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Comparison of selected reduced-tillage planting systems in cotton and soybeans

Mark S. Kearney

To the Graduate Council:

I am submitting herewith a thesis written by Mark S. Kearney entitled "Comparison of selected reduced-tillage planting systems in cotton and soybeans." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biosystems Engineering.

Fred D. Tompkins, Major Professor

We have read this thesis and recommend its acceptance:

Bobby Bledsoe, C. Roland Mote

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COMPARISON OF SELECTED REDUCED-TILLAGE PLANTING SYSTEMS IN COTTON AND SOYBEANS

A Thesis

Presented for the

Master of Science

Degree

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Mark S. Kearney

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ABSTRACT

Performances of five commercially available no-tillage and reduced-tillage planting systems were evaluated for cotton and soybean production at the Milan Experiment Station in Gibson County, Tennessee. Evaluations were based upon consistency of seed placement, ability to produce a viable stand, soil moisture preservation, and crop yield.

Seed placement data were collected from randomly selected row segments seeded with each planter. Seeds were excavated and coefficients of variation were determined for both seed depth and spacing.

Stand counts, canopy measurements and relative root length determinations were taken during several stages of plant growth. Stand and canopy dimensions varied at times due to planting system, and in some cases root growth also differed by row spacing and sampling depth.

Soil cores were extracted on 18 August 1987 for soil moisture and plant root length determination. These cores were taken both directly in the drill and in the row middles to a depth of 90 centimeters in 15-centimeter depth increments. Tillage treatment, and on several occasions row spacing, were found to significantly effect both soil moisture and relative root length. A combine was used to harvest soybeans. Cotton plots were stripper harvested since row spacing was less than that required for conventional picker harvesting. Planting system

had no significant effect on yields of either soybean or cotton.

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CHAPTER I

INTRODUCTION

Background and Statement of Problem

Various conservation tillage systems have been developed to reduce soil erosion and lower crop production input costs. These systems range from no-tillage planting, which leaves as much as 62.3 percent of soybean residue as soil cover, to a till-planting method which leaves only 18.5 percent of the soybean residue as cover (Burr et al., 1987). Progress in herbicide development has eliminated much of the need for mechanical cultivation to control weeds. Improvements in coulter designs and seed placement mechanisms enable the farmer to seed with increased accuracy in untilled soil. The choice of tillage system to be used on a particular field can now be appropriately made on the basis of soil properties and anticipated crop performance rather than on pest problems or machinery limitations (Kladivko et al., 1986).

Problems associated with use of reduced-tillage planting have surfaced as these practices have been adopted. Poor seed placement, resulting in inadequate plant stands, has been a primary concern of no-tillage researchers (Erbach, 1980). Agronomists have also found that not all tillage systems are suitable for all soil types, climates and topographies (Anonymous, 1985a).

Continued planter performance studies can lead to identification of no-tillage and reduced-tillage planting systems that will permit greater soil conservation and reduced economic burden for the farmer. Results of such studies can lead to development of practical guidelines for selection of an appropriate tillage system for different soils in a state or region (Galloway et al., 1977).

Objectives

The purpose of this study was to evaluate the performances of five commercially available no-till and reduced-tillage planting systems used for cotton and soybean production. Specific objectives include:

1. To evaluate planter and component performance on the basis of depth, spacing, and coverage of soybean (*Glycine max*) seeds when planted in typical wheat stubble conditions.

2. To compare plant stands and morphological characteristics of cotton and soybeans seeded with no-tillage, ridge-tillage, and in-row subsoiling planting systems.

3. To compare the no-tillage, ridge-tillage, and in-row subsoiling planting systems on the basis of soil moisture preservation and alleviation of soil compaction as indicated by plant rooting depth.

4. To compare soybean and cotton yields and cotton

ginning properties from plants grown using no-tillage, ridge-tillage, and in-row subsoiling.

CHAPTER II

REVIEW OF LITERATURE

Challenges of No-Till Planting Systems

In 1796 Charles Neubold received a patent for a cast iron plow. The early 1830's brought the introduction of the steel moldboard plow. Since then, primary and secondary tillage implements have evolved into highly sophisticated units capable of moving vast amounts of soil (Phillips, 1970).

In recent years the trend toward extensive seedbed preparations and inter-row cultivation has reversed somewhat as some farm advisors have stressed putting away traditional tillage equipment and switching to the no-tillage method of planting crops. The no-tillage practice requires only enough tillage to produce a narrow slot for seed placement (Anonymous, 1985a). No-till planting systems have been proven effective in lowering production costs and conserving soil and water while maintaining acceptable yields, but not without problems (Dickey et al., 1982). No-till requires above average managerial skills and may not be feasible for all types of crops and soils. Use of no-till for soybean production in Tennessee has dropped substantially since tillage acreage estimates began in 1983 (Brantner and Guinn, 1987). Recognition of potential advantages in conjunction with identification of problem areas specific to no-till has lead to further development of conservation tillage methods. Ridge-planting, in-row subsoiling, and narrow row planting of soybeans and cotton are among these methods.

Successful no-till crop production demands a high level of management and the ability to adapt to new technological packages (Phillips et al., 1970). Unfortunately, many farmers have relied on their basic knowledge of and experience with conventional tillage systems and have had difficulty meeting the challenges presented by no-till. For example, weed and pest problems normally alleviated by tillage must be controlled by herbicide and pesticide applications in no-till production (Anonymous, 1985a). Proper selection and application of these chemicals leaves little margin for error.

Performances of no-till planting systems have also been found to be affected by the inherent characteristics of certain soil types. Wet soils may adhere to planter disks, coulters, and press wheels resulting in poor plant stands (Erbach et al., 1983). Mulvaney and Paul (1984) found that continuous no-till corn production in Illinois led to a build-up of detrimental levels of weeds. Voorhees and Lindstrom (1984) also questioned whether the failure to control wheel traffic patterns on no-tilled soils can compact the soil, thus negating benefits in soil structure resulting from limited tillage.

Certain crops perform more favorably than others when planted using no-till. An example is cotton, a crop traditionally sown in well-tilled soil. Under no-tillage culture, herbicide use is substituted for mechanical cultivation. Some chemicals used to control cocklebur or other broadleaf weeds have been found to reduce vigor of cotton seedlings resulting in delayed maturity and/or reduced yields (Hoskinson and Hayes, 1984). Harden (1984) also found that young cotton plants were injured if these plants were not shielded during post-emergent herbicide application. Questions have also been raised concerning the suitability of using no-tillage systems to produce another common crop, soybeans. Because of greater disease pressures associated with continuous no-till soybean production on heavy silty clay loam soils, Ohio agronomists have stressed the importance of proper variety selection when no-tillage production is maintained on these soil types (Anonymous, 1985a).

Decline of No-Till in Tennessee

The acreage of soybeans and other crops grown in Tennessee under no-till and other conservation tillage systems continued to decline in 1987 (Brantner and Guinn, 1987). Reasons for this reduction in no-till acreage include a drop in total crop acreage and a lack of awareness by farmers as to the benefits of no-till and conservation tillage.

The Food Security Act of 1985 represented a government effort to assure that crop production practices did not adversely affect the land resource. Specifically, compliance provisions were established which required development of conservation plans for marginal lands in order for a landowner to be eligible for federal farm aid programs (Arbegast, 1987). Farmers may have been reluctant to risk any chance of losing these payments and left questionable land idle.

Other reasons for the decline in no-till production range from weather to commodity prices. A wet fall may have resulted in fewer acres of winter wheat being planted, thus effecting soybean acreage planted no-till after this crop. Also, no-tillage acreage may have declined due to a reduction in the demand for and price of wheat utilized in this wheat-soybean double-crop system. Finally, a drop in soybean prices would usually result in lowered soybean production.

Leuthold and Hart (1987) found in a survey of western Tennessee farmers that many producers failed to accurately assess the level of soil erosion from the land on their farms. This lack of awareness of soil erosion on the farmer's own soil was similar to that observed in other studies (Novak, 1983). Thus farmers may not feel that they need to use no-tillage if conventional practices produce satisfactory results.

Although no-till use has been found to be an effective method of preventing soil erosion on West Tennessee cropland, most farmers are still testing no-till planting on an annual basis to assess the effectiveness of no-till when compared to conventional tillage methods (Shelton and Bradley, 1987; Leuthold and Hart, 1987). Studies have also shown that a high discontinuance rate of an improved farm practice, such as no-till, by users who adapted to the practice early is associated with slow acceptance of the practice by other farmers in the community (Rogers, 1983; Leuthold, 1986).

The trend of declining no-till use in Tennessee continues as total area planted with this type of system fell from a high of 77,297 hectares in 1984 to a 1987 low of 30,353 hectares (Brantner and Guinn, 1987). Although this trend may not hold true for Tennessee, the United States Department of Agriculture recently estimated that by the year 2000 about one-half of the total crop production in the United States will employ no-till methods (Giere et al., 1980).

Cropping Systems

Recent changes in tillage systems have been motivated in part by the desire to decrease the number of machinery trips over the soil and to reduce the amount of soil manipulation, thereby lowering production costs. The amount performed on the soil has been reduced without an adequate understanding of the exact physical conditions required for optimum emergence and growth of crops (Larson and Gill, 1973). Examples of reduced-tillage cropping systems include no-till, ridge-till and strip tillage using under-the-row subsoiling.

No-Till

Phillips (1970) describes no-tillage as "the introduction of seed into untilled soil by opening a narrow slot, trench, or band of sufficient width and depth for seed coverage and contact." This no-till procedure can be accomplished through use of modified conventional planters (50 to 100-centimeter row spacing) or grain drills (13 to 25-centimeter rows). By either method, soil and existing stubble remains relatively intact during and after planting. A disk coulter is typically used to cut through stubble, and a furrowing device opens a slot just large enough for proper seed placement. Press wheels cover the seeds to enhance germination. No-till, because it involves planting directly into the undisturbed stubble of the previous crop, can leave 90 to 100 percent of the residue from the previous crop on the soil (Anonymous, 1985a). With this planting method, no cultivation for seedbed preparation and weed control is required. Weeds and pests are controlled by using herbicides and pesticides. Thus, planting in this fashion requires fewer passes over a field than for conventional seedbed preparation.

Grain drills, formerly used almost exclusively for pasture renovation and small grain planting in conventionally prepared seedbeds, are being tested for possible yield and physiological advantages when planting row crops. Davis (1981) found that Essex soybeans produced significantly greater yields at row spacings of 25 and 50 centimeters when compared to a 76-centimeter row spacing. Study results compared well with those of Graves et al. (1980) who found that the average response to 25-centimeter row spacing over 50-centimeter row spacing was a 120 kilograms per hectare increase for four soybean varieties.

Weed pressure has been a concern in the production of no-till cotton, and drilling this crop may show promising results. Cotton planted in narrow rows may grow a closed canopy, shading out weeds before they become competitive. Further, this closed canopy may take maximum advantage of available light. Environmental conditions associated with narrow-row production of cotton have been found to promote earlier plant maturity and increase yield (Ray, 1971). Therefore, narrow-row planting of some traditional row crops deserves further investigation.

<u>Ridge-Till</u>

A study of bed-farming practices used for production of cotton and other high-value crops indicated several advantages of planting on an elevated ridge. Advantages in the areas of drainage of the soil, soil temperature, and low total power requirements for seedbed preparation led to the development of the ridge-farming concept in the 1950's (Buchele et al., 1955).

The ridge-till planting system can be used to produce a row crop with a limited amount of soil disturbance (Wittmus et al., 1969). With this system, crop residues that retard early crop growth and reduce soil temperature are placed between crop rows rather than adjacent to or over the crop plants (Burrows and Larson, 1962). An existing, well-ridged row from a prior row crop represents the optimum conditions for starting spring planting (Fisher and Lane, 1973). The planter runs atop this ridge, which is approximately 38 centimeters high; and a shallow sweep pushes aside the top of the ridge (Buchele et al., 1955). Deflectors move residue out of the planting area. The deflector is followed by a runner and opener which allow fertilizer and seed placement. These components are followed by a narrow, semi-pneumatic wheel which presses the seed into the soil at the bottom of the runner opening. A drag line then acts to cover the seed with soil.

Two cultivations are made per growing season. During the first, the soil is directed away from the ridge by a forward cultivation tool and moved back toward the row by following tools. The objective of the second cultivation is to develop a ridge to serve as a planting bed for the next year's crop. Therefore, at least one cultivation is necessary to restore the ridge (Fisher and Lane, 1973). Wittmus and Lane (1969) found time requirements and power inputs to be low, amounting to 0.04 man-minutes per cubic meter of corn and 3.45 kilowatt-hours per hectare for cereal crops produced.

The adverse effect of surface residue on soil temperature and plant growth in the northern Corn Belt was found to be offset by ridge-till planting, as most residues are scraped off the row area. Soil temperatures from ridge-till planting have been found to be close to those obtained from plowed soil (Galloway et al., 1977). Ridge-planting was proven to be a viable conservation system on poorly drained soils, as the removal of residue from the row area aids in moisture evaporation. This accelerated drying provides an advantage from a planting date standpoint as well (Eckert, 1987).

<u>In-Row Subsoiling</u>

Yield reductions caused by soil compaction have become an increasing concern to soil scientists (Steinhardt, 1984). The combination of heavy equipment and shallow plowing commonly results in compaction beyond the depth of plowing. Soil compaction reduces pore space. This pore space reduction slows the rate of water infiltration, leading to runoff and erosion (Anonymous, 1984). Practical equipment for precision tillage under-the-row was developed in an effort to improve root growth and water infiltration on soils with compaction problems while maintaining soil conservation (Arthur, 1987).

An example of in-row subsoiling equipment is the Brown-Harden Ro-till planter. This implement employs a serrated coulter to cut stubble. This leading coulter is followed by a heave limiter and a subsoiler shank capable of a 20 to 40-centimeter working depth. Fluted coulters confine soil to the row area, and rolling baskets or cultipackers aid in final seedbed preparation. A planter unit, attached by means of a tool bar, is placed directly behind the Ro-till unit (Anonymous, 1987a). The result is a tilled strip just wide enough for fertilizer and seed placement: the area between rows is left undisturbed. The Ro-till practice may lead to improved air permeability between rows, which has been found to improve soil structure and continuity of pores on poorly structures soils (Heard et al., 1987).

Despite its apparent advantages in relieving soil compaction, a major drawback of the Ro-till concept has been the inability of this planting method to establish good plant stands. Trouse and Reaves (1980) used a planter with subsoiling shanks following a smooth or ripple coulter which severed trash. However, the deep furrow created by the subsoiler caused problems with seeds being placed too deeply. These results agreed with those of Grisso et al. (1984a), who used both a planter preceded by a subsoiler that passed about 10 to 13 centimeters deep through under-row soil and a Kelley sub-soiler planter implement. Cotton stands on non-subsoiled plots were higher than those on subsoiled plots. This may have been due to poorer seeding depth control in the subsoiled plots, resulting in poorer emergence.

Continued cropping systems research will provide farmers with choices among a variety of tillage options which can result in yields comparable to those obtained with conventional tillage. At the same time, the conservation tillage system may be superior in soil and water conservation and also offer savings in time, labor and fuel compared to conventional moldboard plow tillage methods (Swan et al., 1984)

Planter Mechanisms

Seed Metering Devices

The seeding mechanisms used on the planters included in this experiment can be classified either as drill or precision seeders. Drill seeding, by definition involves the random dropping and covering of seeds in furrows to create definite rows (Kepner et al., 1980). Grain drills commonly include a fluted metering device with delivery varied by changing the drive gear ratio or by exposing different lengths of the rotor to the seed hopper. A positive-type feed, this mechanism is well adapted for use with light and irregular seeds (Hunt, 1983).

Precision planting involves accurate placement of single seeds at about equal intervals in rows (Kepner et al., 1980). Precision seeding devices included in this study are the air-assisted, finger pickup and seed cup systems.

One manufacturer uses an air-assisted metering unit wherein seeds are fed under air pressure from a central seed hopper through a delivery chute to a seed drum. Air pressure in the drum is changed by adjusting tractor pto speed or by adusting a flow control valve on the hydraulic pump driving the air supply system. A leveling bar maintains 5 to 8 centimeters of seed in the bottom of the seed drum. As the drum rotates, seeds are picked up in perforated pockets. The speed at which the seed drum rotates is determined by ground speed and the sprocket combination selected on the seed drive transmission. Seeds are held in place by positive air pressure from within the drum pushing against the seed while some air moves around the seed to escape through perforations at the bottom of the seed pocket. A seed cutoff brush removes excess seed. These excess seeds are prevented from entering the seed manifold by a deflector screen. Seeds are released when wheels block perforations at the bottom of seed pockets on the drum, allowing seed to be drawn into the seed manifold and into seed delivery tubes. The seeds, forced by air, travel through seed delivery tubes to the individual row units. The Prairie Agricultural Machinery Institute (1984a) found this type of seed metering mechanism gave "good" performance, especially with small, round seeds. One type of plateless seeding system uses a finger pickup device. Finger pickup metering devices mounted on a vertical plane operate to pick up seed at the bottom of each of the planter seed hoppers. These devices consist of spring-loaded, cam-operated fingers which rotate against a stationary vertical disk or carrier plate. The fingers close and trap kernels as they rotate through the small seed reservoir formed by a seed baffle. Excess kernels escape as the fingers pass over small indentations and a nylon brush at the top of the carrier plate. The seeds then pass through an opening in the carrier plate to a celled seed belt. The seed travel down a delivery tube to the ground by gravity.

Ground wheels provide drive power for these metering devices, and power is delivered through a central seed drive sprocket transmission. PAMI (1984b) rated this type of system as "very good" for metering seed, especially seed of medium round size.

Another type of plateless planter makes use of a seed cup as the seed meter. Cells which are similar in size and shape to the seed being planted are positioned around the edge of the cup. The cup rotates in a vertical plane and traps seeds in the cup cells while passing through the seed supply. Cells are filled properly by means of a seed guide, which allows seeds to fall into a tube for delivery to the furrow (Jacobs and Harrell, 1983).

Soil Engaging Components

The main soil engaging components of reduced-tillage planters include some type of coulter or residue cutting device, a furrow opener, and a mechanism to properly cover the seed.

Coulters

Four types of coulters are commonly used on no-till planters: ripple, fluted, smooth, and serrated. The major function of the coulter is to cut through the mulch and penetrate the soil deeply enough for disk openers to place the seed at the proper depth (Flinchum, 1983). Therefore, coulters are essential components of tillage and planting equipment used in conservation farming systems (Tice et al., 1987).

Ripple coulters have a straight, sharp edge with ripples located near the edge (Flinchum, 1983). This type of coulter opens a very narrow band in the soil. Bell (1984) found that a 2.5-centimeter ripple coulter gave significantly better seeding depth consistency when compared to a 2.5-centimeter fluted coulter. The ripple coulter tended to penetrate the soil to a greater depth than the fluted coulter under similar field conditions, although no difference in uniformity of in-row spacing was found during this comparison. Ripple coulters were also observed to slip less than smooth coulters when operated in soft soil and under heavy residue conditions (Erbach and Choi, 1983).

Fluted coulters have curved edges and disturb the soil more than the other types. Planter speed must be regulated to prevent throwing soil from the prepared slot with this type of coulter (Flinchum, 1983). Allen at al. (1975) reported that a fluted coulter mounted in front of a planting unit provided more uniform seed placement at the desired depth in large amounts of residue than did a grain drill with single-disk furrow openers. Logan and Gowan (1977) found that a fluted coulter mounted either ahead of or behind double-disk openers improved in-furrow soil condition in a wet clay soil. The drawbacks to this coulter type appear to be the substantial draft requirement under difficult field conditions and the inability to shear stubble over a wide range of soil strength conditions (McClure et al., 1968; Erbach and Choi, 1983).

Moncrief et al. (1985) reported that corn stand reduction on well-drained soils was rare when the row tillage during planting was performed only by a fluted coulter. Despite this finding, use of clearing disks or sweeps to keep the row area clear when planting corn in heavy residue was advised.

Smooth coulters have been found to cut residue straw more cleanly than ripple-edged coulters (Krall et al., 1978). The smooth coulter has a sharp, smooth edge and moves through the soil causing a minimal amount of disturbance. PAMI (1984a; 1985) tested several no-till drills and planters equipped with smooth coulters for cutting trash in front of furrow openers. They obtained satisfactory results except in heavy or wet soils. Schaaf et al. (1980) recommended that cleaning scrapers be used to remove any soil that may adhere to the sides of coulters under these conditions.

Gallaher (1980) found that coulters with a serrated edge cut better and needed less weight for penetration, but did less tillage than fluted and rippled coulters. A serrated coulter has smooth sides and leaves a narrow, clean slot in the soil similar to that formed by a smooth coulter. An advantage of the serrated coulter is that it tends to slip less than smooth coulters in heavy straw and soft soil. However this coulter lacks in straw cutting performance if the serrated sections do not penetrate the soil (Triplett et al., 1963; Smith, 1983).

Modern planters use springs, weights, or hydraulics to maintain adequate downpressure on coulters during operation. This pressure is usually effective for slicing through stubble residue on firm, supportive soil. Even minor tillage ahead of the coulter will impede cutting of surface residues. When this cutting is impeded, the surface residues may be pushed into the soil slot. Some seeds are then placed in contact with residues instead of soil. This poor seed placement may result in uneven seedling emergence (Throckmorton,1986). Poor seed-to-soil contact has been a major problem involving no-till and reduced-tillage planting systems.

Furrow Opening Devices

Furrow openers enable proper seed placement in the soil and can be classified as either fixed or rotating openers (Kepner et al., 1980). Fixed openers are stationary and include hoe, shoe and runner types. These units are non-rotating and are pulled through the soil. Hoe-type openers, when equipped with a spring trip, are suitable for hard, rocky soils where good penetration is needed (Hunt, 1983). Erbach (1980) found hoe openers able to penetrate soil under most conditions, but they tended to become blocked with residue. Runner openers have a shape much like a hull of a boat and form a furrow by compressing the soil downward and outward. Runner openers work well at medium depths in mellow soil which is free of trash and weeds (Kepner et al., 1980). Shoe openers are found on some forage seeders. In some older machines, the top of the shoe was curved forward to aid in soil penetration, but this configuration increased the hazard of damage from underground obstructions. Rigidly-mounted shoe openers offered less precision in seed placement on uneven soil surfaces (Throckmorton, 1986).

Inability to perform well under heavy residue conditions appears to be the main drawback of fixed-type openers. Baker et al. (1979) reported that some type of disk component was essential to proper operation of non-rotating furrow openers because no disk or coulter mounted in front of the opener was capable of cutting all residue under a wide range of field conditions.

Rotating openers employ disks with either straight or convex blades that are set at an angle to the direction of travel to open a furrow as they roll through the soil. Seeds are usually dropped from a tube into the furrow created between the two disks (Erbach, 1980). Although disks are normally placed side by side, one manufacturer uses offset disk openers, placing one disk in a position slightly leading the second. PAMI (1984a) found this configuration to perform excellently in all field conditions tested.

Depth of seed placement is controlled by gauge, transport, or press wheels, or by means of depth bands on double-disk furrow openers. PAMI (1984a; 1984b) reported that gauge wheels and depth bands controlled seeding depth very well in most field and operating conditions. Because the soil surface with conservation tillage tends to be less uniform than with well prepared, clean-tilled seedbeds, planters that use a press wheel or transport wheels for depth control frequently place seeds at uneven depths (Baumheckel, 1976).

Covering Devices

Covering a seed with soil may be the final operation in planting, but by no means is it the least important operation. Use of a steel or rubber-covered press wheel is the most common method of seed coverage utilized in conservation tillage. Schaaf et al. (1980) divided press wheels into four classifications according to the shape of the soil contacting surface. These classifications are convex, " V " type, flat, and concave.

Convex press wheels have been found to conform fairly well to the shape of the furrow created by the opener and to provide maximum compaction at the furrow center where the soil is loosest (Schaaf et al., 1980). When tested on a commercially available no-till grain drill, this type of press wheel gave good seed coverage under normal field conditions, although performance was affected slightly by ground speed and coverage was reduced in hard-packed ground and in trashy conditions (PAMI, 1985).

Double-wheel packers or " V " type press wheels collapse the seed trench from the sides and firm the soil around the seed while leaving loose soil on top of the seed. Schaaf et al. (1980) observed that this type of press wheel sealed the side wall of the furrow, and PAMI (1984b) confirmed this finding, adding that seed coverage was consistently very good in tested field conditions. Smith (1983) recommended that press wheels that firm the seedbed from each side of the furrow would normally be more desirable than wheels that firm the zone directly over the seed as the latter would encourage soil crusting. Soil crusting generally results in reduced germination.

Flat and convex press wheels accommodate other seedbed conditions. Uniform soil compaction across the width of the furrow is characteristic of flat press wheels, whereas concave press wheels provide maximum compaction at the outer edge of the furrow (Schaaf et al., 1980). Regardless of planting system used, the press wheel and furrow opener should be matched to assure optimum potential for seed germination.

Tillage Effects on Plant Performance and Soil Moisture

Plant Root Growth

Plant roots perform four principle functions: plant anchorage, storage of plant metabolites, water uptake, and nutrient uptake (Allmaras et al., 1973). Soil properties including density, porosity, aggregation, and infiltration capacity as well as water distribution within the soil profile resulting from a particular tillage practice affect amount, size, and pattern of crop roots (Griffith et al., 1986). Therefore, producing an environment that is conducive to root growth is important for conservation tillage systems.

The most obvious difference between direct drill seeding crops and conventional tillage is that crops planted using the former method frequently become established more slowly (Russell et al., 1975). This reduced early growth may be associated with modifications of the plant root system. The main roots may at first elongate more slowly and become profusely branched (Ellis and Elliot, 1975). Mechanical impedance due either to greater compaction of the surface soil or to smearing of the walls of the furrow in which the seed is placed appears to be a possible cause. However, if sufficient water and nutrients are absorbed for growth to continue, early retardation of root growth may not lead to a corresponding reduction in yield (Russell et al., 1975). Work by Keen and Russel (1937) showed that although reduced cultivation sometimes restricted the early stages of plant growth, differences due to tillage would disappear by harvest.

Soil bulk density affects the movement of water through the soil, aeration, and the degree of root penetration (Russell et al., 1975). A United States Department of Agriculture study indicated that soil bulk density in the top 23 centimeters of soil was greater under no-tillage than in conventional tillage. However, root growth appeared to be unaffected by high bulk densities, possibly due to the increased aggregation of soil in no-tillage fields. Root growth follows paths of weakness between aggregates, and the more structured no-till soil allows better water and nutrient movement as well as root growth (Anonymous 1985c).

Tillage may also affect water-conducting channels in the soil profile. To a certain degree, roots are capable of increasing or decreasing their diameter in order to enter these pores to access water and nutrients (Russell et al., 1975). Heard et al. (1987) found that soybeans planted with a ridge-till system had significantly more large channels than either a chisel or no-tillage treatment at the 10-centimeter depth on a silt loam soil. Although no-till had the least number of channels at a 10-centimeter depth on a silty clay loam, the no-till treatment tended to have more continuous channels with increasing soil depth.

Compaction appears to be a problem on many soils of the southern United States. Compaction, caused by tillage and wheel traffic, reduces the size and distribution of pore space, which affects root growth (Hayes, 1982). In-row subsoiling may help alleviate this problem. Alabama researchers found rapid growth when soybeans were planted after slicing through a plow pan with a 38-centimeter knife-like blade (Anonymous, 1984). Arthur (1987) also reported increased root growth after in-row subsoiling which resulted in fracturing the subsoil structure. This deep tillage method was found to improve the downward movement of water and fertilizer, enabling extensive root growth to the untilled subsoil between planted rows.

Soil Moisture

Tillage practices may influence soil moisture throughout the growing season. Reduced-tillage systems decrease evaporation losses, if residue remains on the surface, and increase rainfall infiltration due to increased surface roughness and/or the presence of the residue. Water runoff is slowed by both roughness and residue, allowing more time for infiltration; and surface residues tend to prevent soil crusting, thus increasing infiltration. The net effect from surface roughness and/or presence of the residue is usually less variation in soil water during summer months and more plant-available water in the soil profile (Griffith et al., 1986).

Burr et al. (1986) found that a no-till planting system left the greatest level of soybean residue cover after planting, 62.3 percent, significantly greater than eight other systems including conventional seedbed preparation and a till-plant system. This residue reduces water loss from evaporation before the crop canopy closes (Unger and Parker, 1968). Besides greater total water storage with no-tillage, much of this water was found to be stored near the surface (Unger and Phillips, 1973). This finding compares well with other reports which indicated that 20 to 30 percent more water is available in the top 8 centimeters of soil when crops were planted with no-tillage (Anonymous, 1986). This area near the soil surface is the critical zone for germination and early seedling growth. Greater water contents near the surface of no-tilled soil also increased the efficiency of surface-applied fertilizers through increased solubility and greater plant uptake (Moschler et al., 1972).

Ridge-till planting systems have been found to have high water storage capacity and increased infiltration over conventional tillage. Nebraska studies showed that the area between the elevated ridges, where most residue is mixed during cultivation, conserved more water than six other tillage systems ranging from conventional plowing to no-till (Hayes, 1982).

Buchele et al. (1955) observed that after each rain the surface of the ridge dried before the furrow because of its greater elevation. Height of the ridge established a moisture tension of approximately 30 centimeters, which is equivalent to one-half of that required for drainage of soil macropore space. This tension was sufficient to cause rapid drainage of the ridge after a rain and reduced the period of saturation of the root zone.

Ridge-till attributes, including greater water storage capacity and enhanced infiltration of water into the soil, help retain a high percentage of total rainfall (Buchele et al., 1955). This moisture may be beneficial to plants during stressful periods.

Coastal plain soils in the Southeastern United States often have root-restricting layers located 15-25 centimeters below the surface. These layers reduce the quantity of plant-available water (Griffith et al., 1986). Under-the-row subsoiling has been used as a means of alleviating soil hard pans and making soil moisture more available for plant use.

Arthur (1987) reported that with one strip-tillage planting, there was an immediate elimination of compaction conditions and an improvement in soil structure resulting in increased water percolation. Surface runoff of rainfall, a common problem associated with no-tillage, was practically eliminated under this type of planting method. On the other hand, studies have also shown that in-row subsoiling did not guarantee adequate moisture for crops, but did improve the potential for reserve moisture supply during short drought periods (Hayes, 1982).

Establishment of Viable Plant Stands

Establishment of viable plant stands under no-tillage systems may be hampered by several factors including poor seed-to-soil contact due to residue pushed into seed furrow during planting, possible germination inhibition due to crop residue exudates, and cooler soil temperatures at planting (Moncrief et al., 1985; Hayes, 1982). Thus matching the appropriate minimum tillage system with a particular soil type can reduce risk of these damaging factors and encourage plant growth.

Greater soil moisture content near the surface is characteristic of soil cropped no-tillage. This greater moisture enables a more shallow seeding depth than conventionally tilled seedbeds, thereby increasing the potential for germination and early seedling growth (Unger and Phillips, 1973; Griffith et al., 1986). No-till planting does have its drawbacks on poorly drained soils. Bone et al. (1977) determined that the success of no-tillage planting on these soils was dependent on adequate tile drainage.

Commercially available no-till planters have been found to place seeds at a uniform depth and cover seeds adequately with soil. Bell (1984) found that a planter utilizing a ripple coulter and a double-disk furrow opener placed soybean seeds at an average depth of 3.3 centimeters with a coefficient of variation of 16 percent. " V " shaped press wheels left less than one percent of metered seed uncovered by soil. Another planter employing clearing disks and offset double-disk openers placed seeds at an average depth of 2.5 centimeters with a coefficient of variation of 30 percent. Center-rib press wheels left three percent of the soybean seeds uncovered. Both planters were tested in wheat stubble, common to no-till wheat-soybean rotations.

Till-planting systems seem to offer the best seedbed conditions for germination on soil types ranging from sandy loam to silty clay loam (Mannering et al., 1975). Ridging systems permit an early planting date on cold, poorly drained soils. Planter-mounted sweeps used in this system aid in removing residue while improving drainage and warming of the soil for enhanced germination (Eckert, 1987). Buchele et al., (1955) also found that characteristics inherent to the soil ridge promote drainage, thus reducing the time a seed or seedling must spend in a saturated soil.

Bell (1984) found that a commercially available ridge planter placed soybean seeds at a mean depth of 4.1 centimeters with a coefficient of variation of 32 percent. Also, less than one percent of all seeds metered by the planter were left uncovered. This planter utilized a smooth coulter followed by a runner-type opener and a multiple press wheel configuration and was operated in wheat stubble.

Moncrief et al. (1986) found that soybeans planted on ridges produced greater plant populations than those drilled in a seedbed disked or chiseled in the spring, but produced fewer plants than soybeans drilled on moldboard plowed fields. An excessively drained sandy soil may have affected ridge-till performance.

Poor emergence in under-the-row subsoiling systems has been found to be due to poor seeding depth control (Grisso et al., 1984b). Grisso et al. (1984b) found better stands from cotton planted by no-till than from subsoil-planted cotton.

No-till cotton is frequently planted in a legume cover crop such as crimson clover. A stand problem was observed by researchers who believe that a chemical in legume mulch may harm cotton seedlings or that mulch harbors disease organisms that infect young cotton (Kidwell, 1984). Further studies are needed to improve the potential for growing no-till cotton in legume cover crops.

Tillage Influences on Soybean and Cotton Yields

With the exception of cotton, no-tillage/reduced-tillage systems have produced crop yields comparable to conventional tillage systems. Kladivko et al. (1986) found that soybean yields from no-till and ridge-till systems improved with time and often exceeded those from conventionally tilled plots on poorly drained soils with low organic matter. Moncrief et al. (1986) reported that cultivation and tillage, including no-till and ridge-till, did not affect soybean yields on Minnesota mollisols.

Narrow-row soybean production seems to be the trend of the future. Graves et al. (1980) found average soybean yield response to 25-centimeter row spacing over 50-centimeter spacing to be 120 kilograms per hectare. In fact, one study showed that soybean yields were best with 15-centimeter rows. A 520 kilogram per hectare increase resulted from reducing row spacing from 76 to 38 centimeters on West Tennessee loess soils (Anonymous, 1985d).

Soybean yields from fields subjected to in-row subsoiling have been comparable to conventional tillage on sandy Coastal Plain soils in the Southeast (Anonymous, 1987a). This subsoiling aids in breaking up shallow fragipans which restrict rooting and decrease yields of soybeans (Tyler et al., 1987).

Hayes (1982) reported seed cotton yields were equal in systems involving a modified no-tillage planting method and conventional seedbed preparations. Seed cotton yields following wheat or rye have also been high with no-till outperforming tilled planting (Rickerl et al., 1984).

Rickerl et al. (1984) studied the effects of in-row subsoiling on cotton production and found an interaction between this tillage treatment and fertilizers. Seed cotton yields were lower without fertilizer, but increased when starter fertilizer and a soil fumigant were used.

Tillage Effects on Cotton Lint And Fiber Properties

Lint studies by Matocha and Bennett (1984) revealed that tillage techniques did not significantly influence long-term average fiber quality. Tillage treatment effect on cotton fiber strength appeared maximum in seasons when soil moisture was not limiting and production was at a high level, though high lint production levels were not always associated with improved fiber quality. In general, minimum and no-tillage systems produced cotton with fiber quality comparable to that produced using other tillage systems.

CHAPTER III

EXPERIMENTAL METHODS

Planting System Description

Performances of five selected reduced-tillage planting systems for cotton and soybeans were compared at The University of Tennessee Milan Experiment Station near Milan, Tennessee. Each system had a planter unit and standard components configured for the particular reduced-tillage system. A detailed description of each tillage-planting system is presented in Table 1.

Case-International provided the Case-International Model 800 Cyclo-Air planter for Milan Experiment Station use. Double-disk furrow openers for fertilizer placement and clearing disks were removed prior to crop planting (Figure 1). This four-row, air-assisted planter utilizes offset double-disk furrow openers and gauge wheels for seed placement and depth control, respectively. Two parallel furrow closure disks are followed by a pneumatic, center-rib press wheel to close the furrow and cover seed with soil. Pressurized air for the seed metering system was provided through a fan driven by a hydraulic motor. The transport wheels drove the metering cylinder.

Table 1. Descriptions of reduced-tillage planting systems used for comparison at the Milan Experiment Station, 1987-88.

System	Description
Case-International Model 800 Cyclo-Air Planter.	Air seed metering system driven by transport wheels. 4 rows equipped with 34-cm diameter double-disk seed furrow openers with 38-cm diameter, 8-cm width depth gauge wheels; two 16-cm diameter furrow closure disks per row; 30-cm diameter, 17-cm width pneumatic press wheels with 1.3-cm tall, 1.3-cm wide center ribs. 76-cm row spacing. Trail-type planter with hydraulic pump hook-up at tractor pto shaft.
John Deere Model 7100 Max-Emerge Planter.	Finger-pickup seed metering device driven by two ground contacting wheels. 8 rows equipped with 41-cm diameter, 2.5-cm wide ripple coulters; 33-cm diameter furrow openers with 38-cm diameter, 8-cm width depth gauge wheels; two 30-cm diameter, 2.5-cm cast iron press wheels in "V" configuration per row. 50-cm row spacing. Three-point-hitch mounted with two hydraulic lift-assist wheels. Weight bracket located on lift-assist wheel frame for suitcase-type weights.
Fleischer Manufacturing Company, Buffalo All-Flex Planter.	Seed-cup metering mechanism driven by the smooth coulter on each row. 4 rows equipped with 46-cm diameter smooth coulters with welded depth bands; a 53-cm runner-type furrow opener directly in-line; three 25-cm diameter semi-pneumatic press wheels, with the first following the opener setting the seed, the second and third wheels acting from either side to cover the seed with soil. 76-cm row spacing. Three-point-hitch mount to tractor.

Table 1. (Continued).

Allied Products Corporation, Bush Hog Model 8100 Ro-Till	2-row model. Two 50-cm concave disk blades; heave-limiting wheels; subsoiling shank with working depth of 20 to 38-cm; one pair of 50-cm waffle coulters to contain soil in each row; adjustable, reversible rolling baskets or cultipacker for seedbed finishing. Toolbar mounted Allis-Chalmers planters (1987), John Deere Model 7100 Max Emerge planters (1988). 33-cm diameter double-disk furrow openers; 46-cm diameter, 18-cm width pneumatic press wheels with 2.5-cm tall, 2.5-cm wide center ribs. Plate-type seed metering device driven by press wheels. Seeding depth controlled by press wheels. 76-cm row spacing. Mounted to tractor by three-point-hitch.
Marliss Pasture King No-Till Drill.	Ground wheel driven fluted feed metering device, seeding rate adjusted by changing drive gear ratio. 10-row model. Ripple-type coulter with heavy duty (182 kg.) coulter spring; double-disk openers with blade guard; convex, semi-pneumatic press wheels. 20-cm row spacing. Weight bracket, for suitcase-type weights, located on lift frame. Three-point-hitch mounted to tractor.

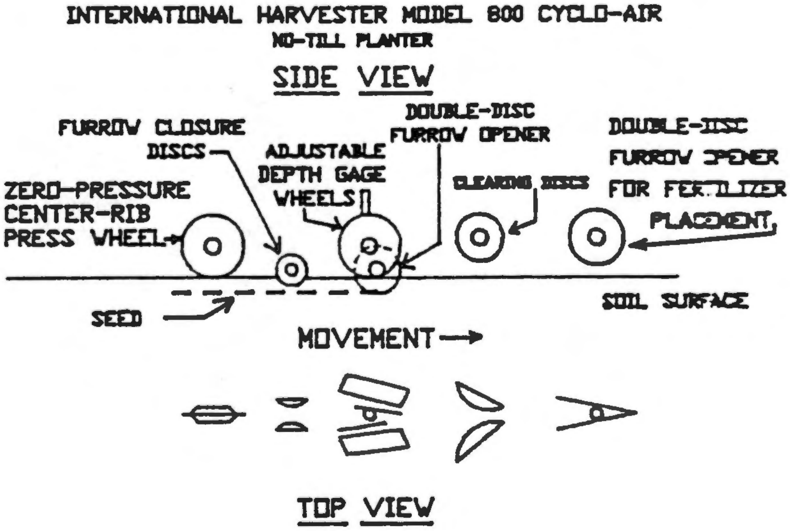

Figure 1. Schematic of soil engaging components on the Case-International Model 800 Cyclo-Air planter.

A John Deere Model 7100 Max-Emerge planter was furnished by Deere and Company for Milan Experiment Station use. This eight-row planter is equipped with ripple coulters in front of each row to sever trash, double-disk furrow openers and gauge wheels to control seed placement, and " V " shaped cast iron press wheels to close the furrow and cover the seeds, completing the planting process (Figure 2). A finger-pickup device driven by two ground contacting wheels meters seed on each row unit.

Ridge-till planting was conducted using a Buffalo All-Flex planter. The Fleischer Manufacturing Company provided this unit for Milan Experiment Station use. Smooth coulters with welded depth bands cut through stubble and runner-type openers push away trash and a thin layer of ridge soil while opening slots for seed placement. A triple, semi-pneumatic press wheel configuration pushes seed into the furrow before covering with soil (Figure 3). The seed-cup metering device is driven by smooth coulters on each of the 4 rows.

A Bush Hog Ro-Till implement, with attached Allis-Chalmers planting units (1987) and John Deere planting units (1988), was used for in-row subsoil planting. Bush Hog/Allied Corporation representatives assembled and operated this implement for demonstration at the Milan Experiment Station's 1987 No-Till Field Day. Concave disk

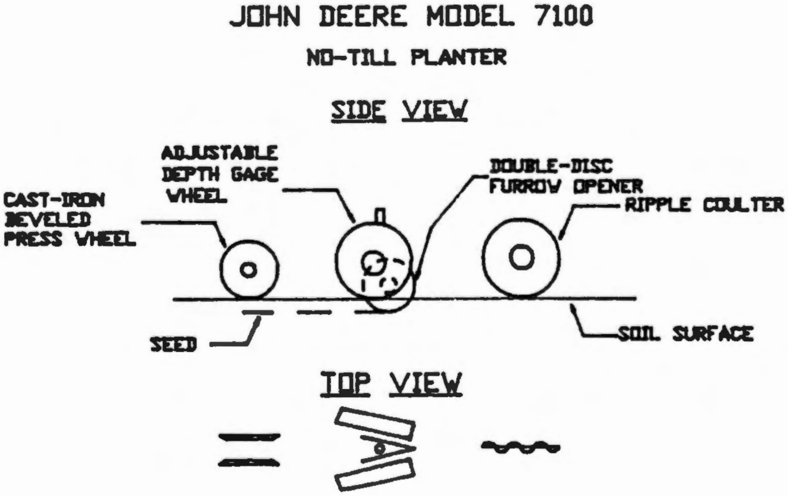

Figure 2. Schematic of soil engaging components on the John Deere Model 7100 Max-Emerge planter.

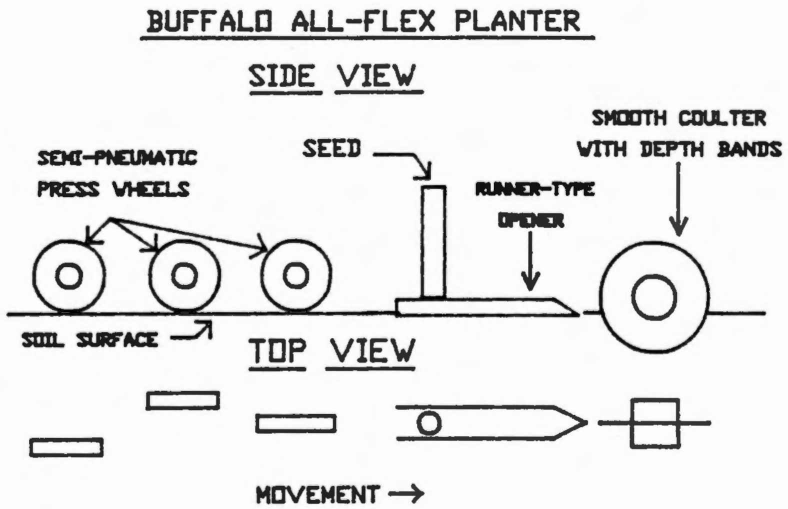

Figure 3. Schematic of soil engaging components on the Buffalo All-Flex planter.

blades act to push away residue from the row area while a subsoiling shank works the soil directly under the row.

Heave limiting wheels and paired waffle coulters help keep soil confined in-row (Figure 4). A toolbar is used to mount the planting unit to place seed in the strip tilled directly preceding the planter.

Finally, Marliss provided Milan Experiment Station with a Pasture King model No-Till drill. This drill was also demonstrated at the 1987 Experiment Station No-Till Field Day. Ten 20-centimeter rows are formed with ripple coulters to cut trash, double-disk furrow openers, with disk cleaning devices, to open a slot for seed placement and convex, semi-pneumatic press wheels to cover the seeds (Figure 5). The fluted seed metering mechanism is driven by a lift-assist ground wheel. Suitcase-type weights can be mounted on the lift frame for added soil penetration.

Production Plot Conditions and Treatments

Production plots of soybeans and cotton were planted as part of the reduced-tillage planting systems evaluation. Plots for each crop were arranged in a randomized complete block design with four blocks planted with the five planters in random plots. Tables 2 and 3 list soil conditions and treatments for soybean and cotton plots, respectively.

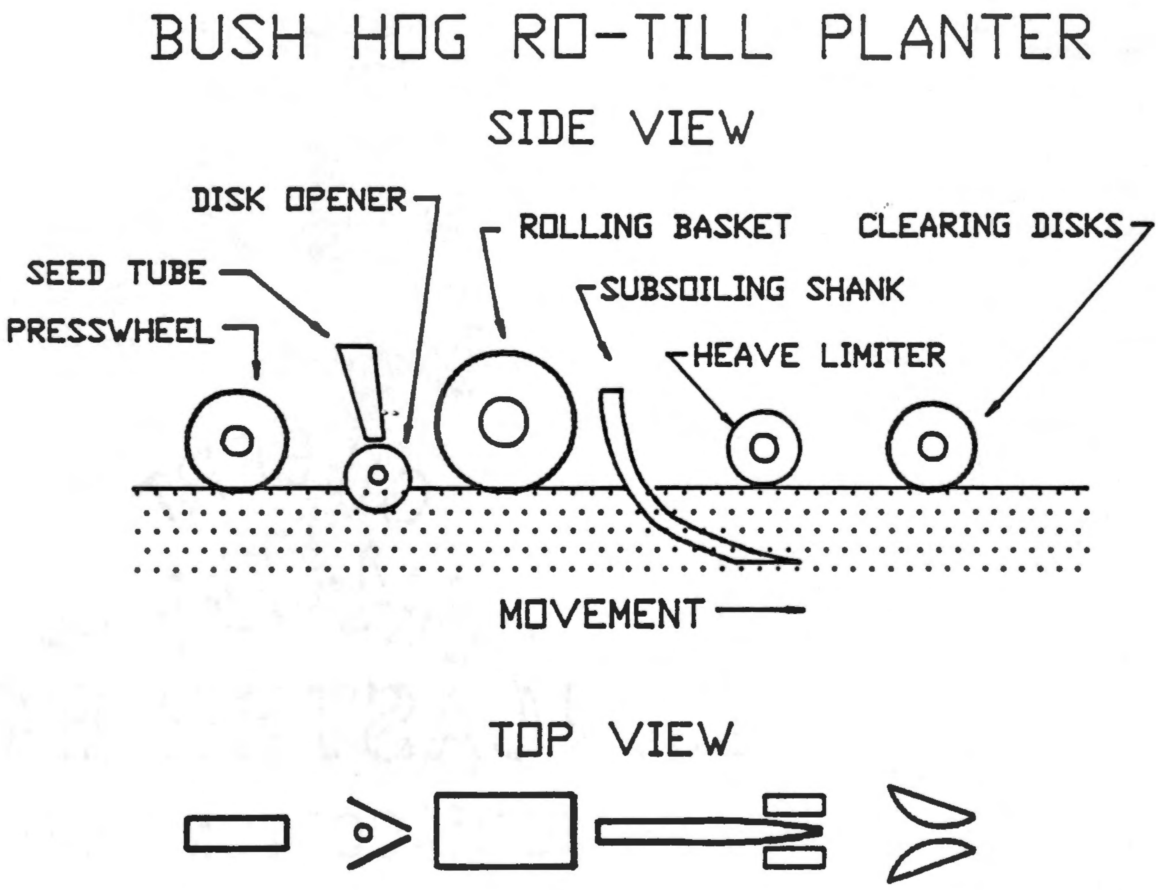

Figure 4. Schematic of soil engaging components on the Bush Hog Ro-Till implement with attached planting unit

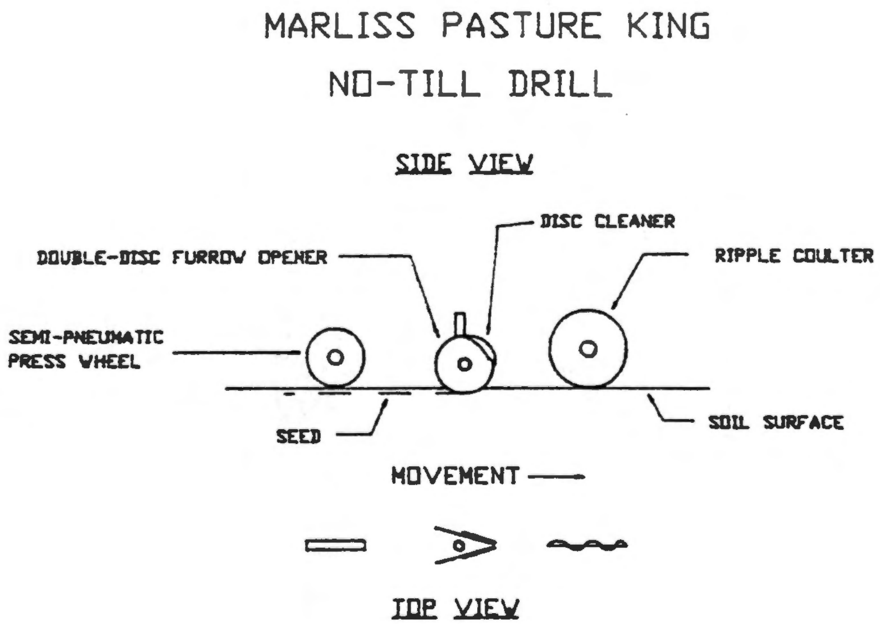

Figure 5. Schematic of soil engaging components on the Marliss Pasture King drill.

Table 2. Soil conditions and production plot treatments for soybeans planted at the Milan Experiment Station, 1987-88.

Previous Crops			Record of treatment operations:	
1986	1985	1984	Date	Treatment
Corn	Soybeans	Soybeans	3/13/87:	fertilized 0-91-91 kg/ha
			4/22/87:	sprayed 2.4 L/ha Roundup
			5/2/87 :	planted; sprayed 4.5 L/ha Lasso 2.4 L/ha Roundup
			6/6/87 :	sprayed Basagran & Blazer
			10/13/87:	harvested by combine 3@76-cm rows X 16.8m 4@50-cm rows X 16.8m 2.2m of drill plots

Soil type: Grenada Silt Loam (0-2% slope)
Plot size: 6.1m X 16.8m
Variety: Bay
(treatments duplicated in 1988)

Table 3. Soil conditions and production plot treatments for cotton planted at the Milan Experiment Station, 1987-88.

Previous Crops			Record of treatment operations:	
1986	1985	1984	Date	Treatment
Soybeans	Corn	Soybeans	4/22/87:	sprayed Roundup 2.4 L/ha & surfactant
			4/24/87:	fertilized 68-91-91 kg/ha
			5/2/87 :	Planted, sprayed 1.7 kg/ha Cotoran & 1.2 L/ha Prowl
			9/30/87:	sprayed 1.8 L/ha defoliant 4.5 L/ha preparation
			11/2/87:	cotton stripped 5@76-cm rows X 13.7m 7@50-cm rows X 13.7m 4m of drill plots

Soil type: Loring Silt Loam (0-2% slope)
Plot size: 6.1m X 13.7m
Variety: M[c]Nair 235
(treatments duplicated in 1988)

Rainfall was reported by Milan Experiment Station employees in 1987 as being adequate during the spring growing season, but drought-like conditions prevailed from July through September. Drier than normal conditions prevailed through the 1988 growing season, though rainfall was considered more adequate.

Data Collection

Planter Performance Characteristics

Data for seed depth and spacing were gathered by excavating 0.6-meter random row sections. Seeds were carefully exposed in the furrow, and depth was measured in centimeters to the soil surface. Seed spacing was taken as the measured distance between adjacent seeds in a row. The number of seeds dropped, but not covered with soil was also recorded for each row section.

Eight row sections were selected for each planter. Two sections per row were used from each of the 4-row planters, one section per row from the 8-row planter and eight rows from the 10-row drill. The number of seeds placed in the 0.6-meter section was also recorded to give an expected seeding rate to be used in calculating germination rates. Two sets of data were gathered on separate occasions.

Planters were operated under wheat stubble conditions during the first collection period, and young soybeans were mowed to provide a residue situation for the second data collection period. Pioneer 9591 soybeans were used for planter trials and emergence tests. These seed placement tests were conducted in plots near the cotton and soybean production plots.

Means and standard deviations for seed depth and seed spacing were calculated for each sample. Means and standard deviations were also determined for each system by pooling the sample row segments. Coefficients of variation were calculated by using the following equation (Tasman and Lamborn, 1974):

$$\text{Coefficient of variation} = \frac{\text{standard deviation}}{\text{mean}} .$$

Plant Growth and Stand

Plant stand data were taken on both production and planter trial soybean plots. Plant stand data for cotton was taken on production plots only. The number of plants in a randomly selected 0.9-meter row section within each plot was counted in the production plots. One 0.9-meter section was randomly selected in each of four rows in the trial plots. Emergence data from trial plots was taken on soybeans planted on three separate dates. These data were used to calculate an average number of plants emerged per meter of row. This number divided by the number of seeds expected per meter was used as an estimate of the ratio of seeds germinated to the total seeds planted. The following equation was used to calculate percent germination:

$$\text{Percent germination} = \frac{\text{plants/meter}}{\text{expected seeds/meter}} \times 100 \quad .$$

No estimation of cotton seed germination was attempted.

Plant growth characteristics were determined by measuring plant canopy and height. Ten random height and canopy measurements were taken in each soybean and cotton production plot eight weeks after planting in 1987, and 12 weeks after planting in 1988. The same number of random measurements were taken in each of the 1987 soybean planter trial plots four weeks after planting. All measurements were recorded in centimeters.

Soil Moisture Determination

A total of 900 soil samples were taken from the 1987 soybean and cotton production plots at plant maturity to determine the effect of tillage on soil moisture. In two random locations per plot, an auger was used to take a soil sample at 15-centimeter increments from the surface to a 90-centimeter depth. Two repetitions per sample were used to determine soil moisture by gravimetric analysis.

The following procedure was used for soil moisture determination:

1. Weigh soil in a clean, dry container of known mass.
2. Dry soil in a drying oven maintained at 110 +/- 5^{o} C. for 16 hours.
3. Remove samples from oven and place in a desiccator for one hour.
4. Re-weigh dried soil and container
5. By definition, moisture content is the ratio (expressed as a percentage) of the weight of water in the soil sample to the total weight of water and solids in the sample (Liu and Evett, 1984).

Soil moisture was calculated on percentage wet weight basis. With this definition, the moisture content is proportional to the weight of the water present. This characteristic makes the moisture content as defined above one of the most useful and important soil parameters (Liu and Evett, 1984).

Root Length Determination

Taproot lengths of 10 and 20-day old soybean plants were determined by carefully removing the plant from the soil, removing soil from the roots, and measuring the taproot with a ruler. This work was performed on the 1988 planter trial plots.

Root samples were taken at plant maturity in 1987 from both soybean and cotton production plots. Samples were taken according to procedures outlined by Tyler et al. (1987), who conducted root studies on similar west Tennessee soils. Core samples were taken in-row, 25, and 50 centimeters perpendicular to the row for a 76-centimeter row spacing; in-row, 15, and 30 centimeters perpendicular to the row for a 50-centimeter row spacing; and in-row and 10 centimeters perpendicular to the row for 20-centimeter drilled rows. These cores were extracted at depths of 15, 45, and 76 centimeters; two cores per plot.

Samples were air-dried and root length was estimated by using a modified line intercept method described by Tennant (1975). Individual samples taken in-row and perpendicular to the row of a common depth were washed free of soil in a fine mesh container, and placed on a one-half centimeter grid. The number of intercepts of roots crossing a grid line was recorded, and root length calculated.

Newman (1966) derived the following formula for estimating the total length of a root on an extracted sample:

$$R = NA/2H \quad .$$

Root length (R) was estimated by counting the number of intercepts (N) of roots in a regular area (A) with randomly located and oriented lines of total length (H). In principle, the longer the root, the more intercepts it makes with the randomly arranged lines.

With this procedure, length rather than root weight data were made feasible indices of the functional size of root systems. Estimated root length at the three depths were compared to determine any variability caused by tillage system.

Yields

A combine was used to harvest soybeans. Moisture content of harvested soybeans was measured and yield was expressed in kilograms per hectare at 13 percent moisture content.

Because of difficulties that may have been encountered with handling narrow-rows, cotton was harvested with a stripper. Yields were given in kilograms of seed cotton per hectare. After ginning, cotton yields were given in kilograms of lint per hectare.

CHAPTER IV

RESULTS AND DISCUSSION

Planter System Performance

Table 4 presents seed placement depth and in-row spacing data for the Buffalo All-Flex planter. Mean seeding depths ranged from 2.9 to 4.6 centimeters, with an overall mean of 3.9 centimeters. Data indicated more variation in seeding depth from the pooled data than from individual samples. Some variation may have been caused by the clogging of the runner-type furrow opener when operated under extremely trashy conditions, though this occurred infrequently. Minimum seed depth was 2.2 centimeters and no seeds were placed over 5.7 centimeters deep. Seed spacing ranged from 0.3 to 7.6 centimeters. No seeds were found in direct physical contact with each other, and no seeds were left uncovered with soil. The consistency of seed depth and spacing reflects the ability of this planter to cut and push away surface trash from the seeding area.

Table 5 presents seed placement data for the Case-International Cyclo-Air planter. Seed placement depths ranged from 1.3 to 4.1 centimeters, with a mean of 2.6 centimeters. Pooled coefficient of variation for seed depth was 21.1 percent. Seed spacing ranged from 0.3 to 10.8 centimeters, with a mean of 3.1 centimeters. Several

Table 4. Seed depth and in-row spacing data for Buffalo All-Flex No-Till planter.

Sample	Maximum	Minimum	Mean	Coefficient of Variation(%)
		Seed Depth (cm.)		
1	4.1	2.9	3.6	10.9
2	5.1	3.5	4.5	7.9
3	3.5	2.2	2.9	15.1
4	5.1	2.5	3.6	14.4
5	4.8	3.2	3.9	12.1
6	5.7	4.1	4.6	9.2
7	4.8	3.2	4.0	10.2
8	4.4	2.9	3.7	11.5
Pooled	5.7	2.2	3.9	16.4
		Seed Spacing (cm.)		
1	7.6	0.3	2.6	81.3
2	5.7	0.3	2.4	84.7
3	7.3	1.3	4.2	48.1
4	7.3	0.6	3.1	65.0
5	7.0	0.3	3.0	50.5
6	4.4	1.0	2.8	39.4
7	5.1	1.9	3.7	20.2
8	6.3	0.3	3.4	49.3
Pooled	7.6	0.3	3.1	56.4

Table 5. Seed depth and in-row spacing data for the Case-International Cyclo-Air planter.

Sample	Maximum	Minimum	Mean	Coefficient of Variation(%)
		Seed Depth (cm.)		
1	2.9	1.3	2.3	18.7
2	3.2	1.6	2.4	18.8
3	3.2	1.9	2.5	15.3
4	3.2	2.2	2.7	11.6
5	3.2	1.9	2.5	15.1
6	4.1	2.9	3.6	10.9
7	3.8	1.6	2.5	26.7
8	3.2	2.2	2.6	10.7
Pooled	4.1	1.3	2.6	21.1
		Seed Spacing (cm.)		
1	10.8	0.3	3.9	72.7
2	6.7	0.3	2.6	80.5
3	6.3	0.3	3.1	54.6
4	7.6	0.3	2.8	73.6
5	6.7	0.3	2.7	76.6
6	7.6	1.3	3.5	56.9
7	5.7	0.9	3.7	37.9
8	7.0	0.3	2.9	77.8
Pooled	10.8	0.3	3.1	67.3

instances of seeds being spaced more than 5.1 centimeters apart accounted for the spacing coefficient of variation in the pooled data of 67.3 percent. Operated in dry soil, this planter cut through heavy residue well, aiding in seed placement.

Table 6 summarizes performance data for the John Deere Model 7100 planter. Seven seeds were placed on the soil surface with others being placed as deep as 5.1 centimeters below the soil surface. The planter placed several seeds over 7.6 centimeters apart and, in some cases, as much as 19.0 centimeters apart. Average seed spacing was 4.1 centimeters. This high variation in seed depth and spacing may have been caused in part by the condition of the sampling field. All planter trials were conducted on the same field. This field was used for ridge-till production some three years earlier with ridges still being somewhat prevalent during sampling. Changes in soil elevation, such as planting across old ridge-till furrows and ridges, may affect the performance of this planter. That possibility is certainly reflected in the differences in depth coefficient of variations for individual row samples.

Table 7 presents planter performance data from the Bush Hog Ro-Till operated with the John Deere planting unit. Some seeds were found on the soil surface, while others were found to be placed 5.1 centimeters below the soil surface. The subsoiling shank brought up dry, hard

Table 6. Seed depth and in-row spacing data for the John Deere Model 7100 No-Till planter.

Sample	Maximum	Minimum	Mean	Coefficient of Variation(%)
		Seed Depth (cm.)		
1	2.5	0.0	1.1	67.3
2	2.5	0.0	0.8	99.3
3	4.1	2.5	3.2	13.7
4	3.8	0.0	2.4	40.9
5	4.8	3.5	4.1	12.0
6	5.1	3.2	4.1	19.0
7	3.5	1.3	2.7	23.5
8	2.5	0.6	1.7	39.5
Pooled	5.1	0.0	2.5	54.5
		Seed Spacing (cm.)		
1	11.4	0.3	4.5	57.0
2	8.6	0.3	4.5	64.5
3	9.9	1.3	3.7	63.1
4	8.6	0.3	3.6	61.9
5	7.6	0.3	3.0	59.9
6	19.0	0.6	4.9	96.9
7	9.5	1.6	5.0	58.1
8	17.8	0.3	4.5	112.2
Pooled	19.0	0.3	4.1	77.7

Table 7. Seed depth and in-row spacing data for the Bush Hog Ro-Till with John Deere planter.

Sample	Maximum	Minimum	Mean	Coefficient of Variation(%)
		Seed Depth (cm.)		
1	1.3	0.6	1.0	33.8
2	2.9	0.3	1.7	54.0
3	5.1	0.0	2.6	65.2
4	3.8	0.0	1.0	66.5
5	4.0	0.3	2.1	48.6
6	2.5	0.0	1.6	52.6
7	2.5	0.3	1.1	64.2
8	3.2	0.0	1.4	79.4
Pooled	5.1	0.0	1.6	67.8
		Seed Spacing (cm.)		
1	14.0	0.3	5.8	87.3
2	11.4	0.3	5.7	64.0
3	13.3	0.3	5.1	81.4
4	13.3	0.3	4.0	96.1
5	10.2	1.3	4.6	57.0
6	16.5	0.3	5.9	78.9
7	23.5	2.5	7.9	90.4
8	10.8	0.6	4.6	66.8
Pooled	23.5	0.3	5.2	79.8

soil clods which were not satisfactorily crushed by the trailing cultipacker unit, thus resulting in the lack of uniformity in seed placement. Seed spacing data from the John Deere unit operated under these conditions were very similar to spacing data from this planter when operated under no-till conditions (Table 6).

Table 8 includes summarized data from the Marliss Pasture King No-Till drill. Seeding depth varied substantially, ranging from 0.6 to 4.9 centimeters. This is reflected in the 33.3 percent depth coefficient of variation for depth. Spacing of seeds also varied considerably, with seeds spaced as close as 0.3 centimeters and as far apart as 25.4 centimeters. This inconsistency in seed spacing may be due to the fluted seed metering mechanism which produces a flow of seeds, but lacks in seed spacing control. No seeds were found uncovered on the soil surface. The fully weighted drill severed ground trash well, but may not have penetrated the dry soil uniformly, as suggested by the fluctuating seeding depths.

Figure 6 presents an overall summary of seed depth placement perfomance based on pooled coefficient of variation figures. Figure 7 includes summarized in-row seed spacing data from the five reduced-tillage planting systems tested.

Table 8. Seed depth and in-row spacing data for the Marliss No-Till drill.

Sample	Maximum	Minimum	Mean	Coefficient of Variation(%)
		Seed Depth (cm.)		
1	4.4	2.5	3.6	12.5
2	2.9	1.6	2.1	18.5
3	2.3	0.6	1.5	27.6
4	2.9	1.6	2.2	15.0
5	2.5	1.0	2.0	24.4
6	3.8	0.6	2.8	26.8
7	3.2	1.3	2.0	24.6
8	4.8	1.3	2.4	32.0
9	2.9	1.9	2.2	16.2
10	3.8	2.5	3.0	15.6
Pooled	4.8	0.6	2.3	33.3
		Seed Spacing (cm.)		
1	12.7	0.3	3.6	105.2
2	11.1	0.3	5.3	72.6
3	5.7	0.3	2.6	68.1
4	10.2	0.3	3.1	80.7
5	11.1	1.3	4.8	62.5
6	9.9	0.3	3.3	85.0
7	8.3	0.3	2.4	84.5
8	9.5	0.3	2.9	88.9
9	13.7	0.3	4.6	83.1
10	25.4	3.5	10.7	73.4
Pooled	25.4	0.3	3.7	96.0

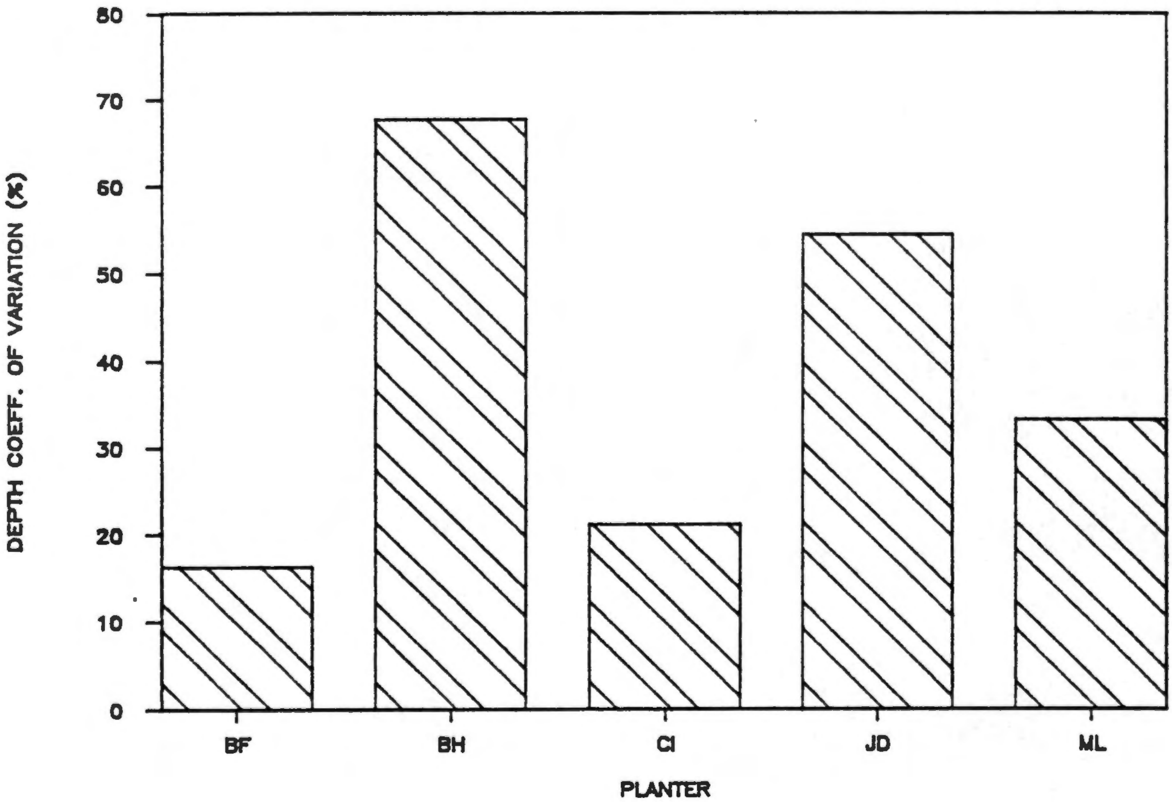

Figure 6. Depth coefficient of variation summary for the five reduced-tillage planting systems studied. (BF=Buffalo All-Flex planter, BH=Bush Hog Ro-Till with John Deere unit, CI=Case-IH Cyclo-Air planter, JD=John Deere Model 7100 planter, ML=Marliss No-Till drill)

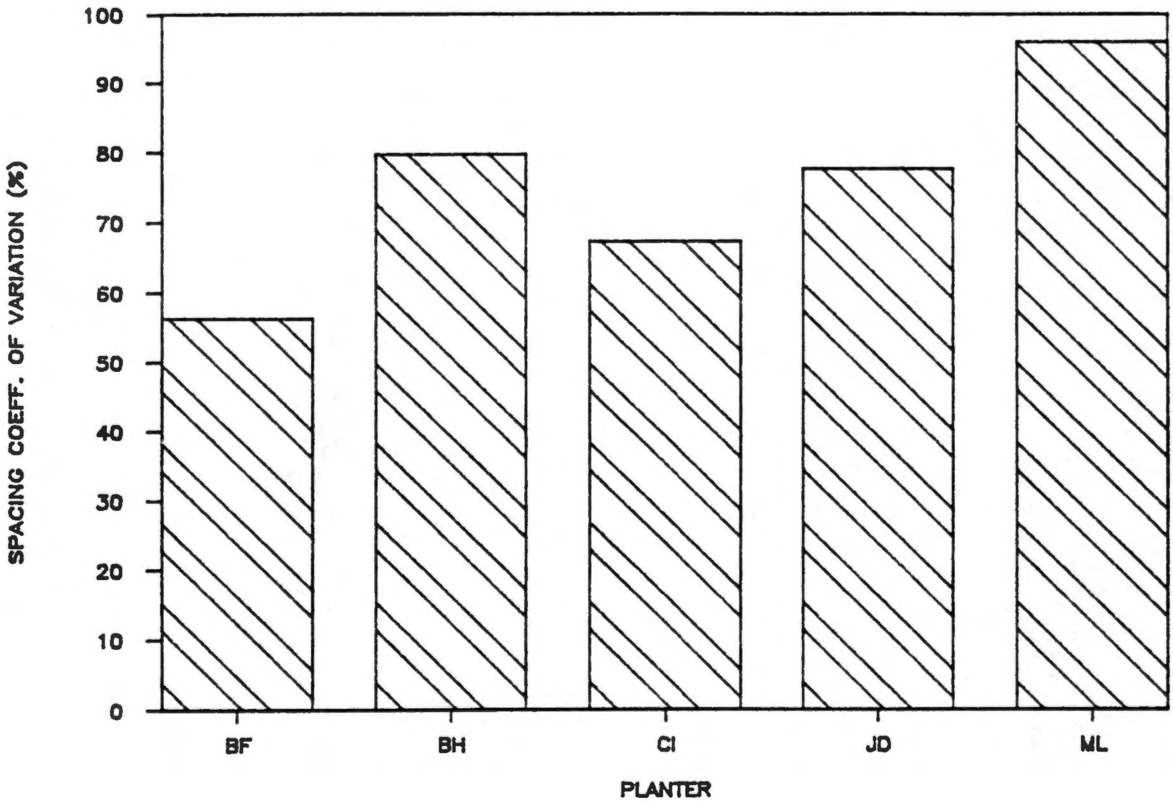

Figure 7. In-row spacing coefficient of variation summary for the five reduced-tillage planting systems studied. (BF=Buffalo All-Flex planter, BH=Bush Hog Ro-Till with John Deere unit, CI=Case-IH Cyclo-Air planter, JD=John Deere Model 7100 planter, ML=Marliss No-Till drill)

Soybean Plant Growth Characteristics

Table 9 summarizes plant canopy development data taken 36 days after planting in 1987. Soybeans planted with the Case-IH no-till planter exhibited the most development, having the largest mean height and canopy width. No significant difference was found between the Case-IH no-till planted soybeans and the height of either ridge-tilled or no-till drilled soybeans, although the Case-IH no-till plots had plants which were significantly taller than Ro-tilled soybeans and soybeans planted with the John Deere no-till planter. Mean plant height measurements ranged from 24 to 39 centimeters. Canopy width means of the Case-IH no-till planter were not significantly different from ridge-tilled beans or those planted with the John Deere no-till planter, but greater than canopy width means of the no-till drilled and Ro-tilled soybeans. The less mature Ro-till soybeans may have been caused by poor seed placement during planting, as this has been frequently reported in prior Ro-till studies (Grisso et al., 1984b).

Table 10 presents canopy development data 72 days after planting in 1987. Canopy widths ranged from 28 to 41 centimeters. Ro-tilled soybeans grew significantly wider at this stage than the other treatments. At 36 days, the Ro-till produced beans with the narrowest canopy width.

Table 9. Soybean canopy development 36 days after the 31 July 1987 planting date for five reduced-tillage seeding systems at the Milan Experiment Station.

Planter System	Tillage System	Plant Canopy Height(cm.)	Plant Canopy Width(cm.)
Case-IH Cyclo-Air	NT	39^{a}	30^{a}
Buffalo All-Flex	RT	31^{ab}	24^{ab}
John Deere # 7100	NT	29^{b}	23^{ab}
Marliss Drill	NT	31^{ab}	21^{b}
Bush Hog Ro-Till	IR	24^{b}	20^{b}

Means within the same column followed by the same letter are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

Table 10. Soybean canopy development 72 days after the 2 May 1987 planting date for five reduced-tillage seeding systems at the Milan Experiment Station.

Planter System	Tillage System	Plant Canopy Height(cm.)	Plant Canopy Width(cm.)
Case-IH Cyclo-Air	NT	93^{b}	34^{b}
Buffalo All-Flex	RT	98^{a}	35^{b}
John Deere # 7100	NT	100^{a}	35^{b}
Marliss Drill	NT	98^{a}	28^{c}
Bush Hog Ro-Till	IR	92^{b}	41^{a}

Means within the same column followed by the same letter are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

In-row subsoiling may have enabled this change in plant growth.

Mean plant height ranged from 92 to 100. centimeters. Although Ro-tilled soybeans developed the widest canopy, these plants were shortest at this point. After 110 days of growth, no significant difference was found among plant canopy characteristics (Table 11).

Cotton Plant Growth Characteristics

Table 12 summarizes plant growth data for cotton planted 2 May 1987. Canopy width and height measurements were taken 72 days after planting date. Canopy width means ranged from 38 to 53 centimeters. Cotton planted with the Case-IH No-Till planter, ridge-till and Ro-till methods had significantly wider canopies when compared to the remaining tillage treatments. These data compare fairly well with the soybean plant growth characteristics at the same stage of plant development (Table 10). Plant height means ranged from 86 to 105 centimeters. Ro-tilled cotton produced significantly shorter plants than any of the remaining treatments. These data are also comparable to soybean growth data at the same point in development (Table 10). This similarity in plant growth characteristic data infers that these tillage methods may affect plant growth in nearly the same manner in the production of these two crops at this stage in plant development.

Table 11. Soybean canopy development 110 days after the 2 May 1988 planting date for five reduced-tillage seeding systems at the Milan Experiment Station.

Planter System	Tillage System	Plant Canopy Height(cm.)	Plant Canopy Width(cm.)
Case-IH Cyclo-Air	NT	112	52
Buffalo All-Flex	RT	112	51
John Deere # 7100	NT	105	58
Marliss Drill	NT	110	53
Bush Hog Ro-Till	IR	104	55

No significant difference among means found at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

Table 12. Cotton canopy development 72 days after the 2 May 1987 planting date for five reduced-tillage seeding systems at the Milan Experiment Station.

Planter System	Tillage System	Plant Canopy Height(cm.)	Plant Canopy Width(cm.)
Case-IH Cyclo-Air	NT	102[a]	53[a]
Buffalo All-Flex	RT	104[a]	49[a]
John Deere # 7100	NT	103[a]	43[b]
Marliss Drill	NT	105[a]	38[c]
Bush Hog Ro-Till	IR	86[b]	50[a]

Means within the same column followed by the same letter are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

Table 13 summarizes cotton canopy develpment data taken after 110 days of growth. Both plant height and canopy width varied significantly depending on the type of planter used. The Buffalo ridge-till planting system produced plants with the tallest and widest plant canopy at this growth stage, whereas the John Deere no-till planter and the Marliss no-till drill produced plants with the shortest and most narrow canopies. Overall canopy heights ranged from 78 to 124 centimeters. Canopy widths ranged from 36 to 87 centimeters.

Soybean Plant Stands and Emergence

Tables 14 and 15 summarize measurements taken to characterize the plant stands and emergence potential of each system. Production plot soybean plant stands ranged from 7.2 to 25.6 plants per meter of row. The Case-IH no-till planter produced the greatest emergence rate in these plots, at 83.5 percent, while no-till drilled soybeans emerged at a rate of only 34.4 percent. Plant stands from soybeans planted 31 July 1987 produced stands varying from 7.5 to 19.4 plants per meter. These poor stands were probably due to extremely dry planting conditions and are reflected in lowered emergence rates ranging from 30.2 percent to 76.1 percent.

Denser plant stands from soybeans planted on the two dates in August, 1988 could have been attributed to adequate rainfall before and after planting. On these

Table 13. Cotton canopy development 110 days after the 2 May 1988 planting date for five reduced-tillage seeding systems at the Milan Experiment Station.

Planter System	Tillage System	Plant Canopy Height(cm.)	Plant Canopy Width(cm.)
Case-IH Cyclo-Air	NT	96^{c}	56^{c}
Buffalo All-Flex	RT	124^{a}	87^{a}
John Deree # 7100	NT	78^{d}	36^{d}
Marliss Drill	NT	81^{d}	39^{d}
Bush Hog Ro-Till	IR	116^{b}	78^{b}

Means within the same column followed by the same letter are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

Table 14. Soybean emergence and plant stand data for five reduced-tillage seeding systems at the Milan Experiment Station.

		Planting Date			
		2 May 1987		2 May 1988	
		Emergence			
Planter System	Tillage System	Plants/m	%	Plants/m	%
Case-IH Cyclo-Air	NT	25.6	83.5	12.5	66.6
Buffalo All-Flex	RT	22.3	65.4	15.4	62.7
John Deere # 7100	NT	15.4	61.6	15.7	45.0
Marliss Drill	NT	8.2	39.9	7.2	34.4
Bush Hog Ro-Till	IR	12.8	50.3	7.5*	38.8*

*-Ro-Till unit equipped with John Deere planting unit

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

Table 15. Soybean emergence and plant stand data for trials of five reduced-tillage seeding systems at the Milan Experiment Station

		Planting Date					
		7/31/87		8/18/88		8/29/88	
		Emergence					
Planter System	Tillage System	P/m	%	P/m	%	P/m	%
Case-IH Cyclo-Air	NT	13.1	42.8	15.7	83.5	19.0	73.7
Buffalo All-Flex	RT	16.1	46.7	11.2	45.3	22.0	97.5
John Deere # 7100	NT	19.4	76.1	23.9	67.9	14.1	66.2
Marliss Drill	NT	10.5	50.9	9.2	77.2	7.2	60.7
Bush Hog Ro-Till	IR	7.5	30.2	18.0*	91.7	19.4*	90.8

*-Ro-Till unit equipped with John Deere planting unit

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

test plots, nearly all seeds planted with the Ro-Till/John Deere system emerged, whereas fewer of the seeds emerged from those planted with the John Deere no-tillage system. The John Deere planter appeared to place and cover seeds better in the "Ro-Tilled" seedbed, while leaving some seeds uncovered when operated solely as a no-till planter.

Cotton Plant Stands

Table 16 summarizes cotton plant stand measurements. Stand data varied greatly between the two years sampled, with only the Marliss no-till drill and Ro-Till systems having substantial consistency in plant numbers.

Soil Moisture

Tables 17 and 18 present data pertaining to available soil moisture for each tillage system. Soybean soil moisture over all depths sampled ranged from 11.5 percent to 12.5 percent, with in-row subsoiling having significantly greater soil moisture than the other tillage treatments. Overall differences in soil moisture from cotton treatments were less distinct, ranging from 10.6 percent to 11.8 percent.

No rainfall was recorded at the Milan Experiment Station from 4 July 1987 until early September, 1987. The difference between soybean and cotton moisture figures may be due, in part to plant, water useage. Longenecker and Erie (1968) reported that in high-humidity, low-elevation

Table 16. Cotton plant stand data for five reduced-tillage seeding systems at the Milan Experiment Station.

		Planting Date	
		2 May 1987	2 May 1988
		Emergence	
Planter System	Tillage System	Plants/m	Plants/m
Case-IH Cyclo-Air	NT	7.9	10.2
Buffalo All-Flex	RT	12.8	4.9
John Deere # 7100	NT	8.5	16.4
Marliss Drill	NT	5.2	6.2
Bush Hog Ro-Till	IR	7.2	9.2*

*- Ro-Till unit equipped with John Deere planter

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

Table 17. Soybean soil moisture data for five reduced-tillage seeding systems at the Milan Experiment Station.

Planter System	Tillage System	Soil Moisture (% Wet basis)
Bush Hog Ro-Till	IR	12.5[a]
Buffalo All-Flex	RT	11.8[b]
John Deere # 7100	NT	11.7[b]
Marliss Drill	NT	11.5[b]
Case-IH Cyclo-Air	NT	11.5[b]

Means with same letter within columns are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

Table 18. Cotton soil moisture data for five reduced-tillage seeding systems at the Milan Experiment Station.

Planter System	Tillage Systems	Soil Moisture (% Wet basis)
Bush Hog Ro-Till	IR	11.8[a]
Case-IH Cyclo-Air	NT	11.3[ab]
Marliss Drill	NT	11.1[ab]
John Deere # 7100	NT	10.8[b]
Buffalo All-Flex	RT	10.6[b]

Means with same letter within columns are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

areas of the Southeast, cotton required 76 to 90 centimeters of water for consumptive use. On the other hand, a good crop of soybeans would require only about 50 to 75 centimeters of water (Carter and Hartwig, 1967).

Table 19 summarizes soybean soil moisture data by sampling depth. The in-row subsoiling treatment had higher soil moisture at all levels except the 75 to 90-centimeter depths. This superior moisture level was distinguishable from that in other tillage treatments from the soil surface to an 45-centimeter depth. From 45 to 75-centimeter depths, means were not significantly different. At the deepest sampling level (75 to 90-cm), ridge-tillage and the Ro-Till system had significantly more soil moisture available than the Case-IH no-till planter, but was not significantly different from either the no-till drilled or John Deere no-till planted soybeans. Ridge-tillage yielded the highest soil moisture (14.7 percent) at the deepest sampling level.

Table 20 presents cotton soil moisture data by sampling depth. At the 0 to 15-centimeter level, soil moisture ranged from 6.6 percent for ridge-tilled cotton to 8.2 percent for in-row subsoiling. Ro-tillage soil moisture was significantly different from John Deere no-till and ridge-tillage, but could not be separated from Case-IH no-till and no-till drilled cotton. Cotton soil

Table 19. Soybean soil moisture data by sampling depth under five reduced-tillage systems in 1987 at the Milan Experiment Station.

		Soil Moisture (%wb) at depths of					
Planter System	TS	15cm	30cm	45cm	60cm	75cm	90cm
Bush Hog Ro-Till	IR	9.7^{a}	12.6^{a}	12.6^{a}	12.3^{a}	13.4^{a}	14.6^{a}
Buffalo All-Flex	RT	8.9^{b}	11.2^{b}	11.2^{b}	11.8^{a}	13.1^{a}	14.7^{a}
Case-IH Cyclo-Air	NT	8.8^{b}	11.3^{b}	11.2^{b}	11.7^{a}	12.6^{a}	13.6^{b}
John Deere # 7100	NT	8.4^{b}	11.5^{b}	11.5^{b}	11.5^{a}	13.3^{a}	14.1^{ab}
Marliss Drill	NT	8.3^{b}	10.5^{b}	11.3^{b}	12.0^{a}	13.0^{a}	14.3^{ab}

Means with same letter within columns are not significantly different at 0.05 level.

TS=Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

Table 20. Cotton soil moisture data by sampling depth under five reduced-tillage systems in 1987 at the Milan Experiment Station.

		Soil Moisture (%wb) at depths of					
Planter System	TS	15cm	30cm	45cm	60cm	75cm	90cm
Bush Hog Ro-Till	IR	8.2[a]	11.6[ab]	11.7[b]	11.5[a]	13.0[a]	15.0[a]
Buffalo All-Flex	RT	6.6[b]	10.3[c]	12.2[a]	11.0[ab]	11.0[c]	12.8[b]
Case-IH Cyclo-Air	NT	7.7[ab]	12.1[a]	11.6[b]	10.9[ab]	12.2[ab]	13.6[b]
John Deere # 7100	NT	7.2[b]	11.0[bc]	11.5[b]	10.5[b]	11.4[bc]	13.0[b]
Marliss Drill	NT	7.5[ab]	12.4[a]	11.8[b]	10.7[ab]	11.5[bc]	13.1[b]

Means with same letter within columns are not significantly different at 0.05 level.

TS=Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling moisture varied from 10.3 percent for ridge-tilled cotton to 12.4 percent for no-till drilled cotton at the 15 to 30-centimeter depth. No-till drilled cotton and cotton planted with the Case-IH no-till unit had superior soil moisture compared to ridge-till, but could not be distinguished from Ro-till treatment effects. Likewise, at this depth ridge-till effects were not significantly different from John Deere no-till planted cotton. Ridge-tilled cotton had significantly more soil moisture available over any of the other treatments at a 30 to 45-centimeter soil depth. In-row subsoiling had higher soil moisture at the remaining depths (45-90cm), more than the John Deere no-till planter at 45 to 60 centimeters; no-till drilled, John Deere no-till and ridge-tilled cotton at 60 to 75 centimeters; and had significantly more soil moisture available for plant use over all other treatments at the 75 to 90-centimeter level.

These data may support claims that the breaking of a compacted soil layer under the row helps increase water percolation and reduces surface runoff after rainfall. It is unclear as to what caused the variation in soil moisture trends, especially between the two crops. These data were also analyzed on the basis of row spacing. This study found that a 76-centimeter soybean row spacing resulted in significantly higher soil moisture at a 0 to 15-centimeter depth than soybeans planted in 50 or 20-centimeter rows, but at a 15 to 30-centimeter depth a 76 or 50-centimeter soybean row spacing provided significantly more moisture than no-till drilled soybeans. Drilled cotton (20-centimeter row spacing) had significantly higher soil moisture than the other row spacings at a 15 to 30-centimeter depth. In all other cases, row spacing did not effect soil moisture, but in most cases, in-row subsoiling may have produced slight soil moisture advantages over the other tillage treatments, but this trend toward increased moisture availability may not be significant.

Root Growth

Tables 21 and 22 summarizes relative root length for the five tillage systems studied. Tillage practice did not effect the overall mean length of soybean roots. Soybean mean root lengths ranged from 217.8 centimeters for the Case-IH no-till planting unit to 264.7 centimeters for no-till drilled soybeans. Mean root lengths ranged from 110.7 centimeters for no-till drilled cotton to 211.0 centimeters for ridge-tilled cotton. Ridge-tilled and ro-tilled cotton produced significantly longer cotton roots than either no-till drilled or Case-IH no-till cotton, but not significantly different from John Deere no-till cotton. John Deere and Case-IH no-till cotton roots were also significantly longer than no-till drilled cotton.

The difference observed in overall root length means between cotton and soybeans may be explained by the

Table 21. Soybean root development 109 days after the 2 May 1987 planting date for five reduced-tillage seeding systems at the Milan Experiment Station.

Planter System	Tillage System	Overall	Soybean Root Lengths (cm.) Sampling depth 0-15cm	30-45cm	60-75cm
Case-IH Cyclo-Air	NT	217.7	464.8	137.7	50.8
Buffalo All-Flex	RT	247.4	600.7	98.0	45.5
John Deere # 7100	NT	246.6	542.5	146.3	51.1
Marliss Drill	NT	264.7	579.4	159.5	55.4
Bush Hog Ro-Till	IR	263.4	520.4	182.9	87.4

Means are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

Table 22. Cotton root development 109 days after the 2 May 1987 planting date for five reduced-tillage seeding systems at the Milan Experiment Station.

Planter System	Tillage System	Cotton Root Lengths (cm.) Overall	Sampling depth 0-15cm	30-45cm	60-75cm
Case-IH Cyclo-Air	NT	148.8^{b}	263.4^{b}	133.9^{ab}	49.5^{a}
Buffalo All-Flex	RT	211.1^{a}	433.1^{a}	127.3^{ab}	72.6^{a}
John Deere # 7100	NT	180.8^{ab}	359.9^{a}	110.2^{ab}	74.2^{a}
Marliss Drill	NT	110.7^{c}	196.1^{b}	81.8^{b}	54.4a
Bush Hog Ro-Till	IR	199.6^{a}	370.1^{a}	166.9^{a}	62.5^{a}

Means are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

respective plant root physiology. Research on field-grown soybeans indicated that this plant lacked a distinct taproot, with a major portion of the root system consisting of lateral roots arising from the upper 10 to 15-centimeter section of the primary root. Soybean roots may extend as far down as 183.0 centimeters into the soil (Mitchell and Russell, 1971; Raper and Barber, 1970). In contrast, by plant maturity, 55 percent of a cotton plant's root system was found to be below a 61.0-centimeter depth. In addition, Stockton (1964) also found it not uncommon for cotton roots to extend to a 183.0-centimeter depth, while King (1922) traced some cotton taproots to depths of 3.4 meters. This information could help explain why soybean roots were found to be somewhat longer than cotton roots at all sampling depths.

Table 23 summarizes soybean taproot length data for 10 and 20-day old plants . The combination Ro-Till/John Deere planting system produced young plants with significantly longer roots than the remaining systems at this stage of plant growth.

Table 21 presents soybean root length data for each tillage system studied. Soybeans planted using the ridge-till method had the longest roots at the 0 to 15-centimeter soil depth. In-row subsoiling produced plants with the longest roots at the two deepest sampling levels. No-tillage treatments produced plants with roots that varied

Table 23. Soybean root development after the 18 August 1988 planting date for five reduced-tillage seeding systems at the Milan Experiment Station

Planter System	Tillage System	Soybean Taproot Lengths (cm.) After 10 days	After 20 days
Bush Hog Ro-Till*	IR	8.3[a]	21.4[a]
Case-IH Cyclo-Air	NT	5.7[b]	13.0[b]
Buffalo All-Flex	RT	5.5[b]	8.3[b]
John Deere # 7100	NT	5.7[b]	8.0[b]
Marliss Drill	NT	5.4[b]	11.5[b]

Means are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

*-Bush Hog Ro-Till equipped with John Deere planting unit.

somewhat regardless of soil depth, but were shorter than that of either ridge-till or in-row subsoiling at any sampled depth.

Ridge-till soybean data compares well with that of Heard et al. (1987) who found significantly more large water conducting channels at a shallow soil depth in ridge-till plots than in soybean plots planted with a no-tillage treatment. These channels may promote root growth.

Root length data from the in-row subsoiling treatment somewhat supports the theory that the Ro-till planting method may help alleviate soil compaction. Although this subsoiling device has a working depth of only 20 to 38 centimeters, this treatment produced the longest soybean roots at soil depths of 45 and 75 centimeters. The ability of these roots to exhibit increased growth at these deeper soil levels may result in a greater number of large soil pores deeper in the soil, thus helping to reduce soil compaction.

Any advantage by tillage system in soybean root growth was slight, as tillage effects were not significant at any sampled depth. Variation was more attributed to block or block*planter interactions.

Table 22 summarizes root length data for each tillage system. Ridge-tilled cotton produced the longest roots at the 0 to 15-centimeter soil depth. At this level, Ridge-till, Ro-till and John Deere no-till cotton had significantly longer roots than cotton planted with the Case-IH no-till unit or the no-till drill.

In-row subsoiling had the longest cotton roots at a soil depth of 30 to 45 centimeters. Here the Ro-till had significantly longer roots than the no-till drilled cotton, but could not be separated from the remaining tillage treatments.

At the deepest sampling level (60-75cm) no significant difference in cotton root length was found according to tillage treatment. Root lengths ranged from 49.5 centimeters for the Case-IH no-till to 74.2 centimeters long for the John Deere no-till unit.

Row spacing was found to have an effect on cotton root length. Cotton planted in 76 or 50-centimeter rows had significantly longer roots overall and at a 0 to 15-centimeter soil depth than did drilled cotton. At 30 to 45 centimeters below the soil surface, a 76-centimeter row spacing enabled significantly longer root growth than did drilled cotton, but cotton planted in 50-centimeter wide rows could not be separated from the other row widths (Table 24).

Soybean root data compared well with that of Tyler et al. (1987) who conducted similar root studies on a Grenada silt loam in West Tennessee. This gave confidence that the technique for determining root length was performed in a

Table 24. Effects of row spacing widths on relative root length for cotton planted with five reduced-tillage planting systems in 1987 at Milan Experiment Station.

Row Spacing (cm.)	Overall	Mean Root Length (cm.) at Depths of 0-15cm	Mean Root Length (cm.) at Depths of 30-45cm
76	186.4[a]	358.4[a]	142.7[a]
50	180.8[a]	355.6[a]	110.0[ab]
20	110.7[b]	196.1[b]	81.1[b]

Means with same letter within columns are not significantly different at 0.05 level.

proper manner. Such a comparison for cotton root length was not available.

Yield

Table 25 presents soybean yield data from this experiment. Yields ranged from a low of 1650 kilograms per hectare for the no-till drilled soybeans, to a high of 1840 kilograms per hectare for the soybeans planted with the John Deere no-till planting system.

Table 26 summarizes seed cotton, percent gin turnout, and lint yields. Seed cotton yields ranged from a high of 3690 kilograms per hectare for the John Deere no-till cotton to a low of 2610 kilograms per hectare for the ridge-tilled cotton. Gin turnout ranged from 29 percent lint for no-till drilled cotton to 35 percent lint for ridge-tilled cotton. The Case-IH no-till unit produced the most cotton lint at 1230 kilograms per hectare, whereas the ridge-tilled cotton also produced the least lint, at 890 kilograms per hectare. No significant difference was found between any of the seed or lint yields.

Table 25. Soybean yield under five reduced-tillage planting systems in 1987 at Milan Experiment Station.

Planter System	Tillage System	kg/ha
Buffalo All-Flex	RT	1710
Bush Hog Ro-Till	IR	1810
Case-IH Cyclo-Air	NT	1820
John Deere # 7100	NT	1840
Marliss Drill	NT	1650

Means are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

Table 26. Cotton yield under five reduced-tillage planting systems in 1987 at Milan Experiment Station.

Planter System	Tillage System	Seed Cotton kg/ha	Gin Turnout %	Lint kg/ha
John Deere # 7100	NT	3690	33	1220
Bush Hog Ro-Till	IR	3280	34	1120
Case-IH Cyclo-Air	NT	3510	35	1230
Marliss Drill	NT	3180	29	920
Buffalo All-Flex	RT	2610	34	890

Means are not significantly different at 0.05 level.

Tillage systems- NT=No-till, RT=Ridge-till, IR=In-row subsoiling

CHAPTER V

SUMMARY AND CONCLUSION

Summary

Performances of five commercially available no-tillage and reduced-tillage planting systems were evaluated for soybean and cotton production. Objectives of this study were: (1) to evaluate planters and components on the basis of depth, in-row spacing and seed coverage, (2) to use stand counts and plant morphological characteristics to compare the abilities of planters to produce viable plant stands, (3) to discern any advantages among the planting systems as to soil moisture preservation and plant root growth, and (4) to compare any advantages in crop yields of cotton and soybeans and ginning qualities in cotton as related to planting system.

Planter systems were operated at the University of Tennessee Milan Experiment Station near Milan, Tennessee. Seed depth, seed spacing, plant height and plant canopy measurements were analyzed statistically, with means and/or coefficients of variation determined for each planter system.

Soil core samples were taken in-row and between row middles to determine soil moisture and plant root length. Soil moisture was determined by gravimetric analysis, while mature plant root length was determined by using a line-grid intercept method. Young soybean plants were excavated and taproot length measured with a ruler. An analysis of variance was conducted to determine if tillage systems had any effect on these properties.

Soybeans were harvested with a combine, while cotton was stripped and evaluated for gin turnout. An analysis of variance was conducted to determine if tillage systems had any effect on the yields of both crops and gin return of cotton.

Examination of planter performance data resulted in the following summary of results.

1. All planter systems generally performed satisfactorily with respect to field operation and seed placement. However, the John Deere Model 7100 left several seeds on the soil surface or uncovered with soil after being placed in the furrow.

2. Coefficients of variation for depth of seed placement ranged from 16.4 to 67.8 percent. Mean seeding depths ranged from 1.6 to 3.9 centimeters.

3. Coefficients of variation for seed spacing ranged from 56.4 to 95.9 percent. Mean seed spacing ranged from 0.3 to 24.5 centimeters.

4. Soybean canopy height and width measurements taken 36 days after planting ranged from 24 to 39 centimeters and 20 to 30 centimeters, respectively. Seventy-two day measurements of soybean canopy height and widths ranged

from 93 to 100 centimeters and 28 to 41 centimeters; cotton data from the same growth stage ranged from 86 to 105 centimeters and 38 to 53 centimeters, respectively. Measurements of cotton plants at 110 days revealed significant differences in plant growth characteristics, whereas soybeans measured at this growth stage exhibited no significant differences as a result of tillage treatment.

5. Soybean plant stands ranged from 7.2 to 25.6 plants per meter of row, and emergence ranged from 30.2 to 97.5 percent. Cotton plant stands ranged from 5.2 to 16.4 plants per meter. Tillage practices did have a significant effect on plant stand and seed emergence.

6. Mean overall soybean soil moisture ranged from 11.5 to 12.5 percent (wet basis). Overall cotton soil moisture ranged from 10.6 to 11.8 percent (w.b.). Tillage treatment was found to have a significant effect on soil moisture. Row spacing was also found to have a significant effect on soil moisture on several occasions.

7. Mean overall mature soybean root lengths ranged from 217.7 to 264.7 centimeters. No significant difference was found among tillage treatments. No-till drilling of soybeans produced slightly longer roots than soybeans planted with the two other no-tillage treatments. Ro-tillage produced 10 and 20-day old soybeans with significantly longer taproots than other remaining planting systems. Mean overall cotton root lengths ranged from

110.7 to 211.1 centimeters. Tillage treatments and row spacing were found to affect cotton root length.

8. Soybean yields were found to be not significantly different and ranged from 1650 to 1840 kilograms per hectare. Cotton lint yields ranged from 890 to 1220 kilograms per hectare. These figures were also not significantly affected by tillage treatment.

9. Gin turnout percentage of cotton lint ranged from 29 percent for no-till drilled cotton to 35 percent for Case-IH no-till cotton.

Conclusion

The reduced-tillage planting systems evaluated in this study offer choices in cotton and soybean production methods that result in similar crop yields. However, plant growth characteristics for crops planted with the various planting systems may vary at given points in a crop production cycle.

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