Chapter 9

REDUCED-TILLAGE SYSTEMS

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INTRODUCTION

Tillage has been one of the most important production tools available to cotton (*Gossypium hirsutum* L.) producers in the United States. The average annual number of tillage operations varies from state to state but generally involves 8 to 12 tillage operations (Reeves, 1975). At least half of these are specifically for the control of weeds.

In cotton production, a number of terms describe tillage operations and the interchangeable use of many of these has been confusing. In this report, "no-till" is defined as tillage restricted to the immediate seed zone (Figure 1). "Minimum-tillage" and "reduced-tillage" implies that the entire surface is tilled, but that there are fewer tillage operations per year than when compared to conventional tillage systems. "Conservation-tillage" is defined as reduced-tillage or minimum-tillage systems in which 30 percent or more of the previous crop residue remains on the surface as a cover after planting.

Despite the success utilizing reduced-tillage systems in cotton production, such systems have not been as readily adopted for cotton as for other crops. Young (1982) reported that technology for reduced-tillage systems of cotton is presently at about the level of soybeans in the early 1970s. McWhorter and Barrentine (1988) reported that more members in the Weed Science Society of America survey, regardless of region or type of employment, ranked conservation tillage the most important crop or situation that needed new and improved weed technology. With the development of needed technology, cotton grown on erodible soils will probably be cultured with some form of conservation tillage involving a reduced number of tillage operations.

Figure 1. Cotton seedlings four days after emergence in no-tillage production research at Stoneville, Mississippi. (Photo by C. T. Bryson.)

HISTORY OF TILLAGE IN COTTON

Weeds have been a major problem in cotton production. In early cotton production, human energy, hand-hoeing and animal power were used to control weeds. Animal power was replaced by tractors in the 1930s and 1940s. Since the 1950s, herbicides have been used to supplement mechanical tillage and hand-hoeing.

In 1983 Block (1984) estimated the American farmer had tripled his use of conservation tillage during the last decade to one of every three acres planted. He also projected that, by the year 2010, conservation-tillage would be utilized on more than 90 percent of the land planted. King and Holcomb (1985) predicted that conservation-tillage will be used on 50, 80 and 95 percent of planted land in 1990, 2000 and 2010, respectively. This prediction of greater use of conservation-tillage indicates that reduced tillage practices are expected to increase greatly for all crops, including cotton.

Historically, mechanical tillage has been the most important tool for weed control in cotton production. Mechanical tillage in cotton can be categorized as preplant tillage and postplant tillage. Wiese and Chandler (1979) estimated that 50 percent of all preplant tillage is for weed control. Tillage, in addition to controlling weeds at preplanting, is helpful in forming planting beds which promote uniform stands of cotton and provide a smooth surface for postemergence weed control (Kempen, 1987). Postplant tillage is used extensively to control weeds growing between the rows. These cultivations alone are inadequate to control weeds along the rows and are performed simultaneously with postemergence, directed, herbicide sprays to control weeds within the row (Foy, 1959; Holstun, 1963; Upchurch and Selman, 1968).

The moldboard plow, one of the primary tillage tools used in the United States, is an efficient tool for burying weeds and crop residues (Raney and Cooper, 1968; Kempen and Greil, 1985; King and Holcomb, 1985). However, burial of plant residues, once believed to be a beneficial practice, leaves the soil surface unprotected resulting in loss of soil from wind and water erosion (Kaddah, 1977; King and Holcomb, 1985; Unger *et al.*, 1977; Webb *et al.*, 1986). The loss of soil due to water erosion for different crops and regions is summarized in Tables 1 and 2[1].

Webb *et al.* (1986) reported that about 47 million acres of major cropland, including summer fallow and hay, are highly erodible and fragile land (sheet and rill erosion only) (Table 1). On highly erodible acres, those planted to soybeans and corn have the highest erosion rate, with 29 tons per acre per year (TAY) for soybeans and 23 TAY for corn. Although 13 million acres of hayland are potentially highly erodible and fragile, the relatively low erosion rate of hayland (3.2 TAY) indicates that soil erosion is low as long as the land remains covered and is not tilled. Cotton has the smallest percentage (three percent) of highly erodible and fragile land among the seven major crops corn, soybeans, sorghum, cotton, wheat, oats and barley, and about 13 percent of the total erosion from cotton production comes from this three percent of the land. Cotton is grown on about 383,000 acres of fragile land and 170,000 acres of highly erodible land (Table 2).

Most of the highly erodible and fragile land is in the Southwest with the rest in the Mid-South, Appalachian, and Southeast regions[2] (Tables 1 and 2; Webb *et al.*, 1986). Hanson (1982) reported that wind erosion is also wreaking havoc, as five TAY of cropland are lost annually in the 10 Great Plain states. Three states, Colorado, New Mexico, and Texas, each have annual wind erosion rates above eight TAY.

When fully implemented, the conservation compliance provisions of the 1985 Farm Bill should drastically increase the number of cotton acres in reduced-tillage production systems especially on sandy or highly erodible soils. This bill states that producers must have an acceptable conservation plan in place by 1990 which must be fully implemented by 1995. Full compliance is required for producers to qualify for future federal farm payments or loans.

Historically, the total number of cotton acres planted no-till has been low. Lessiter (1988) reports that 1710 acres of cotton were planted no-till in 1972. He predicted that no-till cotton acreage will increase by three percent during 1988

[1]All of the tables in this chapter are in the Appendix at the end of the chapter.

[2]In this Chapter Regions in the Cotton Belt and states within each region will be as follows: Southeast—Alabama, Georgia, Florida, North Carolina and South Carolina; Mid-South—Arkansas, Louisiana, Mississippi, Missouri and Tennessee; Southwest—Oklahoma and Texas; and West—Arizona, California and New Mexico.

from the 13,464 acres in 1987, but the total no-till cotton acres across the Cotton Belt are down by 2,000 acres from a high in 1983.

Vast losses of soil from water and wind erosion, and the need to reduce production costs, are causing producers and researchers to reevaluate previous tillage practices. Leaving crop and weed residues on the soil surface (including crop/weed stubble) reduces raindrop impact and velocity of runoff water, thus limiting the detachability of soil particles (King and Holcomb, 1985). Surface residue also reduces wind erosion as it absorbs wind energy. Thus, tillage equipment, such as chisel plows, disks, etc., which leave much plant residues on the soil surface are used more frequently, and a trend exists to limit tillage to essential operations only. The basic tillage systems and other operations evaluated for establishing cotton stands are shown in Table 3. Tillage system "E" represents the most frequently used conventional tillage system in cotton production. Today's conventional tillage system in cotton consists of between 11 to 15 trips across the field (Reeves, 1975). This is very similar to the nine operations that are commonly used preplanting in California (Carter and Colwick, 1971). An addition of three to four postplanting cultivations brings the total to 13 or 14 operations per year.

Some of the earliest reduced-tillage research in cotton was conducted by Harris (1964) from 1950 to 1963 in Mississippi (Figure 2). He successfully eliminated postemergence cultivations and increased yields and profits by utilizing herbicides instead of tillage to control weeds. In addition to hand hoeing, Harris used broadcast preemergence applications and postemergence directed and spot sprays of herbicides to control weeds. Usually, neither multiple applications of spot spraying nor hand hoeing are profitable for today's cotton farmer.

Other early research from 1954 to 1957 was conducted in Arizona by Kaddah (1977). He reported that minimum-tillage treatments produced higher yields than conventional treatments in cotton. The increased profit from additional yield and the reduced-tillage indicated that not all conventional tillage practices were essential.

Success with early minimum-tillage systems for cotton production encouraged additional research to determine which tillage practices were essential for weed control, yet would conserve the soil and reduce crop production costs.

Each basic tillage system (Table 3), which will be discussed in detail later, seems to fill a need for a certain region or local/national problems. From our literature search, the concentration of past research efforts in the Southwest (31 percent), Mid-South (22 percent), Southeast (36 percent) and West ($\leq$ 11 percent) is probably directly related to erodible and fragile land in these regions. If suitable reduced-tillage practices are developed which reduce production costs of crops, this should also increase incentives for adopting reduced-tillage practices on non-erodible land. From a practical standpoint, conservation-, reduced-, or no-tillage systems usually are not adopted in a locality unless there is an economic advantage over conventional tillage (Wiese and Chandler, 1987).

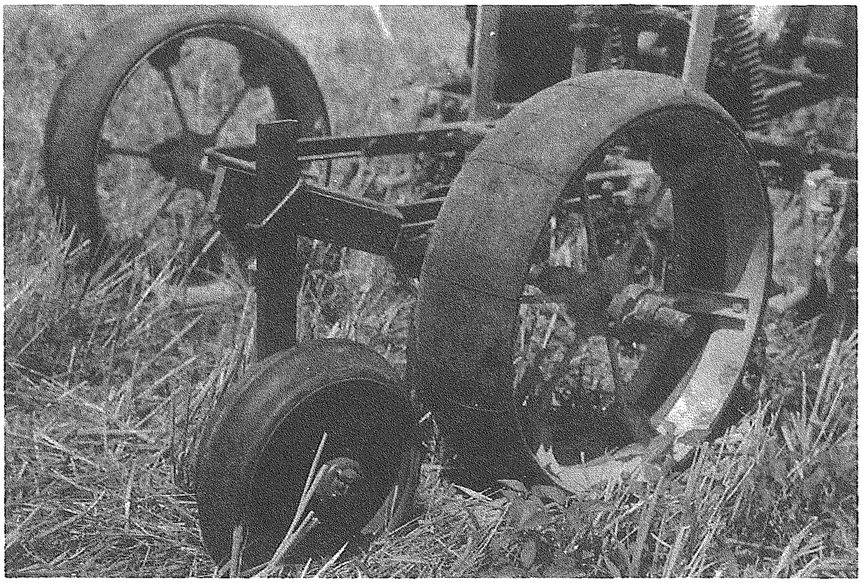

Figure 2. Cotton planted no-till in research experiments at Stoneville, Mississippi in the 1950s. (Photo by anonymous.)

ADVANTAGES AND DISADVANTAGES OF REDUCED- AND NO-TILLAGE COTTON PRODUCTION

In addition to reviewing the literature on reduced tillage systems of cotton, we conducted a survey in early 1987 among extension and research scientists in most of the cotton producing states to determine the most important advantages and disadvantages of reduced-tillage production systems in cotton in the United States. Reduced soil erosion was the most important advantage listed in the survey (Table 4). Soil residues of the previous crop and weeds (stubble and surface residues) remaining on the soil as a mulch should reduce wind and water erosion in cotton production as in other crops. These effects have been reported for other crops by Harrold (1972), Larson *et al.* (1970), Phillips and Young (1973), Triplett *et al.* (1973) and Woodruff (1972). McWhorter and Jordan (1985) stated that the crop residue in cotton would also provide protection for the seedling crop from wind and sand damage. Losses of soil through erosion in cotton have been estimated to range from seven to eight tons per acre per year (TAY) in Mississippi (Brandon, 1978) to over 40 in Texas (McWhorter and Jordan, 1985). Losses in minimum-tillage in Mississippi averaged four tons per acre per year of soil when compared to average losses of seven to eight in conventional tillage systems of cotton production.

Hanson (1982) reported that the tolerance level of soil erosion (the rate that soil may be replaced) ranges from two to five tons per acre per year, indicating that the soil lost by water erosion under minimum-tillage in the above study was within the acceptable range. King and Holcomb (1985) reported for the Soil Conservation Service that conservation-tillage reduces soil erosion 50 to 90 percent compared with conventional tillage, with the percentage of surface covered by residue being the most important factor in determining the amount of the reduction. Mutchler *et al.* (1985) reported acceptable soil losses of 0.5 tons per acre per year with no-till cotton following no-till soybeans and wheat compared to less than 20 tons per acre per year with conventional tillage.

A number of advantages in reduced tillage systems in cotton production in our survey are closely related. Reduced production costs, including less labor and tractor time, with reduced equipment horsepower, reduced energy inputs, and lower capital investment in equipment are all expected from reduced tillage. These advantages are very similar to those given by Spurgeon *et al.* (1974) for limiting the number of operations in preparing a seedbed. These advantages include: (a) reduced cost for labor and equipment, (b) reduced fuel usage, (c) easier timing of operations since seedbed preparation is faster and simpler, (d) increased yield and return per acre (probably the most important advantage), (e) less soil erosion during winter and early spring rains which results in reduced soil compaction from tractor implements, (f) earlier harvest of cotton which usually brings increased prices and (g) fewer tractors required for a given size of farm.

Actual monetary savings reported from the use of reduced- or no-tillage *vs.* conventional tillage ranged from $37 to $135 per acre (Brandon, 1978; Carter and Colwick, 1971; Reeves, 1975; Wiese and Harman, 1982; Wiese *et al.*, 1988; Worsham, 1977; Wuertz, 1975). This does not include additional profit if yields were greater with reduced tillage. These profits are considered to be conservative estimates; profits in the 1970s have not been adjusted for inflation that has occurred in the last 10 or more years. Although the savings seem somewhat insignificant, one cotton producer (Wuertz, 1975), who farmed 15,800 acres in Arizona, indicated that a savings of $74 per acre could amount to the price of one or two new tractors each year. Based on production costs projected for cotton in California (Zelinski, 1987), tillage costs can represent as much as 15 percent of the total production costs. If total tillage costs could be reduced by 50 percent (from $120 to $60 per acre), as much as $60 per acre could be saved by reducing tillage practices in California.

Improved soil moisture, another advantage with reduced tillage, is especially important in the dryland cotton production area of the Southwest (Hanson, 1982; Keeling and Abernathy 1988; Wiese and Harman 1982; Waddle, 1984). Waddle (1984) reported that 20 inches of precipitation is needed to mature a cotton crop at yields of 0.75 bales per acre. This amount of precipitation approaches that of some areas of the High Plains of Texas and Oklahoma. Therefore, a small improvement of soil water storage in those areas could improve yields more than in areas of the Mid-South and Southeast that receive 47 to 60 inches of precipitation and areas of the West that have to be irrigated to produce crops. Wiese and

Harman (1982) reported that when wheat stubble contributed about 2007 pounds per acre of residue, there was about 1.2 inches more available stored moisture in the upper 2.6 feet of the soil profile at planting; and cotton yielded up to 90 pounds per acre more lint under no-tillage than under conventionally tilled practices (Figure 3). In another study, Unger *et al.* (1977), reported that many crops in the Southwest produce residues of less than 4000 pounds per acre, which is considered the amount of residue needed to contribute substantially to storage of soil moisture. According to Mutchler *et al.* (1985), the residue cover of cotton is less than that of soybeans and corn, and the tap root system of the cotton plant contributes little to holding soil in place.

Improved soil fertility resulting from reduced tillage is probably due to increased organic matter and available nutrients from surface plant residues and cover crops (Hanson, 1982; King and Holcomb, 1985; Waddle, 1984). Also, Hanson (1982) reported that some soil scientists estimate that it takes more than $6 worth of fertilizer to replace nutrients lost in a ton per acre of eroded topsoil.

Improved cotton yields, along with several other advantages shown in Table 4, ranked lower in importance in our survey than advantages discussed above. Yields are not necessarily greater with reduced- or no-tillage practices when compared to conventionally tilled cotton. However, as shown in Table 5, over twice as many research studies reported higher yields than reported lower yields. Difficulty in establishing cotton (or poor crop growth in cover crops) and inadequate weed control were most frequently cited as limiting causes for poor cotton yields in reduced-tillage. Since the majority of studies (85 percent) reported equal or higher yields under reduced-tillage of cotton, reduced-tillage, particularly where soil is conserved and production costs are reduced, holds considerable promise for the future in cotton production.

The two most frequently cited disadvantages for reduced-tillage in cotton production in our survey were the increased cost for weed control and weed control difficulties (Table 6). Knake *et al.* (1965) indicated herbicides can replace much of the tillage carried out for many agronomic crops including cotton. In many cases, herbicides are more expensive than tillage operations. Worsham (1977) stated that successful weed control holds the key to the success or failure of reducing tillage. He emphasized that reducing tillage should not be attempted on land where perennial weeds are troublesome. He also pointed out that ecological shifts in weed populations can appear quickly with continuous use of reduced-tillage production. Frans (1977) and Abernathy *et al.* (1984) emphasized that adequate weed control must be achieved to obtain good yields of cotton. This research indicated that postemergence cultivation was needed regardless of the method of seedbed preparation (either no-, reduced-, or conventional tillage) and cotton yields were reduced with poor weed control.

Another disadvantage to no-till or reduced-tillage cotton production is soil compaction by machinery required for herbicide and/or insecticide application, planting, harvesting and stalk removal. In the Delta Region, soil compaction is a

Figure 3. Cotton planted no-till in wheat stubble in the Southern Plains of Texas. (Photo by A. F. Wiese.)

cotton yield limiting condition that requires subsoiling to disrupt a hard pan zone of soil. McConnell *et al.*(1989) report that subsoiling increases lint yield between 12 and 41 percent. They also indicate that shallow tillage pans of select soil types are more detrimental to cotton development than deeper tillage pans.

Herbicide application errors can be more costly to the producer in reduced tillage production than in conventionally planted crops since backup cultivation may be more difficult or impossible. Errors frequently cited include the failure to use preplant foliar herbicides and/or a surfactant, poor spray coverage, and spray volumes which are too low.

In general, present research results indicate weed control can be obtained under reduced-tillage systems (as evidenced by equal or better yields), although better management may be required under reduced-tillage than under conventional tillage systems.

The lack of good seedbed preparation and difficulty of obtaining good cotton stands were mentioned in our survey as primary concerns associated with reduced-tillage culture of cotton. Results of research do not indicate that poor stands were a common problem in reduced-tillage production systems; however, in no-till systems, cotton stands may be affected by environmental conditions and by hard or crusty soils. Mullins *et al.* (1977) observed that no-tillage planters left depressions over the cotton seed allowing water and herbicides to concentrate in the seed area interfering with the emergence and growth of cotton. Although they observed that crusting of the soil also interfered with cotton emergence, they found that the crust-resistance strength of no-tillage soils was about twice that of conventional-tillage soils.

High salt concentrations also contribute to stand and cotton growth problems in the Southwest (McWhorter and Jordan, 1985), and subsoiling has been shown to be beneficial in breaking soil pans and reducing salinity problems (Waddle, 1984; Kaddah, 1977). The possibility of stand problems occurring with reduced-tillage production means that good management will be required to obtain an adequate seedbed for the emergence and growth of cotton.

One disadvantage cited in our survey was the increase in insect and disease problems which might occur in reduced-tillage cotton production systems. Crop diseases and other pest problems in soybeans and corn are sometimes more severe in no-tillage or reduced-tillage systems than in conventional production systems (Larson *et al.*, 1970; Lessiter, 1974; Shear, 1968; Wiese, 1977). As early as 1879, Comstock reported fall plowing, especially in the northern part of the cotton producing areas of the Southeast, aided in the destruction of bollworms (*Heliothis* spp.) by bringing them to the soil surface where they are killed by cold temperatures during the winter months (Comstock, 1879). Fall stalk destruction, the shredding and incorporation of cotton stalks into the soil, is a sanitary measure required by law in the Southwest to control cotton pink bollworm [*Pectinophora gossypiella* (Saunders)] (Anonymous, 1984). A key management strategy for boll weevil [*Anthonomus grandis* (Boheman)] is also the reduction of overwintering populations by early harvest and prompt shredding and plowdown of cotton residues (Anonymous, 1984; Kaddah, 1977; Ridgway, 1984). Similarly, tillage is performed to manage certain diseases of cotton. McWhorter and Jordan (1985) point out that there has been little research on cotton diseases in cotton grown with reduced-tillage systems. Clean tillage practices that completely bury cotton debris as soon as possible after harvest are important for preventing buildup of inoculum and early-season infections by some seedling pathogens, foliar pathogens and viruses (Bell, 1984). Although unknown, it would appear that many insect and disease problems would be difficult to manage if tillage was drastically reduced.

In some areas, continuous use of reduced-tillage in cotton may not be possible because of the lack of technology to control weeds. It then becomes important to control weeds by rotating tillage systems or rotating crops which permit the use of a wider range of herbicides than in a monoculture system. A crop rotation of soybeans for three consecutive years following cotton has been shown to reduce bermudagrass [*Cynodon dactylon* (L.) Pers.] populations by as much as 70 to 90 percent in three Mississippi Delta fields (Bryson, 1985). Usually crop rotation practices are determined by commodity prices and maximum production rather than weed control problems or soil conservation efforts, although these are often interrelated.

REDUCED-TILLAGE/CROPPING SYSTEMS FOR COTTON PRODUCTION

Basic types of tillage systems and types of planting evaluated for establishing cotton stands are summarized in Table 3. Unlike system "E," systems "A" to "C" contain relatively few operations. Although all of these systems are shown as following a cotton crop, they could follow other crops and planting would be accomplished with either a conventional planter after some tillage or with a no-till planter into the previous crop stubble/residue. System "A," the ratooning of cotton, which was practiced on a small scale in some areas of Arizona at one time, may involve the fewest operations of all systems. However, even with this system, herbicides were usually incorporated into the planting beds after stalks were shredded. This system was reevaluated in 1978 to 1980 as a potential practice for Arizona. Although occasional yield advantages were observed, the increased insect (especially the boll weevil in Arizona and California), disease and weed problems appeared too difficult to manage with present technology (Van Brackle, 1979, 1980a, 1980b).

Without the bedding operation, system "B" would be considered no-tillage culture (only tillage at planting in the drill row). Apparently some growers prefer to keep the same planting beds for more than one year (Fields, 1982). But even with rehipping, the same beds (including the desired firmness of beds) could be maintained. Also herbicides could be incorporated into beds as beds are made before planting (Wiese and Chandler, 1987). Hamilton (1987)[3] reported that this method is sometimes used in Arizona to incorporate herbicides, but poor weed control and excessive crop injury may occur.

System "C" would be a better choice for a tillage system when little tillage is desired and subsoiling is needed to reduce soil compaction and salinity problems (Carter *et al.*, 1965; Carter and Tavernetti, 1968; Carter and Colwick, 1971; Kaddah, 1977; Waddle, 1984; Stockton *et al.*, 1964). Since subsoiling is beneficial to many types of cotton soils, it appears that system "B" would only be used in instances where soil compaction and/or water infiltration were not problems. Fall tillage (plowing or disking) needed for destroying winter annual weeds, or for other reasons, could be substituted for or used in addition to subsoiling in system "C."

System "D" would be especially suited for areas where a cover crop is needed during fallow periods to prevent water and wind erosion (Brown *et al.*, 1985; Hardin, 1984; Hurst, 1983; Touchton *et al.*, 1984; White *et al.*,1986; White and Worsham 1990). When following a legume or cereal crop, cotton could be seeded, without tillage, with a no-till planter directly into the stubble/residue of the legume or cereal crop. If a legume or cereal crop is planted as a special need for cover, some light disking might be needed as shown in establishing the cover

[3]Personal correspondence with K. C. Hamilton, Univ. of Arizona, Dept. of Plant Sci., Tucson, AZ 85721.

crop, and a herbicide plus shredding would probably be needed to kill the cover crop before no-till planting of cotton. It appears that several legumes have been successful in serving the dual purpose of supplying nitrogen and providing cover. One study showed it was advantageous to plant the legume in the standing cotton stalks (rather than after shredding as shown in Table 3) after defoliation and before harvesting. Earlier warm temperatures in the fall and longer growing periods in the spring resulted in the earlier reseeding of the legume. Early cover crop reseeding was considered essential because the legumes did not have to be planted each year and cotton planting was not delayed (Touchton *et al.*, 1984).

Cover crops and crop rotation systems in cotton present unique possibilities for protection of soil movement as well as potential problems as weeds. Hairy vetch and crimson clover (White and Worsham, 1990) were successfully utilized for winter cover, but additional herbicide inputs are required to burn down these plants prior to cotton planting. Double cropping with sorghum (Keeling and Abernathy, 1989) and barley (Wiese *et al.*, 1988) may require herbicide inputs to control unwanted volunteer crops in cotton, but Wiese *et al.* (1988) reported that although costs were higher, increased yield and reduced machinery depreciation made no-tillage over $40 per acre more profitable than conventional tillage in no-till cotton after irrigated barley production systems.

The additional operations and kinds of tillage tools shown for tillage system "E" would be beneficial in incorporating crop debris into the soil, a practice required by regulation in the Southwest (Kaddah, 1977). Both the deep burial of weeds by plowing and the extra tillage, if timely, are useful in destroying weeds. Other methods of tillage, such as landplaning, are especially required periodically where furrow irrigation is practiced. In general, conventional tillage systems vary depending on the particular year or needs of the land. Research indicates some operations commonly used in conventional tillage systems are not essential for the successful culture of cotton.

Regardless of the tillage system used (Table 3), herbicides could be applied as preplanting, preemergence and postemergence treatments as needed. Also, postplanting cultivations can usually be conducted as needed. However, cultivations are more difficult in fields with high levels of crop residues (surface residues/stubble). Other tillage systems than those listed in Table 3 are possible, but these represent the basic systems evaluated and reported. Specialized systems for specific soil types, such as the one presented by Morris *et al.* (1990) for clay soils may require a more timely use of limited-tillage and herbicide inputs because of environmental conditions and soil texture. Weed control problems ranked first as the most important limiting factor of reduced-tillage systems in cotton production in the United States (Table 7).

MOST TROUBLESOME WEEDS

The ranking of troublesome weeds in cotton by research and extension personnel is shown in Tables 8, 9 and 10. Cotton losses due to weeds are shown in Table 11. The herbicides used to control weeds in cotton are shown in Table 12. Although herbicides are used in combination with an average of two to four postemergence cultivations, weeds still reduce cotton yields six percent or more in most regions (Chandler *et al.*, 1984; Chandler, 1984; and Table 10). Cotton losses reported in Table 11, where state losses were averaged by regions, do not vary greatly (six to eight percent). Chandler *et al.* (1984) reported losses ranging from a low of 8 percent for the Southwest to a high of 16 percent for the Southern Plains. Estimated losses for the Southeast and Mid-South were 11 and 15 percent, respectively.

McWhorter and Jordan (1985) state nearly 66 percent of all cotton losses due to weeds have been caused by five species: johnsongrass [*Sorghum halepense* (L.) Pers.], cocklebur (*Xanthium strumarium* L.), prickly sida (*Sida spinosa* L.), morningglory (*Ipomoea* spp.) and nutsedge (*Cyperus* spp.). In our 1987 survey of research and extension personnel, these five weed species ranked at the top of the list in conventional-tillage and herbicide systems being utilized in the cotton producing belt (Table 8). Johnsongrass, morningglories, cocklebur, prickly sida, yellow nutsedge (*Cyperus esculentus* L.) and purple nutsedge (*Cyperus rotundus* L.) (Figure 4) were placed in the top ten most troublesome weeds by 94, 82, 71, 66 and 35 percent of the research and extension personnel responding to our 1987 survey. Bermudagrass (Figure 5) and pigweeds (*Amaranthus* spp.) were also placed in the top ten most troublesome weeds in conventional tillage systems by greater than 50 percent of the researchers and extension personnel. Our results are similar to estimated reduction in percent cotton yields by weeds and estimated cotton acreage infested by weeds reported by Whitwell and Higgins (1986) and in a list of the most troublesome weeds in cotton by states in the Southeast (Elmore, 1986).

When research and extension personnel were requested to project the 15 most troublesome weeds in reduced-tillage systems in cotton production systems nationwide, johnsongrass ranked number one and was placed in the top ten most troublesome weeds in the reduced-tillage cotton systems by all individuals responding (Table 9). From research in conservation tillage and tillage rotation systems including cotton in the Blacklands of Texas, Brown *et al.* (1987) found that the predominant weeds were johnsongrass and brown-top panicum (*Panicum fasciculatum* Sw.). Yellow nutsedge, bermudagrass, morningglories, purple nutsedge, prickly sida and cocklebur ranked as the top ten most troublesome weeds in reduced tillage systems as they had been ranked for conventional tillage systems. However, trumpetcreeper [*Campsis radicans* (L.) Seem. ex Bureau] and horseweed [*Conyza canadensis* (L.) Cronq.] (Figure 6) ranked in the top ten most troublesome weeds of cotton in reduced-tillage systems. Both these weeds,

Figure 4. Difficult-to-control perennial weeds such as purple nutsedge are often well established in no-till cotton productions systems. (Photo by C. T. Bryson.)

Figure 5. At harvest, bermudagrass causes reduction in lint grades in addition to reductions in yield due to competition. (Photo by C. T. Bryson.)

Figure 6. Comparison of (a) no-till *versus* (b) conventional-tillage cotton production systems at Stoneville, Mississippi where horseweed, trumpet creeper, and honeyvine milkweed were weed problems at the time of crop establishment. (Photo by C. T. Bryson.)

as well as perennials and winter annuals, are currently controlled by preplanting tillage operations. Reduction of tillage would require additional preplant-foliar herbicide applications to control these and other weeds as has been demonstrated in reduced-tillage cotton production by Brown and Whitwell (1987) and in no-till corn by Wilson *et al.* (1985).

A number of weed species ranked in the top ten regionally as the most troublesome weeds in reduced tillage cotton production systems in the United States but were not listed among the top ten nationwide (Table 8). For example, giant foxtail (*Setaria faberi* Herm.) ranked as the fifth most troublesome weed in Missouri. Silverleaf nightshade (*Solanum elaegnifolium* Cav.) and buffalobur (*Solanum rostratum* Dun.) were important weeds in Oklahoma and northern Texas. Devil's claw (*Proboscidea louisianica* (Mill.) Thuellung) which is highly competitive with cotton is an important weed of Texas. In the West, black nightshade (*Solanum nigrum* L.) and hairy nightshades (*Solanum sarrachoides* Send.) are important in cotton production in California. Lambsquarter (*Chenopodium album* L.) is important in the Southeast and the Tennessee River Valley in Alabama. In the Southeast and Mid-South, a number of scientists expressed concern about the importance of honeyvine milkweed [*Ampelamus albidus* (Nutt.) Britt.] and jimsonweed (*Datura stramonium* L.) in reduced-tillage cotton production.

Sicklepod (*Cassia obtusifolia* L.) ranked number ten as the most troublesome weed presently occurring and projected for reduced-tillage cotton production systems. Although this weed does not occur nationwide, the importance placed on it in the Southeast ranked sicklepod among the top ten weeds. Sicklepod is a major weed problem in the Southeast and is moving north and west in its distribution. In contrast, velvetleaf (*Abutilon theophrasti* Medik.) and giant foxtail, which are important weeds in soybean in the Midwest, are moving toward the Southeast and may become major cotton weeds further south and eastward.

In general, the data presented in Tables 10 and 11 complement one another, *i.e.*, the most common weeds reported in Table 11 account for the majority of the losses reported in Table 10, and data in both tables agree with the general ranking of weeds for the total Cotton Belt in Table 8. The weed genus *Echinochloa* was about the only genus infesting large acreages that was not listed as one of the top ten troublesome weeds. Other weeds ranked in the top ten, either in our survey or those reducing yields, were also the same weeds infesting the greatest acreage of cotton land. For additional information see Chapters 4, 5 and 6.

WEED CONTROL

Supplementing mechanical cultivation with applications of herbicides has been the accepted practice for managing weeds in cotton (Holstun and Wooten, 1968; Kempen and Greil, 1985). Although cultivation is helpful in the Southwest for establishing planting beds and furrows for carrying irrigation water, the primary role of cultivation is for weed control, as demonstrated by Buchanan and Hiltbold (1977). They reported, over a three- to five-year period with two different soil types, cotton yields did not vary with different cultivation practices. Cultivation resulted in cotton yields equivalent to but no greater than those for chemical or hand removal of weeds when cotton was grown without cultivation. Cotton yield reductions were reported to be 90 to 95 percent at two locations when weeds were not controlled.

Herbicides are especially useful for controlling weeds in the drill row of crops where weeds escape because of improper cultivation or where size prohibits their coverage with soil during cultivation (Kempen, 1987; Chandler, 1984). Yield losses due to weeds are indicative of the severe weed problems that occur throughout cotton producing areas, and indicate the reason for high herbicide usage reported in Table 12 (See also Chapters 5 and 7). As shown in Table 12, six methods of herbicide application are used in conventional tillage systems in current cotton production. These include: (a) preplanting foliar applied, (b) preplanting soil incorporated, (c) preemergence, (d) postemergence, (e) spot treatment and (f) layby. Based on the estimates provided in Table 12, 80 to 90 percent of cotton acres are treated with a preplant soil incorporated herbicide(s). Also, since sufficient and timely rainfall usually occurs in the Mid-South and Southeast to incorporate surface-applied herbicides, 80 to 90 percent of cotton acres in those two regions receive a preemergence application of one or more herbicides.

The higher annual rainfall, previously reported, in cotton producing areas of these two regions probably increases weed problems and accounts for the greater use of postemergence treatments in these regions as well. However, many acres are also treated in the West and Southwest with postemergence herbicides (directed or spot sprays) before or at cotton layby.

In no-tillage production, preplant incorporated herbicide treatments would be eliminated. The predominant use of preplant incorporated herbicides in the West and Southwest would appear to preclude the use of this tillage system (Weaver, 1986; Table 12). In situations where preplant incorporated herbicides are necessary, a reduced-tillage system may be required, especially where grasses and small seeded annuals are a problem. Also, where no-tillage cotton production is desired and preplant incorporated and preemergence herbicide treatments cannot be used, control of grasses could be accomplished with postemergence applications of Fusilade® (fluazifop), Poast® (sethoxydim) or Whip® (fenoxaprop). However, where broadleaf weeds are a serious problem, adequate or economical control may not be possible without additional new herbicides.

The herbicides listed in Table 12 include most of the herbicides that are registered for use in cotton and are the most common applied for the management of weeds in cotton (Kempen, 1987; Whitwell and Higgins, 1986). When weed control practices are compared between conventional and reduced-tillage systems, the increased use of herbicides to replace tillage previously used in conventional systems represents the greatest change in managing weeds in reduced-tillage systems (Tables 13 and 14). Some reports indicate reduced-tillage systems would be less economical than conventional tillage because of increased herbicide costs (Frans, 1977; Harman and Wiese, 1985; Worsham, 1977).

In reduced- or no-tillage production of cotton, a preplant foliar application of a herbicide(s), usually Gramoxone® (paraquat), MSMA or Roundup® (glyphosate), almost always is needed to control emerged weeds (McWhorter and Jordan, 1985) (Table 13). Effectiveness and the cost of a herbicide used at a rate high enough to control weeds preplanting is somewhat dependent on weed size, but costs may be more expensive than preplant tillage (Frans, 1977; Harman and Wiese, 1985; Worsham, 1977). Although these treatments are used to a limited extent in all regions, preplant foliar applications are not a common practice (Table 12).

Other herbicide treatments—preplant incorporated, preemergence and postemergence—will continue to be used in reduced tillage as they have been in conventional systems (Table 13), but preemergence treatments will be used only in areas that have adequate rainfall or are equipped to incorporate herbicides with sprinkler irrigation. Also, when preplant incorporated treatments are used in reduced-tillage systems, it will be necessary to incorporate the herbicides when planting beds are formed with listers, disk bedders, or other equipment (Wiese and Chandler, 1987; Tables 15 and 16). McWhorter and Jordan (1985) suggested that the preplant incorporated herbicides could be applied immediately after hipping over old beds. This would be accomplished about two weeks before planting with the use of a rolling cultivator or a Do-all on sandy or silt loam soils where the soil is well pulverized after hipping or rehipping operations. Since preemergence herbicides must be activated through rainfall, and rainfall is not always timely, cotton producers may place more dependence on effective postemergence herbicides for weed control. Postemergence herbicides that could be used either selectively over-the-top or as directed sprays are shown in Table 12.

Previous research indicates that good weed control usually can be obtained now in reduced-tillage systems of cotton (Table 13). Adequate weed control was obtained in reduced-tillage systems of cotton in about 80 percent of the experiments covered in our review. Some effective herbicide treatments used in reduced-tillage are shown in Table 13 and are discussed below. As expected, since relatively few good foliar herbicides are available, Gramoxone®, MSMA and Roundup® were the three herbicides applied most frequently for killing established weeds during a fallow period after a crop was harvested or sometime before planting when tillage was not used. Another frequent use of these herbicides was to kill a cover crop just before cotton planting. Many herbicides, such as Cotoran® (fluometuron), Caparol® (prometryn) or one of the dinitroanilines [Prowl® (Pendimethalin) or Treflan® (trifluralin)], were combined with the above foliar herbicides to provide residual control until crop planting or even extending until crop harvest. Prowl® and Treflan® were commonly used as soil incorporated treatments, whereas Cotoran®, Caparol®, Bladex® (cyanazine), Zorial® (norflurazon) or others were applied at planting as overlay treatments. Most of the herbicides shown in Table 12 as postemergence treatments were applied in one or more studies as directed sprays either early in the growing season or up to layby time of cotton. MSMA, Fusilade® or Poast® were applied either as broadcast over-the-top treatments or as spot sprays. When Roundup® was applied as a broadcast treatment, it was applied with a special applicator.

Although there have been more successes than failures, weed control problems have occurred in reduced-tillage systems of cotton. Most failures have occurred because perennial weeds were not controlled adequately (Hamilton[3]; Lyon, 1975; Triplett *et al.*, 1983; Van Brackle, 1980; Worsham, 1977). Herbicide treatments have failed to control annual weeds as well in some reduced-tillage cotton production systems (Brown and Whitwell, 1985; Brown and Whitwell, 1988; Unger *et al.*, 1977). Reports indicate that horseweed increased without fall or late winter tillage (Brown and Whitwell, 1988) and additional herbicide inputs are required to control this weed (Hayes *et al.*, 1988; Keeling *et al.*, 1989). Since winter annuals may begin germinating in early to late fall, they can become rather large by early spring making control of these large plants difficult with foliar sprays before or at the time of cotton planting.

Whether reduced- or no-tillage production of crops will have a significant influ-

[3]Ibid.

ence on the difficulty of control of winter annuals is not known, but there are probably many winter annuals presently controlled by tillage which would present a problem if they are not controlled by tillage. Hamilton[3] reported that control of the perennial silverleaf nightshade, is easier to obtain in tillage systems where moldboard plowing is used. Plowing in general has been helpful in managing weeds, especially perennials (Raney and Cooper, 1968; McWhorter and Jordan, 1985). The success shown by the selective grass herbicides, Fusilade®, Poast® and Whip® in controlling annual and perennial grasses in cotton in conventional tillage systems indicates that they will be useful in managing both annual and perennial grasses in reduced-tillage systems of cotton. Similar herbicides with selectivity on cotton and activity on broadleaf weeds would be extremely helpful in the successful management of these weeds in reduced- or no-tillage systems of cotton.

Regardless of the herbicides utilized for weed control in cotton production, reduced- or no-tillage systems are probably more effective in Texas and Oklahoma because the state had less severe weed infestations than in the Mid-South or Southeast. One of the last regions to possibly adopt minimum- and reduced-tillage cotton production systems is the Mid-South due to the highly fertile alluvial soils and high rainfall in addition to the high growth rate and reproductive capability of weeds in this region. Research, previously discussed in this chapter, has demonstrated that reduced-tillage can be utilized in the Mid-South. The lack of reduced- and no-till cotton production systems now being utilized in the Mid-South is due in part to the development and registration of new highly selective herbicides.

The number of acres of cotton irrigated in the Southeast and Mid-South has increased over the past decade. This has increased the possibility to utilize chemigation for weed control; however, this technology has not been widely used. Commonly utilized methods of irrigation include over-the-top sprinkler, furrow irrigation and trickle irrigation. Some of these irrigation systems may not be compatible in reduced-tillage cotton production because one or more additional cultivations are required to properly shape cotton beds for furrow irrigation or drainage of excess water. Barney and Whitmore (1989) reported that Prowl® applied preplant and incorporated with irrigation water applied immediately after application proved to be effective in controlling weeds common to west Texas without injuring cotton. Peacock and Goldhamer (1984) reported cotton yields were reduced in the West when weed control traffic occurs with furrow irrigation practicies. They reported that cotton yields were lower in rows (beds) with adjacent wheel traffic than in rows without traffic.

[3]Ibid.

SUMMARY

The increased stored soil moisture created by reduced-till production and the reduction in water and wind erosion of soils will be highly advantageous in cotton production throughout the United States. However, it has been demonstrated that no-tillage and reduced-tillage systems are most useful on well-drained and sloping soils which are highly susceptible to water erosion. Yields may be greater with conventional cultivation systems than with no-till or reduced-till on poorly drained soils.

Trumpetcreeper, honeyvine milkweed, nightshades, nutsedge, bermudagrass, and johnsongrass are perennials that often increase in severity in reduced-tillage systems. In addition, annual weeds such as velvetleaf, jimsonweed, hemp sesbania, and sicklepod may increase in other regions of the Cotton Belt. Many of these weeds are now causing yield losses of 5 to 10 percent within specific states or regions. Often these weeds are among the most difficult to control. In no-till and reduced-till systems, these weeds frequently necessitate preplant applications of herbicides for adequate control. Regardless of the tillage system, the single most important need today in cotton production is a selective herbicide that can be applied broadcast over-the-top for control of a wide spectrum of broadleaf weeds.

The usage of no-till or reduced-tillage offers the producer a management tool for solving cotton production problems that include moisture conservation, and wind and water erosion. Because weed control has been obtained without adversely affecting cotton yields, the total acreage of reduced-tillage in the Cotton Belt is expected to increase in the future.

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Chapter 9

APPENDIX

This appendix contains all of the tables referred to in Chapter 9. For Tables 8, 10, 11 and 12 the regions are as follows: West–Arizona, California and New Mexico; Southwest–Oklahoma and Texas; Mid-South–Arkansas, Louisiana, Mississippi, Missouri and Tennessee; and Southeast–Alabama, Georgia, Florida, North Carolina and South Carolina.

Table 1. Crops and their acreage of highly erodible and fragile land excluding wind erosion). (Adapted from Webb *et at.*, 1968).

Crops	Area	Proportion of cropland	Annual erosion rate	Percent of total erosion from erodible acres
	(Mil. acres)	(%)	(Tons/A)	(%)
Row crops				
Corn	13.3	14.6	23.0	51.1
Soybean	7.2	10.8	28.6	43.6
Sorghum	1.5	8.7	15.9	31.0
Cotton	0.6	3.6	14.1	13.0
Subtotal	22.6	11.8	24.1	45.0
Small grains				
Wheat	7.2	8.2	12.7	32.3
Oats	1.4	15.4	10.3	38.5
Barley	0.7	8.8	9.6	30.5
Subtotal	9.3	8.9	12.0	32.9
7 major crops	31.9	10.8	20.6	42.6
Summer fallow	2.1	7.6	8.8	24.3
Hay	12.8	25.2	3.2	63.6
Subtotal	46.8	12.5	15.3	41.1

Table 2. Cotton cropland, highly erodible land, and fragile land, by regions. (Adapted from Webb et al., 1986.)

Region[2]	Total cotton	Highly erodible and fragile lands				
		LG4[1]	LG5[1]	LG6[1]	Total	Percent of region's cotton cropland
		(Acres x 1,000)				(%)
Northeast	2	0	0	0	0	0
Appalachian	367	44	17	11	72	19.6
Southeast	767	23	6	11	40	5.2
Delta States	2,662	57	12	21	90	3.4
Corn Belt	315	0	0	0	0	0
Lake States	0	0	0	0	0	0
Northern Plains	3	0	0	0	0	0
Southern Plains	10,198	12	0	328	340	3.3
Mountain	590	0	0	8	8	1.4
Pacific	1,599	0	0	4	4	.3
U.S. total	16,502	136	35	383	554	3.4

[1]LG4 and LG5: land groups with high erosion potential; LG6: land group with fragile land.
[2]Regions with cotton production are Southeast; Delta States = Mid-South; Southern Plains = Southwest; Pacific = Western.

Table 3. Operations [least (A) to greatest (E)] in establishing a cotton stand.

A	B	C	D	E
1. Shred stalks	1. Shred stalks	1. Shred stalks	1. Shred stalks	1. Shred stalks
2. Grow ratooned ("stub") cotton from previous crop	2. Bed (1 or more)	2. Chisel (subsoiling) or precision till in fall or spring	2. Plant covercrop	2. Disk (1 or more)
	3. Plant conventionally	3. Bed (1 or more)	3. Light disking	3. Chisel (subsoil) if needed
		4. Plant conventionally	4. Apply herbicide to kill covercrop	4. Disk (1 or more) with 2nd at angle
			5. Shred covercrop if needed	5. Bed (1 or more)
			6. Plant with No-Til planter	6. Condintion bed
				7. Plant conventionally
	could omit bedding and apply herbicides if needed	could subsitute or include as extra operation sweep or moldboard plowing or disking for step 2.	could plant in previous years crop stubble/residue with No-Till planter	Moldboard plowing could be an additional operation between steps 3 and 4. Land planing could be additional operations between steps 4 and 5

All systems could have postemergence (early and/or late, preplant, and preemergence herbicides applied if needed. Nematocides, if needed, could be applied after bedding. In systems B and C, cotton could be planted on old or new cotton bed. Bed conditioning might also be needed for systems B, C, and D. An additional bedding might be done for fertilization. Postplanting cultivations could be conducted if needed.

Table 4. The 15 most important advantages of reduced-tillage systems in cotton production in the United States as ranked by 29 research and extension agronomy, crop science, and weed scientists from AL, AR, AZ, CA, GA, LA, MO, MS, NC, NM, OK, TN and TX in 1987.

Advantage	Weighted[1]
1. Reduce soil erosion	100
2. Reduce total production costs	90
3. Reduce labor and tractor time	55
4. Saves soil moisture	50
5. Saves time	40
6. Lower horsepower equipment required	30
7. Reduce energy inputs	30
8. Reduce soil compaction	30
9. Improves soil fertility	25
10. Improves yields	20
11. Lowers capital investment in equipment	20
12. Presents double cropping opportunities	20
13. Easier crop establishment on clay soils	20
14. Improves yields on clay soils	10
15. Better field access (on wet soils)	10

[1]Average rank on a scale of 0 (least important)—100 (most important) as to most important advantages listed.

Table 5. A summary of literature citations on cotton yield responses as a result of practicing reduced- or no-tillage culture of cotton.

Poorer yields than conventional-tillage	Equal yields to conventional-tillage	Better yields conventional-tillage
Brown and Whitwell (1984)	Alston *et al.* (1976)	Harmon and Wiese (1985)
Bryson (1988)	Brandon (1978)	Kaddah (1977)
Grisso *et al.* (1984)	Brown *et al.* (1985)	Mutchler *et al.* (1985)
McConnell *et al.* (1989)	Brown and Whitwell (1985)	Touchton *et al.* (1986)
Morrison *et al.* (1990)	Bryson (1988)	Van Brackle (1980b)
Roach and Culp (1984)	Dale (1987a)	Wiese and Harman (1983)
Whitwell and Brown (1981)	Dale (1987b)	Wiese *et al.* (1987)
	Derting (1990)	Williford and Fulgham (1973)
	Frans (1977)	
	Grisso *et al.* (1984)	
	Harman and Wiese (1985)	
	Hoskinson and Hayes (1984)	
	Hurst (1983)	
	Lloyd *et al.* (1987)	
	Lyon (1975)	
	Phillips (1968)	
	Roach (1981)	
	Roach and Culp (1984)	
	Spurgeon *et al.* (1974)	
	Stevens *et al.* (1986)	
	Stibbe and Hadas (1974)	
	Touchton *et al.* (1984)	
	Touchton *et al.* (1986)	
	Van Brackle (1980b)	
	White *et al.* (1986)	
	White and Worsham (1990)	
	Whitwell and Brown (1981)	
	Wiese and Harman (1982)	
	Wiese *et al.* (1988)	
	Williford and Fulgham (1973)	
	Worsham (1977)	
	Wuertz (1975)	

Table 6. The 15 most important disadvantages of reduced-tillage systems in cotton production in the United States ranked by 29 research and extension agronomy, crop science, and weed scientists from AL, AR, AZ, CA, GA, LA, MO, MS, NC, NM, OK, TN and TX in 1987.

Disadvantage	Weighted[1]
1. Increased costs—weed control	100
2. Weed control difficult	85
3. Increased perennial weeds	65
4. Higher management levels required	65
5. Problems with stand establishment	45
6. Increased insect problems	45
7. Increased disease problems	35
8. Lack of good seedbed preparation	30
9. Technology lacking	15
10. Inability to incorporate herbicide	15
11. Annual weeds more difficult to control	15
12. Weed ecology shifts	15
13. Reduced cotton grades (trash due to weeds)	15
14. Old stalk removal	15
15. Poor cotton production/yields	15

[1]Average rank on a scale of 0 (least important)—100 (most important) as to the most important disadvantages.

Table 7. The 15 most important limiting factors of reduced-tillage systems in cotton production in the United States as ranked by 29 research and extension agronomy, crop science, and weed scientists from AL, AR, AZ, CA, GA, LA, MO, MS, NC, NM, OK, TN and TX in 1987.

Limiting factor	Weighted[1]
1. Weed problems	100
2. Technology/know how	40
3. Attitude of farmers	40
4. Stand establishment	35
5. Economics (cost more)	35
6. Reduces yields	32
7. Management problems	32
8. Increased diseases	20
9. Lack of properly designed machinery	19
10. Perennial weeds	19
11. Drainage of flatlands	19
12. Need to deep till (subsoil)	19
13. Requirement to cut/destroy stalks	19
14. Increased insects	16
15. Soil salinity	16

[1]Average rank on a scale of 0 (least important)—100 (most important) as to the most important limiting factors.

Table 8. The most troublesome weeds in cotton in the United States as ranked by research and extension agronomy, crop science, and weed scientists from AL, AR, AZ, CA, GA, LA, MO, MS, NC NM, OK, TN and TX in 1987.

	Region				
Rank	West	Southwest	Mid-South	Southeast	Beltwide
1.	Morningglories	Johnsongrass	Morningglories	Cocklebur	Morningglories
2.	Nightshades	Nightshades	Prickly sida	Sicklepod	Cocklebur
3.	Johnsongrass	Pigweed	Johnsongrass	Nutsedges	Johnsongrass
4.	Nutsedges	Nutsedges	Cocklebur	Prickly sida	Purple nutsedge
5.	Pigweed	Morningglories	Nutsedges	Bermudagrass	Prickly sida
6.	Groundcherries	Unicorn plant	Bermudagrass	Morningglories	Yellow nutsedge
7.	Bermudagrass	Bermudagrass	Spurges	Pigweed	Pigweed
8.	Barnyardgrass	Sidas	Hemp sesbania	Johnsongrass	Spurges
9.	Field bindweed	Texas panicum	Broadleaf signalgrass	Spurges	Bermudagrass
10.	Lambsquarter	Spurges	Barnyardgrass	Goosegrass	Sicklepod

Table 9. The projected 15 most troublesome weeds in reduced tillage systems of cotton production in the United States as ranked by 29 research and extension agronomy, crop science, and weed scientists from AL, AR, AZ, CA, GA, LA, MO, MS, NC, NM, OK, TN and TX in 1987.

Weed(s)	Weighted[1]	Placed in top 10 most troublesome
		(%)
1. Johnsongrass	100	100
2. Yellow nutsedge	75	83
3. Bermudagrass	55	83
4. Morningglories (annual)	50	75
5. Purple nutsedge	45	42
6. Trumpet creeper	42	58
7. Prickly sida	35	67
8. Horseweed	32	50
9. Cocklebur	30	42
10. Sicklepod	28	33
11. Spurges	25	42
12. Pigweeds	25	42
13. Redvine	24	33
14. Texas panicum	20	25
15. Bigroot morningglory	25	17

[1]Average rank on a scale of 0 (least important)—100 (most important) as to the most troublesome weeds.

Table 10. Estimated cotton acreage infested by weeds in regions in 1985. (Adapted from Whitwell and Higgins, 1986.)

Weed genera	Regions			
	West	Southwest	Mid-South	Southeast
	(Acres X 1000)			
<u>Grass Weeds</u>				
Brachiaria	—	—	610	17
Cynodon	91	10	474	57
Cyperus	254	550	413	154
Digitaria	—	650	905	273
Echinochloa	610	1180	480	20
Eleusine	—	—	662	94
Panicum	19	910	188	92
Sorghum	175	2075	1048	166
Other	279[b]	—	—	1[b]
<u>Broadleaf Weeds</u>				
Abutilon	—	—	35	10
Acanthospermum	—	—	—	66
Amaranthus	1401	4175	742	356
Ambrosia	—	—	110	51
Anoda	7	50	35	15
Cassia	—	—	34	259
Chenopodium	42	—	51	50
Convolvulus	65	27	—	—
Croton	—	—	—	160
Euphorbia	35	8	1167	185
Franseria	—	300	—	—
Helianthus	22	65	—	—
Ipomoea	205	520	1420	355
Melochia	—	—	—	5
Physalis	386	500	2	—
Polygonum	—	—	35	6
Portulaca	300	—	186	—
Proboscidea	—	3040	—	—
Salsola	34	1000	—	—
Sesbania	40	—	215	12
Sida	—	—	742	349
Solanum	565	2660	119	—
Sonchus	40	—	—	—
Xanthium	92	510	1185	442
Other	902[c]	100	742[eg]	47[adf]
Total cotton acres (X 1,000)	1785	5055	2262	1160

[a]Vines; [b]*Setaria* sp.; [c]*Brassica* sp., *Sisymbrium, Capsella,* Volunteer Cereals; [d]*Desmodium* sp.; [e]*Hibiscus* sp.; [f]*Abutilon, Amaranthus, Ambroais, Anoda, Polygonum* sp.; [g]*Brunnichia, Cyananchum,* and *Campsis.*

Table 11. Estimated reduction in percentage of cotton yields by weeds (weed genera) in 1985. (Adapted from Whitwell and Higgins, 1986.)

Weed genera	Regions			
	West	Southwest	Mid-South	Southeast
			(%)	
Grass weeds				
Brachiaria	—	—	2	1
Cynodon	4	1	3	4
Cyperus	13	1	5	8
Digitaria	—	1	5	2
Echinochloa	5	1	2	—
Eleusine	—	—	3	3
Panicum	1	3	1	2
Sorghum	8	11	7	6
Other	4	—	1	—
Broadleaf Weeds				
Abutilon	—	—	1	1
Acanthospermum	—	—	—	1
Amaranthus	10	30	4	5
Ambrosia	—	—	—	1
Anoda	4	1	2	1
Cassia		—	—	9
Chenopodium	1	—	—	1
Convolvulus	1	1	—	—
Croton	—	—	—	7
Euphorbia	—	—	9	2
Franseria	—	3	—	—
Helianthus	1	3	—	—
Ipomoea	15	7	18	15
Melochia	—	—	—	1
Physalis	6	1	—	—
Polygonum	—	—	1	—
Portulaca	—	—	1	—
Proboscidea	—	5	—	—
Salsola	—	2	—	—
Salvia	—	2	—	—
Sesbania	1	—	2	1
Sida	—	1	12	7
Solanum	14	20	1	—
Xanthium	1	4	18	19
Other	2	2	3	4
Total % crop lost	6	6	7	8
Total bales (X 1,000)	4870	4560	3339	1542
Bales lost (X 1,000)	138	274	179	125

Table 12. Estimated herbicide use (X acres treated) in cotton by regions in 1985. (Adapted from Whitwell and Higgins, 1986.)

Herbicide treatement	Regions			
	West	Southwest	Mid-South	Southeast
	(Acres X 1000)			
Preplant-Foliage				
MSMA	0	1	2	1
Paraquat	1	0	2	1
Roundup®	1	1	5	1
Other	2	0	0	0
Preplant-Soil-Incorporated				
Treflan®	40	64	41	58
Prowl®	26	20	35	34
Caparol®	9	0	2	0
Treflan® + Caparol®	10	0	0	0
Prowl® + Caparol®	8	0	0	0
Other		4[b]	9[abf]	1[abf]
Preemergence				
Bladex®	0	0	5	1
Cotoran®	0	1	62	60
Karmex®/Dynex®	0	0	10	6
Zorial®	0	0	33	13
Other	3	21[bdeh]	1[g]	1[g]
Postemergence				
MSMA/DSMA	5	11	58	59
Bladex® ± MSMA	1	0	24	22
Cotoran® ± MSMA	0	0	60	21
Caparol® ± MSMA	9	3	20	2
Karmex®/Dynex® ± MSMA	3	0	35	1
Dinitro	1	0	20	3
Poast®/Fusilade®	1	12	13	13
Goal®	0	0	2	0
Spot Treatment				
Dowpon®	1	0	2	1
Roundup®	9	31	13	3
MSMA	1	0	1	3
Poast®/Fusilade®	1	9	23	3
Layby				
Karmex®/Dynex®	5	1	16	2
Lorox®	0	0	22	6
Bladex®	7	0	8	7
Other	38[c]	1[c]	1[g]	1

a = Treflan® + Cotoran®; b = Basalin®; c = Caparol®; d = Sancap®; e = Surflan®; f = Zorial®; g = Cotoran®; h = Dual.®

Table 13. Weed control literature references on studies of reduced- or no-tillage *vs*. conventional tillage production systems of cotton, and some common herbicide systems used for weed control.

References reporting adequate weed control in reduced-tillage systems of cotton	References reporting poor weed control in reduced-tillage systems of cotton	Most common herbicides used in reduced-tillage systems of cotton
Abernathy *et al.* (1985)	Alston *et al.* (1976)	Preplant foliar/residual
Alston *et al.* (1976)	Brown & Whitwell (1985)	Gramoxone®, Roundup®,
Barnes and Whitmore (1989)	Bryson (1988)	Cotoran®, Caparol®,
Brandon (1978)	Lyon (1975)	Karmex®, Zorial®,
Brown and Whitwell (1984a,b)	Triplett *et al.* (1983)	Prowl®, Treflan®
Brown *et al.* (1987)	Unger *et al.* (1977)	
Brown & Whitwell (1985)	Van Brackle (1980a)	Preplant
Bryson (1988)	Worsham (1977)	Prowl®, Treflan®, Bladex®,
Dale (1987a)	Young (1982)	Zorial®, Caparol®, Cotoran®
Derting (1990)		
Fields (1982)		Preemergence
Frans (1977)		Bladex®, Cotoran®, Karmex®,
Grisso *et al.* (1984)		Zorial®, Caparol®
Hardin (1984)		
Hayes *et al.* (1988)		Postemergence
Hoskinson & Hayes (1984)		MSMA/DSMA ± Bladex®,
Hurst (1983)		Cotoran®, Caparol®, Karmex®,
Kurtz & Hurst (1982)		Roundup®, Fusilade®, Poast®,
Keeling and Abernathy (1988)		or others
Keeling and Abernathy (1989)		
Keeling *et al.* (1989)		
Lloyd *et al.* (1987)		
Stevens *et al.* (1986)		
Van Brackle (1979)		
White *et al.* (1986)		
Whitwell & Brown (1981)		
Wiese & Harman (1982)		
Wiese & Harman (1983)		
Wiese & Harman (1985)		
Wiese (1987)		
Wiese *et al.* (1987)		
Wiese *et al.* (1988)		
Williford & Fulgham (1973)		
Worsham (1977)		
York & Byrd (1986)		
Young (1982)		

Table 14. Definition of terms relating to basic conservation tillage systems.

1. No-till	Sometimes called zero tillage, chemical tillage, or slot planting and is the ultimate conservation-tillage system. The seedbed is prepared and crop is planted in a single trip (Wiese and Harman, 1985).
2. Ridge-plant	Sometimes called till-plant (ridge), this system entails planting the crop with little or no preliminary tillage on ridges formed or built up during the preceding crop season (Wiese and Harman, 1985; Young, 1982).
3. Disk/Chisel-plant	This system differs from no-till in that you disk or chisel either in the fall or spring, or both in fall and spring. The equipment is designed and adjusted to leave most residue on the soil surface. You also may harrow the land to break up clods before planting row crops (Wiese and Harman, 1985; Young, 1982).
4. Strip-till	Sometimes called till-plant (flat). A specialized planter is used, equipped to incorporate or push aside residue to form clean narrow strips for planting (residue incorporated or tilled with sweeps, disk blades, or tillers) (Wiese and Harman, 1985; Young, 1982).
5. Eco-fallow Chemical-fallow	An improved method of stubble-mulch tillage. A system commonly used on the Great Plains and western regions where wheat is the primary crop and fallowing—leaving the ground idle a season—is common practice. The followup crop is planted into the stubble by no-till planting or some other form of reduced tillage (Wiese and Harman, 1985).
6. Sod-planting	Sod-planting is really a variety of no-till. A no-till planter in a single operation either plants grass seed to renovate pasture or plants row crops or forage in pasture or meadow sod (Wiese and Harman, 1985).
7. Precision	A western cotton production practice that involves shredding the cotton stalks in the fall, subsoiling and bedding in the spring, and planting with precision directly over the subsoiled slot. It is a strip-tillage system where the wheel never runs over the subsoiled slot (Carter *et al.*, 1965; Carter and Tavernetti, 1968; Carter and Colwick, 1971; Elliot *et al.*, 1966).

Table 15. Tillage implements and their primary use.

Tillage implements	Primary use of tillage implements
Moldboard plow	Used for covering crop and weed debris in primary tillage. (Wiese and Harman, 1982; Wiese and Harman, 1985). They have a higher power requirement than the disk or harrow and are more expensive to operate. The most common primary tillage tool used in the U.S. regardless of row crop. (Elliot *et al.*, 1966)
Disk harrow	Used for land preparation and herbicide incorporation (Wiese and Harman, 1982). The offset disk is the most commonly used disk in irrigated agriculture for primary tillage. The tandem disk is widely used on loam soils and is usually a lighter-duty disk for secondary tillage. Now second only to the moldboard plow in use in the U.S. (Elliot *et al.*, 1966).
Disk plows (vertical and tilted)	Use similar to moldboard plow, but leaves the soil surface rougher than a modlboard plow (Elliot *et al.*, 1966). This is advantageous in increasing water infiltration and retarding wind erosion.
Chisel plow	Used as the moldboard plow for primary tillage but leaves the soil surface rough and covers only about 20-75 percent of crop/weed residue per trip over the field (coverage of residue depends somewhat on type of shank—twisted/straight—used).
Spring-tooth harrow	May substitute for disk harrow in land preparation and herbicide incorporation. Secondary tillage (Wiese and Harman, 1982).
Powered rotary tillers	Increasing in use for preparing cotton land. Useful for pulverizing clay loam of cloddy soils for rowcrop seedbed preparation. Till soils from two- to five-inch depths and are often combined with bed shapers to give a precise row-crop bed. Power requirements are high (Elliot *et al.*, 1966; Wiese and Harman, 1982).

Table 15. Continued

Lister	Throws soil to both sides, leaving a furrow where lister runs (Elliot *et al.*, 1966).
Subsoilers & chisels	Operate in soil 18-30-inches to shatter compacted soil (Elliot *et al.*, 1966).
Sweeps	Used where shallow-tillage will suffice for cotton land preparation and surface trash is not a problem (Elliot *et al.*, 1966).

Table 16. Methods of reduced-tillage that have been used or are now being used in grain-producing areas of the world.

1. Plow-plant in one operation: In earlier years of the trend to reduced tillage, this method was used on a number of farms in several areas of the country.

2. Plowing and planting, in two operations: Provided the same benefits and suffered about the same disadvantages as plow-plant techniques. Required one additional trip over the field after plowing.

3. Wheeltrack planting in plowed, or plowed and harrowed soil: This method allows the farmer to attain a slightly better degree of timeliness than with plow and plant or plow-plant methods. Moisture conditions at planting are slightly less critical than for the two previously listed methods.

4. Lister planting, or modified lister planting: This method is practiced in drier areas used for row-cropping. Since ridging is a major characteristic of this method, it may not be as suitable for use in crop rotation as other methods. More power is required than for no-tillage.

5. Strip-till planting: This method differs from most no-tillage planting techniques according to the width and depth of the strip of soil that is manipulated. Strip-till planting may be accomplished by commercially available till planters, modified lister planters or rotary strip-till planters.

6. Field-cultivator planting: This method does not eliminate the plow, but it may eliminate the soil compacting problems found with disking/harrowing.

7. Chisel-plow planting: This method is gaining popularity even though it is second only to conventional-tillage in operation costs, number of soil manipulations, machinery investment, horsepower requirements and labor needs. Some farmers chisel-plot in the fall and then chisel-plow-plant in the spring. Others precede the planting operations with a field cultivator. Crop residues must be chopped to permit efficient operation of chisel plows and field cultivators. Slow seedling emergence and poor stands are likely if the surface of chiseled fields are left too loose or too rough. Soils warm up in the spring slower than with conventional tillage.

8. Aerial seeding: Rice, corn, soybeans, grain sorghum, pastures and small grains have been successfully seeded by aircraft, although some tillage may be performed after the seeding.

Table 16. Continued.

9. Stubble-mulch planting: Typical stubble-mulch systems make almost full use of crop residues and sharply reduce wind and water erosion, and are adapted mostly to the drier areas of the Corn and Wheat Belts in North America.

10. Non-inversion tillage: Includes disk-tillage, chisel-tillage, rotary-tillage, and sweep tillage (as it sounds, tillage that does not invert the soil).

Definition of reduced-tillage proposed by Young (1982) = reducing tillage to only those operations that are timely and essential to producing the crop and avoiding damage to the soil and growing crops (another minimum-tillage system by Hayes) (49).