicides have made our American agricultural system so efficient. Without that effort, they who eat will be impacted with greater food and fiber costs. That may not affect the middle classes but it may affect the poor, if we return to paying 23 percent of our disposable income for food as in 1951 as the National Agricultural Chemical Association (NACA) suggests, rather than the 16 percent we spend now (Anonymous, 1987).

## THE CONSULTANTS ENTER THE SCENE

Consultants are relatively new to weed management aspects of agriculture. Few independent consultants work on weeds alone. Most advice to growers from consultants come from those who also sell the product.

Nationwide, independent consultants have organized into a group called the

"National Alliance of Independent Crop Consultants (NAICC).[2] There are about 200 members in this organization. Members provide general and specific advice to farmers. While crop protection advice generally is the major service provided, services also include agronomic, horticultural, economic, legal (litigation) and other advice. Some of the consultants also do independent research on agricultural chemicals. The organization's objectives are to share the latest technology and, through monitoring of member performance, meetings, etc., improve the professional standards.

In the area of the Cotton Belt from the Carolinas to the Rio Grande Valley in Texas, there are state and regional organizations of independent consultants. There are some 320-350 independent consultants who work with farmers. In this area, growers appear to use independent crop consultants more widely than in the West. Many focus on entomological and weed management services to growers. Some focus on scouting insects and making recommendations. They usually hire temporary help to do the scouting. If they "do weeds", they must monitor and advise growers themselves since it is too complicated for novices. Many also serve as production consultants, being opportunistic in providing whatever service they can for whatever fee they can get. Relationships are all-important. They source information from university academic and extension staff and regularly attend industry programs on their products. They key in on competent specialists wherever they can find them and thereby try to provide the best information to their grower clients.

In the West, most consultants sell agricultural chemicals to growers as well as provide recommendations (usually written) on the use of all crop protection chemicals including herbicides. In California they are called "Pest Control Advisors" (PCA's). They have organized into an advocacy and upgrading group called the California Agricultural Production Consultants Association (CAPCA). Of the 3,921 registered with the California Department of Food and Agriculture, about 10 percent work with cotton.[3] They must meet educational standards set by a group that is advisory to the Director of the Department. To become a PCA, minimum college requirements must be met, such as a B.S. degree in Biological Science, Agricultural Sciences or Pest Management, or 60 semester units of such coursework, plus two years of internship to a licensed PCA. Other specific coursework such as chemistry, production and pest management and then completion of examinations in laws and regulation, plus each category of crop protection must be met. Of interest is that municipal district pest control employees in cities and irrigation districts must also meet these requirements beginning in 1992. Fees for registration are $80.00 biennially.

Since herbicides are now widely used, pest control advisors have become proficient in weed control practices as well as with insecticides and fungicides (Figure 7). Some also sell fertilizers and rarely crop seeds. They see their larger-

[2]Personal communication with Dr. Louise Henry of NAICC, May, 1988.

[3]Personal communication with Mac Takeda, CDFA, September, 1990.

Figure 7. Consultants monitor grower fields and repeatedly learn of interactions such as here between phorate and trifluralin (1965).

acreage growers weekly during the production season and monitor the progress of the crops enroute to harvest and advise the grower on needs, formulations and technique. They are "on call." Some, through their dealer or distributor franchises, provide in-field application services while others only sell the product and leave the application to commercial applicators or to the grower's staff. On the largest farms, managers have a resident agronomist or other technical employees who are college-educated and who provide recommendations to field staff who manage segments of the agricultural operation (Figure 8). Very few provide independent weed management consulting services for a fixed per-acre fee, citing liability as the chief reason. As do independent consultants in the South, these resident experts seek out the counsel of specialists who they feel are most competent. They do not stop at the local county specialist, but go anywhere in the state, nation, and sometimes internationally to get the information they need. These people need and use the best written material and computerized databases on the subjects for which they are responsible.

Because of the increasing complexity of regulations, including the requirement for written recommendations by regulatory agencies (and by some growers), private consultants are finding a larger proportion of their expertise diminished by paperwork. But the increased complexity logically mandates more written recommendations for applicators, be they commercially hired or farmer managed. Computers are being utilized by some to facilitate the transfer of accurate recommendations and environmental precautions and, no doubt, their use will

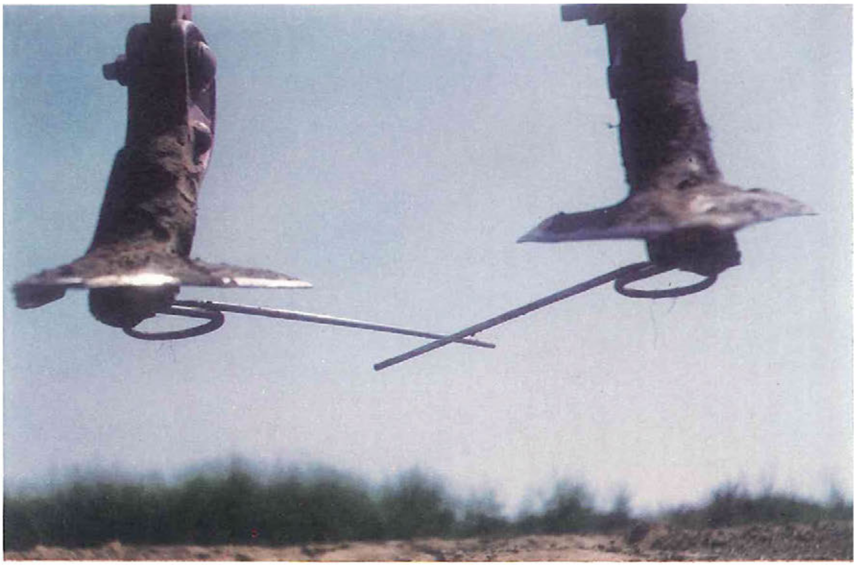

Figure 8. Farm agronomists often find very simple answers to weed problems like this tine weeder for removing seedling weeds out of 8-24″ cotton (1972).

be increased in the future. They also may lead to more regulatory controls and result in more problems, such as recent California plant-back restrictions which are legal, not scientific (Kempen, 1987). Full reporting of all pesticide applications by site were required by California law beginning in 1990. The intended objective is to show that not all registered pesticides are being used.

The requirements of the laws—including groundwater contamination rules, plant-back restrictions, cancer or birth-defect considerations, endangered species, transportation, hazardous waste and storage considerations—are becoming so complex that the smaller dealers are unable to cope with the problem. Larger ones increasingly are using computers to keep track of all the detail so as to aid the consultant.

The need to be accurate on weed identification, herbicide application rates, timing, weather conditions, irrigation and regulations, along with grower capabilities and limits, makes the need for a weed consultant logical (Kempen, 1977). Public agency personnel cannot provide all the service needed to growers and growers cannot do it themselves because the circle of technology and regulations have continued to expand. Since many crops are grown with cotton in the West, consultants find themselves limited by time more than anything when getting the best information for the problem. Many become exceptionally competent, since they see many situations in many fields unlike an individual farmer who must keep his shadow in the field. If they monitor the results of their own weed recommendations, they can become very precise in future recommendations. However, often they do not have time to do this. If selling consultants were paid for monitoring crop protection needs by the acre, or salesmen had larger margins of profit, they could provide growers with the depth of service needed. But competition between dealers plus the growers' acute concern for keeping costs down prevent that. Therefore, all the consultants must rely on public and industry researchers to provide side-by-side comparisons and evaluations of products under many environmental conditions. They also must rely on public agency reseachers for identification of specific weeds new to them.

Consultants are now a most important link in the line of cooperative effort to get from original synthesis of a new herbicide to its fit in a reliable, integrated weed management program. Some also sell herbicide products, but they are reliable because growers are their source of repeated sales. Not many mistakes are allowed. Increasingly, the consultant is the grower's first reliable contact for all crop protection decisions.

## THE CAPABILITY OF THE FARMER

Extension and industry managers have determined long ago that there are innovative growers, early acceptors, go-alongs and late adaptors. They tend to work with the innovative growers because other farmers recognize these as the leaders and emulate their newly developed practices.

It is the innovators who are continually involved in the development of new weed management practices. These growers are willing to risk loss from tests or demonstration plots because they get to see the results first and have an advantage over their "competitor" neighbors. Of course, it does take more management to provide this service to cooperating university and industry researchers, but they see the value and the prestige of doing so.

Often they are well-educated individuals and have a flair for doing things well. Their greatest help to researchers is that they can see the "fit" of a new practice and are quick to point out the flaws and limits of it. This is acutely valuable to researchers of new products because no one can afford to waste time on a product that won't be a "new mouse-trap." Growers usually know equipment, irrigation interactions, timely operational requirements, varietal aspects and other "little things" that can make or break a new product. Researchers often are not farmers, and in recent times, most were never reared on a farm. So, the help of various farmers is essential to successful field research. Conditions on various farms vary considerably and growing techniques also vary. Such farmers may permit a new product to become established, or after years of use, develop a new modification of practice which permits greater utility. They are also quick to find out if the product is not reliable from season to season. (Figure 9)

While the use of a new piece of equipment may permit successful usage of a given product, the market potential or penetration of the market is reduced or delayed if growers do not have the proper equipment in hand. A good example

Figure 9. Growers on sandy loams developed this 8-row incorporator-planter unit—called ROCAP (Rolling Cultivators At Planting) in California—for applying trifluralin into moist soil (1963).

of that is the use of sled-shoes (or oiling shoes) in California. They have been used successfully for 35 years in the South because of their need with products like herbicidal oil, and dinoseb (before it was banned in 1986). More recently diuron (Karmex®, etc.), prometryn (Caparol®, etc.), cyanazine (Bladex®), and methazole (Probe®) are combined with MSMA as post-directed sprays. But they have not been needed in California. Recent research has shown that they would be very useful for control of nightshade—a more recent weed problem in cotton—but grower acceptance has been slow due to lack of understanding of the concept (Figure 10). In large part this is due to the unavailability of equipment both on the farm and at the equipment dealer.

As a group, growers are lacking with respect to introduction of new herbicides in that they are too quick to jump into a new practice after one successful experience. Extension and industry advisors know from their broad base of experience that more than one trial and one year is needed before reliability is established. In recent times, the extremely long lag period between efficacy trials and registration of new herbicides makes the chance of risk with newly registered herbicides less, but nonetheless still real. While other new agricultural practices may be advantageously accepted by innovators, they are more likely to experience periodic problems with new herbicides. New, more stringent regulations on research are tending to make field research more precise but less broadly based. This probably will make for more risk with new herbicides. For the grow-

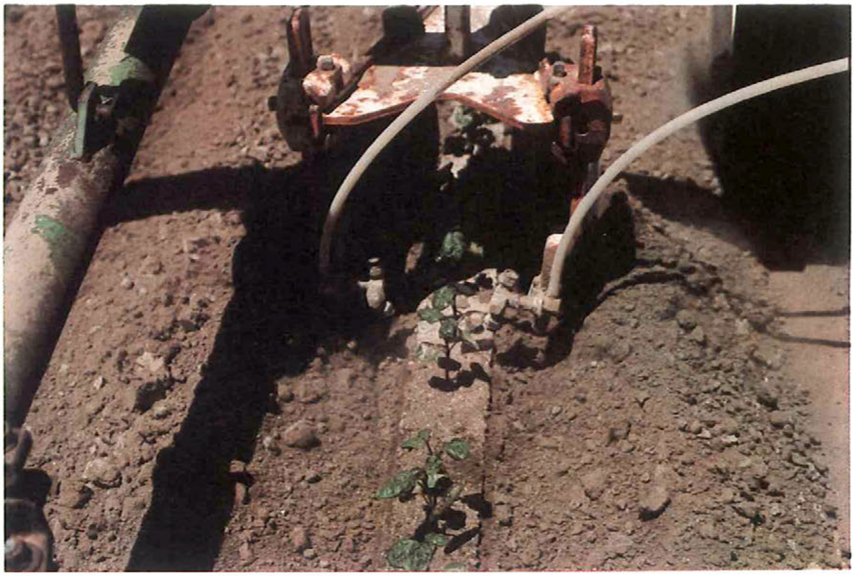

Figure 10. A post-directed spray (PDS) unit set-up by a California production consultant (PCA) for nightshade control in cotton. "Oiling shoes" have been used in the South for decades. Now, this concept is needed in the West (1988).

ers sake, extension leaders should continue to suggest limited treatment with new herbicides.

Growers generally do not know their soil types very well. Most have "light" and "heavy" soils on their farm. But these soils may all be sandy loams or all clay loams. This makes it difficult for them when herbicide recommendations based on soil type are made. They do tend to use minimum label rates when first using new herbicides. Sometimes they discard them because they failed to provide adequate weed control due to too low a rate.

The concept of depth of application was very important with the dinitroaniline herbicides. Some time elapsed before western growers finally switched from disc-harrows designed for field tillage to finishing discs for soil incorporation of herbicides. In the South, growers often disced in trifluralin and then bedded (hipped) up and planted on top of the bed. Roots didn't penetrate the treated zone until corrective practices overcame "cotton stunt" or "saw-tooth" growth in the early season. All in all, it is those growers who have learned to apply science to their farming operations that have survived the agricultural economic recession of the mid-80s.

## REGULATORY CONTRIBUTIONS

Regulatory agencies are probably mentioned more frequently in unkind terms than all other cooperators to scientific utilization of weed management. They may deserve it, but often their efforts and actions are little understood by farmers and their advisors, and rarely are regulatory personnel allowed the chance to defend themselves.

Regulatory agencies have done the herbicide industry many favors. When 2,4-D was first introduced, it was seen as a valuable tool but little was known about its downside risks. It caused all sorts of damage to neighboring crops, often for many miles downwind. But the regulatory agencies, such as the California Department of Food and Agriculture through its Title 3 regulations (California Code Section 6464) were able to develop rules and guidelines which allowed end-users to take advantage of its value for the past 40 years. Today millions of acres of crops are still treated with 2,4-D although Cotton Belt users are not kindly disposed to it. One pound can destroy 1000 acres of cotton (Miller *et al.*, 1963).

The greatest regulatory impact is at the beginning of herbicide development. The rules for proving the safety of a new chemical product have expanded enormously and show little sign of abating (USEPA, 1984). Yet in France, by contrast, pesticides were not legally registered until 1990. Perhaps the name accounts for a difference in attitude. In France they call pesticides "produits phytosanitaire."

Single interest advocacy groups have been highly successful in the arena of toxicology and environmental protection, using the mass media to their advantage with a public sector who knows little of agriculture. Yet new products are necessary if we are to continue to protect our crops against a dynamic Mother Nature. Perhaps recent research reported by Ames, Magaw and Gold (1987) or Ames and Gold (1990) showing that many natural carcinogens and anticarcinogens exist in man's diet and pose a greater risk than pesticides will alleviate the major concern that the general public has for agricultural chemicals.

How the regulatory sector—which now includes many non-agricultural groups such as water quality, air quality, health, ecology, fish and wildlife and transportion—will respond to agriculture's needs will determine the future of weed management in cotton and other crops. If biotechnology is accepted by the general public, it might allow American agriculture to advance without many herbicides because several promising techniques could allow the efficiencies we need to afford our current standard of living. But the crop protection industry must remain economically viable, with enough resources to carry on the research needed to meet the broadening requirements of regulatory agencies. Otherwise the entire chemical industry will stagnate and the chances for maintaining today's standard of living in America will diminish.

## SUMMARY

Putting together all the elements that make an acceptable end-product, namely a successful weed management program for cotton, involves the efforts of many people who are employed by several different organizations. It is highly systematic and is most effective when people work well together. The system has worked well resulting in excellent improvements to management of weeds in cotton, particularly due to the introduction of several unique herbicides. It has taken many man-years of in-field research, education and servicing to enable it all to happen. Refinements continually occur due, in some cases, to shifts in weed species and, in other cases, higher standards of excellence that are demanded by cotton growers. Getting the best from the herbicides without the problems that can occur requires intensive inputs from manufacturers, distributors, dealers, university and federal research staffs, extension specialists, consultants and the farmers themselves. More recently, consultants have enabled growers to best utilize weed management technologies. With increasing environmental restrictions, they will be more needed by growers in the future.

# LITERATURE CITED

Anonymous, 1987. NACA Fact Sheet. Natl. Agr. Chem. Assoc. Washington, D.C. 8 pp.

Archibald, S. O. And Winter, C. K. 1989. Pesticides in Food: Assessing the Risks. University of California Agricultural Issues Center, Oakland, California.

Ames, B. N. 1983. Dietary carcinogens and anticarcinogens. Science 221:1256-1264.

Ames, B. N., R. Magaw and L. S. Gold. 1987. Ranking possible carcinogenic hazards. Science 236:271-280.

Ames, B. N. and L. S. Gold. 1990. Too many rodent carcinogens: Mitogenesis increases mutagenesis. Science 249:970-971.

Arle, H. F. and K. C. Hamilton. 1963. Chemical Control of Annual Weeds in Cotton. Bull A-28. Coop. Ext. Serv. and Agr. Exp. Sta., University of Arizona. 12 pp.

Baker, R. S., H. F. Arle, J. H. Miller, and J. T. Holstun, Jr. 1969. Effects of organic arsenical herbicides on cotton response and chemical residues. Weed Sci. 17:37-40.

Bandeen, J. D., G. R. Stephenson, and E. R. Cowett. 1982. Discovery and distribution of herbicide resistant weeds in North America. Pages 9-27 *in* H. M. LeBaron and J. Gressel, eds. Herbicide Resistance in Plants. John Wiley and Sons, Inc., New York.

Brown, H. B. and J. O. Ware. 1958. Cotton and the Growth of the American Economy. 3rd ed. McGraw-Hill, New York. 400 pp.

Buchanan, G. A. and E. R. Burns. 1970. Influence of weed competition on cotton. Weed Sci. 18: 149-154.

Buchanan, G. A. and E. R. Burns. 1971. Weed competition in cotton. I. Sicklepod and tall morning-glory. Weed Sci. 19:576-579.

Buchanan, G. A. and E. R. Burns. 1971. Weed competition in cotton. II. Cocklebur and redroot pigweed. Weed Sci. 19:580-582.

Buchanan, G. A. and R. D. McLaughlin. 1975. Influence of nitrogen on weed competition in cotton. Weed Sci. 23:324-328.

Chandler, J. M. and W. R. Meredith, Jr. 1983. Yields of three cotton *(Gossypium hirsutum)* cultivars as influenced by spurred anoda *(Anoda cristata)* competition. Weed Sci. 31:303-307.

Coble, H. D. and J. W. Schrader. 1974. Weed population shifts in three-year rotation. Proc. South. Weed Sci. Soc. 27:151.

Dale, J. E. 1978. The rope-wick applicator—A new method of applying glyphosate. Proc. South. Weed Sci. Soc. 31:332.

Dawson, J. H. 1963. Development of barnyardgrass seedlings and their response to EPTC. Weeds 11:60-67.

Day, B. E. 1983. The resistance of agricultural pests to control measures. Council for Agricultural Science and Technology. Report No. 97. Ames, Iowa. 18 pp.

Dowler, C. C. and E. W. Hauser. 1974. Crop-herbicide sequences on a southeastern coastal plain soil. Weed Sci. 22:500-505.

Dowler, C. C. and E. W. Hauser. 1974. The effect of cultivation on weeds controlled by fluometuron in cotton. Proc. South. Weed Sci. Soc. 27:112-115.

Dowler, C. C. and E. W. Hauser. 1975. Weed control systems in cotton on Tifton loamy sand soil. Weed Sci. 23:40-42.

Dowler, C. C., W. A. Rohde, L. E. Fetzer, D. E. Scott, Sr., T. E. Sklany, and C. W. Swann. 1982. The effect of sprinkler irrigation on herbicide efficacy, distribution, and penetration in some coastal plain soils. The University of Georgia. Res. Bull. 281. 27 pp.

Dunster, K. W. 1982. Who will do applied research in the future? Proc. West Soc. Weed Sci. 35: 109-112.

Evans, J. A. 1938. Recollections of Extension History. Ext. Circ. No. 224 North Carolina Agr. Ext. Serv. 45 pp.

Gaylor, M. J., G. A. Buchanan, F. R. Gilliland, and R. L. Davis. 1983. Interactions among a herbicide program, nitrogen fertilization, tarnished plant bugs, and planting dates for yield and maturity of cotton. Agron. J. 75:903-907.

Gressel, J., N. U. Ammon, H. Fogelfors, J. Gasquez, Q. O. N. Kay, and H. Kees. 1982. Discovery and distribution of herbicide resistant weeds outside North America. Pages 32-55 *in* H. M. LeBaron and J. Gressel, *eds*. Herbicide Resistance in Plants. John Wiley and Sons, Inc., New York. 401 pp.

Harvey, R. G., P. B. Chykaliuk, R. H. Crowley, J. E. Dale, J. F. Mason, J. E. Nelson, P. A. O'Sullivan and W. H. Zick. 1986. Directory of North American Weed Scientists and WSSA Members Worldwide. Weed Sci. Soc. America. Champaign, Illinois. 173 pp.

Haigler, W. E., B. J. Gossett, and J. R. Harris. 1986. Organic arsenical-resistant common cocklebur biotypes. Proc. South. Weed Sci. Soc. 39:105.

Higgins, J. M., R. H. Walker, T. Whitwell, and J. A. McGuire. 1983. Coffee senna interference in cotton. Proc. South. Weed Sci. Soc. 36:19.

Holstun, J. T., Jr. 1966. Placement of herbicides as it affects weeds and crops. Proc. South. Weed Conf. 19:27-34.

Keeley, P. E. and R. J. Thullen. 1975. Influence of yellow nutsedge competition on furrow-irrigated cotton. Weed Sci. 23:171-175.

Kempen, H. M. 1977. A weed management experience in California's irrigated crops. Proc. European Weed Res. Soc. pp. 53-57.

Kempen, H. M. 1987. Alternatives to lost herbicides due to CDFA "plant-back" restrictions in 1986. California Weed Conf. 39:178-181.

Kempen, H. M. 1989. Growers Weed Management Guide. 2nd Ed. 1989. Thomson Publications, Fresno, California. 250 pp.

Klingman, G. C. 1964. Whirl chamber nozzles compared to other herbicide nozzles. Weeds 12:10-14.

McWhorter, C. G. 1963. Effects of surfactants on the herbicidal activity of foliar sprays of diuron. Weeds 11:265-269.

McWhorter, C. G. 1970. A recirculating spray system for postemergence weed control in row crops. Weed Sci. 18:285-287.

Miller, J. H., H. M. Kempen, J. A. Wilkerson and C. L. Foy, 1961. Control of barnyardgrass *(Echinochloa crusgalli)* in western irrigated cotton. Weeds 9:273-281.

Miller, J. H., C. L. Foy, H. M. Kempen, L. M. Carter, and M. Hoover. 1962. Weed Control in Cotton. Bull. 791. Callifornia Exp. Stn. 30 pp.

Mudge, L. C., B. J. Gossett and T. R. Murphy. 1984. Resistance of goosegrass *(Eleusine indica)* to dinitroaniline herbicides. Weed Sci. 32:591-594.

Oliver, L. R., J. M. Chandler and G. A. Buchanan. 1981. Influence of geographic region on jimsonweed *(Datura stramonium)* competition in soybeans and cotton. Proc. South. Weed Sci. Soc. 34:260.

Parochetti, J. 1982. Who will do the research in the future? Proc. West. Soc Weed Sci. 35:7-12.

Patterson, M. G., G. A. Buchanan, J. E. Street and R. H. Crowley. 1980. Yellow nutsedge *(Cyperus esculentus)* competition with cotton *(Gossypium hirsutum)*. Weed Sci. 28:327-328.

Patterson, M. & D. Monks. 1987. Report of the 1986 Cotton Weed Loss Committee. Pages 361-364 *in* 1987 Proc. Beltwide Cotton Research Conf.

Robinson, E. L. 1976. Yield and height of cotton as affected by weed density and nitrogen level. Weed Sci. 24:40-42.

Rogers, N. K. and G. A. Buchanan. 1976. Influence of row spacing on weed competition in cotton. Proc. South. Weed Sci. Soc. 29:79.

Slater, D. S. 1984. Susceptible and resistant goosegrass *(Eleusine indica)* response to selected dinitroaniline herbicides. M. S. Thesis. North Carolina State Univ. 52 pp.

Snipes, C. E., J. E. Street and G. A. Buchanan. 1983. Determination of cotton yield loss from mixed populations of sicklepod and pigweed. Proc. South. Weed Sci. Soc. 36:342.

Street, J. H. 1957. The New Revolution in the Cotton Economy. pp. 139-143. University of North Carolina Press. Raleigh, North Carolina. 194 pp.

Turner, J. 1981. White Gold Comes to California. John Turner, Publisher. Bakersfield, California. pp. 114; 130-131.

USEPA, Washington, D.C. 1986. Guidelines for carcinogen risk assessments. Federal Register 51. p. 33992; mutagenicity p. 34006; developmental toxicants p. 34028; chemical mixtures p. 34014; estimating exposures p. 34042.

Whelan, E. 1990 "Big Fears...Little Risks." Videotape narrated by Walker Cronkite. American Council on Science and Health, Washington, D.C.

Whitwell, T. and J. H. Higgins. 1985. Report of the 1984 Cotton Weed Loss Committee. Pages 206-210 *in* 1985 Proc. Beltwide Cotton Prod. Res. Conf.

Chapter 14

# APPENDIX

## USEFUL WEED MANAGEMENT PUBLICATIONS

**State Extension publications on recommended chemicals (herbicides) such as:**

Recommended Chemicals for Weed and Brush Control. Univ. of Arkansas Coop. Ext. Serv., Little Rock, AR 72203.

Growers Weed Management Guide, *2nd Edition*. 1989. Harold M. Kempen. Thomson Publications, P.O. Box 9335, Fresno, CA 95618 (Written for irrigated farming areas, with specific recommendations on 22 crops including cotton. Also weed susceptibility charts and seven chapters on weed management, safety, herbicide use guide and organic farming. $25. 250 pp.).

**Other weed management/herbicide publications such as:**

Farmers Weed Control Handbook. 1985. King, R, A. Appleby, R. Fawcett, G. Kapusta, G. Mullendore and D. Murray. Doane Publ. 11701 Borman Drive, St. Louis, MO 63146 (A national publication on wheat, corn, soybeans, cotton and milo. It provides good concepts with very good sections on calibration, weed and herbicide basics, label interpretation, safety. Written for farmers for $15-20. 240 pp.).

Delta Crop Digest or California-Arizona Crop Digest. Annually updated. Farm Press Publ. P.O. Box 1420, Clarksdale, MS 38614 (A summary of production and crop protection information from University sources, on major crops. A good source book for farmers and consultants. $7 or less. 215 pp. with advertising).

The Quick Guide. Annually revised. B. C. Page & W. T. Thomson. Thomson Publications, P.O. Box 9335, Fresno, CA 93791 (A listing of insecticides, herbicides and fungicides registered, what organisms they work on, conversions and calibrations and basic manufacturers in the world.).

Crop Protection Chemicals Reference. Updated annually. John Wiley & Sons, Inc., 605 Third Ave., New York, NY 10158. (A compilation of most national crop protection chemical [pesticide] labels in one hardcover book. About $60, but worth it to professionals. 2021 pp.).

Weed Control Manual. Updated annually. Ag Consultant and Fieldman, 37841 Euclid Ave., Willoughby, OH 44094. (A listing by crop of registrations, including weeds, herbicide combinations and rates. About $25. 386 pp.).

Principles of Weed Control in California. Revised, 1988. California Weed Conf. Thomson Publications, P.O Box 9335, Fresno, CA 95618 (Written by 70 specialists for California college students. Hardbound, it includes general crop-by-crop information and weed science aspects. About $29. 474 pp.).

**University and regional IPM Manuals on cotton, such as:**

IPM for Cotton in the Western Region of the U.S. ANR Publ. 3305. DANR, Univ. of California, 6701 San Pablo Ave., Oakland, CA 94608-1239. (Primarily weed identification and monitoring with some information on herbicidal and other techniques.) 144 pp. with color photos. $15.00.

Weed Identification Guide, Set I, II, III, IV. Elmore, C. D., W. A. Skroch, E. C. Murdock, J. F. Miller, E. J. Retzinger, Jr., D. Hall, L. R. Oliver, R. D. Williams and C. Bryson. Southern Weed Science Society. (Available from WSSA, 309 W. Clark St., Champaign, IL 61820 for a fee. Excellent colored photos of 200 weeds of the South).

Growers Weed Identification Handbook. *#4030* University of California Cooperative Extension Offices (County Farm Advisors), or directly from UC at DANR Publications, U.C., 6701 San Pablo Ave., Oakland, CA 94608-1239. (An excellent colored photo guide to crop weeds. About $60.00. 247 weeds in 1990).

Common Weed Seedlings of the U.S. and Canada. Miller, J. R., R. E. Higgins, O. E. Strand, R. D. Palmer, A. H. Lange, B. B. Fischer, J. V. Parochetti, D. G. McClure, G. A. Mulligan, F. E. Westbrook, and L. C. Gibbs. Weed Science Soc. of America. (A 32 page colored ID guide to 72 seedlings. $2.00).

Identifying Seedling Weeds common to the Southeastern United States. Stucky, J. M., T. J. Monaco, and A. D. Worsham. Bull. 461. 197 pp.

Weeds of California. 1951. Robbins, W. W., M. K. Bellue and W. S. Ball (Available from University of California campus bookstores. A weed identification book for professional weed management advisors. 546 pp.).

Herbicide Manual: A Water Resources Technical Publication. 1984. U.S. Department of Interior; Bureau of Reclamation. Denver. 346 pp.

**Publications below available from the Weed Science Society of America, 309 W. Clark St., Champaign, IL 61820. (Prices subject to change):**

Adjuvants for Herbicides. $10.00

Weed Control in Limited-Tillage Systems. $22.50

Composite List of Weeds. $10.00

Films Involving Weed Science and Weed Identification Publication. Free

5th Edition Herbicide Handbook. $10.00

Germination and Establishment of Weeds for Experimental Purposes. $10.00

Crop Losses Due to Weeds in Canada and the United States. $2.00

Methods of Applying Herbicides. $35.00

Bibliography and Cross-Reference of Weed-Crop Interference and Crop Losses Due to Weeds. $12.00

WSSA Weed Management Database. © 1991. (A listing of 750 extension publications from the United States and Canada. $20.00).

Weeds of the West. 1991. Whitson, T. D. *et al.* (Color photos of weeds of major western states. Available from each state's Extension Service publicatoins office. Approx. $20.00. 630 pp.).

## OTHER SOURCES OF INFORMATION

Proceedings of annual Beltwide Cotton Production Research Conferences. National Cotton Council of America, P.O. Box 12285, Memphis, Tennessee 38182.

Weed Science. Journal of the Weed Science Society of America.

Weed Technology. (A less basic weed management publication of the Weed Science Society of America.).

Proceedings, Research Abstracts and publications of annual regional weed science conferences, such as the Southern Weed Society and the Western Society of Weed Science.

Proceedings of state weed conferences.

Manufacturers' special bulletins and guides. (Often very descriptive and useful, and a legal extension of the label.).

World's Worst Weeds. 1991 (reprint). Holm, *et. al.*, Kreeger Publishing Co., P.O. Box 9542, Melbourne, FL 32902-9542. (A text for academics and interested amateurs. $35 + 609 pp.).

Library computer "searches" for specific topics, using key words. (County and university libraries).

University Extension and Industry meetings, field days and weed tours.

University and private short courses.