THE EFFECTS OF WHEAT DRILLS AND PRIMARY TILLAGE ON STAND ESTABLISHMENT AND EARLY GROWTH OF WHEAT

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Wheat is grown in almost all countries around the world because it is a major food for most of the world's population and has wide adaptability. Success in getting satisfactory wheat yields often depends on seedbed environment created by tillage and planting equipment. While favorable seedbed conditions encourage emergence and seedling development, harsh seedbed environments may cause delayed germination and poor stands. In wheat production, like other crops, obtaining a quality stand is essential for maximum yield, since there is an optimum plant population for each given situation.

Mulch tillage conserves soil moisture, reduces soil erosion, and saves time, money, fuel, machinery costs, and labor in many cases. However, in Oklahoma, planting winter wheat in no-till frequently results in stunted plants and lower grain yields than conventional planting methods. Generally no-till reduces wind and water erosion of top soil by means of surface residue. Surface residue helps conserve moisture in the soil profile by reducing evaporation from the soil surface. In dry years, this conserved moisture allows earlier planting in the fall. But, the use of no-till may create some production problems for the farmers too. The crop residue left by no-till cultivation may harbor insects and disease organisms. Previously, weeds have been controlled by tillage operations, but in a no-till system now they must be controlled with herbicides.

Grazing of wheat in the Oklahoma during fall and winter has economic importance in terms of beef production. Many of the wheat growers in Oklahoma graze winter wheat until late winter and then harvest it for grain. However, soil moisture effects of grazing wheat fields may create problems in seedbed preparation and seeding operations of wheat, Krenzer et al., (1989).

Soil compaction or hard pans, created by several factors including livestock and field traffic, can be a limiting factor to wheat yield under certain circumstances. A compacted layer not only increases soil bulk density but physically prevents crop roots from developing properly. It also slows water movement through the soil. Tillage with a moldboard plow can alleviate the compaction, however it buries the crop residue leaving the soil surface unprotected and susceptible for both wind and water erosion. Tillage implements which loosen the soil underground while leaving the surface undisturbed are desirable. The parabolic shank subsoiler (Big Ox) and the bent leg subsoiler (Tye paratill) may be desirable, yet additional information about their effects on wheat growth is needed.

Today, there are many kinds of wheat seeding drills that have been in use for different soil conditions. Although drills have different kinds of openers, seed metering systems, and fertilizer placement systems, they are basically characterized according to their ability of seeding in no-till conditions. Some drills are designed only for conventional tillage, while others are used primarily for no-till conditions. Certain drills can be used in both conventional and no-till systems. Drills which are able to perform satisfactory in both conditions are desirable. Thus, drills should be rated for residue handling, soil penetration, uniform seed placement, seedling emergence under various types of tillage conditions.

More information is needed about the best planting equipment and tillage methods in monoculture grazed winter wheat production in order to get high stand establishment and good seedling development. The effects of tillage and planting equipment on germination, stand establishment, main stem leaf stage, and % tiller formation of winter wheat should be determined for different soil types of Oklahoma.

Thus, this study was designed to evaluate the two new drills compared to an existing drill, in relation to stand establishment and early plant development (stand, seeding depth, mainstem leaf stage- MSL, and percent of the plants having the early tillers present).

CHAPTER II

LITERATURE REVIEW

Seedbed conditions and early plant growth environment are integral parts of obtaining high wheat forage and/or grain yields. Several factors such as soil moisture, soil temperature, soil aeration, soil texture, soil compaction, and residue conditions may independently or interactively determine seedbed quality. Favorable seedbed conditions enhance seedling emergence while harsh seedbed environment can result in erratic, poor stands, thus limiting the crop's productive potential (Wilkins et al., 1982). Therefore, the main objective of selecting appropriate tillage and planting equipment is to ensure placing seeds in favorable seedbed conditions.

The important measurement which is most often used to evaluate the seedbed conditions created by tillage and planting systems is plant stand. Stand is the number of plants per unit area, and shows how many of the planted seeds developed into plants. Stand counts, taken periodically during the emergence process, can be used to identify the amount of stress imposed by the seedbed conditions (Wilkins et al., 1982). In case of any kind of seedbed stress, delayed emergence or a slow rate of emergence can be observed. A nonuniform emergence is the result of varying degrees of stress on the emerging seedlings due to compaction, nonuniform seed placement, dry soil, poor soil-seed contact, or a combination of these constraints. Assuming a uniform planting depth, plants that emerged earlier would have had the better seedbed conditions than those which emerged later.

Seeding depth, previous tillage, soil moisture, and soil temperature are important factors in stand establishment. When the soil surrounding the seed has 9% moisture or greater, emergence is enhanced, but if the soil moisture surrounding the seed is 6% or less germination will be reduced (Wilkins et al., 1983). If the seeding depth of wheat exceeds 5 cm, stand reduction can be expected (Hadjichristodoulou and Phatiades, 1984). Burleigh et al., (1965) got better emergence at 5 cm planting depth than at 7.5 or 10 cm depths at both 10^0 C and 32^0 C (soil surface temperature). They found greater reductions in emergence as seeding depth increased at 32^0 C than at 10^0 C. In addition to seeding depth, Wilkins et al., (1989) determined that preplant tillage improved emergence compared to no preplant tillage.

Besides seedbed conditions, the quality of the early growth environment also has an important effect on production of forage and/or grain yields. Surface residue conditions, compaction, soil moisture, temperature, and photosynthetically active radiation (PAR), are some of the factors that comprise early plant growth environments.

Soil compaction created by livestock or field traffic can physically restrict root development. Plants grown in such conditions are reduced in size, they have a smaller number of leaves and stems/plant are reduced in stature (Peterson et al., 1984). Deep or shallow profile disruption by subsoiling usually promotes root penetration through the hard pan or compacted zone (Ide et al., 1984).

Sometimes no-till planting may result in reduced root development of cereals. Ellis et. al., (1977) found less early growth of seminal roots in spring barley grown under no-till, as compared to conventional tillage. No-till planting also can affect root distribution. Hodgson et al., (1976) found a lower root proportion in 2.5-12.5 cm soil horizon of no-till plots than in shallow or deep tilled plots.

Tillage systems also have an important affect on early shoot development of wheat. Chevalier and Ciha (1986) reported that early wheat stands under conservation tillage may appear nonuniform. Additionally, they found reduced rate of leaf production and a reduced rate of tiller production in no-till plots compared to conventional tillage plots. Although soil moisture was available, Elliot et al., (1977) observed less early growth of no-till barley seedlings compared with the other treatments in a dry spring. However, grain yields over five years were not different.

Residue left by tillage and drilling operations affects the soil temperature by changing surface reflectance. A naturally vegetated surface reflects more sunlight than a bare surface (Benoit and Lindstrom, 1987). An increased reflectivity means lower net radiation absorbed resulting in lower soil temperature (Johnson and Lowery, 1985), and increased stored water (Blevins et al., 1971) in conservation cultivation. Higher soil water content and higher reflectivity on no-till plots with surface residue causes cooler temperatures in the rooting profile. Krenzer et al., (1985) reported that the highest temperature at 5 cm depth on no-till plots was 8^0 C cooler than the plowed plots during late August and early September. Although such differences may have deleterious effects on spring wheat germination, it would encourage germination of seed planted in August. Quantities of mulch up to 4.5 ton/ha can be used without deleterious effects on the wheat, while greater quantities should be managed either with tillage or drill implements (Anderson and Russell, 1964).

Morphological changes in plants have been detected visually and recorded quantitatively to determine the relative influences of environmental factors on plant growth. Higgins et al., (1964) observed wheat development by recording on each observation day the total number of leaves on the main stem and the fraction of the unfolding leaf. By using multiple regression analysis, Higgins et al., (1964) determined the effect of day length, temperature, solar radiation and soil moisture on the rate of daily leaf development under field conditions. They stated that significant agreement between computed and actual leaf development readings were obtained. This fact implies the utility of quantitative morphologic methods in determining the influences of environmental factors on plant growth.

Wheat development can be quantified in the field by visual observations (Haun, 1973). The Haun growth stage scale assigns a number to each leaf on the main stem. The leaves are numbered consecutively in the order of their appearance.

Klepper et al., (1982) combined Haun's scale and the tiller labelling system developed by Jewiss (1972), and described a leaf and tiller identification system. According to Klepper's definition, leaves are numbered in the order of their appearance. The coleoptile is (L0), the first leaf is (L1), the second leaf (L2), and so on. Main stem leaf stage (MSL) is described by counting the number of fully expanded leaves and the fraction of the length of the last leaf similar to Haun (1973). Klepper et al., (1982) called the tiller which developed at the base of the coleoptile "T0", the tiller which developed in the axil of the first foliar leaf "T1", that from the second leaf "T2", that from the third leaf "T3". Percent tiller formation (%TF) is the percentage of plants having the tiller which is under consideration.

The development stage of wheat can be determined easily and accurately by accumulating growing degree days (GDD), since plant development is influenced by heat units or GDD (Bauer et al., 1984). Growing degree day (GDD) is computed by summing ((Max.T + Min.T) / 2) -Base T, where Max.T is the highest temperature of the day, Min.T is the lowest temperature of the day, and Base T is the temperature below which no development occurs (0^0 C) over a growth period (Baker et al., 1986). In order to reach an equivalent main stem leaf stage, wheat plants grown in different environments accumulate the same amount of GDD. This method has also been used by researchers to measure the timing of the morphological development of wheat (Deibert and Utter, 1990; Rickman et al., 1983).

Rickman et al., (1983) found that 50% emergence occurred for Stephens winter wheat in Oregon near 100 GDD from planting. Tiller 1, T2, and T3 occurred at about 250, 300, and 375 GDD respectively in a fertile seedbed with adequate moisture. However, Bauer et al., (1984) in North Dakota found that spring wheat planted in moist soil without residue on the surface took 180 GDD from planting to emergence.

Growth environments affect the GDD required for reaching a particular stage. Nipp et al., (1991) showed that under low moisture conditions wheat required 101.9 GDD per leaf whereas 86.9 GDD per leaf was required under high moisture conditions. The lower GDD value, the faster leaves appear. Deibert and Utter, (1990) found 1182 GDD were required from emergence to 6-leaf main stem Haun stage in 1988 where the long term average was 946 GDD. Excessive temperatures in 1988 apparently caused high evaporation rates or plant stress that resulted in slower plant development. Leaf emergence rate increased with temperature until an optimum point was observed. A linear relationship between the number of leaves per stem and accumulated degree-days was reported by Cao and Moss (1989a) for wheat and barley at different constant temperatures in growth chambers. Increased leaf emergence rate (leaves/day) was obtained as day length increased, (Cao and Moss, 1989b) as well. Reduced tiller formation was obtained with reduced temperature and PAR-the rate of incident photosynthetically active radiation due to the high amount of residue (Wilkins et al., 1989).

Mainstem leaf stage (MSL) can be used as a measure of the preemergent seedbed environment (Klepper et al., 1982). They suggested that MSL rate was a function of accumulated GDD from emergence, however, others have discovered that MSL is affected by moisture (Nipp et al., 1991 ; Baker et al., 1986), and PAR (Rickman et al., 1985). Also, cultivars may be significantly different in MSL appearance in a particular environment (Nipp and Krenzer 1991). Thus, MSL should be used as a measure of the preemergent and postemergent seedbed environment reflecting the overall quality of the growth environment until the time of measurement.

Percent tiller formation (%TF) can be used to measure the amount of stress experienced by plants during the early developmental stages (Klepper et al., 1982). The absence of a particular tiller indicates that stress was present during that developmental stage. If plants were subjected to environmental stress in a developmental stage, a tiller may be aborted or delayed in forming. A tiller that has not formed, because of environmental stress, may develop later if the stress is removed before that developmental stage passed, (Klepper et al., 1984).

The coleoptile tiller (T0) was a good indicator of seedbed conditions during emergence (Peterson et al., 1982). Its growth was affected by seed zone conditions, such as planting depth and temperature, as well as by irradiance and seed size. Wilkins et al., (1989) observed a higher percent of plants with T0 in shallower seeded plots than in deeper seeded plots. Peterson et al., (1982) stated that T0 development is closely correlated with thin stands. Deibert and Utter (1990) observed that plants neither in plow nor in no-till plots developed T0 and concluded that this finding might be due to the higher stands. However, Rawson (1971) reported that wheat generally produce low T0. Soil moisture also has an important impact on percent T0 formation. Nipp et al., (1991) found that under high moisture treatment plants formed 45.7% T0, but 0% T0 were formed under low moisture treatments. The same moisture treatments had no effect on percent T1, T2 or T3 formation.

Tiller presence was influenced by changes in soil temperature and PAR caused by residue. On no-till plots, plants developed more T1 than those on plow plots (Deibert and Utter, 1990). In a dry year, Cochran et al., (1982) found significantly greater tiller numbers for winter wheat on no-till than in the tilled treatment. But in the second year, with fall rains above normal, they observed reduced tiller numbers in the no-till treatment.

Tillage methods have considerable influence on soil physical properties. Tilled soils generally have lower bulk density, increased macropore volume, reduced penetrometer resistance in the Ap horizon compared with no-till, (Benoit and Lindstrom, 1987). Such changes in soil physical properties and surface residue characteristics cause changes in stored soil moisture and soil temperature that are important for germination and early plant growth.

Animal traffic can affect soil compaction in wheat pasture by increasing soil bulk density and soil strength.

In a recent study reported by Krenzer et al.,(1989), animal traffic caused a 16% increase in soil bulk density, and 270% increase in soil strength in the first 2.5 cm soil depth. Such compacted soils may need special tillage operations to alleviate the compaction, or they may need different types of drills in order to get good seed placement needed for stand establishment.

Subsoilers have been used to alleviate soil compaction. Busscher et al., 1988 compared three subsoilers and reported that all three subsoiling implements effectively disrupted the E horizon regardless of surface tillage, and yields were not significantly different. Of the subsoilers observed, bent leg left the highest amount of residue on the surface.

Many years ago as reduced tillage was being introduced, it was discovered that new types of grain drill were needed to handle the extra residue resulting from high yields of the previous crop. Duley and Russell (1942) showed that 25 cm spaced, semi-deep furrow disc drills mixed too much straw with the seed causing delayed emergence. They developed a new drill which had an angled, flat-disc opener with an adjacent seed boot. The angled disc functioned by cutting residue and opening a seed slot in the soil giving better soil-seed contact. More recently, Allen and Fenster., (1986) reported that double-disc openers cause little soil disturbance, but have difficulty in penetrating firm soil without the help of a coulter. In general, coulters increase the capacity of the drill to operate through stubble. Coulters have not only beneficial effects but also deleterious effects in creating seedbed conditions. They cut residue easily if the soil surface is hard, but they push the residue into loosened, soft soil unless they are sharp, (Morrison and Allen, 1988).

Seeds placed in the zone of abrupt transition from marginal to adequate soil moisture are not likely to germinate (Wilkins et al.,1983). Single disc openers placed more seeds in the transitional moisture zone than did double disk opener. Therefore it is more likely that single disc opener will result in poor germination and thin stands. Lindwall and Anderson (1977) found hoe and shovel openers more effective than double disc openers in seed placement and optimum seed coverage that is necessary to get better germination. The hoe opener pushes dry surface soil aside resulting in the formation of ridges between seed rows. Because of providing better seed-soil contact by narrow seed trench and weighted press wheels, the hoe-press drills produce significantly greater seedling emergence than double disc on most tillage treatments (Allen, 1986). Payton et al., (1985), and Wilkins et al., (1983) reported that double disc openers did not penetrate heavy surface wheat residues well and tended to push straw down into the furrow resulting in poor seed-soil contact. Therefore, double disc opener had the highest stand in the light residue conditions, but the lowest stand in heavy stubble.

The standard deviation (sd) of seeding depth was used as a measure of the uniformity of seeding depth by Allen (1986), and Wilkins et al.,(1983). The more uniform the planting depth, the lower the sd. Standard deviations in seeding depth greater than 1.0 cm indicates lack of uniformity in seeding depth.

Recently, John Deere Co. Inc. developed two new drills; the John Deere 752-single disc opener for conservation or conventional seeding, and the John Deere 9450-hoe furrow opener for seeding in stubble and residue. These are reported to have very good seeding accuracy and depth control.

CHAPTER III

MATERIALS AND METHODS

Drill evaluations were conducted in four environments. There were Bethany silt loam (fine, mixed, thermic Pachic Paleustolls) and Tabler clay loam (fine, montmorillonitic, thermic Vertic Argiustolls) in 1989, and Bethany silt loam and Shellabarger sandy clay loam (fine-loamy, mixed, thermic Udic Argiustolls) in 1990 (Table I). All four environments were at a research location near Hennessey, OK, which represents the major wheat growing area of Oklahoma. This site was also selected because it had been heavily grazed during fall and winter of the previous cropping year followed by grain harvest. It was anticipated that the resulting soil surface compaction would challenge planting and early growth conditions within a no-tillage system.

The design of experiment was a RCB in a split plot arrangement with primary tillage systems assigned to main plots, and drills to subplots. Drill types were randomized within each main plot, and tillage types were randomized within each replication. There were four replications within each environment. An individual plot consisted of one pass of each drill 19 m. in length.

After harvest of the preceding winter wheat crop, the experiments were initiated with primary tillage as follows:

No-till

Chisel: chisel plow

Para Sub (Big ox): Parabolic shank subsoiler

Bent Sub (Paratill): Bent leg subsoiler

i) No-till: No tillage practice was performed on no-till plots. Residue was left standing.

ii) Chisel plow: A tillage implement that tills the soil to 15-20 cm depth. It has 28 duck-foot type legs each having 18 cm width with 30 cm row spacing, and 8 m working width. Parabolic legs bury some residue into the soil while cutting the soil underground.

iii) Para Sub: A parabolic shank subsoiler, designed to operate at 25-40 cm working depth. It has eleven parabolic shanks with 50 cm shank spacing, resulting in a 5.5 m working width. At the tip of each leg there is a 5 cm width piece of steel to make penetration easy through the soil. It buried some residue during soil inversion. Sharp, pointed shanks cut through the soil at a desired depth and break the hard pan created by animal or field traffic. This subsoiler has two pneumatic gauge wheels.

iv) Bent Sub: A bent leg subsoiler that loosens the soil underground without inverting soil leaving most residue on the surface. In a single pass, it reduces soil compaction and produces a ready-to-plant seedbed. The subsoiler is designed to operate up to 35-40 cm working depth. It has 4 legs angled at 45^0 to the side. A spring-loaded, 21.5 cm diameter ripple coulter cuts the residue in front of each leg. The legs are spaced 60 cm apart. There are two pneumatic gauge wheels ahead of the legs and adjacent to the coulters.

Tillage depth was 25-30cm for the Para Sub and 10-15cm for the chisel in all environments. Tillage depth was 40cm for the Bent Sub in environments I and II (Table II). Due to compaction and drier soils, the desired tillage depth could not be obtained with Bent Sub in environment III and IV., 25cm and 30cm were the tillage depths, respectively.

For secondary tillage chisel was used on chisel and big ox plots in early August, then in late August preplanting tillage was done with a field cultivator on chisel, Para Sub, and Bent Sub plots in the first year of experiment. In the second year, Para Sub and chisel plots were disked prior to tillage with these implements at the end of June. As secondary tillage, the chisel was used in late August, and preplanting tillage was performed in early September on all plots except no-till. Wheat residue and stubble were left standing in the no-till plots.

Grain drills included in the study were:

Single disc drill (John Deere 752)

Hoe drill (John Deere 9450)

Double disc (Marliss)

i) The John Deere 752 (Fig.1) is a single disc furrow opener drill for seeding on conservation or conventional seedbeds. Single disc furrow openers make it easy to penetrate into seedbeds with minimum soil disturbance. Openers are independently mounted on iron arms at a 7^0 angle from direction of travel. Single 46 cm flat opener discs provide easy cutting for opening the seed furrow. The gauge wheel contacts with the opener disc, and strips trash and soil from it during operation. The gauge wheel is a 11.5 width and 40.5 cm diameter semi-pneumatic wheel. A 2.5 x 30.5 cm rubber seed-firming wheel follows the opener to push seeds into the bottom of the furrow. Down pressure of this wheel can be adjusted from 12 to 142 (N) pressure. Following the seed-firming wheel is a 30.5 cm diameter press wheel with 7^0 attack angle and 20^0 vertical angle which closes the furrow. This closing wheel can also be adjusted from 12 to 19.5 kg down pressure. Sixteen shanks are mounted on two ranks, which are lowered by a hydraulic lift. Adjustable hydraulic down pressure can reach 2000 (N) per opener. The drill has 3.4 m working width with 21.5 cm row spacing.

ii) The John Deere 9450 (Fig.2) is a hoe furrow opener, press wheel drill, capable of seeding into stubble and residue. It has 17 shanks with hoe furrow openers. The opener shanks are 1.9 x 2.5 cm heat-treated spring steel, and are designed to keep constant depth penetration through the soil. A spring-cushion helps to protect the openers from damage on rocky and/or tough soils. The opener tips are 2.5 cm width shovels. Seventeen openers are arranged in 3 ranks to leave space for natural tunnels through the machine. Furrow openers are lowered by a hydraulic lift system. Seeding depth can also be controlled by this system. The drill has a 367 cm working width with 21.5 cm row spacing. Solid, 66 cm diameter press wheels are used to close the furrows, and to insure good seed-soil contact.

iii) The Marliss (Fig.3) is a no-till drill with a fluted coulter, and a double-disc opener. The drill has 10 shanks 20.3 cm apart which are independently mounted on iron arms. The 34 cm diameter double-disc openers are used to open the seed-furrows. In front of each double-disc opener there is a narrow fluted, 40 cm diameter coulter to cut through residue. Seed slot closure and seed firming is done by a 10 cm wide semi-pneumatic press wheel. Down pressure of press wheels can be adjusted by steel springs.

The three drills have the same kind of metering systems. Fluted feedcups (external fluted rolls) meter from seed box to furrow openers.

Planting was done in early September, the normal time of planting winter wheat used for grazing and grain in Oklahoma (Table I). Seeding depths were set to 2.5-3.5 cm for all the drills. The winter wheat cultivar Pioneer Brand '2157' was used at 90 kg/ha seed rate.

Conventional weed control was practiced, and fertilizer doses were applied according to recommended rate for optimum grain and forage yields. In 1989, after primary tillage but before preplanting tillage, nitrogen and phosphorus fertilizers were broadcast over the experimental area. In the second year, 18:46:0 (NPK) fertilizer was applied at rate 100 kg/ha in seed furrows at planting, then 28:0:0 nitrogen liquid fertilizer was applied on at 100 kg/ha one month after planting. The plots were grazed like other portions of the field.

Six sampling points (1 m length) were chosen for each plot immediately after planting. Stand counts were made at every 2-3 days until a constant stand was obtained. The number of plants/row and row spacing of drills were used in determining stand.

After plots reached the maximum stand count, 3 plants were chosen randomly in each sampling point, and excavated to measure seeding depth (cm). When all plants appeared to have reached 6 to 7 main stem leaf stage, 12 plant samples were collected from each tillage-drill experimental unit (2 plants from each sampling point) to determine MSL, percent T0, T1, T2, and T3 formation. A total of 576 plants were removed from each soil type in each year and placed in labelled plastic bags, and stored at $2^{0}C$ until all samples were evaluated for MSL stage and percent T0, T1, T2, and T3. Percent of plants with a particular tiller was calculated on a plot basis before analysis the data. Standard deviations (cm) were calculated for seeding depth on an individual plot basis. An analysis of variance was run on stand, seeding depth, standard deviation of seeding depth, MSL stage, percent T0, T1, T2, and T3 formation on a plot basis in all environments separately, then combined analysis was conducted. Duncan's multiple range test was used to separate the means.

Because percent tiller formation forms binomial data (tillers are either present or absent) the data were transformed using the arcsine of the square root of percent tiller formation (Steel and Torrie, 1980). An ANOVA was also run on the transformed percent tiller formation values.

Sixteen shanks of single disc drill are mounted on two ranks, eight in front, eight in back. Because eight shanks are placed in front, the rows planted by them are subject to be recovered by the depth bands on the back shanks pushing dry surface soils aside. This results in ridge formation on or near the front rows. Since this potential drawback was identified in the first year of study, observations were made on the basis of front and back shanks in the second year to test if there is significant difference between front and rear ranks of single disc and hoe drills.

CHAPTER IV

RESULTS AND DISCUSSION

Background Information

The following background information describes the conditions under which drills were evaluated. Preplant soil moisture was not different among tillage treatments in the surface 6 cm of soil in any of the four environments (data not shown). After planting, 66 mm of rain was received before final stand counts were taken in 1989. Much of this fell in one day, leaving the field very wet, resulting in abundant moisture for germination of all seeds regardless of seedbed conditions at planting. In the second year, 41 mm of rain was received between planting and final stand counts in env.III, and 35 mm in env.IV. Much of this fell in the first five days after planting.

Prior to planting in env.I, no-till had significantly higher bulk density in 0-3 cm depth than parabolic subsoiler and chisel with bent leg subsoiler being intermediate, however, the four tillage methods had similar bulk density in 3-6 cm depth (Table III). In env.II, no significant differences were found among tillage methods in terms of bulk density in either of soil depths prior to planting. In env.III, parabolic leg subsoiler gave significantly lower bulk density than no-till and bent leg subsoiler in 0-3 cm depth, however, in 3-6 cm depth parabolic leg subsoiler and chisel had significantly lower bulk density than no-till but bent leg subsoiler was intermediate. In env. IV, no-till had significantly higher bulk density than the other tillage methods in both 0-3 and 3-6 cm depth. Except env.IV, bent leg subsoiler ranked second in high bulk density. For the top 6 cm, penetrometer data was similar to those of soil bulk density indicating that soil strength in no-till generally was greater than in tilled treatments (data not shown).

Highly significant differences were found among primary tillage treatments in terms of % ground cover remaining after the primary tillage (Table IV). No-till had the highest % ground cover left in all environments followed by bent leg subsoiler, parabolic leg subsoiler, and chisel. These results agree with findings of Bussher et al., (1988). On the average, significantly higher ground cover values were obtained in 1990 than in 1989 for all primary tillage treatments.

Immediately after planting, the percent ground cover was less than 10% for all tillage and drill combinations except no-till plots (data not shown). The grain drills, however, had different effects on the amount of residue left immediately after planting on no-till plots (Table V).

Single disc opener drill and double disc furrow opener drill left significantly higher amounts of residue on the surface than the hoe opener in env.I and IV while no significant differences were observed in env.II and III. In most no-till stiuations, straw piled behind the hoe drill leaving bare spots in the plots and resulted in less % ground cover.

Final Stand (Plt/m^2)

Tillage x drill interactions were not significant in any environment. Significant env. x tillage, env. x drill interactions and environment effect were found in pooled analyses (Table VI). Significantly higher stand occurred in no-till treatment than tilled treatments in env.IV, and significantly lower stand was obtained from no-till in env.I (Table VII). Among tillage treatments the bent leg subsoiler had significantly higher stand than parabolic leg subsoiler and chisel in only env.I (Table VII).

Double disc drill had the lowest stand in env.III, while single disc drill had the lowest stand in env.IV (Table VIII). In env.I and II drills performed similarly. In general, there was no consistent difference among drills or tillage systems in terms of final plant stand.

Seeding Depth (cm)

A drill is desired which can easily be adjusted to a particular seeding depth and places seed uniformly at that depth. Drills were set to place seeds between 2.5-3.5 cm deep. The double disc drill was the most difficult to obtain a consistent depth from one tillage treatment to another primarily because of the difficulty in getting penetration in no-till. Adjustments were needed on the hoe drill and double disc drill to maintain a desired seeding depth as tillage treatment changed, but no adjustments were needed on the single disc drill. Even with these adjustments, env. x tillage x drill interaction for seeding depth was significant in pooled ANOVA (Table VI).

Significant tillage x drill interactions were detected in env.I and II while drill and tillage effects were significant in env.III and IV (Table IX). Single disc drill gave significantly greater seeding depth than double disc drill on no-till in all environments. But double disc drill tended to have greater seeding depth than single disc and hoe drills on tilled treatments. The hoe drill most often had acceptable seeding depth, while single disc opener drill placed the seeds slightly deeper. These findings are similar to those of Allen (1986). The double disc drill had difficulty in penetrating the soil on no-till plots even when about 350 kg of additional mass was added. These findings coincide with those of Payton (1985), Wilkins et al (1983). In env.III and IV where interactions were not significant, the single disc drill had deeper seeding depth than other two drills. This was caused by single disc drill having problem in obtaining desired seeding depth because of difference between front and back shanks. This is discussed later.

Standard deviation of seeding depth helps evaluate uniformity of seeding depth for a given situation. Smaller standard deviations demonstrate a smaller variance in seeding depth among seeds planted. In the combined ANOVA, env. x tillage x drill interaction was significant for standard deviations of seeding depth (Table VI). A significant tillage x drill interaction was found only in env.III and IV (Table XI). In no-till treatments, drills had similar standard deviations of seeding depth in both years. In chisel treatments, single disc drill had the least uniform seeding depth in env.III. In env.IV drills had similar standard deviations of seeding depth on chisel plots. In suboiler treatments, single disc opener again had the highest standard deviations followed by hoe drill. In general, the single disc drill had problem in uniformity of seeding depth especially in tilled treatments. In the other two environments, there were no significant differences among treatments. Since all standard deviations of seeding depth were 1.1 cm or less, these drills are considered to have uniform planting depth in env.I and II, Allen (1986), Wilkins et al (1983). However, in env.III and IV with the single disc drill in tilled treatments, the standard deviations in seeding depth were above 1.1 indicating poor seeding depth control.

Main Stem Leaf Stage (MSL)

The average MSL was between 5.6 and 6.2 for all environments. Since we did not measure MSL at a specific number of heat units after planting in each environment, it is no surprise to see an environmental effect. In pooled the ANOVA, significant till. x env. and drill x env. interactions were detected (Table VI). There was a tendency for lower MSL in no-till compared to tilled treatments in three environments (Table XII). Lower main stem leaf stage on no-till might be an indication of poor seedbed environment (Klepper et al., 1982) due to compaction, or higher plant residue that reflects more sunlight resulting in lower PAR reaching to wheat seedlings (Rickman et al., 1985). Among tilled treatments there was no significant difference in three environments. Only in env.I parabolic leg subsoiler had lower MSL than bent leg subsoiler.

Drills provided similar main stem leaf stage in env.I and II (Table XIII). While double disc drill had lower MSL than the other drills in env.IV, single disc drill had lower MSL than double disc in env.III. However, it is hard to see a consistent difference among drills that indicates plants on different drill treatments did not experience enough stress to effect the rate of MSL appearance.

Percent Tiller Formation (%TF)

Since the results of ANOVA for transformed and nontransformed data were the same, we used nontransformed data in tables for % tiller formations. Only environment and tillage effects were significant in pooled analysis for %T0 formation (Table VI). No-till had less % T0 than chisel, bent leg and parabolic leg subsoilers, 6%, 12%, 10%, 14% T0, respectively. There were no significant drill effects on % T0 formation indicating all drills created similar growth conditions.

Environment, tillage, and environment x tillage interaction were significant for %T1 formation (Table VI). No-till had significantly lower %T1 than tilled treatments only in env.III (Table XIV). In env.I and IV there were no significant differences among all tillage methods. Among tilled treatments parabolic subsoiler had significantly lower %T1 averaged over drills only in environment II.

Significant environment affect is detected for %T2 formation (Table VI). The fact that all treatments had above 90% T2 in env.I, III and IV indicates little stress was present during the T2 formation period, Klepper et al., (1984). The 87% T2 formation in env.II was significantly lower than other environments that might be due to the soil acidity. No significant differences were found among tillages as well as among drills in each environment.

Significant environment, env. x till, and env. x drill interactions were detected in pooled analyses for %T3 formation (Table VI). Tillage by environment interaction occurred because there were no tillage differences in env.I, II, III, but differences occurred in env.IV in which no-till had significantly lower %T3 than chisel, parabolic subsoiler, and bent leg subsoiler, 81, 89, 94, 94% respectively. Drills gave similar results that %T3 formations in three environments out of four were not significantly different. Double disc drill had significantly lower %T3 than single disc and hoe drills only in env.IV; 82, 94, and 94% T3 formation respectively. Among environments, env.II was significantly lower than env.I, III, and IV; 80%, 95%, 89%, and 90% respectively.

In terms of % tiller production, there was not much difference among drills. Environment II had lower %T0, T1, T2, and T3 than all others. In addition to soil acidity problem considerably higher bulk densities were detected in env.II (Table III). Cooperatively soil acidity and higher bulk density might be the cause of the lower tiller formation in env.II compared with the other environments.

Position of Shanks on the Drills

No significant differences for seeding depth and plant characteristics were detected between front and back shanks of hoe drill. Summary of data comparing back and front shanks of single disc drill is presented with Table XV.

Seeding depth for front shanks was deeper than back shanks in environments III and IV. Satisfactory seeding depth was obtained in rows planted with back shanks in both environments. Significant tillage x rank interaction for standard deviations of seeding depth was found. Front shanks had higher standard deviations on tilled treatments while no significant difference was observed on no-till (Table XVI). Back ranks seeded more uniformly than front ranks. No significant differences in final plant stand, %T0, %T2, and %T3 production were found between front and back ranks. The main drawback of having ununiform seeding depth was delayed emergence in front rows. Later germinated plants had significantly lower MSL stage compared with earlier ones, resulting in a significant difference in main stem leaf (MSL) stage between back and front rows (Table XV). Reduced MSL is caused by delayed emergence. Another important undesirable event resulted from deep seed placement was reduction in the number of TI. In environment III, plants planted by back shanks had significantly higher %T1 than those planted by front ranks. At first stand count, the front rank stand (50 Plt/m^2) was significantly (0.01 level) lower than the rear rank stand (104 Plt/m^2) in Env.IV. Because the rows planted with front ranks were recovered by dry surface soils pushed aside by back ranks, ridges formed on the front rows. To eliminate this problem adjustments are needed on front and back shanks of JD 752.

CHAPTER V

SUMMARY AND CONCLUSION

The hoe drill resulted in significantly lower percent ground cover in two out of four environments. In general hoe opener incorporated more residue than the single and double disc drills. The hoe drill also tended to drag up piles of residue in no-till.

Since double disc drill had a lower stand in one environment, single disc drill had a lower stand in another, no consistent significant difference was found among drills for final stand.

The double disc drill had the most difficulty in obtaining consistent depth from one tillage to another. Especially in no-till without added mass, it did not penetrate soil as effectively as the other drills. Single disc drill and hoe drill were effective in uniform seed placement in no-till. Adjustments were needed on the hoe drill and double disc drill to maintain a desired seeding depth from one tillage system to another. But adjustments were needed on front ranks of the single disc drill. Back shanks of single disc drill resulted in seeding depths close to the initial settings while front shanks always had greater seeding depth than expected in tilled situations.

All drills had standard deviations of seeding depth around 1.0 or less in two environments which indicates seeds on each row were placed uniformly in the first year of study. In the second year, drills did not have uniform seeding depth, moreover, standard deviations of seeding depth changed from tillage to tillage. For uniformity of seeding depth, double disc drill was the best, hoe drill was intermediate, and single disc drill was worst because of differences between its front and back ranks.

Even though no significant differences in MSL and percent tiller formation were observed between the drills, the single disc drill had significant differences in these plant characteristics with plants from rows planted with front shanks having less MSL and tillers than plants from back shanks. Plants from seeds planted by the double disc and hoe drills were uniform regardles of position of the planting unit.

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APPENDIXES

APPENDIX A

TABLES

TABLE I

ENVIRONMENTS INCLUDED IN THE TILLAGE AND DRILL EVALUATIONS

Environment	Year	Soil series	Planting Date
Env. I	1989	Tabler	September 7
Env. II	1989	Bethany	September 7
Env. III	1990	Bethany	September 14
Env. IV	1990	Shellabarger	September 25

TABLE II

TILLAGE DEPTHS (cm) AT FOUR ENVIRONMENTS

Environments	Bent Sub	Para Sub	Chisel
Environment I	40	25-30	10-15
Environment II	40	25-30	10-15
Environment III	25	25-30	10-15
Environment IV	30	25-30	10-15

TABLE III

PREPLANT SOIL BULK DENSITY ON TILLAGE PLOTS IN EACH OF FOUR ENVIRONMENT

Tillage	Depth(cm)	Environment			
		I	II	III	IV
No-till	0-3	1.61	1.60	1.26	1.51
	3-6	1.60	1.65	1.47	1.67
Chisel	0-3	1.37	1.50	1.12	1.23
	3-6	1.55	1.55	1.21	1.43
Para Sub*	0-3	1.39	1.48	1.06	1.25
	3-6	1.50	1.54	1.23	1.42
Bent Sub**	0-3	1.46	1.54	1.22	1.20
	3-6	1.56	1.56	1.33	1.34
LSD (0.05)		0.15	0.11	0.19	0.14

* Parabolic shank subsoiler

** Bent shank subsoiler.

TABLE IV

PERCENT GROUND COVER AFTER PRIMARY TILLAGE IN FOUR ENVIRONMENTS

	Environment			
Tillage	I	II	III	IV
No-till	93	88	93	92
Chisel	40	32	58	44
Para Sub*	47	59	60	60
Bent Sub**	64	61	75	78
LSD (0.05)	8	7	5	8

* Parabolic shank subsoiler,
** Bent shank subsoiler.

TABLE V

PERCENT GROUND COVER IN NO-TILL PLOTS AFTER PLANTING IN FOUR ENVIRONMENTS

	Environment			
Drill	I	II	III	IV
Double disc	78	85	78	92
Single disc	73	85	93	94
Hoe	56	78	77	54
LSD (0.05)	19	ns	ns	15

TABLE VI

POOLED ANALYSIS OF VARIANCE FOR SEEDING DEPTH, STAND, STANDARD DEVIATION OF SEEDING DEPTH, MSL, %T0, %T1, %T2, AND %T3 ACROSS FOUR TILLAGE AND ENVIRONMENT

		Mean Squares							
Source	df	Stand	Seeding Depth	Standard Deviation	MSL	%T0	%T1	%T2	%T3
Environment	3	34151*	1.3*	0.60**	1.2**	5503**	23119**	1042**	1923**
Rep (env)	12	3946	0.4	0.08	0.1	104	1240	582	245
Tillage	3	1374	7.4**	0.33**	0.2**	536*	900**	77	147
Env. x Till	9	6366**	1.2**	0.15*	0.2*	76	482**	58	238**
Drill	2	1508*	3.3**	0.87**	0.0	160	46	50	213
Env. x Drill	6	4705**	3.7**	0.19**	0.1**	218	125	20	420**
Till x Drill	6	910	1.6**	0.31**	0.0	125	63	45	119
Env. x Till x Drill	18	827	1.1**	0.15*	0.0	58	102	27	164
Error	96	676	0.32	0.08	0.03	122	106	37	97

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

TABLE VII

TILLAGE EFFECTS ON FINAL PLANT STAND (Plt/m^2) AVERAGED OVER DRILLS

Tillage	Env.I	Env.II	Env.III	Env.IV
No-till	124 c[+]	246a	220a	234a
Chisel	178 b	231a	218a	210ab
Para Sub*	176 b	228a	209a	207 b
Bent Sub**	214a	245a	205a	203 b

+ Means within environment with the same letter are not significantly different at the 0.05 level using Duncan's multiple range test.

* Parabolic shank subsoiler,

** Bent shank subsoiler.

TABLE VIII

DRILL EFFECTS ON FINAL PLANT STAND (Plt/m^2) AVERAGED OVER TILLAGE

Drill	Env.I	Env.II	Env.III	Env.IV
Single disc	174a*	238a	225a	196 b
Hoe	173a	236a	231a	219a
Double disc	172a	239a	182 b	225a

* Means within environment with the same letter are not significantly different at the 0.05 level using Duncan's multiple range test.

TABLE IX

SEEDING DEPTH (cm) AS INFLUENCED BY DRILL AND TILLAGE IN EACH OF FOUR ENVIRONMENT

Tillage	Drill	Env.I	Env.II	Env.III	Env.IV
No-till	Single disc	4.4abc^{+}	3.7 cd	-	-
	Hoe	4.1abcd	3.1 de	-	-
	Double disc	3.2 d	2.6 e	-	-
	Means	-	-	3.7 b	3.0 c
Chisel	Single disc	3.3 d	3.5 cde	-	-
	Hoe	3.4 cd	3.7 cd	-	-
	Double disc	4.4abc	4.8a	-	-
	Means	-	-	4.3a	4.6a
Para Sub*	Single disc	3.2 d	4.2abc	-	-
	Hoe	4.4ab	3.9 bcd	-	-
	Double disc	4.7a	4.7ab	-	-
	Means	-	-	4.5a	4.5a
Bent Sub**	Single disc	3.6 bcd	3.9 bcd	-	-
	Hoe	3.3 d	3.5 cd	-	-
	Double disc	4.6ab	4.9a	-	-
Tillage		ns^{++}	s	s	s
Drill		s	s	s	s
Tillage x Drill		s	s	ns	ns

\+ Means within environment with the same letter are not significantly different at the 0.05 level using Duncan's multiple range test.

++ ns, s nonsignificant and significant at 0.05 level using Duncan's multiple range test.

*,** Parabolic shank subsoiler, Bent shank subsoiler.

TABLE X

SEEDING DEPTH (cm) AS INFLUENCED BY DRILL AND ENVIRONMENT AVERAGED ACROSS TILLAGE

Drill	Env.III	Env.IV
Single disc	5.5a*	4.6a
Hoe	3.9 b	3.9 b
Double disc	3.7 b	3.7 b

* Means within environment with the same letter are not significantly different at the 0.05 level using Duncan's multiple range test.

TABLE XI

STANDARD DEVIATIONS OF SEEDING DEPTH (cm) AS INFLUENCED BY TILLAGE AND DRILL

Tillage	Drill	Env. III	Env.IV
No-till	Single disc	0.62 d[+]	0.64 d
	Hoe	0.92 cd	1.12abcd
	Double disc	1.05 bcd	0.70 d
Chisel	Single disc	1.65a	1.26abc
	Hoe	0.99 bcd	0.75 bcd
	Double disc	0.93 cd	0.83 bcd
Para Sub*	Single disc	1.70a	1.50a
	Hoe	1.09 bc	1.28ab
	Double disc	0.96 cd	0.74 cd
Bent Sub**	Single disc	1.59a	1.01abcd
	Hoe	1.41ab	0.97 bcd
	Double disc	0.83 cd	0.80 bcd

\+ Means within environment with the same letter are not significantly different at the 0.05 level using Duncan's multiple range test.

* Parabolic shank subsoiler,

** Bent shank subsoiler.

TABLE XII

TILLAGE EFFECTS ON MAIN STEM LEAF (MSL) STAGE AVERAGED ACROSS DRILLS

Tillage	Environment			
	I	II	III	IV
No-till	6.04a[+]	5.66 b	6.05 b	5.73 b
Chisel	5.89ab	5.73ab	6.19a	6.08a
Para Sub*	5.71 b	5.82ab	6.15ab	6.06a
Bent Sub**	5.93a	5.86a	6.19a	6.13a

\+ Means within environment with the same letter are not significantly different at the 0.05 level using Duncan's multiple range test.

* Parabolic shank subsoiler,

** Bent shank subsoiler.

TABLE XIII

DRILL EFFECTS ON MAIN STEM LEAF (MSL) STAGE AVERAGED OVER TILLAGE

	Environment			
Drill	I	II	III	IV
Single disc	5.89a*	5.80a	6.09 b	6.08a
Hoe	5.87a	5.68a	6.12ab	6.09a
Double disc	5.91a	5.82a	6.22a	5.84 b

* Means within environment with the same letter are not significantly different at the 0.05 level using Duncan,s multiple range test.

TABLE XIV

TILLAGE EFFECTS ON PERCENT OF PLANTS WITH T1 AVERAGED OVER DRILLS

	Environment			
Tillage	I	II	III	IV
No-till	84a[+]	49 b	86 b	99a
Chisel	91a	51 b	90ab	99a
Para Sub*	89a	34 c	94a	97a
Bent Sub**	94a	65a	94a	98a

[+] Means within environment with the same letter are not significantly different at the 0.05 level using Duncan's multiple range test.

* Parabolic shank subsoiler,

** Bent shank subsoiler.

TABLE XV

SOME AGRONOMIC MEASUREMENTS MADE ON ROWS PLANTED BY BACK AND FRONT SHANKS OF SINGLE DISC DRILL IN 1990

	Env.III		Env.IV	
Observation	Front	Back	Front	Back
Seeding depth (cm)	5.87	4.26**	5.2	4.0**
Sd. deviation (cm)	1.22	0.66**	0.94	0.63**
Final stand (plt/m^2)	212	225	186	198
MSL stage	5.94	6.22**	5.96	6.20**
% T0 Formation	11	10	28	36
% T1 Formation	82	96*	97	100
% T2 Formation	94	98	97	96
% T3 Formation	85	93	93	95

*, ** Significant difference between front and back shanks within environment at 0.05 and 0.01 levels of probability, respectively.

TABLE XVI

STANDARD DEVIATIONS OF SEEDING DEPTH AS INFLUENCED BY POSITION OF SHANKS AND TILLAGE AVERAGED OVER ENV.III AND IV

Tillage	Position of Shanks	Mean(cm)
No-till	Front	0.60 b[+]
	Back	0.65 b
Chisel	Front	1.15a
	Back	0.65 b
Para Sub*	Front	1.31a
	Back	0.63 b
Bent Sub**	Front	1.26a
	Back	0.64 b

[+] Means with the same letter are not significantly different at the 0.05 level using Duncan's multiple range test.

* Parabolic shank subsoiler,

** Bent shank subsoiler.

APPENDIX B

FIGURES

Figure 1. Single Disc Drill - John Deere 752

Figure 2. Hoe Drill - John Deere 9450

Figure 3. Double Disc Drill - Marliss

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