Chapter 6

THE CHANGING WEED PROBLEM IN COTTON

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INTRODUCTION

Over the past two decades, cotton (*Gossypium hirsutum* L.) researchers, extension personnel and producers have become increasingly concerned with the effects of agronomic practices, especially weed control methods, on the changes observed in weed populations. Numerous instances have arisen which demonstrate that instead of being constant, the weed problem is dynamic and ongoing. Shifts in dominant weeds do occur, and those shifts must be considered when devising weed management systems (Swanson, 1972). The increase in difficult-to-control weeds is a matter of some anxiety. It does little good in the long term to fully control one weed species if the inevitable consequence is its replacement by another weed even more difficult to control. The crops and cultivars grown, cultural methods employed, chemicals used, etc. and all permutations and combinations of such factors can contribute to modification in weed populations. However, no one has described the situation more succinctly than Buchanan (1971b) when he wrote, "Few subjects have been discussed so much with so little data." With that in mind, we proceed.

Holm (1978) estimated that about 200 species are involved worldwide in 95 percent of man's weed problems. He further stated that about 80 species are primary weeds and most troublesome while approximately 120 are secondary. The 200 weeds are drawn from much less than one percent of the world's plant species. Over 100 species of plants are weeds in cotton fields (Holm *et al.*, 1977); but more importantly, some of the world's most noxious weeds are major problems in cotton in the United States including bermudagrass [*Cynodon dactylon* (L.) Pers.] , purple nutsedge (*Cyperus rotundus* L.), barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], goosegrass [*Eleusine indica* (L.) Gaertn.], johnsongrass [*Sorghum halepense* (L.) Pers.] and common purslane (*Portulaca oleracea* L.).

In sharp contrast to most agronomic crops such as corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.], growth of cotton is relatively slow during the first several weeks after planting, thereby offering little competition to weeds.

Consequently, weeds must be controlled especially during that time. Many methods are available to accomplish weed control. Zimdahl (1981) classifies them into biological, cultural (crop rotation and fertility management), mechanical (hoeing, hand pulling, roguing, cultivating, fallowing and mowing), nonmechanical (flaming, mulching and water management), legal (quarantines, entry laws and seed laws) and chemical.

When weed control in the United States is allotted to sources, human labor is responsible for less than 5 percent, tractors and cultural equipment for some 40 percent and herbicides for about 55 percent (Klingman, 1978). According to Zimdahl (1981), no weed control method has ever been abandoned; all are still used regularly in some crops in the world today. In fact, hand labor is still used to some extent on approximately 25 percent of United States cotton. Zimdahl (1981) also pointed out that crops, including cotton, which were manually weeded were also frequently cultivated. He described cotton as being cultivated an average of 2.9 times per year.

In the early 1920s when a production unit was still one man, one mule and 10 to 20 acres of cotton, cultivations were a necessity (Agelasto *et al.*, 1922). Whenever large crabgrass [*Digitaria sanguinalis* (L.) Scop.], johnsongrass, or other weeds were present in abundance, the fields would have to be hoed one to three times per season in addition to numerous cultivations. To illustrate the importance still placed on cultivation in this decade, a progressive cotton farmer (Burnett, 1981) made the clever observation that, "A good cultivator that is properly adjusted can cover up a lot of mistakes." Undoubtedly, he was referring to control of weed escapes. Mechanical cultivation is the most important method of weed control in western irrigated cotton and serves as the base for comparisons there with other control methods (Miller *et al.*, 1977). However, the relative importance of weed control methods has changed; herbicides are now generally the dominant method used in developed countries. Wills (1977) reported that 8 percent of the cotton in the Mississippi Delta in 1952 was treated with herbicides; by 1961, approximately 75 percent of the cotton acreage was treated; and by 1976, herbicide application to cotton averaged more than four treatments per acre. Researchers in the Southwest estimate that 70 to 80 percent of the cotton acreage was treated with herbicides by 1975 and that Treflan® (trifluralin) was by far the most widely used herbicide (Miller, 1976). A more detailed discussion of this topic may be found in Chapter 7 "Herbicide Use Trends in Cotton."

Weed shifts are frequently mentioned in popular publications and abstracts; however, few definitive studies using long-term data have been conducted to document those trends. No doubt, there are weed shifts (sometimes called "ecological shifts") occurring. Are these <u>true</u> ecological shifts resulting in long-term effects, or are the shifts only short-term responses to management? When devising optimum control strategies, it is important to know whether one is coping with changes within species or with changes in relative proportions among species. This chapter describes the changes in the weed spectrum which have occurred over time in cotton fields of the United States. It tells, where possible, why those shifts have occurred; and it suggests appropriate actions to minimize such problems in the future. Included are tables, taxonomic keys and photographs to facilitate the identification of the major weeds in cotton. Proper identification is an essential prerequisite for successful control programs.

HISTORICAL PERSPECTIVE

The changing weed problem in cotton cannot be assessed without also tracing the changes which have occurred in the crop itself. Many developments over time in cotton, especially changes in its geographical distribution and production methods, have impacted on weeds, their development and distribution. The history of crop and weed are intertwined and interdependent.

GEOGRAPHICAL DISTRIBUTION

The first European colonists to grow cotton in the present-day United States were the Spanish in Florida in 1556 (Natural Fibers Econ. Res., 1975). The first attempt by English colonists was at Jamestown, Virginia, in 1607 (Gray, 1933). Cotton was subsequently introduced into North Carolina in 1664, South Carolina in 1733 and Georgia in 1734 or 1735. The French were cultivating the crop in Louisiana by 1758, if not before (Collings, 1926).

Until the invention of the gin by Eli Whitney in 1793, cotton was a relatively minor crop in the colonies and later in the early United States. It was grown as a garden plant (Gray, 1933) for domestic use or in very small fields of two acres (one acre = 0.4 hectare) or less, usually considerably less (Scruggs, 1976). Essentially nothing is known of the weeds in the cotton plantings of that time. However, if gardeners in that era were like those of current times, they classified their plants into two categories, *i.e.*, "favored ones" which were encouraged and "all others" which were not. The degree of weed control likely ran the gamut from none to complete—depending upon the individual. The primary tool of the time for weed control was the hoe (Gray, 1933).

Until 1793, the major limitation to producing cotton was the difficulty in separating the lint from its firmly attached seed. A full day's work was involved in the hand removal of one pound (0.45 kilogram) of lint from its seed (Bruchey, 1967; Scruggs, 1976). As a result, only about 10,000 equivalent 500-pound bales were being produced annually in the United States at that time (Todd, 1950). Whitney's simple (in retrospect), hand-cranked enGINe (Bruchey, 1967; Scruggs, 1976) increased the efficiency of that process 50-fold (Natural Fibers Econ. Res., 1975). With that "tedious, boring, slow" (Scruggs, 1976) problem alleviated to a large degree, acreage and production in South Carolina and Georgia virtually exploded. Within four years, production had doubled that of 1794; and within 10 years, production was greater than eight times that of 1794. Less than 150,000 bales of cotton were being produced in the United States at the end of the War of 1812.

By 1859, production had increased over 30 times that of 1812. The gin made growing cotton enormously profitable, especially if large supplies of cheap labor were available (Gray, 1933). It unintentionally and indirectly perpetuated and encouraged the expansion of slavery (Collings, 1926). Cotton did indeed become "King", but it did so at a fierce human cost. For example, in 1790 a group of counties in middle Georgia had slaves comprising 26 percent of its population; but by 1860, their proportion had increased to 60 percent (Gray, 1933).

As the United States expanded westward, cotton went with it—from the Southeast into the Mid-South, into the Southwest and eventually into the irrigated West. Maps included in Gray's (1933) masterpiece show only limited cotton being produced in South Carolina and Georgia in 1791. By 1801, production had increased immensely in those two states as well as spread into North Carolina, Virginia and Tennessee. By 1811, production had increased greatly in those areas; by then, it included the Territory of Orleans (now Louisiana) as well. By 1821, Mississippi and Alabama also were included. By 1829, cotton had spread into Arkansas, Florida (Gray, 1933) and Indian Territory (now Oklahoma) (Nall, 1977). By 1839, production in most areas continued to expand remarkably, but increased more rapidly in the Mid-South than in the Southeast. Missouri was growing cotton by this time. More than three-fourths of the cotton produced in the United States in 1839 came from east of the Mississippi River (Agelasto *et al.*, 1922).

Although cotton had been grown in Texas since at least 1822 when it was a possession of Mexico (Natural Fibers Econ. Res., 1975), it was not until the late 1840s that the state became a major producer (Gray, 1933). In the Southeast and Mid-South, "the principal outlines of the Cotton Belt were formed in the twenty-five years from 1815 to 1840" (Gray, 1933). Within those states until the 1840s, rivers were the primary means of transportation to markets and supplies; and the first settlements were near them. In 1833, railroads began building in the South; they gradually opened up the interiors of states for settlement and shifted somewhat the channels of trade (Todd, 1950).

In the 1850s, production increased dramatically in Georgia-Alabama-Tennessee, the Mid-South and Texas. In 1859 on the eve of the Civil War, the top 10 cotton-producing states were (in decreasing order) Mississippi, Alabama, Louisiana, Georgia, Texas, Arkansas, South Carolina, Tennessee, North Carolina and Florida (Agelasto *et al.*, 1922; Gray, 1933). In all states, production had increased; but the center of production was shifting westward. In 1801, South Carolina and Georgia produced 80 percent of the crop. By 1842, they produced only 29 percent while Alabama and Mississippi produced 41 percent. By 1859, South Carolina-Georgia had fallen to 20 percent while Alabama-Mississippi produced over 43 percent, Louisiana over 14 percent and Texas about 8 percent (Todd, 1950).

The Civil War and its aftermath created havoc upon the cotton industry. The entire financial, production, marketing, shipping, manufacturing and export networks of United States cotton were disrupted (Todd, 1950). The slave labor force had been freed and, in many cases, was not gainfully employed for one or two years after the War. Ultimately, the sharecropping system was devised (Todd, 1950; Fite, 1979); and acreage and production began to climb once more. However, it wasn't until 1879 that post-War production had recovered to pre-War levels (Fite, 1979). All states that year, except Alabama and Louisiana, produced more cotton than in 1859 (Agelasto *et al.*, 1922). By 1880, the South had twice the railroad mileage it had in 1860 (Todd, 1950). By 1899, cotton was planted in Arizona (Agelasto *et al.*, 1922).

By 1919, New Mexico was planting cotton to stay; and so was California (Agelasto *et al.*, 1922). Sporadic attempts had been made to commercially produce cotton in New Mexico prior to the Civil War (Agelasto *et al.*, 1922) and in California since 1865 (LaFerney, 1975). By 1929, the center of production had shifted westward, largely because of increased acreage in Texas and Oklahoma. Directly or indirectly, the change can be at least partially attributed to the invasion of the boll weevil (*Anthonomus grandis* Boh.), especially into the Mid-South and Southeast. In 1921, about one-third of the United States cotton crop had been destroyed by that one insect. Part of the Southwest and all of the West are hot and dry—conditions considered detrimental to the weevil. The dryness of the region was also considered an advantage in the timely cultivation of the soil, in reducing the number of cultivations required and in suppressing weed growth. Economics of production also were partly responsible for the shift. In the Southeast around 1930, 100 to 125 man-hours of labor were required per acre of cotton; whereas, 50 to 60 hours were required in the Blacklands of Texas, and 35 to 40 were required in West Texas (Landon, 1930). In the Southeast, farms with 10 to 20 acres of cotton were common while in the West, 100 acres of cotton per farm were not unusual (Landon, 1930). In the West (except for the eastern counties in New Mexico), cotton essentially cannot be grown without irrigation.

In the 25-year span from 1950 to 1975, the percentages of cotton production in the United States decreased in the Southeast and Mid-South from 16.7 to 7.3 percent and from 35.1 to 30.0 percent, respectively; stayed approximately the same in the Southwest (31.8 and 30.9 percent, respectively) and increased in the West from 16.4 to 31.8 percent (Sayre, 1979).

EARLY CROP CULTURE

From the late 1700s until the Civil War, the literature dealing with the production of cotton contains numerous experiences, opinions and ideas of plantation owners on the best methods to cultivate cotton and control weeds. As late as 1854, cotton and weed stalks from the previous crop were pulled or broken with clubs, then gathered and burned (Bruchey, 1967). Weed seed destroyed by fire were a benefit, but many seed likely fell to the ground when the plants were pulled or broken. The primary tool for land preparation was the plow stock until 1870 (Smith, 1950). Any working of the land prior to planting would contribute to weed suppression.

Application of livestock manure to cotton fields occurred as early as 1776 (Scruggs, 1976). Increases in productivity were accompanied by introductions of undigested weed seed into the fields in the manure. Philips in 1817 (Turner, 1857) observed marked differences in yield between cotton with *vs.* without manure. In 1842 or 1843, Turner (1857) tested stable manure and cottonseed "as a manure" and doubled yields from less than one-half bale per acre to a bale. He also advocated planting "peas" {probably the cowpea [*Vigna unguiculata* (L.) Walp. ssp. *unguiculata*]} when corn was "laid by," in so doing giving "shade to the land" and a "large amount of manure." He stated that, "Peas gather sustenance from the air as well as the land, and thus you return all to the land taken up by the pea, and more too." He suggested a rotation of cotton, corn, grain and fallow. Summer (Turner, 1857) stated that the original productivity of the soil could be restored by "judicious manuring." Hammond (Turner, 1857) also believed cotton should follow cotton or fallow land, but not small grains or corn. He believed that, "Every kind of manure is valuable for Cotton. Every kind of compost, green crops turned in, cotton seed, and even naked leaves listed and left to rot, improves this crop." By 1860, many Georgia farms had been reclaimed through the application of guano and other fertilizers (Todd, 1950). When receiving an annual application of farmyard manure, cotton could easily be grown year after year for at least 11 years on the same field (Christidis and Harrison, 1955).

Shortly before and after the invention of the gin, most farmers were planting cotton in "hills" (one to several plants clumped together and separated by blank spaces on all sides from adjacent plants). Early planters in Georgia believed that cotton required space to extend its limbs and that branches should slightly interlock in all directions (Turner, 1857); therefore, cotton was planted in hills five to eight feet (one foot = 30.5 centimeters) apart (Gray, 1933). The large spaces between plants were ideal for weed germination and growth. They also contributed to late crop maturity and encouraged late-season insect and disease problems. After 1800, planting on ridges three to six feet apart was generally employed. Planters believed it was necessary to space the ridges farther apart on better ground (Turner, 1857; Gray, 1933). They also tended to plant early by today's standards (Gray, 1933). Hammond (Turner, 1857) believed that planting was generally done too early. One exception he was willing to make was on "new ground and rich fresh land" that has a "tendency to make weed."

A few planters on the richer soil used a "dibble" (a small hand implement to make holes in the soil for the seed) when planting in hills, but most planted in drill fashion (Gray, 1933). Hammond (Turner, 1857) believed the dibble, though "tedious," did not require as much time as to drill and then to thin. The hoe was used for opening the furrow in earlier times; a small plow was used for that purpose later (Gray, 1933). Seed were planted by hand dropping until after 1840 (Danhof, 1972).

Overseeding [three to four bushels per acre (one bushel = 35.2 liters)] was practiced to ensure getting a regular, even stand (Gray, 1933) because the planting seed were of unknown quality and because of the lack of means to cope with seedling disease (Wilkes and Corley, 1968). The planters then thinned (earlier term, "scraped"; later term, "chopped") out the excess cotton seedlings (which in themselves could be viewed as "weeds") by various means (Turner, 1857; Moorhouse and Nicholson, 1908). Subsequently, less seed were planted more carefully to avoid some of the laborious thinning (Gray, 1933). Thinning originally was hand work (Scruggs, 1976); later, the hoe was used for that purpose and for weed control (Gray, 1933).

Early thinning was recommended. Chambers (Turner, 1857) specified the third or fourth true-leaf stage as the proper time for thinning. Some planters thinned their cotton the first time over the field; others gradually thinned to a stand. Chambers in 1852 (Turner, 1857) advocated rows four feet apart with individual plants in the row spaced at distances of 15 to 20 inches (one inch = 2.54 centimeters); whereas, Hammond (Turner, 1857) recommended rows three feet apart with individual plants spaced 14 inches. Thorpe in 1854 (Bruchey, 1967) advised that rows be five to six feet apart with individual plants thinned to 24 inches. Clearly, little consensus on planting distances was evident during this era.

Cotton was a labor-demanding crop. Except for tobacco (*Nicotiana tabacum* L.), sugarcane (*Saccharum* spp.) and certain vegetables, cotton required more labor than any other crop grown in the South (Turner, 1857; Duggan and Chapman, 1941; Todd, 1950). Fields were tended as many as 22 times per year in Mississippi (Hildebrand, 1941) and 19 times per year in Texas (M. L. Verhalen, 1987, personal communication). Originally, the labor was provided by man—later, by man and animal (Gray, 1933).

Around 1790, the tools and implements in use by American farmers were simple and made largely of wood plus some iron. By 1790, seedbeds were being prepared by animal-powered plows (Danhof, 1972); hoes were used through the remainder of the season. In 1797, Thomas Jefferson patented a moldboard plow with an iron shear; by 1837, an all-steel plow was being utilized (Timmons, 1970). From 1790 to 1840, substantial changes were made in the design of tools and implements, in the use of animal for human labor and in the use of metal instead of wood (Danhof, 1972). In the 1840s and 1850s, the idea was expressed as "substituting mule power for man power" (Moore, 1986).

Extensive, rather than intensive, methods of cultivation were employed to produce the maximum crop per hand. Usually advocated were 5 to 10 acres of cotton, five to nine of corn and several of small grains for a total of up to 20 acres per hand (Turner, 1857; Gray, 1933; Bruchey, 1967). Progressive planters used horse-drawn implements as much as possible to minimize hoe labor (Turner, 1857; Gray, 1933). "Inventions and improvements in metal implements and tools came along at a rapid pace, at least by 19th century standards" (Timmons, 1970). The wheel cultivator with steel shovels was invented in 1848, followed by the straddle-row cultivator in 1856 (Timmons, 1970). One tool, the scraper, allowed a hand to clean and thin 1.25 acres per day compared to the 0.75 acres done previously (Gray, 1933).

Planters advocated cultivations every 7 (Hubbard, 1923; Brown, 1927) to 10 (Turner, 1857) to 14 days (Moorhouse and Nicholson, 1908; Christidis and Harrison, 1955), especially after rain (Morrow, 1897; Collings, 1926). It was considered particularly important when cultivating to cover small grass at the base of the cotton plant with soil (Turner, 1857). Most southern farmers, working with hand tools or equipment pulled by one or two mules, exhibited low productivity—about 250 pounds of lint per acre (Fite, 1979). Harvest was by hand picking seedcotton (usually three times per season) and depositing it into sacks tied to the waist. It was later emptied into baskets or onto large sheets (Gray, 1933).

Between 1841 and 1895, the labor required to produce an acre of cotton declined from an estimated 148 man-hours to 102. By 1930, only 71 hours were required in south Texas; fewer still were demanded in northwest Texas. Thus, within 90 years, labor had been reduced over 50 percent in some areas because of the invention and use of better plows, planters, disks and cultivators (Fite, 1950). The equipment used in the field generally progressed in an uneven manner from single-animal (horse or mule), half- or single-row, walking-type implements to multiple-animal, two-row, riding implements. As recently as the 1930s, the mule was "the symbol of southern agriculture" (Fite, 1979). However, over the Cotton Belt as a whole, labor requirements dropped very little between 1895 and 1930 (Fite, 1950; Smith, 1950). Yet, labor productivity did increase. Parker (1979) calculated the preharvest labor required for cotton production in seven regions of the South for two time periods, 1840-1860 and 1900-1920 (Table 1). He assumed that harvest techniques between the two periods had not changed. Taking into account picking time and differential yield levels for the two periods in each region, he calculated that average productivity rose 35 percent between the 1840-1860 period and the 1900-1920 period. About one-third of that amount could be attributed to movement west to new, fertile lands and about two-thirds to other causes. Preharvest labor per acre was less in 1900-1920 in all regions than it had been in 1840-1860. The increased efficiency was less than five percent in the Gulf Coastal Plain and in the Eastern Hilly regions, but it was 32 to 45 percent greater elsewhere. Hoe labor per acre decreased with time in all regions except the Eastern Hilly region; whereas, cultivation labor per acre increased in all except the Western Hilly region.

Before the Civil War, two contemporaneous systems of cotton culture existed throughout the South (Moore, 1986). "Hill farmers" (a) used light "shovel" plows (until 1840) which penetrated only the top two or three inches of the soil, (b) planted up and down hillsides, (c) abandoned older and cleared new fields each year, (d) planted green-seeded cotton cultivars, (e) planted cowpea or other cover

Table 1. Total preharvest, hoe and cultivation labor required for cotton in seven regions of the South for two time periods. (Information adapted from Parker, 1979.)

Regions of the South[1]	Preharvest labor 1840-1860	Preharvest labor 1900-1920	Hoe labor 1840-1860	Hoe labor 1900-1920	Cultivation labor 1840-1860	Cultivation labor 1900-1920
			(man-hours/acre)			
Atlantic Coastal Plain	95.9	64.9	56.2	24.7	12.5	21.7
Gulf Coastal Plain	81.4	77.4	30.4	29.8	19.4	22.8
Piedmont	117.4	74.7	43.6	24.6	21.8	24.9
Eastern Hilly	74.5	72.8	23.6	28.5	18.5	22.9
Western Hilly	88.5[2]	48.4	27.0[2]	17.4	33.3[2]	14.8
River Bottom	98.2[2]	66.3	54.3[2]	31.6	20.2[2]	21.6
Black Waxy-Gulf Prairie	50.4[2]	32.0	18.4[2]	10.7	7.8[2]	8.4

[1]Regions are comprised of portions of states as follows:
Atlantic Coastal Plain —Georgia, North Carolina, South Carolina, Virginia;
Gulf Coastal Plain —Alabama, Louisiana, Mississippi;
Piedmont —Alabama, Georgia, North Carolina, South Carolina, Virginia;
Eastern Hilly —Alabama, Georgia, Mississippi, North Carolina, Tennessee;
Western Hilly —Arkansas, Louisiana, Missouri, Oklahoma, Texas;
River Bottom —Arkansas, Louisiana, Mississippi, Missouri, Tennessee;
Black Waxy-Gulf Prairie —Louisiana, Texas.
[2]Estimated values.

crops in the fall, (f) fertilized corn with cottonseed, (g) tended to use plows rather than hoes and (h) usually used oxen or horses for power. "River planters" (a) plowed deeply with a turning plow, (b) planted on a relatively flat surface or horizontally across hillsides, (c) tended to grow cotton continuously on the same fields, (d) planted a black-seeded cultivar (which outyielded the green-seeded one), (e) did not plant cover crops in the fall, (f) did not use cottonseed for fertilizer, (g) tended to use plows less and hoes more and (h) usually used mules for power. Over time, the hill farmers adopted the higher yielding cultivar and began to lay off sloping rows and drainage ditches to minimize erosion; and the river planters began to plant the cowpea and use cottonseed for fertilizer. In the 1840s and 1850s, the hill farmers replaced their shovel plows with "sweeps, double shovels, side harrows, cotton scrapers and cultivators of adjustable widths." Improved cast iron and steel turning plows and planting machines became common.

Most improvements were forgotten after the War—particularly horizontal culture that didn't become common again until the 1930s (Moore, 1986).

Newsom (Coleman, 1968), a prominent farmer in Washington County, Georgia, authored an incomplete document on cotton culture in the 1880s. He planned on 10 acres of cotton per hand. He incorporated plant debris from the previous crop, cottonseed, manure and guano prior to planting. He wrote that, "Cleaning and raking out my Fence Corners is something I have always neglected or rather I have never had time unless hiring extra for it and always valued the money more than the Extra looks of my Fence." Those weedy fence corners served as sources of weed propagules to reinfest his fields. Newsome wasn't (and isn't today) alone in that attitude.

Recommendations by the Oklahoma Agricultural Experiment Station near the turn of the century (Morrow, 1897) included deep plowing prior to planting in rows 3.5 to 4 feet apart. Plants in the rows were to be thinned early in hills 12 to 24 inches apart (one to three plants per hill). Farmers were strongly advised to keep "weeds and grass" under control, especially when cotton plants were small. In the early days of Oklahoma statehood (1907 and later), cotton in the eastern part of the state was grown in fields of 3 to 20 acres and tilled with single-row implements. In the central and western parts of the state, fields were 60 to 100 acres in size and tilled with multi-row equipment (Nall, 1977).

Averages by areas in 1914 in the Southeast for plowing ranged from five to seven inches deep with 2.5 to 3.5 tillage operations between plowing and planting. Planting was with a drill at a row width of three to four feet with 2.5 to 5.5 pecks (one peck = 8.8 liters) of cottonseed planted per acre. After planting, 5 to 6.5 cultivations were practiced. In the Mid-South, averages by areas for plowing ranged from four to five inches deep with 1.5 to 2.5 additional tillage operations before planting. Planting was at a row width of 3.5 to 4 feet and at a seeding rate of 3 to 5.5 pecks per acre. After planting, 5 to 9.5 cultivations were practiced. In the Southwest, averages by areas for plowing ranged from four to six inches deep followed by 2 to 2.5 tillage operations before planting. Planting was done at a row width of 3 to 3.5 feet with 2 to 5.5 pecks of cottonseed per acre. After emergence, some 4.5 to 5.5 cultivations were practiced. In all three regions, stands in the row after emergence were thinned with a hoe to one or two seedlings 12 to 24 inches apart followed by one or two weedings later in the season (Cates, 1917).

In 1932 (Brown, 1938), a survey of the 15 highest cotton-producing states revealed that planting was being done primarily with one-row planters in the Southeast and Mid-South and with two-row planters in the Southwest and West. Seed planted ranged from 12 pounds per acre to two bushels. The lesser amounts tended to be in the Southwest and West. Average row spacings ranged from three to four feet with 3.5 feet being the most popular. Plant spacings within the row ranged from 6 to 18 inches between hills with one to three plants per hill. Thinning was done almost entirely with hoes. Cultivation was accomplished with one- and two-mule cultivators. Some two-row equipment was in operation, and tractors were beginning to be used in Arizona. Three to nine cultivations were practiced until blooming, the plants got too large and/or until around August 1.

PLANTING, THINNING AND NONCHEMICAL WEED CONTROL

Planting, thinning and cultivating for weed control are interrelated. The practices employed in one phase influence what is done, or not done, in the others. As methods of seedbed preparation and planting evolved, so did techniques of thinning and weed control. By the early 1900s the burning of previous crop residues was no longer recommended (Cates, 1917; Morgan, 1917). Brown (1927) discouraged the practice because of the loss of organic matter, nitrogen and other nutrients. The development of the mechanical stalk cutter facilitated stalk destruction and reduced the advantages associated with burning. About 1925, the two-row, tractor-drawn, rolling-type stalk cutter came into use (Brown and Ware, 1958). Rather quickly, they were expanded into four-row cutters, many of which were custom-made by blacksmiths (M. L. Verhalen, 1987, personal communication). Tractor-mounted stalk cutters and shredders were available by 1957 (Street, 1957b).

Following stalk destruction and disposal, seedbed preparation was accomplished by forming a bed with a middlebreaker or flatbreaking with a plow (Street, 1957b). Flatbreaking was considered essential when cotton followed a hay crop such as alfalfa (*Medicago sativa* L.) or in extremely weedy fields, particularly those with perennials such as johnsongrass, bermudagrass and "coco" or "nutgrass" (purple nutsedge) (Brown and Ware, 1958). For seedbed preparation, Sayre (1979) lists the major developments in cotton mechanization in the 1950s as hardpan breakup through deep tillage using subsoilers, chisels and/or two-way middle busters and moldboard plows; firm seedbeds were created using four-row, front-mounted cultivators combined with four-row, rear-mounted planters; and the application of anhydrous ammonia was accomplished using improved equipment. In the 1960s, he lists "do all" type finishing harrows and mechanically incorporated herbicides. In the 1970s, he cites use of the parabolic curve in tillage equipment, minimum or narrow-skip systems, large horsepower tractors with 8- to 12-row equipment and combination disk-chisel plows.

Typical recommendations for planting, thinning and weed control in the first half of the 20th century are sampled below. Webber and Boykin (1907) advocated rows three to four feet apart and thinning to hills spaced 12 to 20 inches in the row with one to three plants per hill, then thinning a few days later to one plant—the most vigorous in each hill. Morgan (1917) recommended rows 3.5 feet apart and that plants after thinning in poor soils be spaced 12 inches; in medium soils, 18 to 20 inches; and in very productive soils, 24 to 30 inches. Some farmers (Collings, 1926) and researchers (Brown, 1927, 1938) claimed larger yields when two plants were left to the hill; others found no detrimental effects with three (Morrow, 1897; Smith, 1950) or even up to five (Smith, 1950; Christidis and Harrison, 1955). Under boll weevil conditions, earlier thinning and closer plant spacings (6 to 12 inches in the row) were considered superior in terms of yield (Collings, 1926) and earliness (Morrow, 1897; Collings, 1926). Moorhouse and Nicholson (1908) recommended thinning at the third true-leaf stage while Smith (1950) suggested the fourth to sixth true leaf or earlier. When thinning, any weeds in the row were also removed at that time (Moorhouse and Nicholson, 1908; Christidis and Harrison, 1955; Brown and Ware, 1958).

Thinning cotton has been accomplished by various means. Where cotton was planted in hills and the seedlings were clumped together, thinning by hand may have been necessary (Christidis and Harrison, 1955). However, the hoe was much more commonly used (Webber and Boykin, 1907; Bruchey, 1967). The extent of the labor involved can be more fully appreciated if one considers that with 40-inch rows, "A hoe laborer must walk 2½ miles and make at least 20,000 strokes with a hoe to...thin an acre of cotton" (Wilkes and Corley, 1968). After planting, it was not uncommon to harrow across the rows, thereby destroying many small weeds and simultaneously accomplishing some thinning (Collings, 1926). The rotary hoe acts in a similar manner in that many tiny weeds in the row are destroyed; but in the process, some cotton seedlings are sacrificed (Brown and Ware, 1958). Because the tractor is operated at a high rate of speed [5 to 10 miles per hour (one mile per hour = 0.48 meter per second)] (Smith, 1950), the method is not very expensive (Christidis and Harrison, 1955). It can be used until cotton is four to six inches tall or taller (Smith, 1950; Brown and Ware, 1958). However, coarse trash, such as sorghum [*Sorghum bicolor* (L.) Moench] stalks, interferes with its operation (Brown and Ware, 1958). Like the harrow, the rotary hoe is of greater value in weed control than in thinning.

In the 1920s and 1930s, cotton was sometimes cross-plowed at right angles to the direction of the rows, leaving hills so that the fields could be cultivated in two directions (Brown, 1927, 1938). Doing so, eliminated hand thinning and reduced the hoeing necessary for weed control (Wilkes and Corley, 1968). Cross-plowing made it possible to control coco grass (purple nutsedge), but yields were less than with drilled cotton, closer spacing and good cultivation (Brown, 1927, 1938). However, the practice may have been economical when hand labor was scarce and weeds were threatening the crop (Brown and Ware, 1958). The practice was largely restricted to land that was level because it accelerated erosion if the land were sloping at all (Street, 1957b).

Mechanical choppers were used extensively around 1950 (Smith, 1950) and were satisfactory under most conditions (Wilkes and Corley, 1968). These choppers had revolving cylinder knife blades that blocked out hills regular distances apart. The machines required perfect stands, beds of uniform height and few weeds in the row (Brown and Ware, 1958). Studies of the tool in Arkansas showed a savings of 5.85 man-hours per acre. Flame choppers were tried for a time in the 1950s, but they were apparently too hazardous to remaining plants (Smith, 1950).

Cross-plowing, mechanical chopping and flame chopping required uniform stands. Small skips before thinning often became large skips afterwards. Eventually, it occurred to someone that if fewer seed were planted, fewer seedlings would have to be removed in thinning. Planting to a stand became an attainable goal (Duggan and Chapman, 1941) and was in considerable practice by the late 1950s (Brown and Ware, 1958). Seed delinting permitted more accurate metering of seed for precision planting to a desired stand (Wilkes and Corley, 1968). It was also recognized that planting in such a manner was a precondition for the successful use of chemicals in weed control (Brown and Ware, 1958). Planting in hills, rather than heavy seeding in drills, eliminated the need for hand thinning (Sayre, 1979).

Sayre (1979) characterized the major developments in cotton mechanization for planting in the 1950s as encompassing precision seed monitoring, low-mounted hoppers, rubber-tired press wheels, improved openers, high speed hill-drop attachments, widespread use of four-row planters and planter attachments applying liquid fertilizers and herbicides. For the 1960s, he cites unit planters (with tool bar attached) for up to eight rows, larger and higher speed tractors, dual press wheels, removal of hill-drop mechanisms, improved seed delinting and development of planters equipped for pesticide applications. For the 1970s, he lists planters with operating speeds up to 10 miles per hour, planters using vacuum and air pressure metering and depth control and electronic metering systems.

In the early 1900s, tillage practices in cotton were considered to be relatively poor (Morgan, 1917; Collins, 1926). A number of farmers during the 1920s cultivated alternate middles each week, thus making a complete cultivation every two weeks (Collings, 1926).

Most cultivation studies in cotton have demonstrated that it should be shallow and that it should be used only to control weeds. Deep cultivation causes "slight reductions in yields, slower traveling speeds, and higher power requirements" (Wilkes and Corley, 1968). However, cultivation alone is ineffective in controlling weeds (Smith, 1950). It can control weeds between the rows and very small weeds in the row by moving soil to the base of the cotton plant. The hoe was considered necessary to control most weeds in the drill. Brown (1927) stated that, "Hoeing is expensive tillage, but apparently there is no way to avoid it." An attempt to do just that in Mississippi was summarized in 1944 by Williamson (Sayre, 1979) as, "Under favorable weather conditions, cotton was produced without hand labor by cross-plowing, flaming and machine picking; however, the machine-picked cotton was three grades below hand-picked check plots and about 15 percent of the cotton was left in the field."

Flame cultivation, mentioned above, was first used successfully in 1944 and was in widespread use by the late 1950s. Butane and propane were the most common fuels, and treatments were often repeated every four to six days as required (Smith, 1950; Christidis and Harrison, 1955). Flaming controls small weeds in the cotton row and middles. The cotton plants, however, must be at least six to eight inches tall with bark on its lower stem and with a stem diameter at the base of 3/16 inch or more (Brown and Ware, 1958). The size differential between crop and weed was very important. Before herbicides were available, some hand labor usually was required to create that differential and to suppress weeds between planting and the first flaming (Street, 1957b).

Sayre (1979) believes the major developments in cotton mechanization for cultivation in the 1950s to be high speed sweeps, flame cultivation, chemical weed-control equipment, cross-plowing, rolling hoes for light weed control and the use of aircraft for weed-control applications. For the 1960s, he lists the shifting of cultivating equipment from the front to the rear of the tractor, use of shields for herbicide application and rolling shields. For the 1970s, he cites the availability of 8- to 12-row units, improved attachments for postdirected herbicides, the development of the S-tine high-speed cultivator and development of the recirculating sprayer for weed control.

MECHANIZATION

Cotton was "notoriously resistant to mechanization" (Fite, 1950). Reasons can be traced to several plant characteristics of the crop which make it difficult to mechanize, the specialized labor skills required at various times during the season, the plentiful supply of labor until World War II, the small farms of uneven topography on which cotton was generally produced, the inertia of custom and tradition and the sharecropper system then in effect (Fite, 1950).

The first major advance in cotton mechanization was in the use of the tractor. The gasoline-powered, row-crop tractor was introduced in 1924 (Sayre, 1979). The development of tractor-mounted duckfoot and blade cultivators in the 1920s and 1930s aided in the shift from horses to tractors (Timmons, 1970), as did tractor-mounted plows, middlebreakers and planters (Brown and Ware, 1958). During the transition period, it was not unusual for tractors and horses (or mules) to be used for different operations in the same field until it became apparent that anything a horse could do in cotton production, a tractor could do more effectively and efficiently. Cultivation to control weeds could be done in a more timely, uniform, controlled fashion. For example, one cotton producer in Texas (M. L. Verhalen, 1987, personal communication) believed that johnsongrass on his farm got worse each year when cultivating with teams of horses because he couldn't get over his cotton acreage fast enough. The difference that a tractor and implements can make is illustrated by a comparison of areas covered in a day. Tractor-mounted rotary hoes over the row and sweeps in the middles between rows could be used to cultivate 80 acres per day compared to 0.75 acre for a man, mule and half-row cultivator (Street, 1957b). The row-crop tractor was the essential component for clean cultivation of cotton (Sayre, 1979).

By 1927 in Texas, tractors with two- and four-row detachable equipment were allowing 200 acres of cotton to be grown as easily as 25 acres in the Southeast (Fite, 1950). In southwestern Oklahoma, tractors increased from 3,134 in 1929 to

8,200 in 1939 (Nall, 1977). In 1930, only four percent of southern farmers were using tractors. A United States government policy decision, however, quickly changed that percentage. In 1933, the Agricultural Adjustment Act reduced cotton production by approximately 10 million acres. Between 1935 and 1940 as a consequence, numerous sharecroppers were evicted, farm numbers declined, farm size increased and tractor use almost doubled to 7.9 percent of southern farmers (Fite, 1979).

During World War II, the shift to tractors was particularly rapid, primarily due to a shortage of labor (Fite, 1950). From 1939 to 1946, tractor use for breaking cotton land increased from 10 to 38 percent in the Southeast, 16 to 42 percent in the Mid-South, 48 to 84 percent in the Southwest and 81 to 94 percent in the West. For planting, tractor use increased from 2 to 13 percent in the Southeast, 4 to 16 percent in the Mid-South, 42 to 78 percent in the Southwest and 64 to 81 percent in the West. For cultivation, use of tractors rose from 2 to 11 percent in the Southeast, 6 to 18 percent in the Mid-South, 40 to 82 percent in the Southwest and 69 to 87 percent in the West (Brown and Ware, 1958). By 1948, the use of tractors was virtually complete in the San Joaquin Valley of California (Fite, 1950). By 1960, tractors were used for 99 percent of the land preparation, planting and cultivation of United States cotton and for 41 percent of its harvest (Natural Fibers Econ. Res., 1975).

In 1941, an average of about 85 man-hours of labor were required to produce and market one acre of cotton compared to 37 hours for corn, 20 for wheat (*Triticum aestivum* L.), 15 for oat (*Avena sativa* L.) and 16 for hay (Duggan and Chapman, 1941). The two phases of cotton production at that time requiring the most human labor were thinning-weed control and harvest (Duggan and Chapman, 1941; Fite, 1950). Harvest was the more limiting of the two (Agelasto *et al.*, 1922) requiring a third of all hours used to produce the crop (Duggan and Chapman, 1941). Fite (1950) stated that, "Even with primitive one-mule half-row equipment a man can plant and cultivate more cotton than he can pick by hand." Morrow (1897) described harvest as "the most tiresome, troublesome and costly" of cotton operations while Street (1957a) called it "extremely burdensome" and "human drudgery."

Although harvest required more labor than thinning-weed control, it was the first of the two to yield to a solution. The initial patent for a cotton picker (mule drawn) was assigned to Rembert and Prescott in 1850 (Hurt, 1979). Some 1,800+ patents later (Street, 1957a; Hurt, 1979) in 1941, the first commercially successful spindle-type, one-row cotton picker was produced by the International Harvester Co. (Hildebrand, 1941; Fite, 1979; Sayre, 1979). The Depression had retarded commercial sales and use of mechanical harvesters for about a decade. During that era, labor was plentiful and cheap; money was scarce and lint prices were low. The spindle picker of 1958 was 100 times more efficient than hand picking (Brown and Ware, 1958).

The idea of stripping cotton originated in the early 1870s, was tried in 1914 but didn't become a general practice until 1926 (Fite, 1950; Street, 1957a). In 1925, a farmer near Lubbock, Texas, dragged a section of picket fence down the rows in his fields and harvested faster than a dozen men. The following year, "sleds" were constructed that stripped as much in one day as could normally be harvested in three to four weeks (Natural Fibers Econ. Res., 1975). In southwest Oklahoma, one man could gather about nine bales per day with a sled (Nall, 1977). Gins in the Southwest incorporated special equipment to cope with such roughly harvested material (Fite, 1950). Machines to strip cotton were available from Deere and Co. in 1931; but the Depression here also discouraged sales, and production halted (Fite, 1950; Street, 1957a). As shortages of labor began to occur during World War II, use increased. Deere and Co. sold 4,400 units from 1946 through 1948 (Street, 1957a). The machine stripper of 1958 was 200 times more efficient than hand picking (Brown and Ware, 1958).

In 1948, about 5 percent of the United States cotton crop was harvested with machines (Fite, 1950); in 1955, about 25 percent (Street, 1957a); in 1960, about 50 percent; in 1965, about 80 percent (Sayre, 1979) and in 1973, more than 98 percent (Natural Fibers Econ. Res., 1975).

Sayre (1979) records the major developments in cotton harvesting in the 1950s as specialized air and ground application of defoliants; wetting agents for spindle pickers; modified drum heights; synchronization of the picker head with forward ground speed; improved pressure plates, spindle types and plant lifters; the two-row, self-propelled picker; improved air control in the picker head; improved cotton grades from mechanical picking and the development of brush-type strippers flexible for row widths. For the 1960s, he lists improved synchronization of the hydrostatic transmission, air conveying systems, brush stripper rolls, bur-extractor cotton strippers, jet-air boll separators for strippers and the increased capacity of spindle pickers with larger power units and baskets and with more aggressive spindles. For the 1970s, he lists lighter heads with aluminum bars and faster operating speeds; automatic head controls; the seed cotton module system; four-row, brush-roll strippers; increased harvesting capacity in spindle pickers and the water-soluble oil spindle cleaner.

Mechanical harvest necessitated late-season control of fall vines, grass and other weeds (Brown and Ware, 1958). While late-emerging weeds may have little or no effect on yield and few consistent effects on fiber properties of the current crop, they can cause difficulties in harvest and lower lint grades due to increased trash content. Late-season weeds also reinfest the soil with large quantities of seed that increase infestations in future crops.

ADAPTATIONS OF WEEDS TO THEIR ENVIRONMENT

Weeds rapidly adapt to a variety of soils, climatic regimes and cultural practices. The intensity and duration of the selective factors they have faced and their mechanisms of adaptation contribute to current prevalence and persistence of certain species. Weeds are resilient. Even though controlled for many years, they may immediately reappear as serious problems with only a slight reduction in control efforts. Weed scientists are also acutely aware that regardless of how effective and sophisticated their control systems are, there is always "...the weed around the corner waiting to come in..." (Minotti and Sweet, 1981). Effective control of a current problem species can release from competition species previously suppressed. The differences among weed species in morphological and physiological characters, response to control measures and adaptability are likely wide enough to ensure new problems, even in systems making maximum use of crop competitiveness.

Buchanan *et al.* (1975) reported that weeds varied greatly in their ability to tolerate low soil pH. They investigated 10 warm-season and 6 cool-season weeds at soil pH's ranging from 4.7 to 6.3. Showy crotalaria (*Crotalaria spectabilis* Roth), coffee senna (*Cassia occidentalis* L.) and large crabgrass (*Digitaria sanguinialis)* were highly tolerant to low pH while redroot pigweed (*Amaranthus retroflexus* L.) and Florida beggarweed [*Desmodium tortuosum* (Sw.) DC.] among others exhibited severe growth reduction. Although not documented, it is likely that the high pH soils of the West would likewise segregate weeds according to pH.

Hoveland *et al.* (1976) reported broadly different tolerances of 10 warm-season and 7 cool-season weeds to low soil phosphorus or potassium levels. This differential response to soil fertility may partially account for the presence *vs.* absence of weeds among locations, and thus indirectly influence weed control programs. Kempen (1984) reported that weeds in California were clearly associated with certain soil types. Groundcherry (*Physalis* spp.) and field bindweed (*Convolvulus arvensis* L.) were associated with fine-textured soils while black nightshade (*Solanum nigrum* L.) and bermudagrass (*Cynoden dactylon)* were more frequently associated with coarse-textured soils. Hoveland and Buchanan (1972) showed that weeds have differing tolerances to flooded soil conditions. This in part may explain why fall panicum (*Panicum dichotomiflorum* Michx.) is more prevalent in wetter environments than Texas panicum (*Panicum texanum* Buckl.).

Because weed species respond differently to changes in pH, nutrients, moisture as well as temperature and shading, competitive relationships among weeds may vary from season to season and be altered sufficiently to shift dominance from one species to another (Minotti and Sweet, 1981). They observed a field heavily infested with accumulated seed of both common lambsquarters (*Chenopodium album* L.) and redroot pigweed *(Amaranthus retroflexus)*. The species dominating in each growing season depended upon the spring weather conditions. Cooler, wetter springs favored lambsquarters; whereas, pigweed dominated in springs with extended warm periods. To an observer, the environmental differences between successive spring seasons might appear to be causing a shift in the dominance of the weeds present when, in fact, only a short-term response by the weeds to current environment was taking place.

CHEMICALS AND WEED SHIFTS

Controlling weeds with chemicals was the last great frontier crossed in the "total" mechanization of cotton. Brown (1969) cites the application of arsenic compounds to control johnsongrass in Texas before 1900 as probably the earliest recorded use of herbicides in cotton. Oils were used in the 1920s through 1940s for selective control of weeds (Timmons, 1970), but the "true" chemical age in cotton weed control was not firmly established until the mid-1950s (Natural Fibers Econ. Res., 1975) when a concentrated effort was made to substitute chemicals for the hoe (Sayre, 1979). Prior to this time, a number of nonselective chemicals were used as soil sterilants; but these had limited potential for use in crops. The economic benefits of chemicals were quickly realized; and their application became widespread, but not without mishap. In 1951, Premerge® (dinitro, dinoseb) was applied as a preemergence treatment on large acreages in Mississippi. Following a hot dry spring, considerable damage to cotton was encountered. Because of that experience, the impetus to use herbicides was retarded for a few years. However, the incident did impress upon the industry the importance of adequate testing of chemicals prior to widespread use (Brown, 1969; Sayre, 1979).

In 1947, about 150 man-hours of labor (using one-row, mule-drawn equipment) were required to produce a bale of cotton. Approximately 130 of those hours were for weed control and harvesting. Some 20 years later, only 30 hours were required when chemicals were applied (Brown, 1969). In 1957 in the Mississippi Delta, 155 man-hours of labor (using one-row, mule-drawn equipment) were estimated for production of a bale of cotton. With land preparation and cultivation using tractors, it could be reduced to 132 hours. Using the rotary hoe, flame cultivation, mechanical picking and some hand hoeing, the hours per bale could be reduced to about 30. With an assured method of weed control, estimated labor required would be only 10 to 12 hours per bale (Street, 1957b).

With herbicides, many producers no longer utilize hand hoeing. Such a practice is premature in that herbicides are not generally effective over an entire season nor are all weeds adequately controlled by the herbicides available. Herbicides reduce, but do not eliminate, the need for hoeing and/or cultivating. Reduced tillage because of herbicide use allows weeds tolerant or resistant to those herbicides to increase. Minimum tillage exaggerates the problem. Numerous authors (McWhorter, 1962; Frans, 1969; Hamilton, 1969; Smith, 1973; Abernathy, 1975, 1978, 1979; Clayshulte, 1975; Stedman, 1975; Buchanan, 1976; Whitworth, 1977) from throughout the Cotton Belt believe that heavy usage of herbicides has reduced dependence on mechanical weed control, that reduction in cultural practices has indirectly allowed more plants to escape (some of which may be herbicide resistant) and that the invasion of new weed species has generally gone unchecked until they are well established. "Hand labor, including hoeing, grubbing, and spot treatments, should be used as needed to control surviving weeds. Noncontrol of escapes may reduce costs temporarily, but it will perpetuate weed problems; and it may permit disastrous shifting of weed populations from controllable to resistant species" (Holstun and Wooten, 1968).

The response of weed populations to control measures is poorly understood. Although not extensively documented in the literature, cultural practices undoubtedly have produced some shifts in weed species. Herbicides, however, have probably played the major role, and changes in populations of weeds in cotton fields with the continued use of herbicides is one of the principal problems in weed science today (Buchanan, 1971b). Whether combinations of herbicides influenced those shifts is speculative. The position could be taken that the greater the number of species controlled, the greater the probability of an uncontrolled species increasing.

In 1965, Danielson *et al.* (1968) stated that cotton was one of the crops in which herbicide use was increasing most rapidly—in part due to the development and rapid acceptance of Treflan®. By 1968, approximately 85 percent of the cotton acreage in the United States received one or more herbicide treatments (Brown, 1969). By 1974, Buchanan (1974b) reported that over 95 percent of cotton grown in the United States was treated with herbicides; and in 1978, Jordan (1978) reported that almost all cotton growers used herbicides in a management program where they applied from one to five separate treatments per year to a single field. In 1965, cotton producers had treated approximately 49 percent of the harvested cotton acreage with herbicides before the crop emerged and 43 percent after emergence. While the use of preemergence treatments more than doubled from 1962 to 1965, the percentage of cotton treated postemergence increased even more.

Whitworth (1971) recognized that selective herbicides are relied upon almost entirely for weed control in cotton and that, at least in New Mexico, the most difficult-to-control weeds were present in increasing numbers because of the overdependence on those herbicides and because of large reductions in hoeing and cultivation. He specifically attributed problems with field bindweed (*Convolvulus arvensis*), nutsedge (*Cyperus* spp.), johnsongrass, *Flaveria* spp. and spurred anoda [*Anoda cristata* (L.) Schlecht.] to continued use of selective herbicides without adequate supplementation by other methods. Whitworth (1969) had previously stated that, "One must plan ahead to take care of the weeds that tolerate or escape the treatment. Otherwise, the use of selective herbicides will increase rather than decrease the problem of weeds in our cotton fields." Jackson (1970) concluded that the ready acceptance of an easy, time-convenient, preplant application of herbicides as a complete program rather than a tool in a program has led to a simple swapping of one set of weed problems for another. Likewise, Swanson (1972) noted that as effective controls are developed for one weed or group of weeds, a new species soon appears. Whitworth (1978) stated that, "Overdependence on a single herbicide has resulted in a buildup of heavy populations of some species of weeds which have been called pernicious due to their persistent and troublesome nature. Perhaps insidious would be a better term since they have been there all the time just waiting and 'watching for an opportunity to ensnare', and ensnare they did as the use of a single herbicide released these species from the competition of others."

Probably no other group of herbicides has been given so much "credit," or perhaps more appropriately "blame," for causing weed shifts as the dinitroanilines (Treflan®, Prowl®, etc.). In the Southeast, Buchanan *et al.* (1975), Buchanan (1979) and French (1979) attributed the widespread use of dinitroaniline herbicides with a decline in grass weed problems, but with an increase in broadleaf weeds such as prickly sida (*Sida spinosa* L.), tropic croton (*Croton glandulosus* var. *septentrionalis* Muell.-Arg.), common cocklebur (*Xanthium strumarium* L.), sicklepod (*Cassia obtusifolia* L.) and morningglory (*Ipomoea* spp.) and in perennial weeds (most notably nutsedge). The management of some weeds has been so successful that other difficult-to-manage weeds, even though formerly present, are now troublesome. This replacement of one problem species or group of species by another is viewed as a weed shift.

In the Mid-South, Frans (1969) suggested that widespread use of Treflan® with the attendant reduction in cultivation and hand hoeing was responsible for decreased populations of large crabgrass and other annual grasses, but for increased populations of yellow nutsedge (*Cyperus esculentus* L.), purple nutsedge, prickly sida, common cocklebur, sicklepod, bristly starbur (*Acanthospermum hispidum* DC.), johnsongrass and several morningglories. As early as 1970, Ivy and Baker (1972) recognized that Treflan® could not control prickly sida. Although not mentioning the dinitroaniline herbicides specifically, Jordan (1978) noted that continuous use of herbicides in a cotton program had shifted the weed spectrum from easy-to-control annual grasses to difficult-to-control broadleaf weeds, perennial grasses and sedges. The most troublesome weeds cited were perennials such as bermudagrass, johnsongrass and purple nutsedge; species closely related to cotton such as velvetleaf (*Abutilon theophrasti* Medik.), spurred anoda and prickly sida; as well as several members of the spurge family (Euphorbiaceae). Chandler and Oliver (1979) credited the increased occurrence of spurred anoda in a 10-year period with the herbicidal control of annual weeds which had previously hindered its growth.

In the Southwest, Smith (1973) and Abernathy (1975) reported that preplant herbicides had provided excellent control of pigweed (*Amaranthus* spp.) and grassy-type weeds, but had altered competition in favor of species which never before had an opportunity to become abundant. Reduced cultivation also encouraged increase of troublesome annual species, but especially of perennials. Infestations of deep-rooted perennial broadleaf weeds were particularly dramatic on the Texas High Plains. Increases in silverleaf nightshade (*Solanum elaeagnifolium* Cav.), woollyleaf bursage [*Ambrosia grayi* (A. Nels.) Shinners], hogpotato [*Hoffmanseggia glauca* (Ortega) Eifert] and Texas blueweed (*Helianthus ciliaris* DC.) were noted. Abernathy *et al.* (1976) also noted that the continuous use of dinitroanilines had caused an increase in lanceleaf sage (*Salvia* *reflexa* Hornem.), oakleaf thornapple (*Datura quercifolia* H. B. K.), prairie sunflower (*Helianthus petiolaris* Nutt.), rough blackfoot (*Melampodium hispidum* H. B. K.), spurred anoda and tall morningglory [*Ipomoea purpurea* (L.) Roth]. Supak (1978) relates the spread of lanceleaf sage to the widespread use of dinitroaniline herbicides which cannot control it successfully.

In the West prior to 1964, many cotton fields in California were heavily infested with numerous species of summer annual broadleafs and grasses (Fischer, 1975). He stated that as a consequence of the continuous use of dinitroanilines, those weeds were replaced by common cocklebur, tolguacha [sacred datura (*Datura innoxia* Mill.)], common sunflower (*Helianthus annuus* L.), groundcherry, nightshade (*Solanum* spp.), mare's tail {horseweed [*Conyza canadensis* (L.) Cronq.]}, johnsongrass, yellow or purple nutsedge, field bindweed, sowthistle (*Sonchus* spp.) and prickly lettuce (*Lactuca serriola* L.). Taylor and Heathman (1977) likewise observed the exclusive use of dinitroanilines caused an increase in groundcherry, spurred anoda and nutsedge. Whitworth (1977) noted that in situations where the stands of perennial weeds were initially thin and scattered, applications of dinitroanilines removed the early-season annual weeds so that the perennials grew unchecked and became serious problems that herbicides alone could not control. Several other weed problems have also evolved since the introduction of dinitroanilines; Taylor and Heathman (1978) named Wright groundcherry (*Physalis wrightii* Gray); Kempen and Woods (1979) indicated two major solanums [black nightshade and hairy nightshade (*Solanum sarrachoides* Sendtner)] and several other nightshades and groundcherries; and Kempen (1984) added yellow nutsedge to the list.

Herbicides other than the dinitroanilines have also been recognized as causing weed shifts. In a three-year field study, Baker (1982) examined the effects of annual applications of Cotoran® (fluometuron), Bladex® (cyanazine), Karmex® (diuron) and Zorial® (norflurazon) to the same cotton plots each year. In his study, Cotoran® was the most effective herbicide while the others had control problems which, with continued long-term use, could lead to serious weed problems. Bladex® failed to control annual grasses effectively, Karmex® failed to control prickly sida, and Zorial® did not control pitted morningglory (*Ipomoea lacunosa* L.). Dowler and Hauser (1974) repeated applications of Cotoran® for three consecutive years in cotton and caused decreased annual broadleaf weed populations of prickly sida, pigweed, smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb.], sicklepod and tropic croton and shifted the weed population to yellow nutsedge and to annual grass species including large crabgrass, crowfootgrass [*Dactyloctenium aegyptium* (L.) Willd.], goosegrass and Texas panicum. Wills (1977) reported that increased use of herbicides, reductions in cultivation and hoeing and the adoption of skip-row cotton culture allowed purple nutsedge to evolve as a serious weed between 1940 and 1977.

After three annual applications, Weber *et al.* (1974) found that Caparol® (prometryn) and Cotoran® greatly decreased large crabgrass populations and increased populations of yellow nutsedge and crowfootgrass. In contrast, applications of Treflan® greatly decreased large crabgrass and crowfootgrass populations, but the plots became completely infested with yellow nutsedge. Caparol® and Treflan® did not affect total weed density, but did affect which weed species were present. Each herbicide was more effective on certain weed species than on others, and this differential response caused a shift in weed populations as susceptible weeds were replaced by resistant ones.

Weed shifts are not always observed. Dowler and Baker (1975) used five distinctly different weed control systems, including conventional and high-population cotton during a two-year period, to control large crabgrass, Texas panicum and Florida pusley (*Richardia scabra* L.). In this short period, they did not significantly affect weed-species composition. Dowler *et al.* (1974) were unable to show a species composition change following four years of crop rotations and herbicide programs.

Not all weed problems have been solved by herbicides, and herbicides have even caused some weed problems. However, they remain the foundation of the present, highly necessary and largely successful fight against the profit-robbing nature of weeds.

ROTATIONS

Scientists have evaluated the effects of crop rotations on cotton production for many years (Jernigan, 1979). One of the earliest such studies (still in existence) was begun in 1896 at Auburn University to show the value of using winter legumes in a cotton-corn rotation. Much of the initial interest was in fertility rather than in weed control. However, it was recognized as early as 1908 that rotations were useful in the eradication of noxious weeds and in reducing the severity of insects and fungus diseases which can become common under continuous cotton (Moorhouse and Nicholson, 1908).

Prior to the late 1940s, rotations at irregular intervals were practiced in cotton usually with legumes somewhere in the cropping cycle (Cates, 1917). Webber and Boykin (1907) advocated rotations of cotton, followed by crimson clover (*Trifolium incarnatum* L.); corn and wheat, followed by cowpea or cotton; corn, with cowpea and oat, with cowpea. Morgan (1917) listed a number of possible rotations with one or two years of cotton in a three- to four-year cycle. The nitrogen-fixing crops he recommended were crimson clover, cowpea and/or peanut (*Arachis hypogaea* L.). Collings (1926) listed four rotations utilizing velvet bean [*Mucuna deeringiana* (Bort.) Merr.] and soybean. Brown (1927), in the first edition of his book, included three rotations for cotton utilizing cowpea or soybean in combination with corn and oat. When cotton appeared in the rotation, he suggested rye (*Secale cereale* L.) be planted between the crop rows after the first picking. In the second edition, he (1938) recommended the same rotations except that rye and vetch (*Vicia* spp.) were to be planted in the cotton middles. In the third edition (Brown and Ware, 1958), only two rotations were provided; and the crops suggested in sequence are weighted more heavily toward summer legumes such as lespedeza (*Lespedeza* spp.).

In Georgia during a 15-year period between 1931 and 1946, continuous cotton was fertilized annually with 600 pounds of 6-6-4 per acre; and yields remained about the same as cotton grown in any rotation system studied, with or without legumes (Christidis and Harrison, 1955). Anhydrous ammonia (a relatively inexpensive fertilizer) became available to farmers in 1947 and was in widespread use by the mid-1950s (Street, 1957b). As a result, planting winter cover crops essentially ceased during the late 1940s and 1950s (Jernigan, 1979).

More recently, the concept of herbicide and crop rotation for weed control was introduced (McWhorter, 1962; Buchanan, 1974b; Hauser, 1974). To control a broader spectrum of weeds, McWhorter (1962) suggested the rotation of crops to allow the use of different herbicides, while Hauser (1974) recommended alternating herbicides applied to a single crop. Buchanan (1981) offered the example of common cocklebur which is difficult to control in cotton, but which is easily controlled in corn, grain sorghum or soybean with phenoxy herbicides. These authors recognized that weed shifts or management difficulties of specific weeds were increasing and their suggestions for crop and/or herbicide rotations were part of their solutions to the problem.

Research studies provide data on weed shifts as a consequence of certain herbicides and/or crop rotations. A crop-rotation study at Tifton, Georgia, showed that herbicide use killed 99 percent of yellow nutsedge by the end of a three-year rotation of corn, cotton and peanut (Hauser, 1974). Dale and Chandler (1977) reported changes in weed seed composition in the soil because of cropping history. More broadleaf weed seed and fewer grass and nutsedge seed were present in their continuous cotton treatment than when cotton followed corn. In other research, Dale and Chandler (1979) effectively controlled johnsongrass by a cropping sequence of corn-cotton-cotton-corn in which Treflan®, Cotoran® and MSMA were used for weed control in cotton. Likewise, Jernigan (1979) prevented grain sorghum from being infested with johnsongrass by rotating it with cotton and using dinitroaniline herbicides for weed control. Keeley *et al.* (1983) reported that intense management of cotton for three years with multiple herbicide applications and hoeing reduced yellow nutsedge tubers by 98 to 99 percent. They found similar results when cotton was grown in rotation with potato (*Solanum tuberosum* L.) or when land was fallowed following barley (*Hordeum vulgare* L.).

Certain weeds are easier to control in some crops than in others, and single approaches to weed control are not as successful as multiple approaches. Various individuals have investigated the effects of two-, three- and four-year crop-herbicide rotations on the species composition of weed populations. Dowler *et al.* (1974), in a four-year study, compared herbicide-crop rotations involving corn, cotton, peanut and soybean grown continuously or in rotation. They showed that herbicides more effectively controlled weeds than did cultural pracping sequence studied. Although rotation greatly reduced weed numbers, the species composition of the weed population was not altered significantly. They concluded that a study such as this must be continued for longer than four years to eliminate a specific weed or to change the composition of the weed population. Apparently, the supply of viable weed seed in the soil had not been depleted by the end of the study; and/or the reintroduction of such seed had not been prevented.

HERBICIDE RESISTANCE WITHIN WEED SPECIES

Recent documentation of herbicide resistance within certain weed species (LeBaron and Gressel, 1982) is cause for concern as are the reports of several such weeds increasing in number and in geographic distribution. Such trends likely presage even greater difficulties in future weed control and greater prevalence of these species.

A few weeds in cotton have exhibited differential herbicide resistance or tolerance. For example, as early as 1969, it was demonstrated that strains or biotypes of johnsongrass respond differently to DSMA and MSMA (Hamilton, 1969). Some strains were tolerant while others were susceptible. Chandler (1981) documented differential susceptibility to five herbicides at two rates of several bermudagrass biotypes collected in Mississippi cotton fields from a geographical area of only eight Delta counties. Mudge *et al.* (1984) reported the development of a dinitroaniline-resistant biotype of goosegrass in South Carolina.

Horseweed resistance to herbicides, including AAtrex® (atrazine) and methylthio-s-triazines, has been reported in Hungary (Lehoczki *et al.*, 1984). The resistance occurred in vineyards "where atrazine had been applied continuously" for approximately 12 years. Wilson *et al.* (1985) in the United States suspect paraquat resistance in horseweed because of its extensive recovery following treatment with that herbicide. Caparol®, a methylthio-s-triazine, and paraquat are widely used for weed control in cotton produced under conservation tillage. The continued use of those herbicides and the increased prevalence of horseweed pose a potentially serious problem in those areas where the weed and conservation tillage coincide.

To date, the development of herbicide resistance or tolerance has not been a major problem in the weeds of cotton, as it has been for insecticide resistance or tolerance in the insects of the crop (Brown, 1968); but theoretically, it could become one. According to Parker (1977), intraspecific selection for resistant weed strains will tend to occur in monoculture when one class of herbicides is used repeatedly over a number of years. However, with the wide range of herbicides now available, the likelihood of a species developing resistance does not have to be as great as in the past. Combination and rotation of herbicides can be practiced which should help prevent or reduce selection for resistance or tolerance within a species. Parker (1977) states that self-pollinated species will not show increased herbicide resistance as rapidly as those which are cross pollinated. This may be true if the resistance is quantitatively inherited (regulated by many genes each of small effect and greatly influenced by environment) and if the genes are widely scattered throughout the population. It definitely is not true if the resistance is qualitatively inherited (regulated by one or two, never more than a few, genes each of large effect and largely independent of the environment).

INTEGRATED PEST MANAGEMENT

Following an examination of individual management techniques and their effects on weed populations, a consideration of integrated pest management (IPM) would logically be the next step. However, the publications professing to discuss IPM that we examined are actually not doing so in the strict sense of the word. To be IPM, the program must, among other things, actually integrate control or management tactics. In most cases the pest disciplines and the pests classified within them are discussed individually rather than collectively (Cotton Study Team, 1975; IPM Manual Group, 1984). The Cotton Study Team (1975) primarily discusses only insect management in the section on IPM and not the integration of management strategies among pests. The IPM Manual Group (1984) has excellent individual chapters on management and of individual pests within each discipline, but no true integration of these within or among disciplines. Baldwin and Santelmann (1980) have discussed the role of weed science in IPM and some of the obstacles which must be overcome before the discipline can truly be considered as integrated. Recently, scientists (Frick and Chandler, 1978; Gaylor *et al.*, 1983; Miller *et al.*, 1979; Walker and Sciumbato, 1979) have been more frequently conducting and reporting multidisciplinary research; and in the future, more information will undoubtedly be available as the data base expands. However, at present IPM appears to be more a concept or goal than a practice. Until it actually becomes a practice, it can and will have little or no influence on weed population shifts.

SHIFTS BY GEOGRAPHICAL REGIONS

PRIOR TO 1940

Early cotton producers often distinguished between "grass" and "weeds" (Turner, 1857; Bruchey, 1967) with the latter presumably including all unwanted, broadleaf plants. In later times, johnsongrass (Plate 6-39[1]) was discriminated from other grasses—probably because of its great competitiveness and distinctive characters above and below the soil surface. Of course, prior to its introduction into the United States around 1830 for use as a forage crop (Ocumpaugh and Rouquette, 1985), it was not a weed in cotton fields. The introduction of bermudagrass (Plate 6-46) in 1751, or earlier, for the same reason (Burton and Hanna, 1985) was a similar case. Planters realized the importance of weed control, particularly of grass, early in the season. Hammond (Turner, 1857) stated that, "In

[1]Plates are located in the Appendix at the end of this chapter.

cultivating Cotton, whether with the plough or hoe, the chief object is to keep down the grass, which is its greatest antagonist, bringing all, or almost all other evils in its train." He further referred to grass as "that mortal enemy." Fite (1979) wrote that, "Many cotton farmers literally hated grass." The legislators of several southern states, more interested in cotton and corn than in pastures, went so far as to pass laws prohibiting the introduction and planting of bermudagrass (Burton and Hanna, 1985). As might be expected, the laws did not produce their intended effect.

In 1852, Chambers (Turner, 1857) presented an essay on cotton culture before the Southern Central Agricultural Association of Georgia. He reported that the first operation performed after a cotton stand was established was to chop or thin the cotton. A careful plowman followed "throwing a little light dirt into the spaces made by the hoe, and a little also about the roots of the cotton, covering and leaving covered, all small grass which may have sprung up...This is known to practical planters, to be the crop of grass which escapes the hoe, and does mischief to the cotton." Chambers continued to describe tasks performed to control grass, but only occasionally mentioned "weeds."

A colorful description written in 1854 (Bruchey, 1967) describes the general attitude toward weed and grass control:

> "The pleasant month of May is now drawing to a close, and vegetation of all kinds is struggling for precedence in the fields. Grasses and weeds of every variety, with vines and wild flowers, luxuriate in the newly-turned sod, and seem to be determined to choke out of existence the useful and still delicately-grown cotton. It is a season of unusual industry on the cotton plantations, and woe to the planter who is outstripped in his labors, and finds himself 'overtaken by the grass'. The plow tears up the surplus vegetation, and the hoe tops it off in its luxuriance. The race is a hard one, but industry conquers; and when the third working over of the crop takes place, the cotton plant, so much cherished and favored, begins to overtop its rivals in the fields—begins to cast a chilling shade of superiority over its now intimidated groundlings, and commences to reign supreme. Through the month of July,...the plow and hoe are still in requisition."

In a worst-case scenario, however,

> "If it continues to rain after the final planting is finished, then a fresh source of danger is opened. For the grass and the weeds grow as fast as the cotton, and are shortly very difficult to remove. They are not only numerous and well rooted, but cutting them out is difficult to accomplish, without injuring the cotton plants. In the years of labor shortage, it is often impossible to clean the fields, and in midsummer you will see the cotton plants practically concealed under the grass and weeds wav-

ing above them. Such fields 'got in the grass' so badly, that the farmer was unable to secure the labor necessary to clean them. The acreage thus 'abandoned' may amount to a considerable percentage of the total amount..." (Hubbard, 1923).

In 1914, 25 or more farmers in each of 19 areas (primarily counties) throughout the Southeast, Mid-South and Southwest were surveyed as to their usual practices in cotton cultivation (Cates, 1917). That survey serves as a reference point for the actual practice "of the art" throughout the Cotton Belt of the time. All surveyed sites reported that cotton was grown on the best land, that cotton was the principal cash crop, and that no definite crop rotations were practiced, but crops were generally rotated in a sporadic manner. Cotton normally followed cotton, corn or another row crop. The most troublesome weeds at that time by area are summarized in Table 2. By 1914, farmers were discriminating much better than previously among various weeds...though it is not always possible now to identify the weeds indicated. For example, "pigweed" and "careless weed" are now generally regarded as synonyms for the same general type of weed (*Amaranthus* spp.) (Plates 6-3 through 6-6); but from two areas reported, both names were given. No scientific names were provided in the publication. Crabgrass (Plate 6-37), cocklebur (Plates 6-15 and 6-16) and johnsongrass were problems almost everywhere that cotton was grown in 1914. Nutgrass (nutsedge)

Table 2. Most troublesome weeds in 19 cotton-growing areas of 12 states in 1914. (Information adapted from Cates, 1917.)

Most trouble-	Southeast									Mid-South					Southwest					
some weeds[1]	AL	FL	GA[2]	GA[3]	GA[4]	NC[5]	NC[6]	SC	TN	AR	LA	MS[7]	MS[8]	MO	OK	TX[9]	TX[10]	TX[11]	TX[12]	Totals
crab-grass	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*		17
cocklebur	*		*	*	*	*		*	*	*	*	*	*	*	*	*	*	*		16
Johnson grass	*						*		*	*		*	*		*	*	*	*	*	11
morning-glory									*	*		*	*	*	*	*	*		*	9
careless weed									*		*	*		*	*	*		*	*	8
Bermuda grass	*	*		*	*			*		*	*							*		8
nut-grass	*	*						*	*	*		*	*							7
coffee weed	*	*	*	*								*								5
pigweed					*	*					*			*						4
smartweed						*			*						*					3
wild coffee					*			*												2
ragweed			*								*									2
buffalo grass																	*		*	2
wild onion							*													1
hurrah grass																*				1
lamb's quarters															*					1
beggarweed		*																		1

[1]Names (including spellings and capitalizations) as used in the original publication have been retained.

[2]Pike Co. [5]Robeson Co. [8]Monroe Co. [11]Houston Co.
[3]Tift Co. [6]Mecklenburg Co. [9]Ellis Co. [12]Bexar Co.
[4]Bulloch Co. [7]Mississippi Delta. [10]Lavaca Co.

(Plates 6-27 through 6-30) appears to have been originally a weed of the Southeast and Mid-South before spreading to the Southwest. This was probably true for bermudagrass as well. Morningglory (Plates 6-20 through 6-26) was likely a weed of the Mid-South and Southwest before spreading to the Southeast. A number of other weeds [*e.g.*, hurrah grass (assumed to be Texas panicum) (Plate 6-44)] were apparently very local in distribution. Until cotton had spread to an area where a potential weed occurred or *vice versa*, that weed could hardly have been a problem in the crop. Across that vast area from the Carolinas to Texas, the list of most prevalent and troublesome weeds at each location was rather small. A grass was the most prevalent weed reported with 17 of 19 sites listing crabgrass; also reported were 11 sites for johnsongrass, 8 for bermudagrass, 2 for buffalo grass (probably also referring to Texas panicum) and 1 for hurrah grass. Cocklebur was the most reported broadleaf species with 16 out of 19 sites reporting it as prevalent and troublesome. Ten sites reported pigweed while morningglory was reported from nine. Nutsedge was listed for seven sites; and the legumes, coffee weed and Florida beggarweed (Plates 6-50 and 6-51), were reported for seven and one sites, respectively. Depending on the area, "coffee weed" probably indicated either sicklepod (Plates 6-48 and 6-49) in the Southeast or hemp sesbania [*Sesbania exaltata* (Raf.) Rydb. *ex* A. W. Hill (Plates 6-52 and 6-53)] in the Mid-South. Three sites reported smartweed (*Polygonum* spp.) (Plate 6-65), two listed ragweed (*Ambrosia* spp.) (Plates 6-13 and 6-14), one reported lambsquarters (Plate 6-10) and another listed wild onion (*Allium canadense* L.).

A few years later, Collings (1926) reported the most prevalent and troublesome weeds from four areas in the Cotton Belt. In the Yazoo County area of the Mississippi Delta, he listed nutgrass, large crabgrass, common cocklebur, morningglory, johnsongrass, careless weed and coffeeweed. From the Blackbelt area of northeast Texas, were indicated careless weed, bunch grass (identity unknown), common cocklebur, morningglory and johnsongrass. In south-central Tennessee, were inventoried crabgrass, careless weed, nutgrass, common cocklebur, snakeweed (identity unknown), morningglory and johnsongrass. From the Coastal Plain of North Carolina, were reported crabgrass, common cocklebur, snakeweed and pigweed.

As recently as 50 years ago, the cotton farmer's solution to his weed problems was a relatively straightforward attack with physical force. His weapons were animal-drawn tillage implements and, in many situations, his hands or hand-held tools, particularly the hoe.

1940 THROUGH 1969

More than 90 percent of current weed control technology has been developed since 1940 and much of it since 1960 (Shaw, 1979). Neely and Brain (1944) reported that the main problems in the Mississippi Delta were grasses [principally crabgrass and "watergrass" (*Echinochloa* spp.) (Plates 6-41 and 6-42)] and pigweed. They observed that if cotton were only cultivated and not hoed or flamed, "At the time the first picking was made, the cotton plants were completely 'wrapped' in crabgrass, 'watergrass', a species of panicum (Plates 6-43 through 6-45), morningglory, and two other types of 'tie vines'." They also found some "nut grass" and an occasional johnsongrass plant. From these statements, the weed spectrum apparently had changed very little from 1857 to 1944. Grasses continue to be mentioned into the late 1950s and early 1960s. As late as 1953, large crabgrass was still considered a major problem to cotton producers in Missouri; and research was initiated to control it (Foy, 1959). In the early 1960s, Colwick *et al.* (1960) specifically mentioned weedy grasses in cotton and discussed how those grasses affected cotton grades.

In the late 1940s, an effective method for applying anhydrous ammonia was devised (Street, 1957b). How this development affected weed control or shifts in weed species will probably never be known because there was no longer an apparent need to rotate cotton or other crops with legumes to add nitrogen to the soil. This reduction in rotations or shift toward monoculture undoubtedly encouraged some weeds to become more prevalent at the expense of others; and the increased nitrogen level of the soil probably did so as well. The additional nitrogen also likely encouraged more weed growth of all weeds present.

Large-scale use of herbicides for weed control in cotton began in the 1950s, and hand hoeing changed from a primary to a supplementary method of weed control (see Chapter 7 for a more thorough discussion). Throughout the 1950s and early 1960s, much attention was given to minimizing the disturbance of soil treated with herbicides. It was assumed that disturbing treated soil, or movement of soil into treated areas, would be detrimental to the residual action of the chemicals (Holstun and Wooten, 1968).

Weed composition appeared to be shifting in the late 1950s as broadleaf weeds and perennials were cited more frequently as troublesome. A farm survey by Miller and Foy (1956) reported that 12 percent of California cotton was infested with annual grasses [watergrass, hairy crabgrass (large crabgrass), lovegrass (*Eragrostis* spp.) and field sandbur (*Cenchrus incertus* M. A. Curtis) (Plate 6-47)], 13 percent with annual broadleaf weeds [pigweed, common lambsquarters, puncturevine (*Tribulus terrestris* L.) and purslane (*Portulaca* spp.) (Plate 6-66)] and 12 percent with perennials [johnsongrass, bermudagrass, nutgrass (nutsedge), field bindweed (Plate 6-19), Russian knapweed (*Centaurea repens* L.) and white horse nettle (silverleaf nightshade) (Plates 6-69 and 6-70)]. Danielson *et al.* (1968) published the results of a survey conducted from 1959 through 1965 for the five most important weeds of cotton by state. It is noteworthy that no member of the Malvaceae, Euphorbiaceae or Solanaceae families were reported among those weeds, except that Arkansas had about 30 percent of its acres infested with the Malvaceae, prickly sida (Plates 6-55 and 6-56). Alabama and Georgia were the only states to list a Leguminosae family member (sicklepod). The West listed no perennial Convolvulaceae family member. Weeds indicated among the five most important in at least four states were barnyardgrass (Plate

6-42), common cocklebur, crabgrass, johnsongrass, morningglory, nutsedge and pigweed. Of these nationally or regionally important weeds, infestations were reported as declining in two or more states for crabgrass, johnsongrass, morningglory and pigweed.

Wills (1977) reported that in 1957 purple nutsedge (Plates 6-27 and 6-28) was ranked below large crabgrass, morningglory, common cocklebur and ragweed as a severe weed problem in the Mississippi Delta; however, by the 1970s purple nutsedge was a leading problem. Nutsedge control into the early 1960s was accomplished with extensive cultivation (including cross-cultivation) and hand hoeing. When skip-row culture began, cross-plowing was discontinued. The reduced cultivation favored nutsedge, and the large skip area (without shade) also encouraged the weed. Herbicides began replacing hand hoeing; thus, another effective control method was cast aside. The pronounced change to herbicides in the 1960s caused yet even greater weed shifts. The first herbicides successfully controlled many broadleaf and grass weeds. However, those herbicides did not control nutsedge and, in fact, encouraged its growth by removing competition from other weed species.

The use of herbicides increased rapidly in cotton. Between 1959 and 1962, a 250 percent increase was noted in cotton acreage treated (Shaw, 1964). During the same time period, the only major agronomic crops to show a larger increase in acreage treated were soybean and peanut. Shaw (1979) later reported that between 1950 and 1979, mechanical power use increased 30 percent, herbicide use increased 700+ percent and hand labor decreased 40 percent.

1970 THROUGH 1986

Numerous authors (Buchanan, 1974c; Mullendore, 1976; Jordan, 1978; Whitwell, 1982; Bryson, 1985; Vargas and Heathman, 1987) have reported results of surveys and/or projections of important weeds in cotton. In the survey by Buchanan (1974c), among the top 10 most important weeds of cotton were pigweed and nutsedge in 12 states, johnsongrass in 10 and common cocklebur and crabgrass in 8. His survey further showed that Solanaceae weeds were listed by three states, Malvaceae by seven and Euphorbiaceae by eight while four states listed Leguminosae weeds. The inclusions of Malvaceae and Solanaceae weeds were the only major changes from those reported 57 years earlier by Cates (1917). Mullendore (1976) considered the 10 worst weeds in United States cotton to be annual morningglory, johnsongrass, nutsedge, common cocklebur, prickly sida, spurred anoda (Plates 6-57 and 6-58), spurge (*Euphorbia* spp.) (Plates 6-35 and 6-36), croton (*Croton* spp.) (Plates 6-33 and 6-34), silverleaf nightshade and bermudagrass.

Whitwell (1982) summarized the results of the 1981 Beltwide Cotton Production Weed Loss Committee and noted that large-seeded broadleaf annual weeds and perennial weeds accounted for 10 genera in their survey. He also summarized the 10 genera which caused the greatest yield losses and those which infested the largest area. Seven genera were common to both lists—*Ipomoea* (Plates 6-20 through 6-26), *Sorghum, Amaranthus*, *Sida* (Plates 6-55 and 6-56), *Cyperus* (Plates 6-27 through 6-30), *Solanum* (Plates 6-69 through 6-78) and *Digitaria* (Plate 6-37). The genera *Xanthium* (Plates 6-15 and 6-16), *Cynodon* and *Cassia* (Plates 6-48, 6-49 and 6-54) appeared as weeds that severely reduced yields, but did not infest large acreages. *Salsola*, *Echinochloa* and *Panicum* (Plates 6-43 through 6-45) infested large acreages, but did not cause great yield losses. Even after 20 years of dinitroaniline use, the grasses were still present in sufficient numbers to pose a future threat of becoming serious weeds again. They were apparently held in check with effective annual applications of herbicides, but were not eliminated.

In 1971, the Southern Weed Science Society (SWSS) published its first weed survey of the southern states in their Research Report (Buchanan, 1971a). In 1975, the Beltwide Cotton Production-Mechanization Conference published the results of a 1974 weed survey (Hurst, 1975). Results reported in 1971, 1974, 1977, 1980, 1983 and 1986 by the SWSS have been compiled into Tables 3 through 8. The above reporting years correspond to crop years of 1970, 1973, 1976, 1979, 1982 and 1985, respectively. Table 3 includes survey results from the Southeast for the most common (frequently found) weeds in cotton for the above six years. Members of the broadleaf families Amaranthaceae, Compositae, Convolvulaceae, Euphorbiaceae, Leguminosae and Malvaceae were counted among the 10 most common weeds in all years. Cyperaceae and Gramineae were narrowleaf families represented among the 10 most common in all years. Common lambsquarters of the Chenopodiaceae family was common during 1970, 1973 and 1976; but was no longer reported in the Southeast after that time. Pennsylvania smartweed (*Polygonum pensylvanicum* L.) (Plate 6-65) of the Polygonaceae family was listed in 1970 and 1985 only. Florida pusley (Plates 6-67 and 6-68) of the Rubiaceae family was consistently listed in 1973 and thereafter, but only Florida reported this weed as common.

Generally, the Amaranthaceae, Compositae, Convolvulaceae, Cyperaceae, Euphorbiaceae, Gramineae, Leguminosae and Malvaceae families appear among the 10 most common and 10 most troublesome (difficult to control) weeds of the Southeast states (Tables 3 and 4, respectively). Nutsedge and johnsongrass consistently appeared in all years. Bermudagrass appeared in 1970 and in 1979 through 1985 as a most troublesome weed and also appeared on the most common list in 1985. During this 15-year reporting period, no apparent trend existed for reduced numbers of families from either category over time; and in fact, there seems to be a trend for more representatives per family over time. For example, the Gramineae were listed in 1970 with three and four representatives on the most common and most troublesome lists, respectively. By 1985, the most common list showed six grasses while the most troublesome list included seven. One change not illustrated by these tables is that over time, the rankings changed

Table 3. Most common weeds present in cotton of the Southeast in selected crop years.[1]

1970[2]	1973[3]	1976[4]	1979[5]	1982[6]	1985[7]
Amaranthaceae pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed
Chenopodiaceae common lambsquarters	**Chenopodiaceae** common lambsquarters	**Chenopodiaceae** common lambsquarters			
Compositae common cocklebur common ragweed	**Compositae** common cocklebur common ragweed	**Compositae** common cocklebur common ragweed	**Compositae** bristly starbur common cocklebur common ragweed	**Compositae** common cocklebur common ragweed	**Compositae** common cocklebur common ragweed
Convolvulaceae morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory
Cyperaceae nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]
Euphorbiaceae spotted spurge woolly croton	**Euphorbiaceae** spotted spurge tropic croton	**Euphorbiaceae** spotted spurge tropic croton	**Euphorbiaceae** spurge tropic croton	**Euphorbiaceae** spurge tropic croton	**Euphorbiaceae** croton spurge
Gramineae goosegrass johnsongrass[8] large crabgrass	**Gramineae** fall panicum field sandbur goosegrass johnsongrass[8] large crabgrass	**Gramineae** fall panicum goosegrass johnsongrass[8] large crabgrass	**Gramineae** goosegrass johnsongrass[8] large crabgrass	**Gramineae** goosegrass fall panicum johnsongrass[8] large crabgrass Texas panicum	**Gramineae** bermudagrass[8] field sandbur goosegrass johnsongrass[8] large crabgrass Texas panicum
Leguminosae sicklepod	**Leguminosae** Florida beggarweed sicklepod	**Leguminosae** Florida beggarweed sicklepod	**Leguminosae** Florida beggarweed sicklepod	**Leguminosae** Florida beggarweed sicklepod	**Leguminosae** Florida beggarweed sicklepod
Malvaceae prickly sida	**Malvaceae** prickly sida	**Malvaceae** prickly sida	**Malvaceae** prickly sida velvetleaf	**Malvaceae** prickly sida velvetleaf	**Malvaceae** prickly sida velvetleaf
Polygonaceae Pennsylvania smartweed					**Polygonaceae** Pennsylvania smartweed
	Rubiaceae Florida pusley	**Rubiaceae** Florida pusley	**Rubiaceae** Florida pusley	**Rubiaceae** Florida pusley	**Rubiaceae** Florida pusley
			Solanaceae jimsonweed	**Solanaceae** jimsonweed	

[1]Family names listed in bold print; common names of family members listed underneath them.
[2]Information adapted from Buchanan (1971a).
[3]Information adapted from Buchanan (1974a).
[4]Information adapted from McCormick (1977).
[5]Information adapted from Palmer (1980).
[6]Information adapted from Elmore (1983).
[7]Information adapted from Elmore (1986).
[8]Denotes a perennial species or mixtures containing perennials.

somewhat; but any weed that continued to be listed in the top 10 cannot be disregarded from a control standpoint.

The survey results from the Mid-South do not depict a large shift in weed composition over this time period (Tables 5 and 6). For the most part, the species and families occurring as most common weeds also appeared as most troublesome. Pigweed did not appear as one of the most troublesome weeds in 1985, but it had ranked near the bottom of the 10 in previous years. The rankings changed slightly, but the trend was surprisingly often to an even higher ranking in both

Table 4. Most troublesome weeds present in cotton of the Southeast in selected crop years.[1]

1970[2]	1973[3]	1976[4]	1979[5]	1982[6]	1985[7]
Amaranthaceae pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed
	Chenopodiaceae common lambsquarters	**Chenopodiaceae** common lambsquarters			
Compositae common cocklebur common ragweed	**Compositae** common cocklebur common ragweed	**Compositae** common cocklebur common ragweed	**Compositae** bristly starbur common cocklebur common ragweed	**Compositae** common cocklebur common ragweed	**Compositae** common cocklebur
Convolvulaceae morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory
Cyperaceae nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]
Euphorbiaceae croton spurge	**Euphorbiaceae** spurge tropic croton	**Euphorbiaceae** spurge tropic croton	**Euphorbiaceae** spurge tropic croton	**Euphorbiaceae** spurge tropic croton	**Euphorbiaceae** spurge tropic croton
Gramineae bermudagrass[8] fall panicum johnsongrass[8] large crabgrass	**Gramineae** fall panicum field sandbur goosegrass johnsongrass[8] large crabgrass	**Gramineae** fall panicum goosegrass johnsongrass[8] large crabgrass	**Gramineae** bermudagrass[8] field sandbur goosegrass johnsongrass[8] large crabgrass Texas panicum	**Gramineae** bermudagrass[8] broadleaf signalgrass fall panicum goosegrass johnsongrass[8] large crabgrass Texas panicum	**Gramineae** bermudagrass[8] broadleaf signalgrass fall panicum goosegrass johnsongrass[8] large crabgrass Texas panicum
Leguminosae sicklepod	**Leguminosae** Florida beggarweed sicklepod	**Leguminosae** Florida beggarweed sicklepod	**Leguminosae** coffee senna Florida beggarweed sicklepod	**Leguminosae** Florida beggarweed sicklepod	**Leguminosae** Florida beggarweed sicklepod
Malvaceae prickly sida	**Malvaceae** prickly sida spurred anoda velvetleaf	**Malvaceae** prickly sida spurred anoda velvetleaf	**Malvaceae** prickly sida velvetleaf	**Malvaceae** prickly sida spurred anoda velvetleaf	**Malvaceae** prickly sida spurred anoda velvetleaf
	Rubiaceae Florida pusley	**Rubiaceae** Florida pusley	**Rubiaceae** Florida pusley		**Rubiaceae** Florida pusley
	Solanaceae jimsonweed	**Solanaceae** jimsonweed			
			Vines unspecified[8]		

[1]Family names listed in bold print; common names of family members listed underneath them.
[2]Information adapted from Buchanan (1971a).
[3]Information adapted from Buchanan (1974a).
[4]Information adapted from McCormick (1977).
[5]Information adapted from Palmer (1980).
[6]Information adapted from Elmore (1983).
[7]Information adapted from Elmore (1986).
[8]Denotes a perennial species or mixtures containing perennials.

categories. Bignoniaceae was reported by itself for the first time in 1985; this family was probably included previously among the unspecified vines.

In the Southwest, fewer families and species appear as major weed problems (Tables 7 and 8). Perennial weeds occupy several positions in the tables. Pigweed is among the most common weeds, but it is rarely listed as a troublesome weed. Field bindweed, a perennial, has emerged as one of the more troublesome weeds

Table 5. Most common weeds present in cotton of the Mid-South in selected crop years.[1]

1970[2]	1973[3]	1976[4]	1979[5]	1982[6]	1985[7]
Amaranthaceae pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed
Compositae common cocklebur	**Compositae** common cocklebur	**Compositae** common cocklebur	**Compositae** common cocklebur	**Compositae** common cocklebur	**Compositae** common cocklebur
Convolvulaceae morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory
Cyperaceae nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]
Euphorbiaceae spurge	**Euphorbiaceae** spurge	**Euphorbiaceae** spurge	**Euphorbiaceae** spurge	**Euphorbiaceae** spurge	**Euphorbiaceae** spurge
Gramineae goosegrass johnsongrass[8] large crabgrass	**Gramineae** bermudagrass[8] broadleaf signalgrass goosegrass johnsongrass[8] large crabgrass	**Gramineae** bermudagrass[8] broadleaf signalgrass goosegrass johnsongrass[8] large crabgrass	**Gramineae** barnyardgrass bermudagrass[8] broadleaf signalgrass goosegrass johnsongrass[8] large crabgrass	**Gramineae** barnyardgrass bermudagrass[8] broadleaf signalgrass goosegrass johnsongrass[8] large crabgrass	**Gramineae** broadleaf signalgrass goosegrass johnsongrass[8] large crabgrass
	Leguminosae hemp sesbania	**Leguminosae** hemp sesbania		**Leguminosae** hemp sesbania	**Leguminosae** hemp sesbania
	Malvaceae prickly sida spurred anoda velvetleaf	**Malvaceae** prickly sida spurred anoda	**Malvaceae** prickly sida	**Malvaceae** prickly sida	**Malvaceae** prickly sida
	Polygonaceae redvine[8]				

[1]Family names listed in bold print; common names of family members listed underneath them.
[2]Information adapted from Buchanan (1971a).
[3]Information adapted from Buchanan (1974a).
[4]Information adapted from McCormick (1977).
[5]Information adapted from Palmer (1980).
[6]Information adapted from Elmore (1983).
[7]Information adapted from Elmore (1986).
[8]Denotes a perennial species or mixtures containing perennials.

as have several solanums. The addition of the Solanaceae family to the lists of most common and most troublesome weeds is probably the biggest change from the regions east of Oklahoma and Texas. Another major difference is that the Compositae are not on either list for the Southwest.

Sources of information by year for states in the West are footnoted at the bottom of each table. This information was adapted primarily from the Proceedings of the Beltwide Cotton Production Research Conference. If information were given on acres infested by each of the weed species, they were ranked and considered as most common weeds (Table 9). If losses were given, those values were ranked by species and used to establish the most troublesome weed category (Table 10). A definite increase was noted in perennials as most troublesome weeds. Field bindweed was consistently present, but was not listed as troublesome until 1978. The grasses are represented by a small, but relatively consistent, group of two annuals (panicum and barnyardgrass) and two perennials (bermu-

Table 6. Most troublesome weeds present in cotton of the Mid-South in selected crop years.[1]

1970[2]	1973[3]	1976[4]	1979[5]	1982[6]	1985[7]
	Amaranthaceae pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	
					Bignoniaceae trumpetcreeper[8]
Compositae common cocklebur	**Compositae** common cocklebur	**Compositae** common cocklebur	**Compositae** common cocklebur	**Compositae** common cocklebur	**Compositae** common cocklebur
Convolvulaceae morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory
Cyperaceae nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]	**Cyperaceae** nutsedge[8]
Euphorbiaceae hophornbeam copperleaf spotted spurge	**Euphorbiaceae** spotted spurge	**Euphorbiaceae** spotted spurge	**Euphorbiaceae** spotted spurge	**Euphorbiaceae** spotted spurge	**Euphorbiaceae** spotted spurge
Gramineae bermudagrass[8] johnsongrass[8]	**Gramineae** barnyardgrass bermudagrass[8] broadleaf signalgrass goosegrass johnsongrass[8]	**Gramineae** barnyardgrass bermudagrass[8] broadleaf signalgrass goosegrass johnsongrass[8]	**Gramineae** barnyardgrass bermudagrass[8] goosegrass johnsongrass[8] large crabgrass	**Gramineae** barnyardgrass bermudagrass[8] broadleaf signalgrass goosegrass johnsongrass[8]	**Gramineae** barnyardgrass bermudagrass[8] broadleaf signalgrass goosegrass johnsongrass[8]
				Leguminosae hemp sesbania	**Leguminosae** hemp sesbania
Malvaceae prickly sida spurred anoda	**Malvaceae** prickly sida spurred anoda velvetleaf	**Malvaceae** prickly sida spurred anoda velvetleaf	**Malvaceae** prickly sida spurred anoda velvetleaf	**Malvaceae** prickly sida spurred anoda velvetleaf	**Malvaceae** prickly sida
Polygonaceae redvine[8]	**Polygonaceae** redvine[8]		**Polygonaceae** redvine[8]	**Polygonaceae** redvine[8]	**Polygonaceae** redvine[8]
	Vines unspecified[8]	**Vines** unspecified[8]	**Vines** unspecified[8]		

[1]Family names listed in bold print; common names of family members listed underneath them.
[2]Information adapted from Buchanan (1971a).
[3]Information adapted from Buchanan (1974a).
[4]Information adapted from McCormick (1977).
[5]Information adapted from Palmer (1980).
[6]Information adapted from Elmore (1983).
[7]Information adapted from Elmore (1986).
[8]Denotes a perennial species or mixtures containing perennials.

dagrass and johnsongrass). Junglerice [*Echinochloa colonum* (L.) Link] (Plate 6-41) is probably included in the annual grasses because the surveys used listed *Echinochloa* spp. Based on other reports, we assumed that barnyardgrass would appear more frequently than junglerice; therefore, it is listed in Tables 9 and 10.

Tables 11 and 12 summarize distributions by region and state since 1970 for the most common and most troublesome weed families, respectively. Those families occurring most commonly in all regions and states include Amaranthaceae, the annual Convolvulaceae and the annual Gramineae (Table 11). Cyperaceae are listed in all except Tennessee as are the perennial Gramineae in all except Florida. Compositae are common except in the Southwest. Euphorbiaceae are generally common except in the West. Leguminosae and Malvaceae predominate in the Southeast and Mid-South. The perennial Solanaceae are common through-

Table 7. Most common weeds present in cotton of the Southwest in selected crop years.[1]

1970[2,3]	1973[4]	1976[2,5]	1979[6]	1982[7]	1985[8]
				Aizoaceae carpetweed	**Aizoaceae** carpetweed
Amaranthaceae pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed	**Amaranthaceae** pigweed
Chenopodiaceae common lambsquarters					
Convolvulaceae field bindweed[9]	**Convolvulaceae** field bindweed[9] morningglory	**Convolvulaceae** field bindweed[9] morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory	**Convolvulaceae** morningglory
Cyperaceae nutsedge[9]	**Cyperaceae** purple nutsedge[9,10]		**Cyperaceae** purple nutsedge[9,10] yellow nutsedge[9,10]	**Cyperaceae** purple nutsedge[9,10] yellow nutsedge[2,9]	**Cyperaceae** purple nutsedge[9,10] yellow nutsedge[2,9]
	Euphorbiaceae spotted spurge	**Euphorbiaceae** spurge	**Euphorbiaceae** spurge	**Euphorbiaceae** spurge	**Euphorbiaceae** spurge
Gramineae barnyardgrass johnsongrass[9] large crabgrass Texas panicum	**Gramineae** barnyardgrass[2] broadleaf signalgrass browntop panicum[10] johnsongrass[9] junglerice[2] large crabgrass Texas panicum	**Gramineae** barnyardgrass johnsongrass[9] large crabgrass Texas panicum	**Gramineae** barnyardgrass broadleaf signalgrass browntop panicum johnsongrass[9] junglerice large crabgrass Texas panicum	**Gramineae** broadleaf signalgrass browntop panicum johnsongrass[9] junglerice large crabgrass Texas panicum	**Gramineae** broadleaf signalgrass browntop panicum johnsongrass[9] junglerice large crabgrass Texas panicum
	Portulacaceae common purslane	**Portulacaceae** common purslane	**Portulacaceae** common purslane	**Portulacaceae** common purslane	**Portulacaceae** common purslane
Solanaceae horsenettle[9]	**Solanaceae** silverleaf nightshade[9]	**Solanaceae** silverleaf nightshade[9]	**Solanaceae** silverleaf nightshade[9]	**Solanaceae** silverleaf nightshade[9]	**Solanaceae** silverleaf nightshade[9]

[1]Family names listed in bold print; common names of family members listed underneath them.
[2]Oklahoma only.
[3]Information adapted from Buchanan (1971a).
[4]Information adapted from Buchanan (1974a).
[5]Information adapted from McCormick (1977).
[6]Information adapted from Palmer (1980).
[7]Information adapted from Elmore (1983).
[8]Information adapted from Elmore (1986).
[9]Denotes a perennial species or mixtures containing perennials.
[10]Texas only.

out the Southwest and West. Those families most troublesome in all regions and states include the annual Convolvulaceae, Cyperaceae and the annual Gramineae (Table 12). The perennial Gramineae were most troublesome in all states except Florida. Generally distributed throughout the Cotton Belt, but not troublesome in every state, were Amaranthaceae, Euphorbiaceae and Malvaceae. Compositae are most troublesome everywhere except in the Southwest. Leguminosae and perennial vines (Plates 6-8, 6-9 and 6-64) are generally most troublesome in the Southeast and Mid-South, while Polygonaceae is in the Mid-South. Solanaceae, especially the perennials, are most troublesome in the Southwest and West as are the perennial Convolvulaceae.

Table 8. Most troublesome weeds present in cotton of the Southwest in selected crop years.[1]

1970[2,3]	1973[4]	1976[2,5]	1979[6]	1982[7]	1985[8]
Amaranthaceae					**Amaranthaceae**
pigweed					pigweed
Convolvulaceae	**Convolvulaceae**	**Convolvulaceae**	**Convolvulaceae**	**Convolvulaceae**	**Convolvulaceae**
field	field	field	field	field	field
bindweed[9]	bindweed[9]	bindweed[9]	bindweed[9]	bindweed[9]	bindweed[9]
	morningglory	morningglory	morningglory	morningglory	morningglory
Cyperaceae	**Cyperaceae**	**Cyperaceae**	**Cyperaceae**	**Cyperaceae**	**Cyperaceae**
yellow nutsedge[9]	purple nutsedge[9,10]	yellow nutsedge[9]	purple nutsedge[9,10]	purple nutsedge[9,10]	purple nutsedge[9,10]
	yellow nutsedge[9]		yellow nutsedge[2,9]	yellow nutsedge[2,9]	yellow nutsedge[2,9]
				Euphorbiaceae	**Euphorbiaceae**
				spurge	spurge
Gramineae	**Gramineae**	**Gramineae**	**Gramineae**	**Gramineae**	**Gramineae**
barnyardgrass	bermudagrass[9]	johnsongrass[9]	bermudagrass[9]	bermudagrass[9]	bermudagrass[9]
johnsongrass[9]	broadleaf		broadleaf	broadleaf	broadleaf
junglerice	signalgrass		signalgrass	signalgrass	signalgrass
large crabgrass	johnsongrass[9]		johnsongrass[9]	johnsongrass[9]	johnsongrass[9]
Texas panicum	Texas panicum		Texas panicum	Texas panicum	Texas panicum
Malvaceae	**Malvaceae**	**Malvaceae**	**Malvaceae**	**Malvaceae**	**Malvaceae**
prickly sida	prickly sida	prickly sida	alkali sida[10]	alkali sida[10]	alkali sida[10]
	Venice mallow	Venice mallow	prickly sida[2]	prickly sida	prickly sida
				Martyniaceae	**Martyniaceae**
				devil's-claw	devil's-claw
	Portulacaceae	**Portulacaceae**	**Portulacaceae**	**Portulacaceae**	
	common purslane	common purslane	common purslane	common purslane	
Solanaceae	**Solanaceae**	**Solanaceae**	**Solanaceae**	**Solanaceae**	**Solanaceae**
horsenettle[9]	buffalobur	buffalobur	buffalobur	buffalobur	buffalobur
	horsenettle[9]	horsenettle[9]	horsenettle[9]	horsenettle[9]	silverleaf
	silverleaf	silverleaf	silverleaf	silverleaf	nightshade[9]
	nightshade[9]	nightshade[9]	nightshade[9]	nightshade[9]	

[1]Family names listed in bold print; common names of family members listed underneath them.
[2]Oklahoma only.
[3]Information adapted from Buchanan (1971a).
[4]Information adapted from Buchanan (1974a).
[5]Information adapted from McCormick (1977).
[6]Information adapted from Palmer (1980).
[7]Information adapted from Elmore (1983).
[8]Information adapted from Elmore (1986).
[9]Denotes a perennial species or mixtures containing perennials.
[10]Texas only.

Table 9. Most common weeds present in cotton of the West in selected crop years.[1]

1978[2]	1980[3]	1983[4]	1986[5]
Amaranthaceae	**Amaranthaceae**	**Amaranthaceae**	**Amaranthaceae**
pigweed	pigweed	pigweed	pigweed
Chenopodiaceae	**Chenopodiaceae**	**Chenopodiaceae**	**Chenopodiaceae**
common lambsquarters	common lambsquarters	common lambsquarters	common lambsquarters
Compositae	**Compositae**	**Compositae**	**Compositae**
common sunflower	common sunflower	common sunflower	common sunflower
common cocklebur	common cocklebur	common cocklebur	common cocklebur
Convolvulaceae	**Convolvulaceae**	**Convolvulaceae**	**Convolvulaceae**
field bindweed[6]	field bindweed[6]	field bindweed[6]	field bindweed[6]
morningglory	morningglory	morningglory	morningglory
Cyperaceae	**Cyperaceae**	**Cyperaceae**	**Cyperaceae**
nutsedge[6]	nutsedge[6]	nutsedge[6]	nutsedge[6]
	Euphorbiaceae	**Euphorbiaceae**	**Euphorbiaceae**
	spurge	spurge	spurge
Gramineae	**Gramineae**	**Gramineae**	**Gramineae**
barnyardgrass	barnyardgrass	barnyardgrass	barnyardgrass
bermudagrass[6]	bermudagrass[6]	bermudagrass[6]	bermudagrass[6]
johnsongrass[6]	johnsongrass[6]	johnsongrass[6]	johnsongrass[6]
	panicum	panicum	panicum
	Leguminosae	**Leguminosae**	**Leguminosae**
	hemp sesbania	hemp sesbania	hemp sesbania
	Malvaceae	**Malvaceae**	**Malvaceae**
	spurred anoda	spurred anoda	spurred anoda
Portulacaceae	**Portulacaceae**	**Portulacaceae**	**Portulacaceae**
common purslane	common purslane	common purslane	common purslane
Solanaceae	**Solanaceae**	**Solanaceae**	**Solanaceae**
groundcherry[6]	groundcherry[6]	groundcherry[6]	groundcherry[6]
nightshade[6]	nightshade[6]	nightshade[6]	nightshade[6]

[1]Family names listed in bold print; common names of family members listed underneath them.
[2]Information adapted from Everett (1979).
[3]Information adapted from Whitwell *et al.* (1981).
[4]Information adapted from Whitwell and Everest (1984).
[5]Information adapted from Patterson and Monks (1987).
[6]Denotes a perennial species or mixtures containing perennials.

Table 10. Most troublesome weeds present in cotton of the West in selected crop years.[1]

1973[2]	1976[3]	1978[4]	1980[5]	1983[6]	1986[7]
Amaranthaceae		**Amaranthaceae**	**Amaranthaceae**	**Amaranthaceae**	**Amaranthaceae**
pigweed		pigweed	pigweed	pigweed	pigweed
Chenopodiaceae					**Chenopodiaceae**
common lambsquarters					common lambsquarters
Compositae			**Compositae**	**Compositae**	**Compositae**
common sunflower			common sunflower	common sunflower	common sunflower
			common cocklebur	common cocklebur	common cocklebur
Convolvulaceae	**Convolvulaceae**	**Convolvulaceae**	**Convolvulaceae**	**Convolvulaceae**	**Convolvulaceae**
morningglory	morningglory	field bindweed[8]	field bindweed[8]	field bindweed[8]	field bindweed[8]
		morningglory	morningglory	morningglory	morningglory
Cyperaceae	**Cyperaceae**	**Cyperaceae**	**Cyperaceae**	**Cyperaceae**	**Cyperaceae**
nutsedge[8]	nutsedge[8]	nutsedge[8]	nutsedge[8]	nutsedge[8]	nutsedge[8]
Euphorbiaceae	**Euphorbiaceae**		**Euphorbiaceae**	**Euphorbiaceae**	**Euphorbiaceae**
hyssop spurge	hyssop spurge		spurge	spurge	spurge
Gramineae	**Gramineae**	**Gramineae**	**Gramineae**	**Gramineae**	**Gramineae**
barnyardgrass	bermudagrass[8]	barnyardgrass	barnyardgrass	barnyardgrass	barnyardgrass
bermudagrass[8]	johnsongrass[8]	bermudagrass[8]	bermudagrass[8]	bermudagrass[8]	bermudagrass[8]
cupgrass		johnsongrass[8]	johnsongrass[8]	johnsongrass[8]	johnsongrass[8]
johnsongrass[8]			panicum	panicum	panicum
junglerice					
			Leguminosae	**Leguminosae**	**Leguminosae**
			hemp sesbania	hemp sesbania	hemp sesbania
Malvaceae			**Malvaceae**	**Malvaceae**	**Malvaceae**
spurred anoda			spurred anoda	spurred anoda	spurred anoda
Solanaceae	**Solanaceae**	**Solanaceae**	**Solanaceae**	**Solanaceae**	**Solanaceae**
groundcherry[8]	lanceleaf groundcherry	groundcherry[8]	groundcherry[8]	groundcherry[8]	groundcherry[8]
nightshade[8]		nightshade[8]	nightshade[8]	nightshade[8]	nightshade[8]

[1]Family names listed in bold print; common names of family members listed underneath them.
[2]Information adapted from Buchanan (1974c).
[3]Information adapted from Taylor and Heathman (1977).
[4]Information adapted from Everett (1979).
[5]Information adapted from Whitwell *et al.* (1981).
[6]Information adapted from Whitwell and Everest (1984).
[7]Information adapted from Patterson and Monks (1987).
[8]Denotes a perennial species or mixtures containing perennials.

Table 11. Alphabetical list of the most common weed families and their distributions among regions and states (1970 through 1986).[1]

Weed families[2]	Southeast						Mid-South			Southwest		West			
	AL	FL	GA	NC	SC	TN	AR	LA	MS	OK	TX	AZ	CA	NM	Totals
Aizoaceae A										*					1
Amaranthaceae A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14
Chenopodiaceae A				*		*				*		*	*		5
Compositae A	*	*	*	*	*	*	*	*	*			*	*	*	12
Convolvulaceae A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14
P										*		*	*		3
Cyperaceae P	*	*	*	*	*		*	*	*	*	*	*	*	*	13
Euphorbiaceae A	*		*	*	*	*	*	*	*	*	*	*			11
Gramineae A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14
P	*		*	*	*	*	*	*	*	*	*	*	*	*	13
Leguminosae A	*	*	*	*	*			*	*			*			8
Malvaceae A	*		*	*	*	*	*	*	*					*	9
Polygonaceae A				*		*									2
P							*								1
Portulacaceae A										*		*	*		3
Rubiaceae A		*	*												2
Solanaceae A						*									1
P										*	*	*	*	*	5

[1]Information adapted from Tables 3, 5, 7 and 9.
[2]The A following family names indicates annual species while the P denotes perennials.

Table 12. Alphabetical list of the most troublesome weed families and their distributions among regions and states (1970 through 1986).[1]

Weed families[2]	Southeast						Mid-South			Southwest		West			
	AL	FL	GA	NC	SC	TN	AR	LA	MS	OK	TX	AZ	CA	NM	Totals
Amaranthaceae A	*	*		*	*	*	*	*		*		*	*	*	11
Bignoniaceae P									*						1
Chenopodiaceae A				*										*	2
Compositae A	*	*	*	*	*	*	*	*	*			*	*	*	12
Convolvulaceae A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14
P										*	*	*	*	*	5
Cyperaceae P	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14
Euphorbiaceae A	*		*	*	*	*	*	*	*	*		*	*		11
Gramineae A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14
P	*		*	*	*	*	*	*	*	*	*	*	*	*	13
Leguminosae A	*	*	*	*	*			*	*			*			8
Malvaceae A	*		*	*	*	*	*	*	*	*	*			*	11
Martyniaceae A										*					1
Polygonaceae P							*		*						2
Portulacaceae A										*					1
Rubiaceae A		*													1
Solanaceae A	*					*				*		*	*	*	6
P										*	*	*	*	*	5
Vines P	*					*	*		*						4

[1]Information adapted from Tables 4, 6, 8 and 10.
[2]The A following family names indicates annual species while the P denotes perennials.

PRESENT SITUATION AND A LOOK TOWARD THE FUTURE

Over the past three decades, control of weeds in cotton has evolved from a mechanical and hand labor operation to primarily a chemical approach. In some areas, especially the Southeast and Mid-South, more herbicides are used on cotton than on any other major row crop (Banks, 1985). Further, the types of herbicides and methods of application used vary greatly from region to region in the United States (Patterson and Monks, 1987). Preplant foliar applications are not heavily used in any region; however, Louisiana reported treating 20 percent of its cotton acreage with Roundup® (glyphosate). Over 90 percent of the cotton acreage in the Southeast and Southwest received a preplant incorporated treatment of a dinitroaniline alone. The Mid-South treats approximately 80 percent of its cotton with a dinitroaniline alone; however, an additional 10 percent is treated with a preplant incorporated tank mixture which contains a dinitroaniline. Most of the remaining area is treated with other herbicides which results in most land in the Mid-South receiving a preplant incorporated treatment. In the West, from 48 percent of the cotton in New Mexico to 90 percent in California is treated with a dinitroaniline alone. In Arizona, most of the cotton land is treated with a tank mixture which contains a dinitroaniline; while in New Mexico, Caparol® alone is used as a preplant incorporated treatment on 27 percent of the cotton land. Preemergence applications are not used in the arid, irrigated West. Cotoran® is the most heavily used preemergence herbicide in the Southeast and Mid-South, but it is used on less than two percent of land in the Southwest. Generally, postemergence directed treatments are heavily used in the Southeast and Mid-South; whereas, in the Southwest and West, they are used to a much lesser extent. Slightly over 30 percent of the cotton land in Arizona receives post-directed treatments; however, only 6 percent of California cotton is treated in this manner. The selective over-the-top, postemergence herbicides for grass control have been registered for five years; however, by the end of their second year of use they were used primarily as spot treatments on 60 percent of the cotton in Tennessee, 30 percent in Louisiana, 18 percent in Texas, and 15 percent in Alabama and North Carolina. Mississippi, Arkansas, Arizona, Louisiana and Texas report that 50, 30, 25, 20 and 20 percent, respectively, of their cotton land is subjected to spot treatments. Layby treatments are not used extensively in Tennessee, Texas, Oklahoma, Florida or North Carolina. There is considerable usage of such treatments in Arkansas, Louisiana and Mississippi.

In the Southeast and Mid-South, weeds that cause the largest reductions in cotton yield are common cocklebur, morningglory and prickly sida. In the Southwest and West, those weed species are pigweed, nightshade and several species of morningglory. Bonner (1987) reported that in the Southeast and Mid-South, spurge species and prickly sida are becoming more troublesome. Texas and Oklahoma are now listing devil's-claw [*Proboscidea louisianica* (Mill.) Thellung] (Plates 6-62 and 6-63) as a widespread problem in dryland cotton. Thistle species are considered as problems under irrigation in Arizona, California and Texas. Many growers and technical personnel believe the nightshade species are the most serious weed problem in the Southwest and West.

The most recent major change in cotton production has been the renewed interest in no tillage, reduced tillage or conservation tillage. Keeling and Abernathy (1987) claimed that reduced tillage systems can increase yield, decrease production cost and reduce soil erosion; but that new weed control programs must be developed for use in place of traditional preplant incorporated herbicides and tillage operations. Relatively little information describing weed research in cotton to develop no-tillage or minimum-tillage systems has been published. Ordinarily, this would suggest that little work had been done in the area; however, McWhorter and Jordan (1985) conducted a survey among weed scientists in most cotton-producing states and found, to the contrary, that considerable research comparing such systems had been attempted. Little had been published because the results were largely negative, and many experiments were abandoned. The problems most frequently encountered with reduced tillage were in obtaining an adequate stand of cotton, in not controlling perennial weeds and in the greater difficulty of controlling annual weeds. The requirement for cultivation in cotton has diminished over the past 10 years, but cultivation will be required in most situations until a great improvement has been made in efficacy of the herbicides available to producers. The reader is referred to Chapter 9 "Reduced-Tillage Systems."

Porterfield and Davidson (1974) published a study comparing 11 tillage systems at two dryland locations in Oklahoma over a 5-year period. In systems where herbicides were the only or major form of weed control, plots were heavily infested with perennial weeds. In systems combining mechanical and chemical weed control, those weed shifts were less pronounced. Extensive tillage at planting time was essential for satisfactory weed control and maximum lint yield. Yield was enhanced by tillage prior to planting and further enhanced by tillage after emergence. Minimum tillage plots had the highest soil moisture; but they also had the highest soil strength, reduced stands, stunted plants with red stem color, reduced lint yield and often were so weedy as to be rated "unacceptable for machine harvesting."

The report by McWhorter and Jordan (1985) may be used as a base to discuss weeds of the future or the anticipated management difficulty of present weeds. Have we really experienced a shift in weed species composition, or have we only temporarily traded easy-to-control weeds for those which are more difficult-to-control as Jackson (1970) has suggested? As we enter a time when conservation or reduced tillage on erodible acres is apparently to be government mandated, assumptions about weed shifts may be very important. Kempen (1984) reported that after 20 years of usage of dinitroaniline herbicides on cotton, the susceptible weeds (barnyardgrass and pigweed species) were still commonly present. They were not necessarily common problems in fields, but they were present and fully capable of becoming problems if no herbicides were applied. The resilience of weeds was mentioned previously in this chapter, and that characteristic may most accurately describe this dynamic process.

A number of shifts in weed composition are likely to occur with reduced tillage. There undoubtedly will be increased problems with perennials. Among the annual weeds, reduced tillage will favor those which germinate on or near the soil surface and those which germinate early in the season. Species such as annual bluegrass (*Poa annua* L.), large crabgrass, purslane and tumble mustard (*Sisymbrium altissimum* L.) germinate at or near the soil surface. They would have a higher percentage of their seed in a position favorable for germination than if tillage distributed them throughout the soil profile. Thus, reduced tillage provides these weeds an advantage over species such as wild oat (*Avena fatua* L.), annual morningglory and many others that germinate from greater depths. The early germinating species are favored by reduced tillage because some will have already germinated by the time the crop is planted, thus giving them a competitive edge over weeds that germinate later as well as over the crop itself.

With the management tools available to us, we have achieved success in suppressing the populations of some weed species. Some have been so well controlled that they are no longer considered troublesome, but some scientists view such weeds as only "lurking in the shadows," waiting to increase their numbers. We contend that weed species composition has changed little over time; however, the proportions in the composition have changed. No weed has ever become extinct; a superficial examination of escapes in fields and of fence rows, ditches and other disturbed areas should verify that premise. Provided the opportunity, such weeds through time would reexert the prominence once demonstrated.

A diagram (Figure 1) is provided to illustrate perceived shifts, management difficulties and/or emphasis received by four general classes of weeds in United States cotton from 1850 to the present (with projections to the year 2000). The trends described are based on a synthesis of data compiled from numerous formal and informal reports, including testimonials, about the common and troublesome weeds in cotton. The result is an interpretation of past, present and future weed problems in cotton that can be considered from many perspectives. From 1850 (and before) to 1940, annual grasses and small-seeded broadleafs were viewed by most producers as the most serious threats to effective cotton production. With the development of urea herbicides (Karmex®, etc.) during the 1950s, a decline was noted in the prevalence or control difficulty of the small-seeded broadleaf weeds. The grasses declined to some extent during this time, but their major decline did not come until later. As small-seeded broadleaf weeds gradually declined, large-seeded broadleaf and perennial weeds began to increase. The void created as the small-seeded broadleaf weeds were gradually controlled was slowly filled by these "new" weeds. In reality, those weeds had been present all the time, but they were restricted in area of distribution and/or in population size

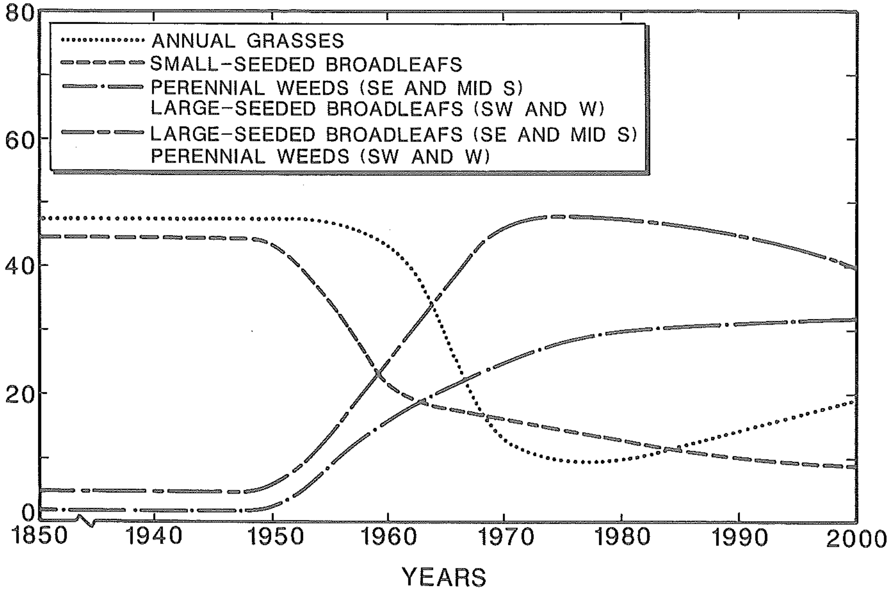

Figure 1. Perceived shifts, management difficulties and/or emphasis received by four general classes of weeds in United States cotton over a 150-year period.

(Whitworth, 1978; M. L. Verhalen, 1987, personal communication). During the 1960s, when the dinitroaniline herbicides were gaining rapid acceptance by cotton producers, a rapid decline in annual grasses and accelerated decline of small-seeded broadleaf weeds was coupled with a proportionate increase in large-seeded broadleaf and perennial weeds.

Differences between regions with respect to relative importance of perennial weeds *vs.* large-seeded broadleafs were apparent. Oklahoma and Texas in the Southwest and New Mexico, Arizona and California in the West may be more accurately depicted at present as having more difficult problems with perennial weeds than from large-seeded broadleaf types; whereas, the reverse is true in the Southeast and Mid-South. During the time span covered by this diagram (Figure 1), a continual decline is traced for the small-seeded broadleaf weeds because a number of herbicides from several chemical families are very effective for control of such weeds (including several chemicals that do not require incorporation). The annual grasses are depicted as slightly increasing in the future primarily because they, as a group, represent a large number of species and they are commonly present. With the likely increased emphasis on reduced tillage and the corresponding decreased use of preplant incorporated dinitroanilines, those weeds will be more likely to escape. The grasses may never again be as prominent as they were in the 1800s to 1940s; but because of the limitations of the selective postemergence grass-control herbicides now available, the grasses will probably exhibit some increase. Because the large-seeded broadleaf types in the Southeast and Mid-South and the perennial types in the Southwest and West have become so important in recent times, it is likely that a great deal of research and development will be centered on those weeds. The slight decline shown in their importance is a prediction of some success in those efforts. Currently, cotton producers would welcome selective over-the-top herbicides for broadleaf weed control. Should herbicide resistance develop, these trends will be influenced depending upon when and in which of the four general classes of weeds it takes place.

The weed problem in cotton is dynamic. Shifts in the abundance and distribution of particular weed species have occurred as producers have moved from one part of the country to another; changed methods of land preparation, thinning and cultivation; employed different management practices and applied different herbicides. In some instances, control has been achieved. In others, one weed, or class of weeds, has simply been replaced by another even more difficult to control. The keys to future success in the struggle between man and cotton *vs.* weeds are to use those techniques which have been proven effective and to continue the investigation of weed ecology and their responses to man's management systems to discover new and better techniques of weed control.

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Chapter 6

APPENDIX

WEED IDENTIFICATION

Weed control may be accomplished by using an array of biological, cultural, mechanical, nonmechanical, legal and/or chemical methods (Zimdahl, 1981). Some methods are more effective against particular weeds than are others. Herbicides, for example, differ both in the spectra of weeds that they affect and in the degree of their control. Regardless of the method used, potentially troublesome weeds can be controlled more efficiently if they are identified early and appropriate control measures implemented, rather than waiting until they have become an established, widespread problem. The adage "Know thy enemy" certainly is applicable. Knowing the characteristics of the weed and its weak points allows the producer to employ the most efficient and effective methods to deal with current or potential weed problems.

To assist the cotton producer and others in the rapid identification of common weeds, a taxonomic key and photographs have been provided. The key and photos describe many, but not all, of the troublesome species likely to be encountered in cotton fields throughout the United States. Individuals ready to provide assistance in identifying weeds and correcting problems include the local county extension agent and the weed science specialists and taxonomists at state universities. The scientific and common names used appear in the "Composite List of Weeds" (Standardized Plant Names Subcommittee, Weed Sci. Soc. Am., 1984).

Although a taxonomic key looks intimidating at first, its use is quite easy. For individuals who have not used one before, the following comments are offered. A key simply presents the user with a progressive series of choices between pairs of alternative features that can be observed. For example, following examination of an unknown weed, the user might be required to choose between "plant a trailing or climbing vine" or "plant erect or prostrate, but not a trailing or climbing vine." Selection of the most applicable alternative leads the user to other pairs of alternatives and ultimately to a scientific name. Using a key is thus analogous to following a path on which each junction is a "Y". To reach the proper destination, the traveler must take the correct fork in the road at each intersection.

The pair of alternative features is referred to as a couplet, and alternatives of a single couplet as leads. To facilitate use of the key, the couplets are successively indented to the right with both leads of a single couplet equally indented and numbered. One commences keying at Couplet 1 by reading both leads, observing the plant's features and making a decision as to which lead applies. After one of the two leads has been selected, proceed to the first indented couplet immediately under the choice. Disregard couplets under nonselected leads. Continue to follow the successively indented couplets until a name is reached. Sometimes the leads of a single couplet will be separated by numerous other couplets; the numbers thus help in locating the leads. Read both leads and observe the plant carefully before making a decision. While the first choice may be applicable, the second may be better. Different characters in the leads are separated by semicolons, while commas are used to separate aspects of one character. Should a couplet be encountered where the selection of a lead is tenuous, proceed both ways. Subsequent inappropriate couplets generally will indicate a wrong choice.

TAXONOMIC KEY TO WEEDS OF COTTON

1. Plants grass-like; leaves linear to lanceolate; veins extending length of blade parallel to each other; fibrous root system; flowers hidden by 1 or 2 brown-green bracts; monocots (other lead No. 1 on page 174)

  2. Stems triangular in cross-section; margins of leaf sheaths fused; ligules absent; flower hidden by 1 scale; nutsedges (*Cyperus* spp.)

    3. Spikelet scales dark reddish brown; leafy bracts below spikelets 3-4, more or less equal in length to inflorescence; spikelets 20-65 . . . . *Cyperus rotundus* (purple nutsedge) Plates 6-27 and 6-28

    3. Spikelet scales golden-brown or golden-green; leafy bracts below spikelets 5-10, longer than inflorescence; spikelets 70-350 . . . . *Cyperus esculentus* (yellow nutsedge) Plates 6-29 and 6-30

  2. Stems round or flattened in cross-section, never triangular; margins of leaf sheaths overlapping; ligules present; flower hidden by 2 scales; grasses

    4. Plants perennial, spreading by rhizomes and/or stolons

      5. Spikelets surrounded by bristles, dropping from inflorescence at maturity, bristles remaining attached to rachis . . . . *Setaria* spp. (foxtails)

      5. Spikelets not surrounded by bristles

        6. Leaf blades 12-25 mm wide with white midrib; rhizomes stout, scaly; spikelets large, borne in pairs in open pyramidal panicles . . . . *Sorghum halepense* (johnsongrass) Plate 6-39

6. Leaf blades 2-5 mm wide with green midrib; rhizomes slender; spikelets small, borne in 1-sided spikes; spikes 3-7, digitate at apex of elongated leafless stem . . . . *Cynodon dactylon* (bermudagrass) Plate 6-46

4. Plants annual, tufted, lacking rhizomes or stolons

7. Spikelets bristly or surrounded by bristles or enclosed in a spiny bur

8. Spikelets enclosed in a spiny bur of stout, sharp, flattened, fused spines; leaf sheaths strongly compressed and keeled . . . . *Cenchrus incertus* (field sandbur) Plate 6-47

8. Spikelets bristly or surrounded by bristles; leaf sheaths round or keeled

9. Spikelets borne in single bristly inflorescence terminating stem; bristles arising below spikelets; ligule a ring of hairs . . . . *Setaria* spp. (foxtails)

9. Spikelets borne in 9-12 short 1-sided racemes arranged along an elongated axis; spikelets bearing stout bristle; ligule absent . . . . *Echinochloa crus-galli* (barnyardgrass) Plate 6-42

7. Spikelets borne in open panicles or in 1-sided spikes and racemes, not surrounded by bristles nor enclosed in a spiny bur

10. Spikelets borne in a cylindrical inflorescence terminating stem; spikelets paired, one sessile and sunken in the rachis, the other smaller and borne on a flattened stalk; inflorescence breaking apart at maturity . . . . *Rottboellia exaltata* (itchgrass)

10. Spikelets borne in open panicles or in 1-sided spikes and racemes; spikelets not paired; inflorescence not breaking apart at maturity

11. Spikelets borne on long or short branches in open spreading panicles

12. Panicles open, spikelets borne near ends of long spreading branches; leaf sheaths without hairs; spikelets without conspicuous transverse ribs ..... *Panicum dichotomiflorum* (fall panicum) Plate 6-43

12. Panicles narrow, spikelets borne along sides of short ascending branches; leaf sheaths with pustulate-based hairs; spikelets with conspicuous transverse ribs ..... *Panicum fasciculatum* (browntop panicum) Plate 6-45

11. Spikelets borne in 1-sided spike and racemes or panicle branches appressed to rachis and spikelets clustered together

13. Spikelets borne in 1-sided spikes, pedicels absent, laterally compressed, each with 3-9 florets; florets dropping from plant at maturity

14. Spikelets with stout bristles; spikes digitate at end of stem; hairs present only on margins of blades ..... *Dactyloctenium aegyptium* (crowfootgrass)

14. Spikelets without stout bristles; spikes subdigitate at end of stem; hairs present on margins and upper surface of blades ..... *Eleusine indica* (goosegrass) Plate 6-38

13. Spikelets borne in 1-sided racemes, pedicels present, dorsally compressed, each with 1 hardened floret; entire spikelets dropping from plant at maturity

15. Racemes 4-6, subdigitate, long; ligules membranous; sheaths with pustulate-based hairs . . . . *Digitaria sanguinalis* (large crabgrass) Plate 6-37

15. Racemes numerous, borne along an elongated axis; ligules absent or ciliate or ciliate-membranous; sheaths with or without hairs

16. Ligules absent; leaf sheaths generally without hairs

17. Plants 30-60 cm tall; spikelets oval, without bristles . . . . *Echinochloa colonum* (junglerice) Plate 6-41

17. Plants robust, 100-200 cm tall; spikelets elliptic, usually with stout bristles . . . . . *Echinochloa crus-galli* (barnyardgrass) Plate 6-42

16. Ligules present, ciliate-membranous or ciliate; leaf sheaths hairy

18. Leaf sheaths hairy only on margins; racemes 2-6 and long . . . . *Brachiaria platyphylla* (broadleaf signalgrass) Plate 6-40

18. Leaf sheaths densely hairy; racemes numerous and short

19. Spikelets 2-3 mm long, with conspicuous transverse ribs, without hairs; ligules ciliate . . . . *Panicum fasciculatum* (browntop panicum) Plate 6-45

19. Spikelets 4-6 mm long, without conspicuous transverse ribs, with soft hairs; ligules ciliate-membranous . . . . *Panicum texanum* (Texas panicum) Plate 6-44

1. Plants not grass-like; leaves broad, variously shaped, rarely linear; veins forming netted pattern; taproot system typically present; flowers visible, not hidden; dicots

20. Plant a trailing or climbing vine; tendrils present or absent (other lead No. 20 on page 177)

21. Leaves opposite; fruits pod-like, 5-15 cm long

22. Leaves simple, triangular-lanceolate to deltoid, cordate; annual from fleshy taproot; flowers white, 4-6 mm long . . . . *Ampelamus albidus* = *Cynanchum laeve* (honeyvine milkweed) Plate 6-7

22. Leaves compound with 9-11 leaflets; perennial from woody roots; flowers orange-red, tubular, 60-90 mm long . . . . *Campsis radicans* (trumpetcreeper) Plates 6-8 and 6-9

21. Leaves alternate; fruits spherical or slightly elongated, less than 5 cm long

23. Flowers small, yellow or yellow-green; tendrils present

24. Leaves simple, ovate to lanceolate; flowers borne in terminal spike-like clusters; fruit a 3-sided achene held at maturity within a green structure 1-3 cm long . . . . *Brunnichia ovata* (redvine) Plate 6-64

24. Leaves compound, the leaflets small, in 3's and toothed; flowers borne in the leaf axils; fruit 3-parted, inflated, 3-4.5 cm in diameter . . . . *Cardiospermum halicacabum* (balloonvine)

23. Flowers large, white or red or pink or blue-purple; tendrils absent

25. Flowers white or white with vertical bands of pink; perennial from long stout root; stems often forming dense tangle; stigmas 2, linear, more or less flattened; cotyledon apex notched, not 2-lobed . . . . *Convolvulus arvensis* (field bindweed) Plate 6-19

25. Flowers blue-purple to red or white or white with purple-red center; annual from slender taproot or perennial from woody tuberous root or perennial from branched roots; stigma 1, spherical; cotyledon apex 2-lobed; morningglories (*Ipomoea* spp.)

   26. Stems bearing fleshy prickles; flowers about 8 cm long, open at night and in early morning; leaves cordate, without hairs . . . . *Ipomoea turbinata* (purple morningglory) Plate 6-21

   26. Stems without fleshy prickles; flowers 1.5-8 cm long, open all morning or all day; leaves cordate or 3-lobed, with or without hairs

      27. Perennial from woody tuberous root; flowers white with purple-red center, 5-8 cm long; seed with fringe of long tawny hairs; point of cotyledon attachment to stem belowground . . . . *Ipomoea pandurata* (bigroot morningglory)

      27. Annual from slender taproot or perennial from branched roots; flower colors various but not white with purple-red center, 1.5-6 cm long; seed without fringe of hairs; point of cotyledon attachment to stem visible aboveground

         28. Leaves deeply palmately 3-7 lobed (almost compound); flowers 1.5-2.3 cm long, pale lavender pink with a dark center; cotyledon lobes very narrow and with little separation; stalks of flowers spirally coiled . . . . *Ipomoea wrightii* (palmleaf morningglory) Plate 6-22

28. Leaves cordate or shallowly 3-lobed; flowers 2-6 cm long, white or blue or lavender; cotyledon lobes broad and angle of separation acute or obtuse; stalks of flowers not spirally coiled

 29. Stems bearing hairs; stalks of flowers bearing hairs bent sharply down; cotyledons moderately indented and rounded

  30. Hairs of stem lying flat; flowers 4-6 cm long, purple to white; sepals short with blunt tips . . . . *Ipomoea purpurea* (tall morningglory) Plate 6-26

  30. Hairs of stem spreading; flowers 2.5-4.5 cm long, lavender to blue; sepals long with abruptly pointed tips

   31. Leaves 3-lobed . . . . *Ipomoea hederacea* (ivyleaf morningglory) Plate 6-25

   31. Leaves cordate . . . . *Ipomoea hederacea* var. *integriuscula* (entireleaf morningglory) Plate 6-20

 29. Stems and stalks of flowers without hairs; cotyledons deeply indented and pointed

  32. Flowers white, rarely lavender, 1.8-2.3 cm long; annual from slender taproot; seed black and shiny . . . . *Ipomoea lacunosa* (pitted morningglory) Plate 6-24

32. Flowers rosy-lavender to purple-rose, 2.8-5.5 cm long; perennial from branched rootstalk; seed dark brown . . . . . . *Ipomoea trichocarpa* var. *torreyana* (cotton morningglory) Plate 6-23

20. Plant erect or prostrate but not a trailing or climbing vine; tendrils absent

33. Stems flat on ground or only tips ascending, spreading radially; annual from slender taproot

34. Leaves 3-6 in a whorl at each node; flowers small, white, borne in leaf axils . . . . . . *Mollugo verticillata* (carpetweed) Plates 6-1 and 6-2

34. Leaves alternate or opposite at each node; flowers borne in leaf axils or at stem tips

35. Leaves opposite, widest below middle, often with a red spot; stems not fleshy; flowers cup-shaped, white, small, with yellow glands, borne in leaf axils . . . . . . *Euphorbia maculata* (spotted spurge) Plate 6-35

35. Leaves alternate or occasionally appearing opposite; flowers white or yellow, small

36. Leaves always alternate, ovate, irregularly toothed; stems not fleshy; flowers borne in leaf axils, white . . . . . . *Solanum sarrachoides* (hairy nightshade) Plates 6-75 and 6-76

36. Leaves alternate or occasionally appearing opposite, widest above middle; stems fleshy; flowers borne at stem tips, yellow . . . . . . *Portulaca oleracea* (common purslane) Plate 6-66

33. Stems erect or ascending, not flat on ground nor spreading radially; annual or perennial

37. Leaves compound, alternate, stipulate; fruit a pea-like pod; flowers resembling butterfly, yellow or white to pink and purple; legumes

38. Leaves with 3 elliptic to ovate leaflets; perennial from woody rootstock; flowers white or pink to purple; pods 1.5-2.5 cm long, with 5-7 round segments each with hooked hairs and separating at maturity . . . . . . *Desmodium tortuosum* (Florida beggarweed) Plates 6-50 and 6-51

38. Leaves with 6-70 leaflets; annuals; flowers yellow; pods 8-20 cm long and not segmented

39. Leaflets 20-70, small; stems 75-200 cm tall; pods 3-4 mm wide and 10-20 cm long . . . . . . *Sesbania exaltata* = *Sesbania macrocarpa* (hemp sesbania) Plates 6-52 and 6-53

39. Leaflets 6-12, large; stems 50-150 cm tall; pods 5-9 mm wide and 8-20 cm long

40. Leaflets 8-12, lanceolate to ovate; pods 7-10 mm wide; conspicuous gland at base of petiole . . . . . . *Cassia occidentalis* (coffee senna) Plate 6-54

40. Leaflets 6, widest above middle; pods 5-6 mm wide; conspicuous gland between lowest pair of leaflets . . . . . . *Cassia obtusifolia* (sicklepod) Plates 6-48 and 6-49

37. Leaves simple, alternate or opposite, with or without stipules; fruit a berry or capsule or achene; flower colors various

41. Leaves all opposite or leaves opposite below and alternate above

42. Leaves opposite below and alternate above; flowers borne in small inconspicuous heads; foliage typically aromatic (camphor or resin) . . . . *Ambrosia artemisiifolia* (common ragweed) Plates 6-13 and 6-14

42. Leaves all opposite; flowers separate or borne in conspicuous heads; foliage with mint-like odor or not aromatic

  43. Stems square; leaves with mint-like odor; flowers blue, borne in terminal racemes . . . . *Salvia reflexa* (lanceleaf sage)

  43. Stems round or flattened; leaves without mint-like odor; flowers inconspicuous or white

    44. Leaves elliptic to oblong, edges toothed

      45. Leaves 2-10 cm long; flowers borne in heads, white; all branches opposite; foliage roughly hairy; fruit an achene . . . . *Eclipta prostrata* =*Eclipta alba* (eclipta)

      45. Leaves 1-3 cm long; flowers not borne in heads; branches alternate; foliage without hairs; fruit a small but conspicuous 3-lobed capsule . . . . *Euphorbia hyssopifolia* (hyssop spurge) Plate 6-36

    44. Leaves widest above the middle, edges smooth or toothed

      46. Flowers borne in spiny heads in leaf axils; spines hooked . . . . *Acanthospermum hispidum* (bristly starbur) Plates 6-11 and 6-12

46. Flowers clustered but separate, not in spiny heads, clusters at ends of stems; stipules forming bristly sheath at node . . . . . . *Richardia scabra* (Florida pusley) Plates 6-67 and 6-68

41. Leaves all alternate

47. Stout spines or bristles present on stems and/or leaves and/or fruits

48. Leaf edges bearing spines; leaves elongated, widest above the middle and clasping the stem; flowers are borne in heads . . . . . . *Sonchus* spp. (sowthistles)

48. Leaf edges not bearing spines; leaves variously shaped; flowers separate or borne in spiny heads

49. Flowers not conspicuous, borne in spiny heads

50. Taprooted annual; leaves large, cordate to deltoid; heads oblong, 2-3 cm long; spines many and hooked . . . . . . *Xanthium strumarium* (common cocklebur) Plates 6-15 and 6-16

50. Rhizomatous perennial forming large colonies; leaves 3-lobed, silvery-gray; heads spherical, 5 mm in diameter; spines 9-15, straight or curved . . . . . . *Ambrosia grayi* (woollyleaf bursage)

49. Flowers conspicuous with showy petals, not borne in spiny heads

51. Stems and midnerve of leaf blades armed with stiff spines or prickles; flowers wheel-shaped or slightly bell-shaped; fruit a berry; stamens opening by apical pores; nightshades (*Solanum* spp.)

52. Flowers bright yellow; sepals densely covered with stout spines; leaves deeply cleft into narrow lobes; taprooted annual . . . . . . *Solanum rostratum* (buffalobur) Plate 6-72

52. Flowers blue-violet to white; sepals without spines; leaves oblong or broad, not deeply divided; perennial from deep rootstock

53. Leaves oblong, silvery gray-green; surfaces velvety due to dense covering of stellate hairs . . . . . . *Solanum elaeagnifolium* (silverleaf nightshade) Plates 6-69 and 6-70

53. Leaves broadly ovate to elliptic, green, irregularly lobed to toothed; surfaces not velvety . . . . . . *Solanum carolinense* (horsenettle) Plate 6-71

51. Stems and leaves without spines or prickles; flowers tubular; fruit a capsule; stamens splitting open by longitudinal slits; thornapples (*Datura* spp.)

54. Corolla 15-20 cm long; calyx tubular in cross-section; branches numerous; perennial . . . . . . *Datura innoxia* = *Datura meteloides* (sacred datura)

54. Corolla 6-12 cm long; calyx angular in cross-section; branches few; annual

55. Stems densely hairy, gray-green; capsules both spiny and hairy . . . . . . *Datura discolor* (small datura)

55. Stems slightly hairy or without hairs, green; capsules spiny but not hairy

56. Spines of capsule 10-30 mm long, flattened at base; capsule spherical; tips of calyx 3-4 mm long, about equal in length . . . . . . *Datura ferox* (no common name)

56. Spines of capsule 3-10 mm long, slightly flattened; capsule slightly elongated, ovoid; tips of calyx 5-10 mm long, unequal in length .... *Datura stramonium* (jimsonweed) Plates 6-79 and 6-80

47. Stout spines not present, stems and leaves variously hairy or lacking hairs

57. Flowers distinctly 2-lipped or butterfly-like; fruit a large elongated pod 3-15 cm long

58. Foliage foul smelling, densely covered with glandular hairs; leaves heart-shaped, 5-20 cm wide, estipulate; fruit splitting at maturity and forming two large curved horns or claws .... *Proboscidea louisianica* (devil's-claw or unicorn-plant) Plates 6-62 and 6-63

58. Foliage without hairs; leaves elongated, widest above the middle, 3-5 cm wide, stipulate; fruit an elongated pod, 3-4 cm long .... *Crotalaria spectabilis* (showy crotalaria)

57. Flowers with radial symmetry, showy or inconspicuous; fruit a capsule or berry or achene less than 2 cm in diamater

59. Petals not showy, flowers small, inconspicuous, often tightly clustered at stem ends or on stalks arising in leaf axils

60. Stems turning red as plant matures and dark longitudinal lines apparent; fruit a small papery achene; flowers with both stamens and pistils, rarely unisexual

61. Leaves linear with 1 major vein; flowers borne in axils of reduced leaves near ends of stems .... *Kochia scoparia* (kochia)

61. Leaves ovate to diamond-shaped with numerous prominent veins; flowers borne in terminal inflorescences above the foliage

62. Leaves lanceolate to diamond-shaped, irregularly toothed, lower surfaces with mealy appearance; flowers 5-sided, grayish-green, borne in branching inflorescences . . . . . . *Chenopodium album* (common lambsquarters) Plate 6-10

62. Leaves ovate, long petioled, edges smooth or wavy, veins conspicuous on lower surfaces; flowers round, green, borne in dense more or less unbranched spikes; pigweeds (*Amaranthus* spp.)

63. Upper portions of stems generally hairy; staminate flowers intermixed with pistillate flowers; sepals of pistillate flowers spathulate . . . . . . *Amaranthus retroflexus* (redroot pigweed) Plates 6-5 and 6-6

63. Upper portions of stems without hairs; staminate and pistillate flowers borne on separate plants; sepals of pistillate flowers oblong to lanceolate . . . . . . *Amaranthus palmeri* (Palmer amaranth) Plates 6-3 and 6-4

60. Stems not turning red nor dark lines apparent; fruit a small but conspicuously 3-lobed capsule splitting to release 3 seed; flowers either staminate or pistillate

64. Flowers without petals or sepals, borne in small cup-shaped structure bearing glands at top; pistillate flower solitary; sap usually milky . . . . . . *Euphorbia heterophylla* (wild poinsettia)

64. Flowers with green sepals, separate, not arising from cup-shaped structure; glands absent; sap not milky

65. Stem and leaves covered with stellate hairs; flowers borne in clusters at top of stems; crotons (*Croton* spp.)

66. Edges of leaves toothed; hairs sparse and plant green; style branches 6 . . . . *Croton glandulosus* var. *septentrionalis* (tropic croton) Plate 6-33

66. Edges of leaves smooth; hairs dense and plant silvery gray; style branches 12 . . . . *Croton capitatus* (woolly croton) Plate 6-34

65. Stem and leaves without hairs or hairs simple not stellate; flowers borne on stalks at tips of stems or in axils of upper leaves

67. Stalks bearing flowers at tips of stems; pistillate flowers surrounded by multilobed bract . . . . *Acalypha ostryifolia* (hophornbeam copperleaf) Plates 6-31 and 6-32

67. Stalks bearing flowers in axils of leaves; pistillate flowers without surrounding bract . . . . *Caperonia castaniifolia* (mexicanweed)

59. Petals showy, flowers conspicuous

68. Flowers of 2 types and tightly clustered in large heads 10-15 cm in diameter; flowers in center brown and tubular; flowers at edge yellow and strap-like; leaves ovate, long petioled; robust annual . . . . *Helianthus annuus* (common sunflower) Plates 6-17 and 6-18

68. Flowers all similar and not clustered in large heads

69. Flowers small, 3-4 mm wide, clustered in dense spikes on stalks above the foliage; stipules forming a sheath about the stem; nodes generally swollen; fruit a black 3-sided achene . . . . *Polygonum pensylvanicum* (Pennsylvania smartweed) Plate 6-65

69. Flowers large, 5-70 mm wide, solitary; stipules if present not sheathing stem; nodes not conspicuously swollen; fruit a capsule or berry

  70. Stamens many and united by their filaments in a column about styles; leaves palmately net veined; fruit a capsule; mallows

    71. Leaves deeply 3-lobed or 3-5 parted, 3-6 cm wide, lobes toothed or cut; flowers sulphur-yellow or whitish with a brown-purple center . . . . *Hibiscus trionum* (Venice mallow) Plates 6-60 and 6-61

    71. Leaves not deeply lobed nor parted; flowers purple or white or yellow

      72. Leaves cordate to round, large, 9-20 cm wide; apex abruptly constricted to point; flowers yellow

        73. Herbaceous annual; petals 6-10 mm long; lobes of capsule with short bristles; ring of bracts not present below sepals . . . . *Abutilon theophrasti* (velvetleaf) Plate 6-59

        73. Woody perennial; petals 50-70 mm long; lobes of capsule without bristles; ring of bracts below sepals . . . . *Hibiscus tiliaceus* (sea hibiscus)

      72. Leaves oblong to ovate to triangular, small, 1-5 cm wide; apex rounded or angled but not constricted; flowers purple or white or yellow

74. Leaves ovate to triangular, usually shallowly 3-lobed; calyx star-shaped; petals pale blue or lavender, 10-25 mm long; hairs simple, often golden and dense . . . . *Anoda cristata* (spurred anoda) Plates 6-57 and 6-58

74. Leaves oblong or ovate-cordate, not lobed; calyx round or angular; petals yellow or white to cream, 5-15 mm long; hairs stellate

75. Foliage densely covered with stellate hairs; flowers white to cream; flower stalks slightly longer than petioles . . . . *Sida hederacea* (alkali sida)

75. Foliage sparsely covered with stellate hairs; flowers yellow; flower stalks shorter than petioles . . . . *Sida spinosa* (prickly sida) Plates 6-55 and 6-56

70. Stamens 5 and not united to each other; leaves pinnately net veined; fruit a berry

76. Flowers white; stamens clustered in center; anthers opening by terminal pores; calyx not inflated around mature berry; nightshades (*Solanum* spp.)

77. Stems distinctly hairy; ripe berries brownish-green; calyx covering ½ of mature berry . . . . *Solanum sarrachoides* (hairy nightshade) Plates 6-75 and 6-76

77. Stems sparsely hairy; ripe berries black; calyx covering ¼ or only base of mature berry

78. Anthers 1.8-2.5 mm long; berries without white flakes; seed 15-60 per berry, 1.8-2.2 mm wide . . . . *Solanum nigrum* (black nightshade) Plates 6-73 and 6-74

78. Anthers 1.3-1.8 mm long; berries with white flakes; seed 50-110 per berry, 1.4-1.8 mm wide . . . . *Solanum americanum* (American black nightshade) Plates 6-77 and 6-78

76. Flowers yellow or white with yellow center; stamens not clustered; anthers splitting open by longitudinal slits; calyx inflated and loosely enclosing mature berry; groundcherries (*Physalis* spp.)

79. Flowers yellow

80. Flowers 10-15 mm wide; corolla with dark center; inflated calyx round, berry filling inside . . . . *Physalis ixocarpa* (tomatillo groundcherry)

80. Flowers 4-12 mm wide; corolla without dark center; inflated calyx elongated, berry not filling inside

81. Leaves ovate-lanceolate; 6-10 mm long . . . . *Physalis angulata* (cutleaf groundcherry) Plates 6-81 and 6-82

81. Leaves lanceolate to linear-lanceolate; 4-5 mm long . . . . *Physalis lanceifolia* (lanceleaf groundcherry)

79. Flowers white with yellow center, 10-20 cm wide . . . . *Physalis wrightii* (Wright groundcherry)

PHOTOGRAPHS OF WEEDS IN COTTON

The following pages contain photographs (alphabetically by families) of many of the most important weeds in cotton. All photographs are referenced in the classification key; however, the key does contain some species not represented by photographs. The common and scientific names of all weeds found here and in the key are from the "Composite List of Weeds" (Standardized Plant Names Subcommittee, Weed Sci. Soc. Am., 1984). Several other scientific names in current use have also been included in the key.

ACKNOWLEDGMENT

The authors of this chapter gratefully acknowledge and deeply appreciate the generosity of Arlyn W. Evans and the E. I. duPont de Nemours & Co., (Inc.) for supplying these photographs.

AIZOACEAE

Plate 6-1. Carpetweed (*Mollugo verticillata* L.)

Plate 6-2. Carpetweed (*Mollugo verticillata* L.)

AMARANTHACEAE

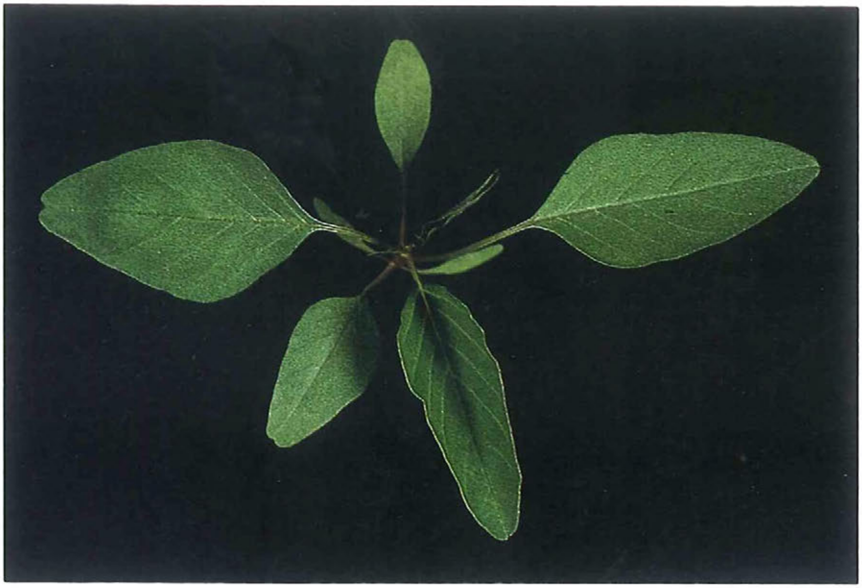

Plate 6-3. Palmer amaranth (*Amaranthus palmeri* S. Wats.)

Plate 6-4. Palmer amaranth (*Amaranthus palmeri* S. Wats.)

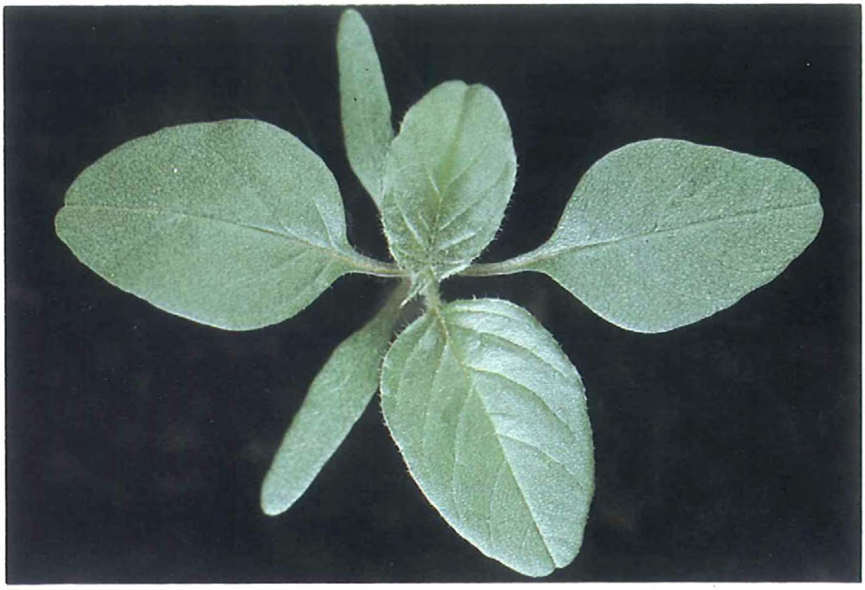

Plate 6-5. Redroot pigweed (*Amaranthus retroflexus* L.)

Plate 6-6. Redroot pigweed (*Amaranthus retroflexus* L.)

ASCLEPIADACEAE

Plate 6-7. Honeyvine milkweed [*Ampelamus albidus* (Nutt.) Britt.]

BIGNONIACEAE

Plate 6-8. Trumpetcreeper [*Campsis radicans* (L.) Seem. *ex* Bureau]

Plate 6-9. Trumpetcreeper [*Campsis radicans* (L.) Seem. *ex* Bureau]

CHENOPODIACEAE

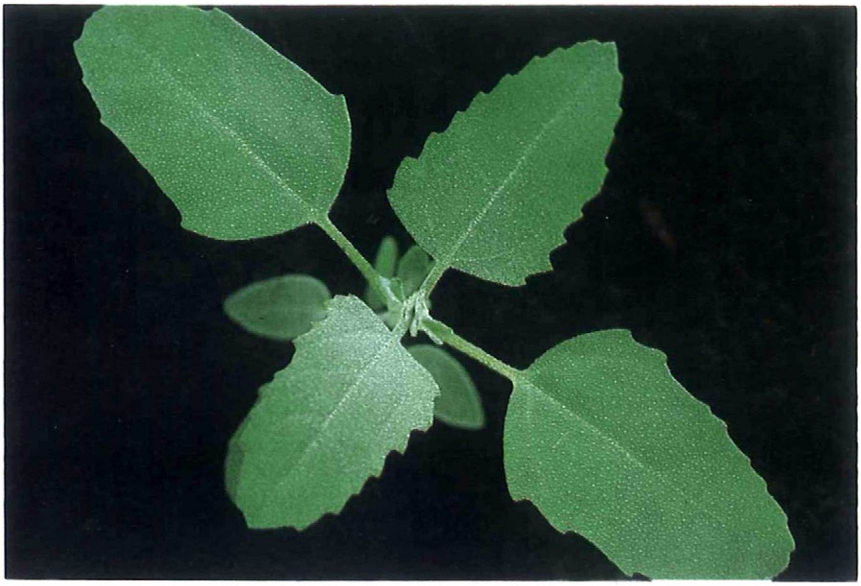

Plate 6-10. Common lambsquarters (*Chenopodium album* L.)

COMPOSITAE

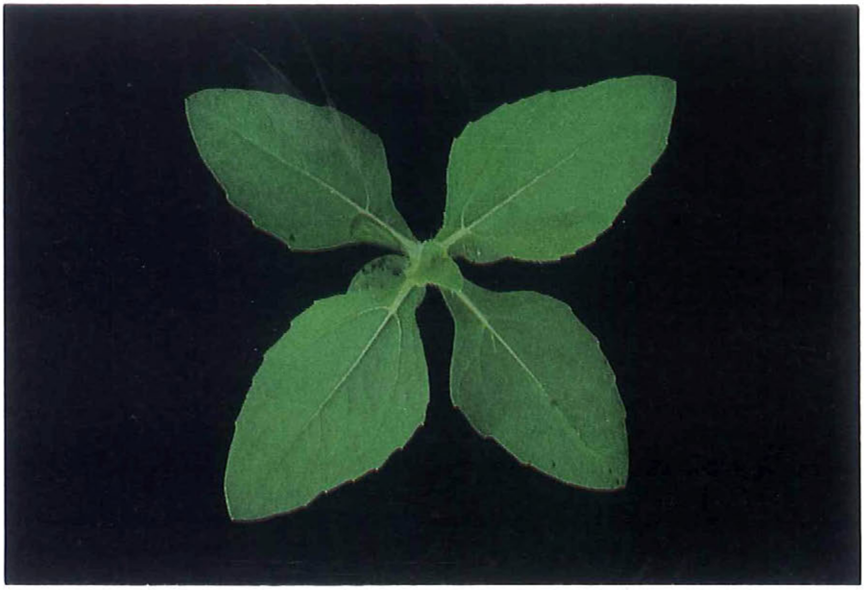

Plate 6-11. Bristly starbur (*Acanthospermum hispidum* DC.)

Plate 6-12. Bristly starbur (*Acanthospermum hispidum* DC.)

Plate 6-13. Common ragweed (*Ambrosia artemisiifolia* L.)

Plate 6-14. Common ragweed (*Ambrosia artemisiifolia* L.)

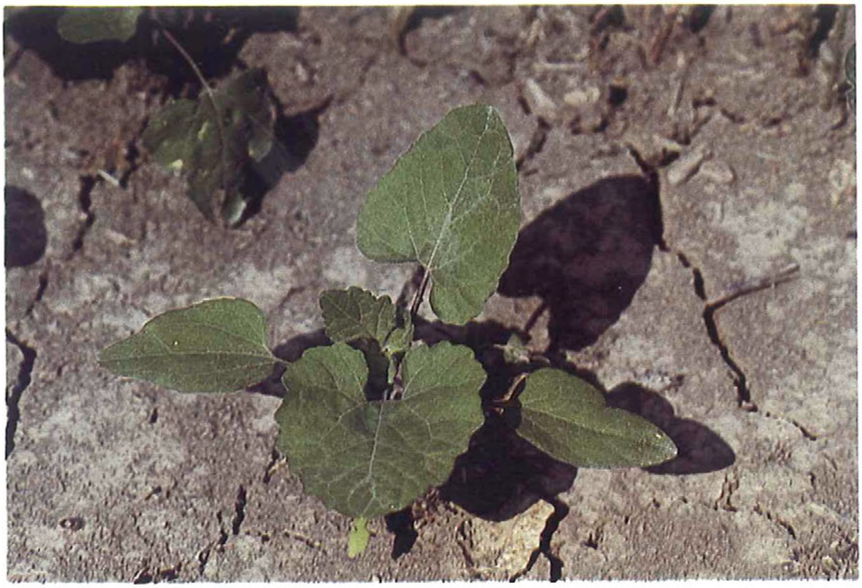

Plate 6-15. Common cocklebur (*Xanthium strumarium* L.)

Plate 6-16. Common cocklebur (*Xanthium strumarium* L.)

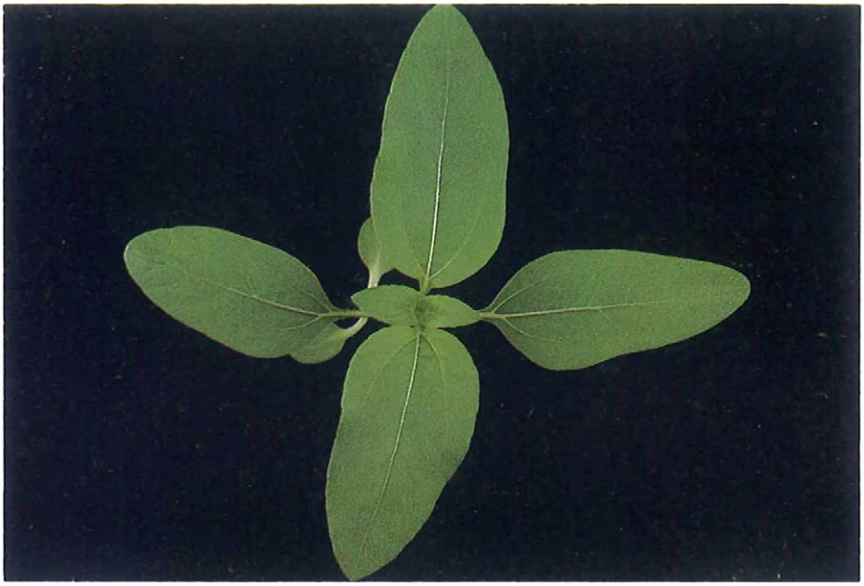

Plate 6-17. Common sunflower (*Helianthus annuus* L.)

Plate 6-18. Common sunflower (*Helianthus annuus* L.)

CONVOLVULACEAE

Plate 6-19. Field bindweed (*Convolvulus arvensis* L.)

Plate 6-20. Entireleaf morningglory
(*Ipomoea hederacea* var. *integriuscula* Gray)

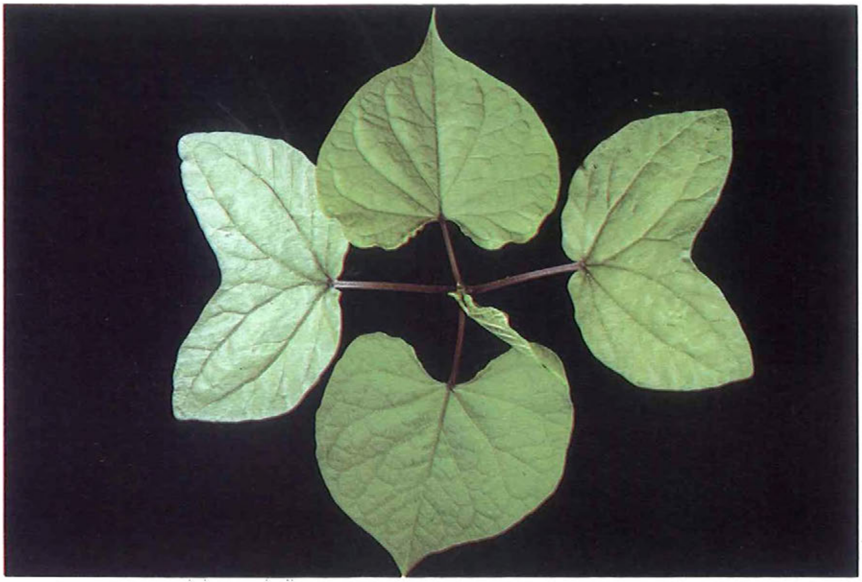

Plate 6-21. Purple morningglory (*Ipomoea turbinata* Lag.)

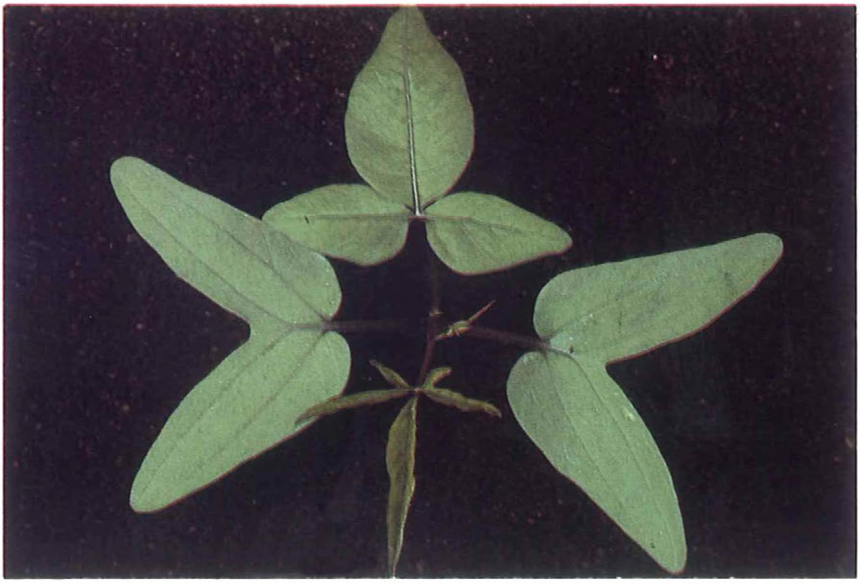

Plate 6-22. Palmleaf morningglory (*Ipomoea wrightii* Gray)

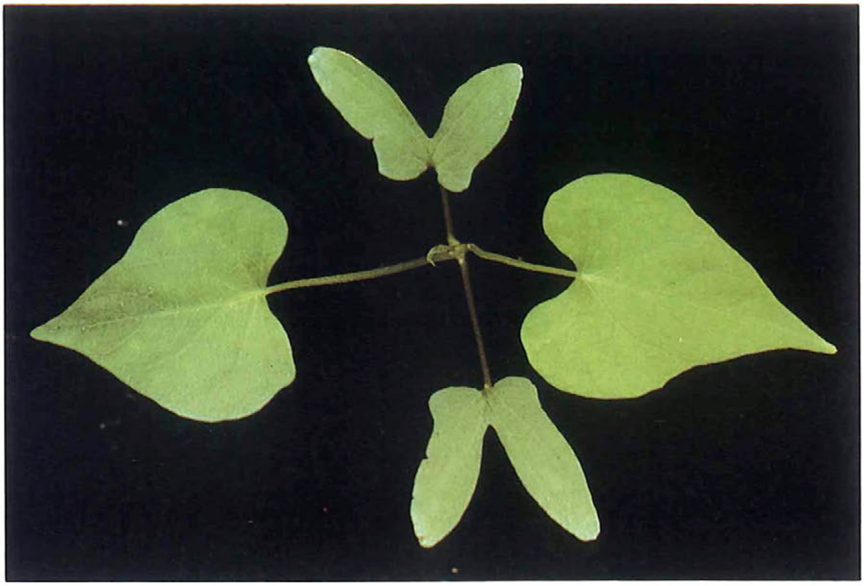

Plate 6-23. Cotton morningglory
[*Ipomoea trichocarpa* Ell. var. *torreyana* (Gray) Shinners]

Plate 6-24. Pitted morningglory (*Ipomoea lacunosa* L.)

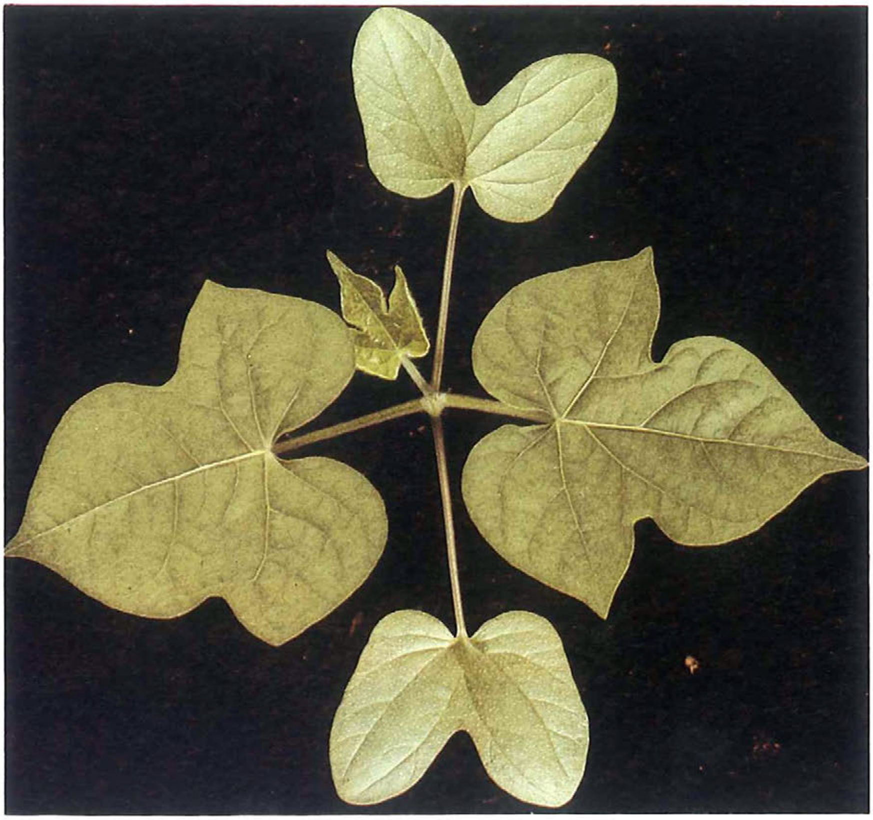

Plate 6-25. Ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.]

Plate 6-26. Tall morningglory [*Ipomoea purpurea* (L.) Roth]

CYPERACEAE

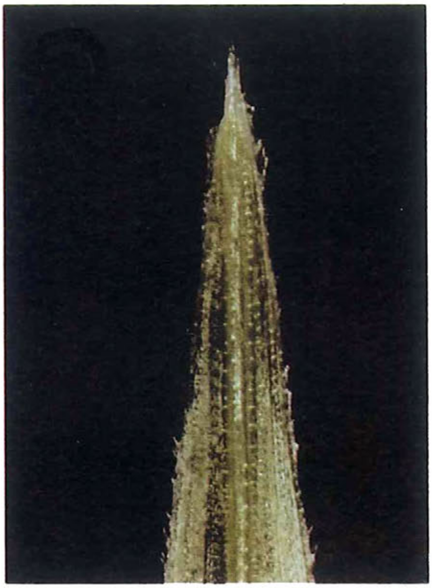

Plate 6-27. Purple nutsedge (*Cyperus rotundus* L.)

Plate 6-28. Purple nutsedge (*Cyperus rotundus* L.)

Plate 6-29. Yellow nutsedge (*Cyperus esculentus* L.)

Plate 6-30. Yellow nutsedge (*Cyperus esculentus* L.)

EUPHORBIACEAE

Plate 6-31. Hophornbeam copperleaf (*Acalypha ostryifolia* Riddell)

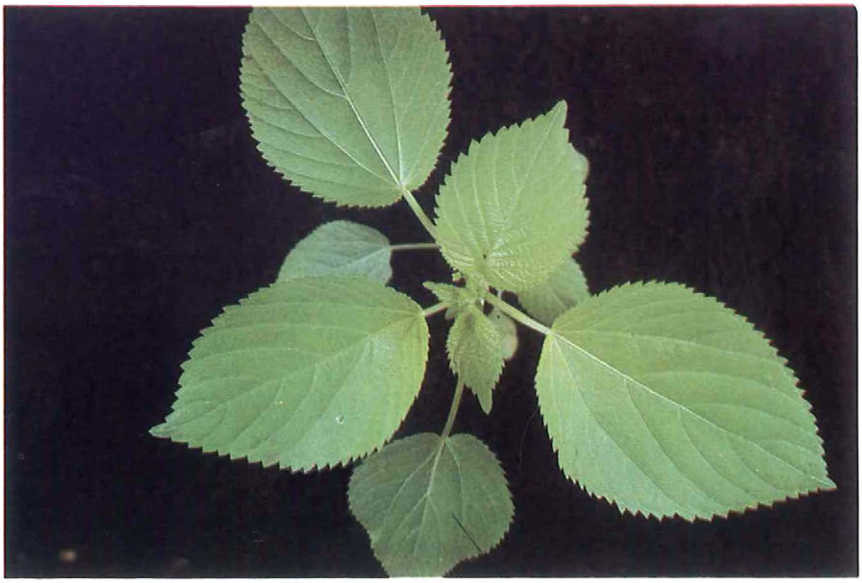

Plate 6-32. Hophornbeam copperleaf (*Acalypha ostryifolia* Riddell)

Plate 6-33. Tropic croton
(*Croton glandulosus* var. *septentrionalis* Muell.-Arg.)

Plate 6-34. Woolly croton (*Croton capitatus* Michx.)

Plate 6-35. Spotted spurge (*Euphorbia maculata* L.)

Plate 6-36. Hyssop spurge (*Euphorbia hyssopifolia* L.)

GRAMINEAE

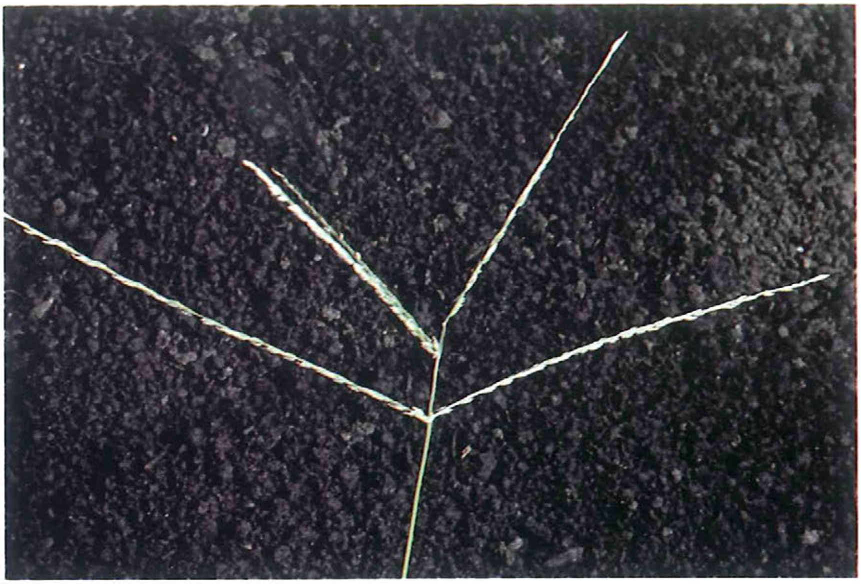

Plate 6-37. Large crabgrass [*Digitaria sanguinalis* (L.) Scop.]

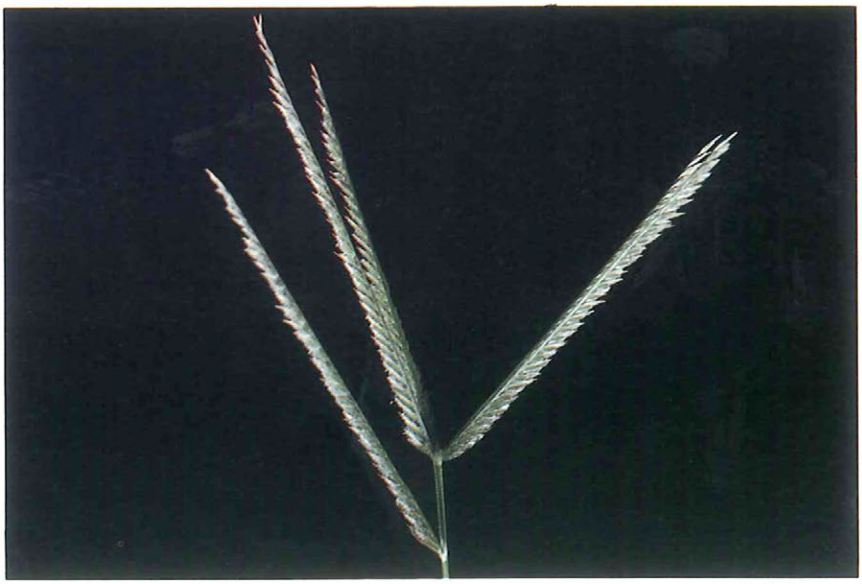

Plate 6-38. Goosegrass [*Eleusine indica* (L.) Gaertn.]

Plate 6-39. Johnsongrass [*Sorghum halepense* (L.) Pers.]

Plate 6-40. Broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash]

Plate 6-41. Junglerice [*Echinochloa colonum* (L.) Link]

Plate 6-42. Barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.]

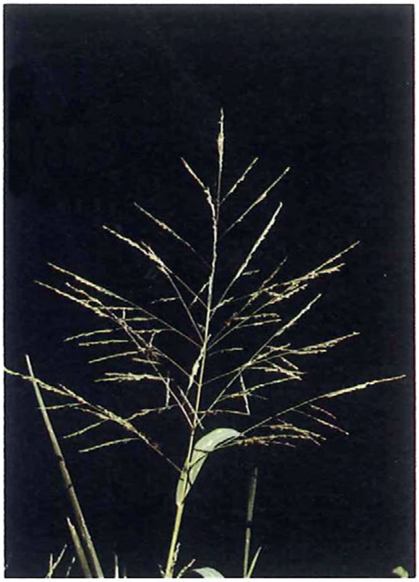

Plate 6-43. Fall panicum (*Panicum dichotomiflorum* Michx.)

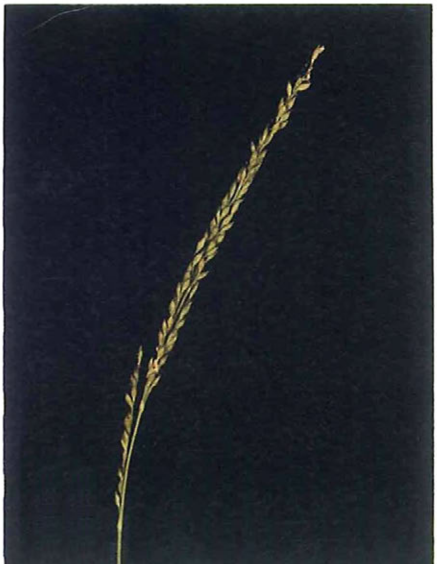

Plate 6-44. Texas panicum (*Panicum texanum* Buckl.)

Plate 6-45. Browntop panicum (*Panicum fasciculatum* Sw.)

Plate 6-46. Bermudagrass [*Cynodon dactylon* (L.) Pers.]

Plate 6-47. Field sandbur (*Cenchrus incertus* M. A. Curtis)

LEGUMINOSAE

Plate 6-48. Sicklepod (*Cassia obtusifolia* L.)

Plate 6-49. Sicklepod (*Cassia obtusifolia* L.)

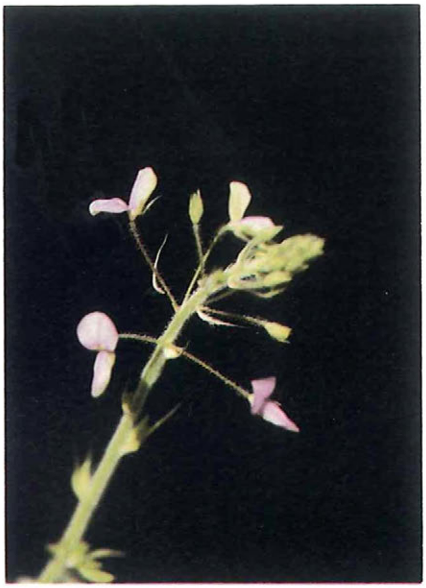

Plate 6-50. Florida beggarweed [*Desmodium tortuosum* (Sw.) DC.]

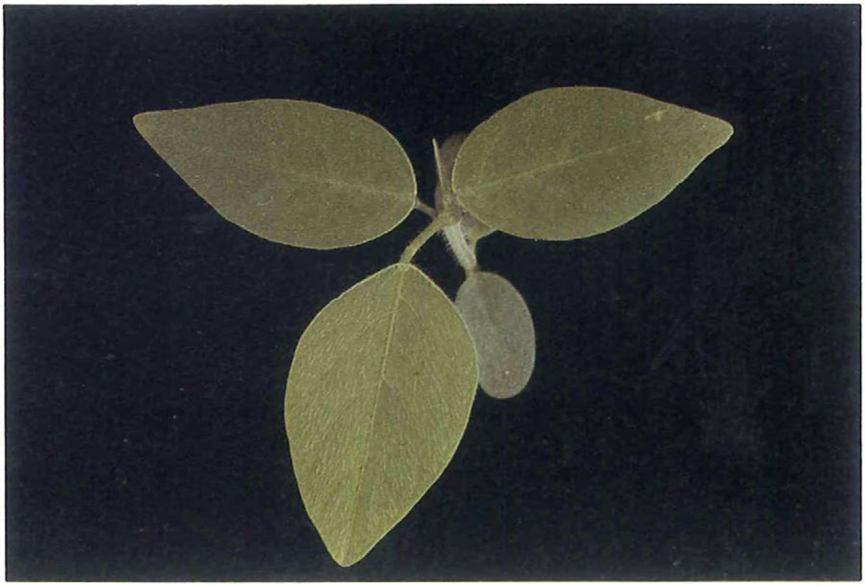

Plate 6-51. Florida beggarweed [*Desmodium tortuosum* (Sw.) DC.]

Plate 6-52. Hemp sesbania [*Sesbania exaltata* (Raf.) Rydb. *ex* A. W. Hill]

Plate 6-53. Hemp sesbania [*Sesbania exaltata* (Raf.) Rydb. *ex* A. W. Hill]

Plate 6-54. Coffee senna (*Cassia occidentalis* L.)

MALVACEAE

Plate 6-55. Prickly sida (*Sida spinosa* L.)

Plate 6-56. Prickly sida (*Sida spinosa* L.)

Plate 6-57. Spurred anoda [*Anoda cristata* (L.) Schlecht.]

Plate 6-58. Spurred anoda [*Anoda cristata* (L.) Schlecht.]

Plate 6-59. Velvetleaf (*Abutilon theophrasti* Medik.)

Plate 6-60. Venice mallow (*Hibiscus trionum* L.)

Plate 6-61. Venice mallow (*Hibiscus trionum* L.)

MARTYNIACEAE

Plate 6-62. Devil's-claw (unicorn-plant)
[*Proboscidea louisianica* (Mill.) Thellung]

Plate 6-63. Devil's-claw (unicorn-plant)
[*Proboscidea louisianica* (Mill.) Thellung]

POLYGONACEAE

Plate 6-64. Redvine [*Brunnichia ovata* (Walt.) Shinners]

Plate 6-65. Pennsylvania smartweed (*Polygonum pensylvanicum* L.)

PORTULACACEAE

Plate 6-66. Common purslane (*Portulaca oleracea* L.)

RUBIACEAE

Plate 6-67. Florida pusley (*Richardia scabra* L.)

Plate 6-68. Florida pusley (*Richardia scabra* L.)

SOLANACEAE

Plate 6-69. Silverleaf nightshade (*Solanum elaeagnifolium* Cav.)

Plate 6-70. Silverleaf nightshade (*Solanum elaeagnifolium* Cav.)

Plate 6-71. Horsenettle (*Solanum carolinense* L.)

Plate 6-72. Buffalobur (*Solanum rostratum* Dun.)

Plate 6-73. Black nightshade (*Solanum nigrum* L.)

Plate 6-74. Black nightshade (*Solanum nigrum* L.)

Plate 6-75. Hairy nightshade (*Solanum sarrachoides* Sendtner)

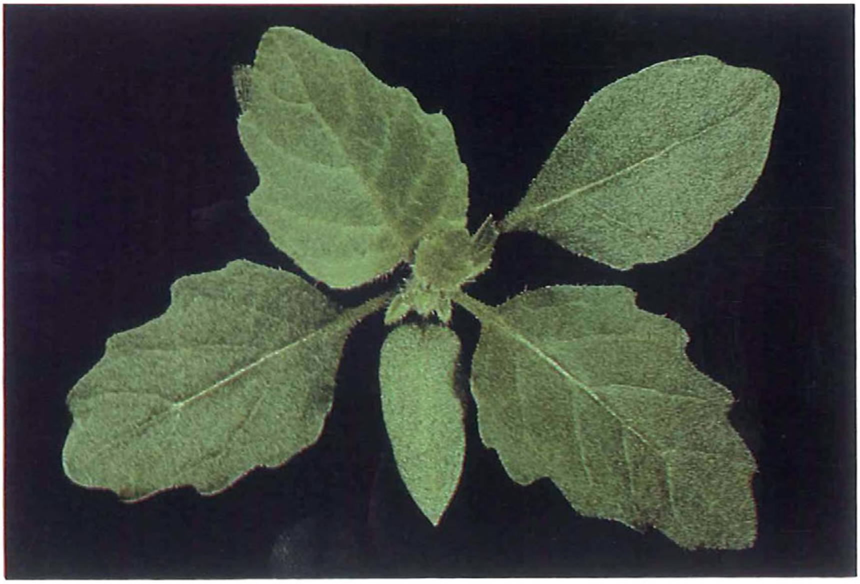

Plate 6-76. Hairy nightshade (*Solanum sarrachoides* Sendtner)

Plate 6-77. American black nightshade (*Solanum americanum* Mill.)

Plate 6-78. American black nightshade (*Solanum americanum* Mill.)

Plate 6-79. Jimsonweed (*Datura stramonium* L.)

Plate 6-80. Jimsonweed (*Datura stramonium* L.)

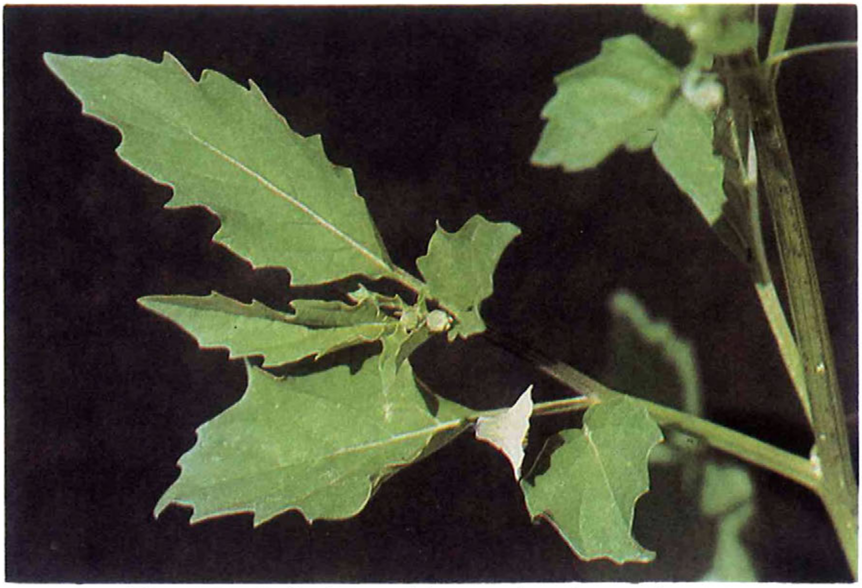

Plate 6-81. Cutleaf groundcherry (*Physalis angulata* L.)

Plate 6-82. Cutleaf groundcherry (*Physalis angulata* L.)