Planter depth control in no-till corn

Jeffery Scott Janke
Iowa State University

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Planter depth control in no-till corn

by

Jeffery Scott Janke

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INTRODUCTION

Proper seed depth is an important factor in the germination and growth of most crops but also one of the most difficult parameters of planting to control. Crop residue on the surface of the soil can impair proper operation of depth control mechanisms. With no-till cultivation seed depth is especially important. The seed needs to be both deep enough to insure that it is placed in moist soil, and shallow enough to insure that the soil temperature is sufficiently warm, so that emergence will be fast and uniform.

The lack of specific data on depth control and seed corn emergence leads to several questions. What is the affect of depth variability on seed emergence rate and total emergence? Can seed depth variability effects be overcome by deeper or shallower planting? What environmental factors influence depth variability and resulting germination the most? How does residue complicate depth control and can detrimental effects of no till be overcome by removing residue? What is the depth control performance of currently available planters? If one wishes to try a no till management system what adaptations can be made to his/her current planter to make it operate efficiently in residue? Questions such as these need to be answered if producer acceptance of no till corn production systems is to increase.

The objectives of this study are:

- To provide specific information on planter seed depth variation as influenced by soil moisture, residue conditions, and tillage.
• To evaluate the effect of slot planting and strip till devices on depth control.
• To determine plant emergence response to depth control.
• To investigate the effect of press wheel design on seed depth.

Items secondary to the main objectives were to design a new strip till device and to compare seed depth determination methods.
In the last 10 to 15 years, conservation tillage practices for the continuous production of corn have become popular with many farmers. Especially noticeable is the use of methods that do not require primary tillage, i.e., slot planting and till planting. Slot planting will be defined for this paper as any planting method that does not disturb the soil more than is needed for passage of the opener. Till planting will be regarded as techniques that remove residue and soil from the row area; the width of the cleared area being no more than half that of the distance between rows. Some strip till planters also contain elements that do some tilling of the soil below ground level in the row area. With both planting methods, corn stalks left from the previous season may have been shredded before planting.

Several advantages are named for the use of conservation tillage methods. The one touted most by soil conservationists and environmentalists is the reduction in soil erosion achieved by leaving residue on the soil surface. Laflen and Colvin (1981) reported that soil with low amounts of residue cover would have increases in erosion rate of large as 10 to 1, after continued simulated rainfall. Soil with high levels of natural residue cover would only have an erosion rate increase of about 3 to 1 after the same amount of rainfall.

Other reasons for the adoption of conservation tillage practices tend to be economic ones. Colvin et al. (1983) determined that on their fields in Southeast Iowa, slot planting and reduced tillage of corn
(disc or field cultivator for primary tillage) required 65% and 71% of the amounts of labor required for the conventional tillage method (fall plowing). Measurements showed that slot planting and reduced tillage fuel consumption were only 41% and 67% respectively of that required for conventional tillage.

These advantages are meaningful only if yields can be maintained at levels equivalent to those of conventional tillage or if they are reduced by a monetary value that is no larger than that of the savings in labor and fuel. The first step in achieving the required yields is planting.

**Slot planting methods**

Several researchers have investigated slot planting techniques at different locations and in different residue conditions. Griffith et al. (1973) used a planter equipped with fluted coulters in their comparison of eight planting systems. The coulter loosened a strip of soil about 5 cm deep and 6 cm wide. Stalks were shredded prior to planting. Mock and Erbach (1977) used straight coulters for their four treatment study. Testing was done with stalks both shredded and unshredded. Morrison (1978) developed a coulter that ran between the double discs of the opener mechanism. The design was notable for its compactness and was patented. Erbach (1982) used a coulter in front of the opener in two treatments of a seven treatment study.

Powered coulters were also investigated by several researchers. Erbach (1978) tried three different methods of powering coulters for
improving residue cutting and handling. The first was called the residue cutting runner. A knife was run partly below ground and extended under and to the front of a rotating coulter. As uncut residue was lifted up by the knife it was caught by the coulter which ran in a slot in the knife. The plant residue sheared between the coulter and knife at the point where the coulter entered the slot.

The second was a notched coulter with the tips offset in opposite directions so a kerf was made in the soil as the coulter was rotated ahead of a stub runner. The stub runner held the furrow open until the seeds were placed. The coulter was run counter to the direction of travel.

The third setup consisted of a notched coulter whose trailing edge was between the front of the double disc openers of the planting unit. It was also rotated counter to the direction of travel but the tips were not laterally offset.

Buchele (1979) designed a rotary tiller slot planter. A subsoiler shank opens the initial seed trench and deposits the fertilizer. Rotary tiller knives cut residue which catches on the subsoiler shank. The rotary tiller knives also supply loose soil to cover both the fertilizer and the seed which is placed above the fertilizer.

Slot planting results

Although slot planting would seem to be a very simple method of reducing tillage, it has some notable drawbacks. While most slot planters use a nonpowered coulter in front of the openers to cut
Residue, the effectiveness of the coulter varies. Choi and Erbach (1983) studied the effects of different coulter shapes and sizes on the efficiency of cutting cornstalks. Percentage of stalks cut depended mainly upon the moisture content of the stalk and the firmness of the soil beneath. Little difference was seen in different shapes or sizes of coulters. Uncut stalks present handling problems for the planter. They can be a source of plugging which requires time to remove. Stalks pressed into the seedbed may have a detrimental effect on germination by preventing proper uptake of moisture by the seed.

Reduced soil temperature in the row area can be related to residue amounts on the soil surface. Because slot planting leaves the bulk of the residue undisturbed the soil temperature in the seed area tends to be lower (Mock and Erbach, 1977 and Griffith et al., 1973).

Reduced stands is another problem that has been associated with slot planting. Mock and Erbach (1977) and Burris and Erbach (ca 1983) report slower emergence in slot till when compared with moldboard plow. This would relate to the final yields which were reported to be lower than in comparable moldboard plots by Griffith et al. (1973).

Strip till methods

Efforts have been made to avoid the problems encountered with slot planting by clearing the residue away from the row area. There are several approaches to this.

The most common method of till planting, especially when done on ridged rows, is the Buffalo till planter. Several versions have been
made. The one feature characteristic of them is the clearing device. It is a pointed shovel that is set to run several centimeters deep and clear away sizable amounts of soil as well as residue. The operation of the planter is described by Wittmuss et al. (1971).

The earliest strip till planter of record was an experimental model reported by Poyner (1950). The planter and strip till assembly were separate units, both tractor mounted. The tillage portion was mounted alongside the front of the tractor and consisted of a combination rolling coulter and gauge wheel followed by a 76 cm sweep over a 63 cm subsweep. Following the sweeps were a set of four rotary hoe wheels to till a 20 cm wide seedbed and to power fertilizer hoppers. It was designed for operation in 102 cm rows leaving only a 25 cm strip of undisturbed soil. The draft requirements of the device were considerable.

Triplett et al. (1963) used a modified form of the Poyner planter for planting in corn stubble. This one had only one 35.5 cm sweep per row. Depth wheel and coulter were separate. Three rotary hoes were used instead of four and were not used to power fertilizer hoppers.

Parsons et al. (1982) compared three strip till attachments, adapted to fit a regular planter, to the performance obtained from a Buffalo planter. The treatments were: sweep and trash guards adapted from a Buffalo planter, factory option vee wing attachment, factory option double disc furrower, no till coulter, and planter without attachments. The last two are not strip till devices. Both factory
options were not meant for strip till, however they concluded that the double disc openers were the most likely to operate trouble free over the widest range of conditions.

A PTO powered rotary tiller for clearing row areas was developed by Griffith et al. (1973). Strips 20 cm wide and 10 cm deep were prepared in rows from the previous year. A conventional planter followed immediately behind.

A wholly different approach was taken by Richey and Griffith (1977). They developed a two row mulcher-ridger. It was used independently of the planter either in the late fall after harvest or in the early spring before planting. It would pick up the residue and move it into valleys formed by ridging discs. Power was PTO supplied. In 1975, a flail shredder was adapted for making ridges and moving residue. Performance was better than with the two row model but some drawbacks still remained. Power requirements were fairly high and one of the ridges made on each pass was always slightly compacted because of the location of the wheels. This method of ridging would also seem to be an extra field operation that should be avoided if possible.

Many strip till and slot till attachments for conventional planters have made their appearance in the last few years. Most use either a shovel or a double disc clearing device and have depth wheels with or without coulters. Because of the number and variety of such devices few attempts have been made to evaluate them. None have been revealed by a search of the literature.
Till planting results

In general, many of the problems associated with slot planting have been alleviated by the strip till method of planting. Soil temperatures for the row areas in strip till were shown to be essentially the same as those for moldboard plow treatments by Griffith et al. (1973), and Richey and Griffith (1977). In the study by Triplett et al. (1963), percent emergence was the same for the strip till planter and the conventional planter. However, Griffith et al. (1973) had consistently good stands with conventional tillage and irregular performance with the strip till planter; sometimes very good and sometimes rather poor depending upon soil type.

However, there are difficulties with machine operation when planting on ridges. Both Parsons et al. (1982) and Richey and Griffith (1977) reported problems with keeping the pull type planters centered on the ridges. Parsons et al. (1982) tried guide cones and stabilizing coulters but stated that both fell short of desired performance levels. Richey and Griffith (1977) tried guide shoes and rolling discs but had scouring problems with both types of guides. Parsons et al. (1982) suggested that the ridge shape might be changed to a flatter and wider profile to allow the planter more room for lateral error without affecting planting performance. None of the planters reported worked well when operated off the ridge.
Important Planter Performance Characteristics

USDA-ARS agricultural engineer Walter Lovely, in an article by Sommers (1973), stated

We don't think that a planter's metering system is a major problem anymore. Properly set up and operated today's planters do an adequate job. We think the big problem is putting seed in the right soil environment—that's where we're losing out. At present, we're only getting 70-80% efficiency out of the seeds dropped—and that's not enough.

Research in the literature supports this. Even in no till planting good spacing uniformity can be achieved (Jasa and Dickey, 1982). The key to a good seed environment would seem to be depth control.

Depth variability studies

Unfortunately, few studies have been conducted on planter depth control for corn. Agnes and Luth (1975) state that "because of the difficulty in taking data, little published information is available on depth variability". Things have not changed much since then. Agnes and Luth (1975) did provide some information concerning the John Deere Max-Emerge units. They indicate that at a speed of 9.7 km/hr and a mean depth of 62 mm the standard deviation was 8 mm.

Bateman (1972) in a study of 32 planters being used by farmers in Illinois, found an average standard deviation of 11.4 mm when the depth setting was for 38.1 mm and the actual average was 40.6 mm. Standard deviation for a depth setting of 76.2 mm was 15.0 mm with an actual average depth of 71.1 mm. The variation in depth helped to explain the variation in number of plants emerged and the delay in emergence. Late
emerging plants tended to be smaller than average and normally did not produce ears.

Two studies exist which give information about seed depth variability in conservation tillage environments. Mock and Erbach (1977) compared the seed depth variability for different treatments as a part of their study. Their results show an increase in seed placement variability with an increase in surface residue. Planters on moldboard plowed plots at an average depth of 60 mm had a standard deviation of 8 mm. The strip till planted seeds had an average depth of 39 mm and a standard deviation of 14 mm. A no till coulter equipped planter operating on ridges in no till had average depths of 47 mm and 62 mm and standard deviations of 28 and 20 mm for stalks not shredded and stalks shredded, respectively. The performance in no till would seem especially poor in light of Bateman's (1972) finding that variability decreased with average depth since the average seed depth in the no till plots is less than in the moldboard plots but the variability is greater.

The other study of planter depth control in various tillages is by Burris and Erbach (ca. 1983). The effect of gauging wheel location was evaluated. Depth wheel gauging at the point of seed drop produced less variation than that produced by gauging with the press wheel but the difference was not statistically significant. Seed depth variation was shown to increase with increasing amounts of surface residue but a powered coulter in no till environments reduced the effect somewhat.
Seed depth evaluation tends to be rather labor intensive if good data is desired. Morrison (1978) used statistical analyses of differences in plant stands as an indicator of depth variability in his studies. This does not give a precise estimate of actual variability however, and can be influenced by many other factors. Sensitivity to planting depth was increased by the use of sweet corn seed that was known to be sensitive to seeding depth.

Triplett et al. (1963) used percentage of planted seeds emerged as an indicator of planter performance.

Agnes and Luth (1975) measured the depths of 150 seeds in the field plots of their study. Seed depth was measured from the top of the seed to a reference level established by the ground level about 100 mm on either side of the row. This reference level would seem to be the source of some error as it is not directly related to the amount of soil above the seed. This would seem especially important considering the shape of the soil left by the closing wheels of the planter under study.

Burris and Erbach (ca. 1983) also made actual measurements of seed depths in the field. The depths of 10 seeds per subplot were obtained by measuring from a reference level to the soil surface and then from the reference level to the seed after it was exposed by removing the soil. The difference between the two numbers is the seed depth.

Mock and Erbach (1977) and Bateman (1972) gave no indication of the method used to obtain their seed depth measurements.
METHODS AND MATERIALS

The field experiment consisted of two parts: a comparison of slot planters and a comparison of strip till planter attachments. All field experimentation was done at the Agricultural Engineering Research Center west of Ames, Iowa. The soil is from the Clarion-Nicollet-Webster association. The crop of interest is corn (Zea mays L.) grown in residue from the previous year’s corn crop, i.e., continuous no till corn.

Strip Till Study

Equipment

Each of the two planters used for the strip till study, an International Harvester Early Riser and a John Deere Max-Emerge model 7100, contained four different devices, one per row. The planters were both originally six row models, but the outside row units were removed so they could be run on four row plots. Using four treatments on each planter had three distinct advantages. The first is that each strip till device would be run at the same speed as the others which would eliminate differences caused by variations in this parameter. The second is that it would require only one of each type of strip till device rather than four. The third is that it saves field space by enabling four treatments to be administered on each planter pass. The disadvantage is that the strip till devices must be randomly switched between rows to prevent any differences between the planting units from being interpreted as strip till treatment effects.
Stalk Skimmer

The strip till devices which were used included one of my own manufacture. The design was suggested by Dr. Wesley F. Buchele. He had seen a device that used a horizontal rotating disc to cut the stalks at ground level. He also suggested that the direction of rotation should be reversible so when the operator changed direction at the end of the field he would not end up with a row with double amounts of residue and another row with no residue. It was decided instead that for the purposes of this study one would be built which would have its own gauging system and turn in one direction only as that would be sufficient to test the principles of its operation.

The device, called the "Stalk Skimmer" is intended to cut the old stalks at or slightly below the soil level. This will keep to a minimum the amount of material that must be handled. It should remove some of the dry soil and leave a level strip of bare soil between 15 and 23 centimeters wide. No disturbance is to be done to the soil below the finished surface. Performance should be the same whether operating on ridged or unridged rows.

The Skimmer was constructed at the Iowa State University Agricultural Engineering Research Center near Ames. Virtually no information, such as expected loads, was available for aid in designing the machine.

The Skimmer (Figure 1) consists of a 25 cm disc driven by a vertical shaft which is contained inside a housing made from thick-
walled pipe. A shroud of 20 cm diameter and 36 cm height is attached to the same shaft as the disc and rotates with it. The shroud is meant to keep cut stalks from falling back onto the cleared row. The disc is held onto the shaft with a large nut and rotated by studs on the bottom inside edge of the shroud that engage studs welded onto the disc.

FIGURE 1. Stalk Skimmer

The disc and shroud are powered by a Char-Lynn hydraulic Orbit Motor. It is supplied and controlled by the tractor remote hydraulics. A 48 tooth sprocket is attached to the motor and connected by a size 40 roller chain to a 14 tooth sprocket keyed to the drive shaft. The Skimmer has a target speed of 1000 RPM. The speed was decided upon after looking at speeds of rotary forage mowers. After some operation,
it was determined that the speed could be reduced without adversely affecting stalk cutting.

Six evenly spaced sickle teeth are welded around the edge of the disc. They extend past the edge of the disc about 1.5 cm. After a few test runs and the planting of several replications, some of the teeth had to be replaced because they fell off. This caused severe shaking of the mechanism and inadequate cutting performance. They were replaced with a type that welded easier after which no more trouble was experienced with them. The teeth provided excellent cutting action but caused a few sparks and flying fragments when stones were encountered. Safety might be a concern in this situation, but the risk of flying objects can be lowered by reducing the speed of rotation of the disc by as much as operating conditions will allow.

Failure of the motor mounting bolts (7.9 mm, 5/16 in dia) and chain stretch during operation became a problem during some of the runs. It was caused by suddenly shutting off the fluid flow to stop the machine when the planter was raised at the end of a row. The motor would lock up and the rotary momentum of the disc, shaft, and shroud had to be absorbed by the chain and mounting bolts. Abrupt stopping of the motor could be reduced somewhat by "feathering" of the valve as it was turned off, but the operator could not be relied upon to do this.

A one-way valve was installed between the supply lines to alleviate the problem. It allowed rotation in the counterclockwise direction only (looking down) but this was acceptable. When the valve was turned off,
the motor would become a pump and push oil out of the outlet where it would go through the valve and back into the inlet. This allowed the rotary elements to coast to a stop and dissipate their energy through hydraulic friction.

The gauging mechanism of the Skimmer consisted of a notched coulter with a depth band. The notched coulter was selected because it was available and of the desired diameter. The depth band was welded to a circular plate and bolted to the coulter. The bearing was mounted to the plate holding the depth band so the coulter could be removed and the Skimmer operated with just the depth band. The bearing is from a cultivator hiller attachment and not very suitable for its intended service. It failed once during the experiment. It is a thrust pad bearing trying to support an axial load. A roller type bearing would have been more suitable.

The coulter and depth band are placed to the side of the row for two reasons; to prevent punching of residue into the seed area and to prevent stalks from being dragged around by the disc. Elimination of stalks from the seed area is desirable for reasons stated in the literature review. The coulter pinches stalks which it cannot cut against the ground on the side of the row. This holds the stalks in position while the blade cuts them, thereby keeping the stalks from becoming wound up on the shroud. To utilize these benefits the disc can only rotate in one direction.
The supports for the coulter and depth band allow for adjustment in three directions; vertically, in the direction of and perpendicular to the direction of travel.

The drive shaft housing and depth regulation unit are connected by an angle iron frame which is attached to the planter with a parallel linkage. The cutter and linkage is pushed rather than trailed in operation. A stiffening member connects each pair of similar links to prevent binding of the linkage as the machine is pushed by the planter tool bar. The bottom stiffener also provides a mounting location for one end of the down pressure spring. The other end is connected to the depth band support brace by a threaded rod which is used to adjust tension in the spring.

Test runs were made to check the operation of the unit before planting. Some redesigning of the Skimmer was deemed necessary after these initial operations because of unforeseen stresses. Additional clamping members were added to the depth band support structure and a heavier mount was made for the motor. No more problems were experienced after these alterations were made.

**Adaptation of strip till devices**

*John Deere planter* The other three strip till devices used for treatments in the experiment were all commercially available units. They were; the Econ-O-Till by Hiniker Corporation, the Trash Whipper by Acra-Plant, and the Ridge Mate produced by Mr. Ernie Behn of Boone, Iowa. They are all advertised as being adaptable to most currently available planters and are made to fit the John Deere model 7100.
The Trash Whipper mechanism (Figure 2) is composed of a mounting bracket and a double disc row clearing component. The notched discs are mounted back to back, concaving away from the row. The discs are set with one slightly ahead of and slightly overlapping the other.

FIGURE 2. Trash Whipper

The Trash Whippers were mounted on John Deere clod mover brackets which are very similar to those supplied by Acra-Plant. This was done so that the mounts which came with the Trash Whippers could be mounted on the International Harvester planter and left in position. This allowed rapid switching of the two Trash Whipper units between planters. The Trash Whippers are held to the mounting brackets by a pin and spring clip. A series of holes is provided in the mounts for depth adjustment. Additional holes had to be drilled in the bottom of the John Deere mounts so the Trash Whippers could be set low enough for operation.
The Ridge Mate (Figure 3) has three basic parts held together by a frame and supported by a four bar linkage which is connected to the planter units' four bar linkage. The first component is the depth gauge wheel, which unlike other strip till gauge wheels does not have a coulter as an integral part of it. The second component is the double disc sweep mechanism which is somewhat similar to that of the Trash Whipper. The third component is the leveling blades that trail the disc sweeps. They are set so the outer portion of the blade is lower than the row section. This leaves the row area slightly higher than the surrounding soil. Each component can be independently adjusted for working depth.

FIGURE 3. Ridge Mate on IH planter, two can be seen
The Ridge Mate has different mounting plates that are supplied as requested for different planters. There are two mounting plates per side which makes the system a separate four bar linkage. The plates are bolted to the connecting links of the planting unit using existing holes. Bushings are provided for pivoting of the links. Since the holes in the plates matched up very well with those in the planter linkage, modification of the unit was not necessary.

The Econ-O-Till (Figure 4) has a 35.5 cm horizontally rotating disc as its main row clearing tool. The disc is unpowered. It is mounted on its own four bar linkage which can be converted to a trailing or pushed mode. The depth gauging wheel is mounted in front of the disc and contains a coulter.

FIGURE 4. Econ-O-Till
The Econ-O-Till unit could only be attached to the outside row on either side of the planter because of interference from the tractor tire and 3-point hitch mounts on the planter. The U-bolts that held the planting units to the tool bar had to be removed and replaced with bolts that ran through both the Hiniker unit and the planter unit mounting plates because the hole spacing on each was the same. This made mounting and dismounting slow and difficult.

After the Econ-O-Till was mounted, clearance problems persisted. Because the John Deere planter was a mounted type, the gauging mechanism came close to the rear wheels of the tractor (Figure 5). Contact between the tire and the Econ-O-Till was minimal.

FIGURE 5. Econ-O-Till position relative to tractor rear wheel
International Harvester planter

Three of the strip till devices used on the John Deere planter were used on the International Harvester Early Riser planter. Mounting and switching of the devices on the International Harvester was somewhat easier because of its pull type design. The Econ-O-Till, Stalk Skimmer, and Trash Whippers were used as before but the Ridge Mate was not. Instead, the fourth treatment was a set of John Deere closing wheels equipped with brackets so it could be mounted on the International Harvester machine in place of the factory closing system. A Trash Whipper strip till device was used with this unit.

The International Harvester covering discs and press wheel were removed and the bracket attached to the covering disc mounting hole which became its pivot point. The roll pin which holds the small rubber seed baffle on the runner was removed so a bolt could be inserted to fasten a bracket, which anchors the end of the closing wheel down pressure spring, to the seed channel. The rubber baffle was then reinstalled. The bracket was made so the John Deere closing wheels would have the same angle with both the ground and the line of travel as they do on a John Deere planter (Figure 6).

The Econ-O-Till unit did not fit the Early Riser planter very well. The holes did not line up with those in the planter unit mounting plate. It was decided to mount the Econ-O-Till against the U-bolts that secure the planter unit to the tool bar. The mounting bolts were angled out to metal plates with holes drilled in them which were placed on the other
FIGURE 6. John Deere closing wheels on International Harvester planter side of the tool bar (Figure 7). The setup was not intended to be permanent but did suit the needs of the experiment.

The Stalk Skimmer was mounted in a similar fashion. Bolts were run to plates in the back of the tool bar.

The Trash Whipper-mounting brackets required some adjustment to fit them to the parallel linkage of the Early Riser. Acra-Plant supplies brackets for the Early Riser that enable the disc unit to be mounted directly to the planting unit. However, it was felt that for a fair evaluation of the device between planters that they should be mounted directly to the links as on the John Deere.

Holes in the parallel links of the planter had to be drilled out to 11.1 mm. The brackets were also about 2.5 cm wider than the horizontal
distance between the links so extra long bushings and bolts had to be used. Holes also had to be redrilled in the mounting brackets to match the vertical dimension between pairs of links on the Early Riser planter.

**Strip till study field layout**

The strip till experiment was laid out in a split plot design. There were five replications, two subplots for planting dates, two subsubplots for tillage conditions, and four subsubsubplots for strip till treatments. The planting dates were selected so the planting would be done in relatively wet and dry soil moisture conditions. The field layouts are shown in Appendix B-2.
Two different target planting depths made up the subsubplot treatments. Depth 1 was to be approximately 64 mm deep and depth 2 about 20 mm deep. The settings were estimated by holding up a gauge wheel and eyeballing the distance from the bottom of the wheel to the bottom of the opener. Admittedly this was not very precise but the objective was to plant at two distinctly different depths.

The subsubsubplot treatments were the strip till devices arranged on the planters as described before.

The date and tillage were assigned as they had been for the study done during the year previous to this one. Planter, target depth, and strip till device arrangement were assigned randomly with a coin toss. Planter and target depth were determined so that there would be equal numbers of each level. Treatments could only be partially randomized within the rows. The Econ-O-Till and Stalk Skimmer were switched between the two outside rows. The Trash Whipper and Ridgemate or Trash Whipper alone and Trash Whipper with substitute closing wheels, depending upon the planter, were switched between the two inner rows.

Planting was actually done on three different days rather than two. The dry condition planting went slowly the first day and only the plots of planter 1 (John Deere) were completed. This was on July 9, 1984. That night it rained so three days later the wet condition planting was done. Sporadic rains held off the dry condition planting for planter 2 until July 23, 1984.
Planting speeds were the same as in the slot plant study. Variations in speed for different planter passes were not so critical here as all treatments of interest were on the planter at the same time and consequently all were operated at the same speed. Target seeding rate for the John Deere planter was 139,900 seeds per hectare. For the International Harvester, one pass was made at 76,000 seeds per hectare for the first pass and then increased to 92,300 seeds per hectare for the rest of the planting. High planting rates were used to lessen the amount of digging required to collect data for initial seed depths.

All of the digging for initial seed depths was successfully completed each day. Sprout length measurements were all taken on one day for the planter 1, dry condition plots, but on every other day for six or eight days for all other plantings in the field. Emergence counts were taken daily until the last day of digging for sprout lengths.

Slot Planting Study

Equipment

In the slot planting experiment, the treatments were 5 planters, each equipped with a different planter assisting accessory. Two planters did not have slot accessories, the Buffalo All-Flex Till Planter and the John Deere model 7100 equipped with disc type clod movers. They were included for a limited comparison of slot and till planting.
Three of the five treatments were on the same John Deere model 7100 planter used in the strip till study. The attachments were: rolling coulters (factory accessory), twin disc clod movers (factory accessory), and basic planter without any opener assist other than the heavy duty down pressure springs. These heavy duty down pressure springs were used for all of the planting done with that planter.

The Buffalo planter was an early All-Flex three point hitch mounted four row model. It was equipped with 25 cm sweeps and seed cover wheels.

The last planter was a two row model with hydraulically powered coulters and John Deere Max-Emerge planter units mounted on a three point hitch toolbar (Erbach, 1978). The powered coulter planter was made with a double 17.8 cm toolbar. The double toolbar was necessary in part to provide room for mounting of a large hydraulic reservoir on the planter. The oil flow for the coulter motors was supplied by a PTO driven pump. The pump was mounted on a special drawbar which replaced the tractor's.

The coulters were driven in a direction opposite to planter travel by hydraulic motors mounted on the planter unit. These were arranged so the coulter (notched) operated in the same position as a factory nonpowered one would normally operate.

Field layout

The slot planting experiment was laid out in a split plot design with 6 replications, 30 main plots, 60 subplots, and 120
subsubplots. The rows ran west to east. Replications contained 80 rows which were 56.4 m long. The main plots contained 16 rows and were randomly assigned one plot to a planter. The subplots were 8 rows wide, two per main plot. On one subplot, the stalks had been shredded the previous fall. The other was left undisturbed. The rows were slightly ridged, the average height being about 10 cm. The randomization used was from the study done on the field during the previous year. A field map is shown in Appendix B-1.

The planting was done on June 6, 1984. The planters were operated by the experiment farm technicians. Target planting rate was 65,500 seeds per hectare for the planters with John Deere units and 64,600 seeds per hectare for the Buffalo.

The planter with the clod movers required some adjustment on replication 1 but the seed depths were only taken from the section where the adjustment was proper. The Buffalo planter also required some adjustment because it tended to plant a bit shallow. It never did seem to plant deep enough and the covering performance was quite poor. The rotary coulter planter had some problem with residue and weeds lodging in the scrapers. The wedging was very tight and took considerable effort to remove.

One replication, number five, was not included in the study although it was planted. Severe rains in late April and May had washed the cornstalks into a small pond that was created in a low spot. The floating stalks were then pushed by the wind to one side. This left
part of the area with a layer of corn stalks 12 centimeters deep and a large part with no residue at all. This was not an acceptable condition for the study.

Seeds were dug for initial depth determination on the same day as planting. Four replications were completed before rain made collection of additional initial depth data impossible. The rain altered the soil surface too much to be able to measure initial depth.

Sprout lengths were measured two weeks after planting. The digging was delayed by rain. All of the sprouts in a 3.04 m section of row were excavated and their lengths recorded.

Data Collection Methods

Seed depth measurements

Two different types of depth measurements were taken, initial seed depth and germinated seed depth or sprout length. The initial seed depth was measured as soon after the seeds were planted as was possible. The sprout lengths were measured after the seeds had germinated. Both depth measurements were taken so that a relationship between the two and between them and emergence performance could be developed.

Initial depths were measured by taking a measurement from a reference level to the soil surface, slowly removing soil until the seed was revealed, and then measuring from the reference to the seed. The difference between the two measurements was the seed depth. The reference level was provided by a short length of string, about 35 cm,
which was stretched between two garden stakes at a height that varied around an average of about 90 mm.

Sprout lengths were measured in the sections used for emergence counts. The plant was pinched off at the surface of the soil and the portion below the soil excavated. Measurement was made from the pinched end down the length of the coleoptile to the point where it was attached to the hypocotyl. The whole length of the coleoptile was measured, including all curves.

Sprout measurements were made on three different days after planting in the strip till study for all plots except the planter 1, date 1 plots. This was done so an average daily emergence length could be calculated to determine which seeds germinated first, those planted deep or those planted shallow. All lengths for the slot plant study were combined into one day because of irregularities in measuring dates due to weather.

In the slot plant study, the digging for initial depths was started about one quarter of the way down the length of the plot. Five seeds were located in each of four rows in a subplot, all four rows being from one planter pass. The 3.05m row sections for measuring sprout lengths were staked out starting from where the last initial depth digging was done.

For the strip till study, the initial depth digging was done on both ends of the emergence test section. Five seeds were measured for initial depth, the emergence section of the row measured, and five more
seed depths measured. The emergence test sections were 3.05 m long for the Early Riser planter on date 2 and 2.44 m for all the rest of the plots.

**Penetrometer and soil moisture measurements**

Penetrometer and soil moisture samples were taken at the end of each day of planting. Two sets of penetrometer readings and one soil sample was taken from each planter pass for both fields. In field 40, for planter 1 dry condition, penetrometer readings were taken from each row.

Penetrometer readings were measured at the surface and at depths of 25 and 50 mm. The cone was 12.7 mm in diameter at the base and had a cone angle of 30 degrees. Force was measured with a Chatillon model DFG100 force gauge and recorded in Newtons.

Soil was collected for moisture samples with a hand sampler 2.54 cm in diameter. Soil was collected from the surface to a depth of 5.1 cm. Samples were then oven dried at a temperature of 100 degrees C for 24 hours. Samples were weighed before and after drying to determine moisture loss.

**Residue cover measurements**

Another parameter of the strip till devices to be evaluated was their residue clearing performance. After all planting was completed, photographs were taken of the row area in the no till sections. A section of row approximately 1 m long was cleared of emerged corn. A
stick with a mark at 38 cm and 76 cm was laid perpendicular to the row with the 38 cm mark on the row. A 35mm camera was used to take a picture of the row area and measuring stick.

Three photographs were taken of each row at approximately equal intervals down the row length. One of the photographs was always taken in the section used for emergence counts. The film used was Kodak Ektachrome 200 slide film.

After the slides were developed, they were projected onto a grid to determine percent residue cover at different distances from the row. The grid consisted of 21 lines; 10 lines on each side of the row and 1 on the row. The lines were placed at distances of 3, 6, 9, 12, 15, 18, 21, 24, 30, and 38 cm from the center of the row. Each line had 10 dots on it spaced 5 cm apart. Percentage residue cover for each distance from the row was estimated by counting the number of dots with residue projected on them and multiplying by 10.

Data analysis

Mean seed depth and standard deviation of seed depth were computed for each row and assigned the variables M and S, respectively. Row sample size for initial depths was 10 seeds in the strip till study and 5 seeds in the slot planter study. The row sample size for sprout length was the number of seeds that germinated in the measured test strip.

The variables M and S were assumed to be normally distributed for two reasons. First, graphs of seed depth frequencies appear somewhat
normally distributed (Figure 8). Also, by the central limit theorem (Box et al., 1978) the sample means and standard deviations calculated from the population will be normally distributed.

Emergence characteristics in the strip till study were evaluated on a row basis using the Emergence Rate Index (Erbach, 1982). They will be referred to as the variable ERI.

All results were tested for significance at the 95 percent confidence level. The least significant difference values were also calculated using a 95 percent confidence t value.
Most of the data analysis was done using statistical software on the Iowa State University computer. Correlations, means, analysis of variance tables, and frequency distributions were done using SAS, the statistical software from SAS Institute in Cary, North Carolina. Plotting of results was done on Hewlett Packard model 150 desktop computers.

Equations needed to calculate the LSD values for the various subplot and subsubplot combinations were obtained from Little and Hills (1978). These were put in a small program that was run on the Hewlett Packard computers.
RESULTS AND DISCUSSION

Strip Till Study Results

Considerations for interpreting results

Because of unforeseen difficulties several things must be taken into consideration when examining the results. The first is that this study is not a side by side comparison of the two different planters. Because of weather, planting in dry conditions had to be conducted on separate days for each planter. These days were about two weeks apart. The effect of this will be greatest in the analysis of emergence as it is very weather dependent. The mean planting depths for the two planters were also not equal. Even though it was attempted to make them close, it is very difficult to do so in practice because the mean depth cannot be determined until all the seeds have been planted.

Difficulties with assembling and preparing the planter equipment resulted in a rather late planting date. The construction of the Stalk Skimmer was not completed until June. Because of the nature of the modifications to the planters, the changes could not be made until the planters were no longer needed by other researchers and the University Farm Services Division. The late date essentially eliminates any possible temperature effects that otherwise may have been observed.

As a result of a planter malfunction, there is a considerable amount of missing data in one portion of the experiment. One row unit on the John Deere planter did not plant any seeds in the wet soil
condition. Unfortunately, this was not discovered until the next day. Therefore, treatments A and D have only one-half the observations of treatments B and C. The tables are noted where this has an effect. Because there is no missing data for the dry soil condition, a separate analysis was done for this set of data and compared with the results of the analysis across dates. The findings were similar. In general, the effects as tested in the analysis of variance tables were either very significant or very insignificant.

On the good side, since there were some rows left over in the no till plots, additional planter passes were made with planter 2 for dry condition. Although this provided additional degrees of freedom for the error term, it had little impact there because of the many degrees of freedom present from the original design. The greatest benefit of these additional values is that they should help to move the experimental mean values closer to the real population mean. Where these extra values occur in the means, they are also noted.

**Seed depth control**

**Soil moisture effects**  Moisture level had no effect on M or S for seeds planted with planter 1 and no effect on S for seeds planted with planter 2. M for planter 2 did show significant moisture and tillage by moisture interaction with both initial depth and sprout length. The effect of soil moisture and tillage on M are shown in Table 1.
TABLE 1. Mean seed depths for planter 2

<table>
<thead>
<tr>
<th>Soil moisture</th>
<th>No till</th>
<th>Moldboard</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>18.5</td>
<td>19.5</td>
<td>18.9</td>
</tr>
<tr>
<td>Wet</td>
<td>35.0</td>
<td>24.0</td>
<td>29.4</td>
</tr>
<tr>
<td>LSD</td>
<td>3.0</td>
<td>3.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The planter put the seeds at a greater depth when the soil was wet than when it was dry. This was because soil strength decreases as moisture content increases. Depth change was less in moldboard plots.
than in till plots. Most of the difference can be accounted for by the much deeper depths of the seeds in the no till plots in the wet condition.

In the wet condition, the M for moldboard is less than that for the no till. This was easily observed in the field. It was caused in part by the strength of the moldboard soil not being adequate to support the strip till devices. Consequently, they tended to remove large amounts of soil from the row area and the planting unit was forced to operate in a rut while the toolbar support wheels held the toolbar at a normal height. This caused the units to operate at their lower limit of vertical travel which did not allow the down pressure springs to provide any assistance for soil penetration. This would have masked the effects of soil moisture. Planter 1 may not have shown any difference between tillages because it was equipped with heavier down pressure springs than was planter 2.

The effect of moisture condition is the opposite of what is desired. Ideally, the seed should be placed deeper in dry soil to ensure that adequate amounts of moisture are available for germination. Although the effect only appears for the one planter, it would be advisable for an operator to check depth continually as moisture and soil strength conditions change.

Tillage effects Tillage effects on depth control with regard to the two planters are similar to those found for soil moisture effects. Variable M for planter 2 is the only place where a significant effect is
found and only in the case of means obtained by initial depth measurements. Mean depth for the no till plots is 25.6 mm and for moldboard plots 21.7 mm. The LSD is 2.9 mm. In practice, this would not present a problem because the units can simply be adjusted to the condition of the field which is being planted.

The lack of a significant effect of tillage upon seed depth variability is again encouraging. It suggests that planters equipped with strip till devices can be expected to plant as accurately in no till as ordinary planters do in conventionally tilled fields.

**Depth effects** Evaluation of M for different target depths is redundant because it was intentionally varied. Depth effect was significant for both planters for both initial depth and sprout length, as was expected.

In addition, target depth has a strong effect on seed depth variability, S. Significant results were obtained with both planters although planter 1 had a positive test for significance with the sprout length evaluation only. The results are shown in Table 2. There were no significant interactions of depth with the other independent variables.

The results shown are consistent with those of Bateman (1972) and Mock and Erbach (1977). A distinct increase in seed depth variation, S, can be seen with an increase in depth. This can be explained by several factors. The most important is that the range of possible values for seed depth is restricted as depth is decreased. A seed depth can never
TABLE 2. Average seed depth (M) and standard deviation (S)

<table>
<thead>
<tr>
<th>Planter</th>
<th>Target depth</th>
<th>Initial depth length</th>
<th>Sprout length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>M</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>8.98 (65)</td>
<td>39.1</td>
<td>8.02 (91)</td>
</tr>
<tr>
<td>2</td>
<td>6.71 (68)</td>
<td>24.0</td>
<td>6.79 (80)</td>
</tr>
<tr>
<td>LSD</td>
<td>0.86</td>
<td></td>
<td>0.74</td>
</tr>
</tbody>
</table>

Numbers in parentheses are number of rows in mean
LSD's are for balanced data set (N=80) at 0.05 significance

be less than zero. There is also a lower limit which will be some value which is considerably less than a true normal distribution's limit of negative infinity.

The lack of significance for depth effect on S when evaluated for initial depths with Planter 1 could be caused by difficulties in measuring the depth of the seed immediately after it is planted. The soil profile over the seed left by the closing wheels, twin cast iron, is very irregular. This makes it very difficult to establish the level of the soil surface, causing the variability due to measurement error to be high. After a rain settles the soil, the surface is tempered...
somewhat and the surface height is easier to establish. This would make the sprout measurements more sensitive to the different effects being tested. Planter 2 by contrast leaves a very smooth and uniform surface which can be established in relation to a reference level quite easily.

**Strip till treatment effects** In general, strip till treatment had no effect on seed depth variability, S. A significant test did show up for Planter 1 but when dry condition data, which was complete, was analyzed independently the F test was negative. Because of the inconsistency of those results, they will not be considered further.

Significance tests for variable M, mean seed depth, were positive for both planters. Because strip till devices would only be of interest in a no till system, a second analysis was done using only the data from the no till plots and using that error term in the least significant difference number. Because tillage by treatment interaction was significant in the analysis with both tillages, this procedure was considered permissible.

The analyses with moldboard data excluded show results consistent with those from the overall analyses. Analyses of initial depth means have a significant strip till treatment effect and strip till treatment by soil moisture effect but not a treatment by depth interaction. Sprout length means were significantly affected by strip till treatment and by interaction of strip till treatment with planting depth. The results for the initial depth analysis are shown in Table 3.
TABLE 3. Mean seed depths (M) for different treatments, initial depths

<table>
<thead>
<tr>
<th>Treat</th>
<th>Soil moisture</th>
<th>Planter 1</th>
<th>Planter 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry (mm)</td>
<td>Wet (mm)</td>
<td>Dry (mm)</td>
</tr>
<tr>
<td>A</td>
<td>25.5 (10)</td>
<td>39.5 (6)</td>
<td>23.7 (13)</td>
</tr>
<tr>
<td>B</td>
<td>21.2 (10)</td>
<td>8.2 (10)</td>
<td>18.1 (13)</td>
</tr>
<tr>
<td>C</td>
<td>36.9 (10)</td>
<td>41.0 (10)</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>28.8 (10)</td>
<td>22.4 (4)</td>
<td>17.2 (13)</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td>15.2 (13)</td>
</tr>
<tr>
<td>LSD (N=10)</td>
<td>10.5</td>
<td>10.5</td>
<td>10.4</td>
</tr>
</tbody>
</table>

LSD for soil moisture w/in treatment (0.05 significance); planter 1 = 13.6, planter 2 = 9.6

Treatment A = Stalk Skimmer  Treatment C = Ridge Mate
Treatment B = Trash Whipper  Treatment D = Econ-O-Till
Treatment E = Trash Whipper w/John Deere closing wheels

Numbers in Parentheses are number of rows in mean (N)

The differences for planter 1 are great enough that the missing data should not affect within soil moisture comparisons. For dry soil, only the highest and lowest values are significantly different, those
for the Trash Whipper and Ridge Mate. For the wet condition, there are three distinct groups; the Stalk Skimmer and Ridgemate, the Econ-O-Till, and the Trash Whipper which was lowest. The rankings are consistent across soil moistures. Two treatments have significant performance differences between soil moistures, the Stalk Skimmer and Econ-O-Till. The number of values in the means for wet condition is rather low for each of these treatments. Considering the small margin between their differences and that which is significant, it may very well be that their performances did not change with change in soil moisture.

Planter 2 had essentially the same depth means for all treatments in the dry condition. The wet condition data show two groups, those treatments with the Trash Whipper and those without. These two treatments were also the only ones to show a difference between moisture means. There is no difference between these two treatments for either moisture condition. The Trash Whippers frequently operated at a height that was too high to clear residue from the row effectively. As a result, the soil height above the seed was defined as the top of the residue. This residue would compress under the pressure of the gauge wheels, however, and place the seed under approximately the same amount of soil as in the other two treatments. In the dry condition, the stalks would fracture when compressed and not affect the measurement as much. In the wet condition, the stalks would have contained more moisture and would spring back after passage of the gauge wheels, causing a false depth measurement.
Sprout length analyses are given in Table 4.

### TABLE 4. Mean seed depths (M) for different treatments, sprout lengths

<table>
<thead>
<tr>
<th>Treat</th>
<th>Planter 1 Depth</th>
<th>Planter 2 Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>46.7 (9)</td>
<td>35.1 (12)</td>
</tr>
<tr>
<td></td>
<td>21.6 (7)</td>
<td>22.6 (10)</td>
</tr>
<tr>
<td>B</td>
<td>28.6 (9)</td>
<td>33.4 (12)</td>
</tr>
<tr>
<td></td>
<td>21.4 (9)</td>
<td>42.2 (10)</td>
</tr>
<tr>
<td>C</td>
<td>54.6 (10)</td>
<td>31.8 (13)</td>
</tr>
<tr>
<td></td>
<td>31.3 (10)</td>
<td>37.5 (10)</td>
</tr>
<tr>
<td>D</td>
<td>36.5 (6)</td>
<td>28.2 (13)</td>
</tr>
<tr>
<td></td>
<td>24.8 (8)</td>
<td>19.2 (10)</td>
</tr>
<tr>
<td>E</td>
<td>----------------</td>
<td>31.8 (13)</td>
</tr>
<tr>
<td></td>
<td>37.5 (10)</td>
<td>9.3</td>
</tr>
</tbody>
</table>

LSD for depth at same treatment (0.05 significance)
planter 1 = 8.8, planter 2 = 9.3

Treatment A = Stalk Skimmer
Treatment B = Trash Whipper
Treatment C = Ridge Mate
Treatment D = Econ-O-Till
Treatment E = Trash Whipper w/John Deere closing wheels

Numbers in parentheses are number of rows in mean (N)

These results are more difficult to explain. For planter 1, the depths are almost all significantly different at target depth 1. Differences at the depth 2 (shallow) level could be accounted for by
differences in soil surface condition left by the till devices. However, the depths for target depth 2 are all virtually the same except for treatment C. Some other factor must be asserting itself here.

Planter 2 data show treatment B and E, the Trash Whipper based treatments, behaving in a manner inconsistent with that of the others. The reason for the mean depth of target depth 2 being deeper than the mean depth for target depth 1 is in total reverse of what should have happened. One possible explanation for this behavior is that an excess number of seeds were planted at a very shallow depth and did not germinate, resulting in their being excluded from the measurements. This would cause the average to be artificially low.

One must also consider that sprout length is influenced by factors other than planting depth. The coleoptile can make many twists and turns on its way to the surface. This adds extra variability to the measurement and might be the cause of some of the reversals. This variability could be a function of the soil condition left by the planter above the seed.

As mentioned before, planter 1 did not show a treatment by soil moisture interaction for sprout lengths. Planter 2 did test positively for this effect. Results are shown in Table 5.

The data in this table again show the two Trash Whipper based treatments being inconsistent. As with the target depth effect, poor germination of shallow seeds might be the cause of the change of mean sprout length with moisture condition. This is especially evident when
TABLE 5. Planter 2 sprout length means (M)

<table>
<thead>
<tr>
<th>Treat</th>
<th>Soil condition</th>
<th>Dry</th>
<th>Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>29.6(13)</td>
<td>29.1(9)</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>25.7(12)</td>
<td>51.4(10)</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>22.8(13)</td>
<td>26.3(10)</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>20.2(13)</td>
<td>52.7(10)</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>9.3</td>
<td>9.3</td>
</tr>
</tbody>
</table>

LSD for soil condition within treatment = 8.5 at 0.05 significance level

Treatment A = Stalk Skimmer
Treatment B = Trash Whipper
Treatment D = Econ-O-Till
Treatment E = Trash Whipper
John Deere closing wheels

Numbers in parentheses are number of rows in mean (N)

Comparing the initial depth and sprout length means. The seed depth distributions for the Trash Whipper on planter 2 are shown in Figure 9. Here one can see the change in distribution shape caused by the failure of the seeds in the 0-5 mm bracket to emerge. The charts have the appearance of a double normal distribution because both target depths are included in the figures.
FIGURE 9. Treatment seed distributions obtained two different ways

Emergence evaluation results
Emergence was evaluated in the same manner as the means and standard deviations of the seed depth, i.e., it is on a per row basis. 

**Soil moisture effects** Seed emergence is very dependent upon weather and soil moisture. The results of effects of soil moisture are shown in Table 6.

**TABLE 6. ERI values for different moisture conditions**

<table>
<thead>
<tr>
<th>Soil Moist</th>
<th>Planter 1</th>
<th>Planter 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>18.2</td>
<td>18.3</td>
</tr>
<tr>
<td>Wet</td>
<td>15.5</td>
<td>19.3</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>1.6</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Note: Dry condition planting date for planters was not the same.

For planter 1 ERI was higher for the dry condition than for the wet condition. This can be explained by the occurrence of a rain the night after planting. It was enough to soak the ground to the point where walking on it was difficult. Planter 2 plots experienced no rainfall after the dry condition planting. Wet condition plots were planted on the same day for both planters. A slight rain occurred two days after the wet condition plantings. The soil retained very adequate
amounts of moisture for seed germination through the duration of the wet condition emergence period.

In general, it can be said that a rain, if it occurs soon enough, will essentially nullify the effects of planting in a dry soil. Otherwise, when temperature is not a restricting variable, seeds planted in a dry soil will germinate slower than those in a moist soil, as occurred with planter 2, when temperature is not a restricting variable.

**Tillage effects** Tillage effects were not the same for both planters. Planter 1 did not show any effect of tillage on ERI. The ERI means for Planter 2 were 17.4 in no till and 20.2 in moldboard, with a LSD value of 2.5. There were no significant soil moisture by tillage interactions.

The no till plot showed slower emergence than the moldboard plot with planter 2. What is probably just as significant however, is that there was no difference in emergence for Planter 1. Some researchers have reported poorer emergence in no till (Mock and Erbach, 1977) and others have reported it to be equal to that of moldboard tillage (Griffith et al., 1973). That the ERI for planter 1 shows no difference and for Planter 2 only a slight one may be because residue left by strip till devices had little effect on temperatures at this late planting date.

**Depth effects** Depth effects were again significant only for Planter 2. The ERI values were 20.9 for depth 1 and 16.1 for depth 2 with a LSD value of 2.3.
Depth 1 was the deeper target depth. The soil dried down very fast at the time these plots were planted (July). Moisture would be more available at the deeper depth enabling those seeds to germinate faster. Planter 1 probably did not show a depth effect because of the amount of rain which fell after the plantings, especially for dry condition. No rain fell after dry soil planting for planter 2. This may explain why the difference is detectable for planter 2.

**Treatment effects** As with seed depth mean and variance, strip till treatment effects are only of interest in a no-till situation. Because the analysis of variance for both planters yielded a positive F test for strip till treatment, a second analysis was done for each using the data from the no till plots only. These gave positive tests for strip till treatment and strip till treatment by date interaction as did the overall analyses. Results are given in Table 7.

The data for Planter 1, dry condition can be divided into two groups; Trash Whipper and the rest. Again, the difference can be explained by the generally poor residue removal performance of the Trash Whipper. The wet condition values can be divided into three groups; the Trash Whipper as lowest, the Ridge Mate and Econ-O-Till as the intermediate set, and the Stalk Skimmer with the best ERI. One must also consider the number of observations in the mean when making the comparisons. Because of the fewer number of observations in the Stalk Skimmer mean the LSD for comparing it with the other groups should really be larger. It would be safer to put it into the same group as the Ridge Mate and Econ-O-Till.
TABLE 7. ERI values for strip till treatments, at different dates

<table>
<thead>
<tr>
<th>Treat</th>
<th>Planter 1 Soil Moisture</th>
<th>Planter 2 Soil Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry</td>
<td>Wet</td>
</tr>
<tr>
<td>A</td>
<td>19.7</td>
<td>22.6</td>
</tr>
<tr>
<td>B</td>
<td>12.9</td>
<td>5.2</td>
</tr>
<tr>
<td>C</td>
<td>19.5</td>
<td>15.1</td>
</tr>
<tr>
<td>D</td>
<td>20.2</td>
<td>15.1</td>
</tr>
<tr>
<td>E</td>
<td>14.8</td>
<td>20.3</td>
</tr>
<tr>
<td>LSD</td>
<td>5.2</td>
<td>5.2</td>
</tr>
</tbody>
</table>

LSD for soil moisture at same or different Treatment; Planter 1 LSD=5.5, Planter 2 LSD=4.7, N=10 (0.05)

Number in parentheses is number of rows in mean

Treatment A=Stalk Skimmer  Treatment C=Ridge Mate
Treatment B=Trash Whipper  Treatment D=Econ-O-Till
Treatment E=Trash Whipper w/John Deere closing wheels

The Trash Whipper is the only treatment for planter 1 to show a significant change across moisture condition. The cause for this change in performance is not known. It may relate to its residue clearing ability in different moisture conditions.
The data for Planter 2 are less consistent. For dry condition, the Stalk Skimmer is different than the Econ-O-Till and the Trash Whipper with John Deere closing wheels. The Trash Whipper alone is not significantly different than any of the treatments. For wet condition, there are two groups, the Econ-O-Till and all the rest. There is no simple explanation for this behavior. The only two treatments which showed different performance for different soil moistures were the two Trash Whipper based ones. These treatments were also the ones which showed differences in mean depths across moisture conditions.

The two Trash Whipper treatments are of particular interest in this table because the only difference between the two was the closing system. Treatment B used the factory system for the planter; twin closing discs and a center ribbed rubber wheels. Treatment E used twin cast iron closing wheel. No difference could be detected between the two for either soil condition. However, the performance of the twin cast iron wheels improved markedly in the wet soil condition when compared to the dry. Soil condition has always been a factor in the selection of closing systems and press wheels. This is another example of varying performance in varying conditions.

Seed depth at date of emergence An average sprout length was computed for each day the sprouts were dug (Table 8). The means for planter 1, dry condition were not obtained because the sprout length determination was all done on one day. The emergence took place over a period of only two or three days after the first sprouts came up.
TABLE 8. Average sprout length on day of digging

<table>
<thead>
<tr>
<th>Wet condition Both planters</th>
<th>Wet condition Both planters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Julian Date</td>
<td>Number Emerged Range Average Length</td>
</tr>
<tr>
<td></td>
<td>199 1610 96 32.00</td>
</tr>
<tr>
<td></td>
<td>200 495 93 34.99</td>
</tr>
<tr>
<td></td>
<td>202 54 70 21.93</td>
</tr>
<tr>
<td></td>
<td>203 121 77 24.87</td>
</tr>
<tr>
<td>Dry condition Planter 2 only</td>
<td>Dry condition Planter 2 only</td>
</tr>
<tr>
<td>Julian Date</td>
<td>Number Emerged Range Average Length</td>
</tr>
<tr>
<td></td>
<td>209 551 68 33.32</td>
</tr>
<tr>
<td></td>
<td>211 577 53 21.34</td>
</tr>
<tr>
<td></td>
<td>213 201 55 21.66</td>
</tr>
</tbody>
</table>

These means are another indication that moisture, rather than temperature, was the limiting variable, which is what one would expect for such a late planting date. Sprouts as long as 100 mm were measured on the first day of digging to measure sprout length of plants planted in the wet soil condition. The soil around the shallow seeds would dry out quickly. The seeds which were planted shallow took several days to
accumulate enough moisture to germinate. The results are illustrated graphically in Figure 10.

**Performance of strip till devices**

The physical performance of each strip till device was measured in two different ways; penetrometer readings and residue distributions. The penetrometer readings were taken at depths of 0 mm, 25 mm, and 50 mm.

Analysis of variance for the penetrometer readings showed the only differences detectable were between tillages at the 50 mm depth. Because the readings were taken at the end of the day when planting was finished the soil had dried out to the depth of the first two readings. The soil was somewhat broken up by the passage of the planter and strip till devices and was very brittle. Accurate readings were difficult to obtain. If the readings had been taken immediately after the planter had passed the test site significant treatment results might have been detected.

Because all the plots were planted from east to west, the residue distribution data were collected and analyzed with regard for directionality. The negative numbers on the graphs are for values to the left of the row and the positive numbers for the right side.

The residue distributions for each planter are shown in Figure 11. Statistical comparison of these curves was not attempted. The values for residue at different distances from the row were used in the correlation with emergence. Significant correlations were not found for
FIGURE 10. Mean sprout lengths for plants emerged at different days
any of the row distances. Apparently the residue values were low enough to not affect emergence or the warm weather overshadowed any effects.

On planter 1, the Econ-O-Till unit removed the most residue from the row area. The other three treatments appear to be essentially equal except for the Stalk Skimmer which has low residue values on the right side.

On planter 2, the Econ-O-Till unit again removed the most residue from the row area followed by the Stalk Skimmer. The Trash Whipper and Trash Whipper with John Deere closing wheels performed the same, which is expected.

A directionality is detectable in the treatments. This would be expected for some. Because the Stalk Skimmer rotates in a counter clockwise direction when viewed from the top, it would tend to pile residue on the left side. The discs of the Trash Whipper are arranged with the left one slightly ahead and in front of the right. Because it encounters the soil and residue first, it would take the greater share and pile it on the left.

Graphs of residue distribution for each treatment are given on a planter by soil moisture condition basis in Figures 12 through 19. Notice the difference in performance for different moisture conditions on planter 1 and the consistency between moisture conditions with planter 2.
FIGURE 11. Residue distributions for strip till devices on 2 planters
FIGURE 12. Planter 1, Treatment A

FIGURE 13. Planter 1, Treatment B
FIGURE 14. Planter 1, Treatment C

FIGURE 15. Planter 1, Treatment D
FIGURE 16. Planter 2, Treatment A

FIGURE 17. Planter 2, Treatment B
FIGURE 18. Planter 2, Treatment D

FIGURE 19. Planter 2, Treatment E
Slot Planting Results

The slot plant study was much simpler to analyze because there was no missing data. Sprout lengths were gathered on several different days and compiled into one data set. There is no ERI analysis, only a percent emergence comparison. Initial depth data were gathered from four replications, sprout length data from five. The difference is because rain disrupted gathering of initial depth data.

Seed depth control

Planter effects The analysis of variance showed no significant effect of planter on seed depth variability, \( S \). This is not to say that the attachments did not have an effect on variability. They all may have affected it in the same way. The attachments were all mounted directly to the planting unit or to the parallel linkage which connected the unit to the tool bar. As these attachments encountered residue and roughness in the soil surface, the force would be fed back to the planting unit. This would cause it to act as though it had encountered the residue or bumps itself. This may be why the planter without any attachments, planter 5, was not significantly different from the rest.

It is also possible that the row sample size, 5, was too small and did not give the row standard deviation of depth, \( S \), enough degrees of freedom. This would have made \( S \) more variable and small differences hard to detect. It is unlikely that all of the planters had the same amount of seed depth variation, especially when one was very different from the rest.
The variable M did have a positive significance test for planter effect. The results are shown in Table 9.

**TABLE 9. Seed depth means for different planters**

<table>
<thead>
<tr>
<th>Planter</th>
<th>Initial Depth</th>
<th>Sprout Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>37.2</td>
<td>30.3</td>
</tr>
<tr>
<td>2</td>
<td>22.5</td>
<td>29.1</td>
</tr>
<tr>
<td>3</td>
<td>37.3</td>
<td>32.5</td>
</tr>
<tr>
<td>4</td>
<td>45.8</td>
<td>43.7</td>
</tr>
<tr>
<td>5</td>
<td>41.8</td>
<td>38.7</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>17.1</td>
<td>12.3</td>
</tr>
</tbody>
</table>

Planter 1 = Max-Emerge w/ clod movers
Planter 2 = Buffalo Till Planter
Planter 3 = Max-Emerge w/ free rolling coulter
Planter 4 = Max-Emerge w/ powered coulter
Planter 5 = Max-Emerge w/ no attachment

The three planter variations that were done with the same machine, 1, 3, and 5, were not significantly different. Planter 4 was also in this group. The low mean depth of planter 2 was caused by many uncovered seeds weighting the data with many zero depths. The closing wheels had trouble covering the seeds. The seed trench cut by the
opener was sufficiently deep but the ground appeared to be too hard for the covering wheels to function correctly. The sprout means show less difference because many of those seeds which were not covered would fail to germinate.

**Stalk effects** Stalk condition had no effect on mean depth. The shredded stalks would be expected to have a deeper mean depth because they should be easier to plant through. Two of the planters were strip till types and removed the residue. This may have masked the effect.

Stalk condition did have a positive test for effect on seed depth standard deviation, both with initial depths and sprouts. Initial depth showed a planter by stalk interaction but sprout length did not. Results are shown in Table 10.

The standout in this table is the performance of planter 5 in the unshredded stalks. It is the only place where a significant difference occurs, both between stalks for a given planter and between planters at a given stalk condition. Planter 5 was the planter with no attachment. The value of devices to help condition corn residue is very evident here. The seed depth was more variable for seeds planted in shredded stalks than it was for those planted in shredded stalks. This effect is illustrated by the distributions of Figure 20.

**Emergence analysis**

Volunteer corn was a problem in this field and affected the final emergence count. The number of emerged seedlings was obtained from the number of sprouts dug in the test sections of the rows. When the
TABLE 10. Effect of stalk condition on seed depth variation (S)

<table>
<thead>
<tr>
<th>Planter</th>
<th>Stalk condition</th>
<th>Sprout lengths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shredded</td>
<td>Unshredded</td>
</tr>
<tr>
<td>1  8.84</td>
<td>8.23</td>
<td>7.63</td>
</tr>
<tr>
<td>2  5.88</td>
<td>6.71</td>
<td></td>
</tr>
<tr>
<td>3  7.47</td>
<td>8.48</td>
<td></td>
</tr>
<tr>
<td>4  6.57</td>
<td>8.84</td>
<td></td>
</tr>
<tr>
<td>5  6.70</td>
<td>12.02</td>
<td></td>
</tr>
<tr>
<td>LSD  4.68</td>
<td>4.68</td>
<td></td>
</tr>
</tbody>
</table>

LSD for difference between stalk w/in planter=5.11
for initial depth means, 0.05 significance level

Planter 1 = Max-Emerge w/ clod movers
Planter 2 = Buffalo Till-Planter
Planter 3 = Max-Emerge w/ free rolling coulter
Planter 4 = Max-Emerge w/ powered coulter
Planter 5 = Max-Emerge w/ no attachment

sprouts were dug, some determination could be made of which were volunteer by examining them for traces of fungicide. By the time the last sprouts were dug however, the seeds were disintegrating and determination of which were volunteer and which were not was very difficult.
Stalk condition had no effect on percent emergence. This is expected because any toxins released by decaying residue would not be removed by shredding. Percent emergence would also not be affected by seed depth variations due to stalk condition because for the most part there were none.

Planter effects were present. Results are shown in Table 11.

The two planters which differ from each other are planter 2 and planter 4. The low emergence of the Buffalo is exaggerated by the lack of volunteer corn not included in its data. Any corn seeds left from harvest would have been swept away by the shovel. Also, a significant portion of the uncovered seeds left by this planter did not germinate. The aggressive action of the powered coulter on planter 4 may have
TABLE 11. Percent emergence for different planters

<table>
<thead>
<tr>
<th>Planter description</th>
<th>Percent Emergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max-Emerge w/ clod movers</td>
<td>100.8</td>
</tr>
<tr>
<td>Buffalo Till-Planter</td>
<td>88.5</td>
</tr>
<tr>
<td>Max-Emerge w/ free-rolling coulter</td>
<td>100.3</td>
</tr>
<tr>
<td>Max-Emerge w/ powered coulter</td>
<td>109.8</td>
</tr>
<tr>
<td>Max-Emerge w/ no attachment</td>
<td>97.7</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Introduced more seeds for volunteer corn by shattering cobs, thereby raising the percent emerged value over the 100 percent level. With such a large LSD it is doubtful that anything conclusive can be drawn from this set of values.

Methods of Analysis

Three methods of evaluating planter performance were used in this study: measurement of initial depth, measurement of sprout length, and measurement of emergence characteristics. This provides an opportunity to compare these methods of planter evaluation.
Evaluation and prediction of emergence

Quality of emergence is the bottom line in planter evaluation. The task of the planter is to distribute seeds evenly and in the most favorable environment with the objective of obtaining a rapid and complete emergence. Emergence Rate Index is one method of quantifying the speed and percentage of emergence. It is an easy measure to collect data for and easy to calculate. However, many factors not influenced by the planter can affect this number; weather conditions being the main one.

Two factors that are planter related are average seed depth and the variation in depth around that mean. These two parameters by themselves are not a good predictor of emergence characteristics. Correlations of M and S with ERI for a given row were calculated for the strip till study. They are shown in Table 12.

The correlation of the mean depth with emergence is higher than the correlation of deviation with emergence, but it still has limited value as a predictor. Each variable, especially M, exhibits a wide range of correlation values.

The difficulty with using mean depth to predict emergence is that the ideal planting depth is not known at the time of planting. If sufficient rain falls immediately after planting, a shallow planting depth may result in the quickest emergence. If dry weather follows, the deeper planting depth might have been the wisest choice. Considering this, perhaps a bit of variability in planting depth is desirable.
TABLE 12. Correlations of ERI with M and S

<table>
<thead>
<tr>
<th>Planter</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil moist Statistic</td>
<td>Initial Sprout depth</td>
<td>Correlations (R)</td>
</tr>
<tr>
<td>Dry M</td>
<td>.676 *</td>
<td>.563 *</td>
</tr>
<tr>
<td>Wet S</td>
<td>.464 *</td>
<td>-.113</td>
</tr>
<tr>
<td>Wet M</td>
<td>.602 *</td>
<td>.352 *</td>
</tr>
<tr>
<td>Wet S</td>
<td>.167</td>
<td>-.126</td>
</tr>
</tbody>
</table>

Asterick indicates R value is significantly different from zero at 95 percent probability level

Evaluating depth control

Initial seed depth measurements have certain problems peculiar to the method. The first is that it must be completed in the shortest possible time after planting to prevent rains from altering the soil surface before completion of the data collection. This requires considerable amounts of labor.

Establishing the location of the soil surface is no trivial matter when dealing with planters with certain typespresswheel type in particular tends to leave a very irregular surface immediately above the
seed. There also exists a continuous ridge above the seed that falls away rapidly in the direction perpendicular to the row. The emerging sprout may or may not travel through the complete ridge to reach the surface.

In this study, it took some time before those measuring the seed depths realized that what the researcher wanted was not the depths of the first ten seeds which they discovered (which were probably laying on the surface), but the depths of ten consecutively planted seeds. There also seemed to be a considerable variation in the length of row that needed to be excavated in order to reveal the required number of seeds.

The distribution of initial seed depths exhibits an obviously unnatural pattern (Figure 21). There are distinct peaks at depths that are multiples of five millimeters. The main cause of this is probably the difficulty experienced in establishing the level of the soil surface.

Measuring sprout lengths can eliminate many of the problems of initial depth measurements but not without bringing in a few of its own. The measurements can be stretched over a length of time which is limited only by the rate at which the plants are growing. This significantly reduces the amount of labor required. Establishing the location of the soil surface is usually a simple matter, especially if rains have evened the soil surface. Rounding of figures is also less of a problem because the sprout can be laid against the ruler and the length read exactly. This is evident in the sprout length distribution shown in Figure 22.
FIGURE 21. Initial seed depth distribution, planter 1

Note the uniformity of the curve when compared to the initial depth distribution.

Sprout lengths will include the effect of certain factors not affecting initial depths. The most important of these would be soil condition and coleoptyl growth characteristics. When the complete length of the sprout is measured, as it was in this study, anything that would cause the sprout to grow in something other than a straight line also affects the data. This can be desirable, however, as it can give an indication of the condition of the environment left by the planter.
Unless unemerged seeds are also measured the data can be easily skewed. If all shallow seeds or all deeply planted seeds did not emerge the averages obtained by this method would be too high or too low and the standard deviation would probably be reduced from the actual. Fortunately, current planters space seeds uniformly enough that unemerged seeds are found relatively easily.

The correlation value for initial depth and sprout length was 0.888. The correlation value for initial deviation and sprout deviation was 0.0916. The relation between initial depth and sprout length is fairly strong but between the two deviations it is rather weak. It
appears evident that many parameters besides initial depth affect the amount of soil a sprout actually has to travel through to reach the soil surface.

In general, the results obtained by analysis of data from each measurement system tended to be the same. There were differences only in some minor instances. The method chosen for planter evaluation would depend primarily upon whether the investigator is interested in the planter as a system or in the performance of a particular element of it.
CONCLUSIONS

Two field experiments were conducted to evaluate planter depth control performance in no till conditions. The first was a slot plant study which evaluated five different slot planting methods using five different planters. The second was a strip till evaluation which used four different treatments on each of two different planters. One of the strip till devices was manufactured by the researcher.

The strip till study revealed that:

- Mean seed depth was affected by soil moisture and type of strip till device. Seed depth increased as moisture increased. The effect of strip till device depended upon the type of device used. The degree of difference was dependent upon planter type also.
- Seed depth standard deviation was affected by only by target planting depth. Standard deviation increased as target depth increased.
- Seed emergence was affected by tillage, planting depth, and strip till device. Emergence was higher for deeply planted seeds. Effect of strip till device again depended upon the device.

The slot plant study revealed that:

- Seed depth variation was not dependent upon planter type.
- Stalk condition affects seed depth variation of planters not equipped with no till devices. Unshredded stalks produced more seed depth variation.
From the analysis of both studies several things can be concluded.

- The effect of depth upon emergence is significant. Seed depth variation by itself did not effect germination, it was probably too small.

- Strip till devices can reduce the variability in seed depth associated with no till to the levels found in conventionally tilled fields.

- A comparison of planter evaluation methods suggests that the particular method used should be determined by the researcher's objectives and resources.

The experimental strip till device, Stalk Skimmer, performed as intended but needs refining.
BIBLIOGRAPHY


ACKNOWLEDGEMENTS

A task such as the one completed here can only be accomplished with the help of others. I would like to list some of those.

My first and greatest thanks go to the Lord for providing me with a capable mind and body and everything else I have needed.

Thanks also to fellow Wisconsinite and more importantly my major professor, Dr. Donald Erbach.

To fellow grad students Randy Raper and Chang Choi I owe special thanks for taking up the work load when my presence was required elsewhere and for always being quick to lend a hand.

To the members of the Seed Diggers Union; Ed Albright, Phil Gassman and Doug Luzbatek, both for collecting data and putting it into files and charts.

To Dr. Wesley Buchele for serving on my committee and providing ideas and suggestions for the Stalk Skimmer.

To Dr. Joseph Burris for serving on my committee.

To Mr. Ernie Behn for the loan of one of his Ridge Mates.

To the State of Iowa for providing the facilities.

And of course parents and family for always pulling for me from backstage.

To all the somebodys who have not been given specific thanks but were nevertheless appreciated.
APPENDIX A

Stalk Skimmer Power Requirements

Testing to determine the power requirements of the Stalk Skimmer was done on November 5, 1984. The test was conducted in the fall so the stalks would not have been weakened by decay and the results would reflect a worst case situation.

A special 3-point hitch toolbar was assembled to which were mounted the Stalk Skimmer, the pressure and flow gauges, and a seat for the observer. An Owatanna portable hydraulic tester, model number Y-90, was coupled into the hydraulic line. The tester contained a pressure, flow, and temperature gauge. The observer also had an electronic digital tachometer, Shimpo model DT-105, which was used to measure the speed of the hydraulic motor.

The experiment was arranged in a factorial design, vehicle ground speed at two levels and Stalk Skimmer rotational speed at three levels. There were six replications. Three measurements each of pressure, flow, and motor speed were taken for each run.

Power demand was calculated two different ways. The first obtained the amount of fluid flow by multiplying the motor speed by its displacement per revolution. A volumetric efficiency of .95 is assumed. The second equation uses the fluid flow value obtained from the flow meter. The equations are given below.

\[
\text{Power 1} \quad P_1 = \frac{N \times D \times P \times E}{(396000) \times 0.746}
\]

\[
\text{Power 2} \quad P_2 = \frac{Q \times P}{1714 \times 0.746}
\]
Where

- P1 and P2 are power in kilowatts
- N is the rotational speed of motor in RPM
- D is the motor displacement in in³/rev
- P is the supply line gauge pressure in PSI
- E is the estimated volumetric efficiency (.95)
- Q is the flow in GPM
- (396000), 1714, and .746 are unit conversion factors.

A linear regression is shown in Figure A-1. GS1 and GS2 are the two different vehicle ground speeds. The point markers are the values of the averages for the six different combinations of vehicle ground speed and Stalk Skimmer rotational speed.

The regression equations for the lines and their correlation coefficients are as follows.

For vehicle ground speed of 3.5 km/hr:

- \( P1 = 0.0014W - 0.348 \quad R = 0.986 \)
- \( P2 = 0.0015W - 0.545 \quad R = 0.996 \)

For vehicle ground speed of 7.7 km/hr:

- \( P1 = 0.0023W - 0.744 \quad R = 0.996 \)
- \( P2 = 0.0021W - 0.751 \quad R = 0.997 \)

P1 and P2 are the required power in kilowatts and W is the rotational speed (RPM) of the Stalk Skimmer disc.

The overall equations are

\( P1 = 0.09V + 0.0076W - 1.36 \)
STALK SKIMMER POWER REQUIREMENTS
GS1=3.5 km/hr, GS2=7.7 km/hr

POWER 1

<table>
<thead>
<tr>
<th>POWER (kW)</th>
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</thead>
<tbody>
<tr>
<td>2.25</td>
</tr>
<tr>
<td>2.00</td>
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<tr>
<td>1.75</td>
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<tr>
<td>1.50</td>
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<td>1.25</td>
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<td>0.75</td>
</tr>
<tr>
<td>0.50</td>
</tr>
<tr>
<td>0.25</td>
</tr>
<tr>
<td>0.00</td>
</tr>
</tbody>
</table>

POWER 2

<table>
<thead>
<tr>
<th>POWER (kW)</th>
</tr>
</thead>
<tbody>
<tr>
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FIGURE A-1.

\[ P2 = 0.08V + 0.0071W - 1.34 \]

V is the vehicle ground speed in km/hr.
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Planter 1 = Max-Emerge w/clod movers  
Planter 2 = Buffalo Till Planter  
Planter 3 = Max-Emerge w/ free rolling coulter  
Planter 4 = Max-Emerge w/ powered coulter  
Planter 5 = Max-emerge w/ no attachment  

U = Unchopped stalks  
UC = Chopped stalks  

T and I are not connected with this study

FIGURE B-1. Slot plant study field layout
Date: 1 = dry condition  2 = Wet condition  
Tillage: 1 = No till  2 = Chisel  3 = Fall moldboard  
Planter: 1 = Max-Emerge  2 = Early Riser  
Depths are target depths  
TRT CMB is arrangement of strip till devices on planter for that plot

FIGURE B-2. Strip till study field layout