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Soil Loading Effects of Planter Depth-Gauge Wheels on Early Corn Growth

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Abstract
Final soil manipulation before seed germination occurs during the planting operation. Contact force of depth-gauge wheels adjacent to the seed opener potentially alters the environment for corn seed germination and early plant growth. A field experiment was conducted measuring seed spacing, spacing variability, seed depth, emergence rate, plant dry matter, final stand, crop growth stage, and extended leaf height with different soil contact loads (light, 18 to 50 kg (40 to 110 lb); medium, 50 to 91 kg (110 to 200 lb); and heavy, over 91 kg (200 lb)) and a range of three soil moistures (dry, moist, wet). A treatment with randomly variable contact load similar to that of a conventional planter (control) was also included.

Emergence rate of corn plants was affected by load level and soil moisture conditions. With moist soil or in wet conditions, corn emerged more rapidly with a low load. In dry soil conditions, corn emerged more rapidly with a heavy load. Corn planted in the control treatment did not emerge as rapidly as the optimal loading for a given soil condition. Even though planter depth settings were set at the same position, seeds were planted deeper (8 to 13 mm (0.3 to 0.5 in.)) when load was heavier on depth-gauging wheels. Average seed spacing, standard deviation of seed spacing, final stand, growth stage, and extended leaf height were not statistically different across load levels. Plant dry matter weight was slightly increased at the V3 growth stage with low load levels in moist soils, but only at a reduced 85% confidence level.

Keywords
Corn, Depth, Emergence, Gauge, Growth stage, Load, Planter, Seed, Soil, Spacing, Wheel

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Keywords. Corn, depth, emergence, gauge, growth stage, load, planter, seed, soil, spacing, wheel

Introduction

Soil compaction, soil moisture, tillage procedures, and surface organic matter impact both early development and yield of crops. Increasing early growth and development rates of corn plants are desirable. Seed placement and soil conditions created by planting equipment ideally should optimize soil conditions around the seed. Gaultney et al. (1982) observed a corn yield reduction of over 50% in Indiana during relatively wet years and in severely compacted plots. In Iowa, significantly higher corn yield was produced when equipment used applied no more than 20 kPa (3 psi) surface pressure as compared to 110 kPa (16 psi) surface pressure in a four year study (Erbach et al., 1991).

During planting, wheels rolling on the soil surface to establish seed release depth (depth – gauge wheels) apply a load to the soil surface. To assist the seed opener to penetrate the soil, weight is typically transferred from the planter toolbar frame through parallel links attaching the row unit to the frame. Once the seed opener is fully inserted into the soil and the depth-gauge wheels are in contact with the soil surface, additional weight transfer adds greater load to the soil surface with the potential to alter seed germination. Planters have conventionally developed down-pressure through springs attached to the parallel link mechanism although some newer planter styles use pneumatic cylinders in place of mechanical springs. Typically on spring-type planters, down-pressure can only be manually adjusted. These adjustments can only be made while the planter is stationary whereas cylinder-type systems may offer load adjustment from the tractor's operator station.

Depth-gauge wheels are customarily mounted immediately adjacent to the seed opener directly impacting soil over the seed zone area (Fig. 1). Variation in down force load of depth-gauge wheels may vary seed depth and compaction around the seed. Information on corn response to load applied by depth-gauge wheels would allow growers a better opportunity to make available adjustments to correctly place the seed in an optimal growing zone and at the same time minimize compaction around the seed furrow at the exact time of seed planting.

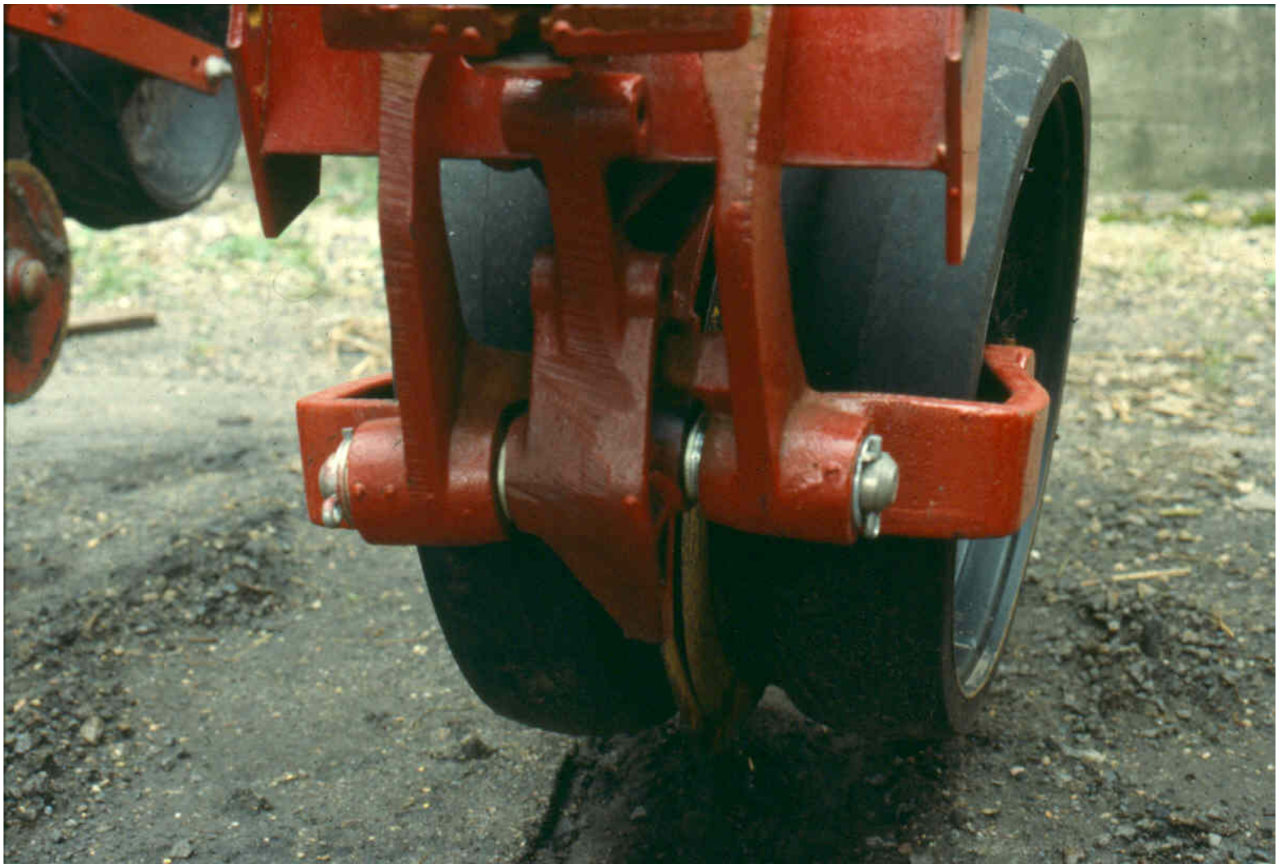

Figure 1. Depth wheels adjacent to seed opener.

Objectives

The objectives of the research were:
1. To determine the optimal contact force between planter depth-gauging wheels and the soil to maximize seed emergence rate, final stand, and early plant growth.
2. To determine the effects of various levels contact force on uniformity of seed depth and seed spacing.
3. To compare effects of "controlled" down force planter units with a conventional planter unit on seeding and crop establishment.

Materials and Methods

Equipment

A Kinze (model PT with Evolution Series planter units, Kinze Manufacturing, Williamsburg, IA), four-row planter was used for planting. On three of the row units, the conventional down-pressure adjustment mechanism was removed and a prototype mechanism designed by Duello Ag Group (Vinton, IA) was mounted which enabled the length of the springs on the parallel links to be changed by hydraulic cylinders operated by electrical solenoids (Fig. 2). As the hydraulic cylinder pivoted a plate to which the springs were attached, down-pressure spring tension (transferring weight from the toolbar to the row unit) could be changed. On these same three row units a load cell was mounted between the depth adjustment and the upper contact point of the depth wheel assembly and row unit.

Figure 2. Down-pressure adjustment mechanism to change spring length on parallel links (seed hopper normally to right removed for clarity).

Load cells measured contact force at 0.131 second intervals. Measurements were recorded on a laptop computer which served as a data logger. Electrical readings from the load cell were correlated with contact force of the depth wheels on a horizontal surface. The formula for the conversion from electrical signal to force was calibrated by putting individual row units on a scale while simultaneously recording measurements of the load cell.

For testing purposes down-pressure spring configuration on the fourth “control” row was unaltered during operation. Immediately prior to each planting, spring tension on the control row was adjusted by the operator to a level that was perceived as just adequate to maintain firm contact of the depth wheels on the soil surface, a customary guideline for optimal planting. During planting all seed hoppers carried a small amount of seed for planting as well as one unopened bag of seed weighing approximately 27 kg (60 lb) to simulate a partially full seed hopper. Although the mean magnitude of the down-pressure could be adjusted by down spring position on the three non-control rows, the instantaneous measured force varied considerably, sometimes over distances of just a few feet.

Load Ranges Tested

Because of load variation, specific ranges of load were selected and then corresponding row segments best exhibiting this loading were indentified to be marked in the field for crop observations. Selection of the ranges for contact force between depth wheels and soil was chosen somewhat arbitrarily after viewing contact load data from several planter passes in the field. It was observed that the least contact load was about 18 kg (40 lb, slightly more than the weight of the depth wheels) and the greatest loads were in excess of 91 kg (200 lb). After these preliminary observations the following load ranges were selected: 18 to 50 kg (40 to 110 lb), low; 50 to 91 kg (110 to 200 lb), medium; and greater than 91 kg (200 lb), high. To increase the chances of creating suitable lengths of row with these loads, exposed rod length of the hydraulic cylinder on each of the three row units was adjusted to 45, 64, or 76 mm (1 ¾, 2 ½, or 3 in.) with the greatest distance being full extension. These lengths were checked prior to each planter pass and readjusted if necessary, as the rod lengths were observed to drift during each planting pass. From left-to-right across the planter, row units were set so as not to cause undue lifting to the left or right side of the four-row planter frame. From left-to-right, row units had the following extended rod length (or "control" without hydraulic cylinder): unit one 76 mm (3 in.), unit two 45 mm (1 ¾ in.), unit three control, and unit four 64 mm (2 ½ in).

A computer spreadsheet program was developed to quickly locate after planting suitable row segments that had been subjected to low, medium, or high load ranges. A total of 10.7 m (35 ft) of row length (approximately 0.0008 ha (0.002 acre) in 76-cm (30-in.) rows) in each planter pass was selected for crop measurement of each load range. Due to the load variation measured along the row, the total 10.7 m (35 ft) length was made up of two to five shorter segments (e.g. the medium load measurement area for the first pass on the first planting date was three segments 5.3, 2.7, and 2.7 m (17, 9, and 9 ft) long, respectively) . Selection of these shorter segments was based on closeness of the mean load to the mean of the desired load range, low standard deviation of the load, and a minimum continuous length of 1.5 m (5 ft) for any of the segments used in the 10.7-m (35-ft) measuring area. Segments were located in the field in relation to physical marker flags whose location was recorded on the electronic data stream during passage of the planter in the field. The 10.7-m (35-ft) control segment was made up of two 5.35 m (17.5 ft) lengths randomly chosen within the row planted by the control unit.

Field Layout

Plots were located on the Iowa State University Sorenson Farm west of Ames. Seed was planted into untilled soil (no-till). Production practice had been no-till for at least the prior two years. Planting was done on three different dates in an attempt to plant in wet, moist, and dry soil conditions. On each planting date the planter made five replicated passes, each pass representing a replicated plot with length of 91 m (300 ft). The plots varied slightly in field elevation, however; they were all within a Canisteo silty clay loam soil type. Three soil moisture samples were taken at planting in a 0 – 51 mm (0 – 2 in.) depth. The first planting occurred on May 17, 2005 at 17.5% soil moisture content, the second planting on June 1, 2005 at 20.8% soil moisture, and the final of the three plantings was on July 15, 2005 at a soil moisture content of 13.9%. On the day of planting, field conditions were judged to be nearly too wet for planting (i.e. avoiding plastic soil plugging the seed opener) on the first date, appearing to be somewhat drier on the surface on the second date, and extremely dry and hard on the surface on the third date. Soil moisture content variations from these surface observations were likely due to slight differences in soil moisture just below the surface but within the 0 – 51 mm (0 – 2 in.) depth at which the soil moisture samples were taken.

Measurements

The following agronomic variables were measured to determine if down-pressure had a detectable effect on them: emergence, seed spacing, seed depth, plant dry matter, plant growth stage, and extended plant height. Emergence rate index (ERI) and standard deviation of plant spacing were calculated from measured data.

Before emergence, measurement areas of low, medium, high, and control loads were marked within each pass in the field after using the computer spreadsheet program and criteria listed above. Emergence counts started on the first day corn emerged and concluded when stand increased less than 1% from the previous day. ERI is a measurement of how rapidly the plants emerged and indicated early seedling vigor. A series of terms are calculated as the ratio of the percentage of newly emerged plants that day to the number of days since planting. This sum described by Erbach (1982) equals ERI. ERI= $\sum_{n=first}^{last} \frac{[\%n - \%(n-1)]}{n}$, where %n is percentage of plants emerged on day n, %(n-1) is the percentage of plants emerged on day n-1, and n is the number of days after planting. The first day is the number of days after planting that the first plant emerged (first counting day) and last day is the number if days after planting when emergence was considered complete (last counting day). Plant spacing measurements were acquired by recording plant spacing along a measuring tape laid beside plants in each measurement area. From these measurements, the mean spacing of all the plants in each section as well as the standard deviation of this spacing was calculated. Shortly after the final stand was reached, usually around V-2 to V-3 growth stages, one-third of the plants in each measured row segment were dug and removed to measure seed depth and plant dry matter weight. To measure plant dry matter weight, after digging, the roots were washed clean to remove any soil aggregates. Plants were then put into a fresh air drying oven, and dried at 140 degrees Fahrenheit for 72 hours (ASAE Standard 358.2; ASAE, 2004). Approximately two weeks later growth stage and extended leaf height were measured on half the plants remaining in each row segment used for measurements.

Data Analysis

Measurements from individual continuous row segments were weighted based on the percentage of the total sample length (10.7 m, 35 ft) represented to calculate a measured value for each load level within each replicated planter pass. Statistical analyses of variance were performed to determine statistical differences. Criteria shown within tables are for a 95% confidence level, however because this was a field experiment, differences as low as an 85% confidence level are noted in the text.

Results and Discussion

Stand

Final stand was generally not affected by load level (table 1). At a reduced level of statistical confidence (85%), stand was greater at the low load level for the June planting. Final stand generally increased with later plantings as soil temperature warmed.

Table 1. Final stand and emergence rate index at different load levels of planter depth-gauge wheels on the soil surface.

	Final stand, plants/acre			Emergence rate index		
Load	17 – May	1-Jun	15-July	17 – May	1-Jun	15-July
Low	28,800	32,200	33,700	12.7	18.6	22.5
Medium	29,600	30,300	31,600	11.6	16.6	22.9
High	27,900	30,200	32,500	10.9	16.0	25.1
Control	28,900	30,300	33,800	10.9	16.0	21.0
$LSD_{0.05}$[a]	NS	NS	NS	0.6	1.9	1.6

[a]Least significant difference between treatments at a 95% level of confidence.

Emergence Rate Index

Emergence rate index, ERI, was significantly affected with the varying load levels (table 1). Seed emerged more quickly with lighter down-pressures in the wetter soil conditions of the first two plantings. In drier soil conditions, however; corn emerged more quickly with a higher down-pressure. Emergence rate under the control load without on-the-go adjustment was less than an appropriately chosen load dependent on soil conditions. Each planting date increased the ERI values. This was expected as the weather was substantially warmer increasing the soil temperatures as the season went on. This caused the corn to emerge more quickly.

Plant Spacing Mean and Standard Deviation

The mean plant spacing and standard deviation were not significantly affected by down-pressure (table 2). Mean spacing among load treatments was different at a reduced 90% confidence level on the first two planting dates. The effect was mixed, however; as spacing was alternatively wide or narrow for a high load.

Table 2. Plant spacing average and standard deviation at different load levels of planter depth-gauge wheels on the soil surface.

	Plant spacing, mm (in.)					
	Mean			Standard deviation		
Load	17 – May	1-Jun	15-July	17 – May	1-Jun	15-July
Low	181 (7.11)	167 (6.56)	163 (6.42)	71 (2.81)	58 (2.29)	56 (2.20)
Medium	178 (7.01)	168 (6.61)	167 (6.58)	71 (2.80)	66 (2.60)	54 (2.12)
High	189 (7.45)	151 (5.93)	168 (6.61)	80 (3.14)	56 (2.21)	63 (2.49)
Control	184 (7.26)	169 (6.65)	162 (6.36)	77 (3.02)	70 (2.77)	47 (1.84)
$LSD_{0.05}$[a]	NS	NS	NS	NS	NS	NS

[a]Least significant difference between treatments at a 95% level of confidence.

Plant Dry Matter

No statistical evidence of plant dry matter differences across the three down-pressure levels was found (table 3). Although there was a trend toward greater plant weight with lower loads in wetter soil conditions (first two planting dates), this was statistically significant only at a reduced (85%) level of confidence.

Table 3. Plant dry matter and seed depth at different load levels of planter depth-gauge wheels on the soil surface.

	Plant dry matter g/plant			Seed depth, mm (in.)		
Load	17 – May	1-Jun	15-July	17 – May	1-Jun	15-July
Low	0.865	1.796	1.544	46 (1.80)	42 (1.64)	38 (1.51)
Medium	0.711	1.635	1.504	53 (2.09)	47 (1.85)	42 (1.67)
High	0.691	1.475	1.693	59 (2.32)	49 (1.94)	49 (1.92)
Control	0.743	1.665	1.538	57 (2.24)	49 (1.94)	41 (1.23)
$LSD_{0.05}$[a]	NS	NS	NS	4 (0.15)	5 (0.21)	6 (0.24)

[a]Least significant difference between treatments at a 95% level of confidence.

Seed Depth

Significant differences in seed depth were detected across down-pressure levels (table 3). Greater down-pressure resulted in greater seed depths. This is a somewhat expected result, as more pressure exerted on moist soil may have caused seed placement to be somewhat deeper than normal. Shallower planted seed emerged more quickly in the wetter soil conditions of the first two plantings (table 1).

Extended Leaf Height and Growth Stage

Extended leaf height and corn growth stage (table 4) were not significantly different at the 95% level for the different loads. Although for some loads plants had emerged more quickly (table 1) plant response was not different for these measurements a few weeks later in the season.

Table 4. Extended leaf height and growth stage at different load levels of planter depth-gauge wheels on the soil surface.

	Extended leaf height, mm (in.)			Growth stage		
Load	17 – May	1-Jun	15-July	17 – May	1-Jun	15-July
Low	1349 (53.1)	1402 (55.2)	968 (38.1)	8.79	9.87	7.48
Medium	1278 (50.3)	1389 (54.7)	965 (38.0)	8.88	9.75	7.47
High	1361 (53.6)	1377 (54.2)	978 (38.5)	8.66	9.59	7.67
Control	1351 (53.2)	1400 (55.1)	960 (37.8)	8.45	9.88	7.50
$LSD_{0.05}$[a]	NS	NS	NS	NS	NS	NS

[a]Least significant difference between treatments at a 95% level of confidence.

Conclusions

Within the range of field conditions tested and load levels of the depth-gauging planter wheels on the soil surface (low, 18 – 50 kg (40 – 110 lb); medium 50 – 91 kg (110 – 200 lb); high, over 91 kg (200 lb)) data support the following conclusions:

- With the same depth setting (relative position of depth wheels to bottom of double-disc seed opener) seeds were planted deeper (8 to 13 mm (0.3 to 0.5 in.)) when load was heavier on depth-gauging planter wheels.
- The rate of corn plant emergence was affected by load level and soil moisture conditions. With moist soil (good soil moisture) or in wet conditions, corn emerged more rapidly with a low load. In dry soil conditions, corn emerged more rapidly with a heavy load. Corn planted in a “control” row without a defined surface loading did not emerge as rapidly as the optimal range of load for a given soil condition.

- For several measures of planter performance and early corn growth and development (i.e., average seed spacing, standard deviation of seed spacing, final stand, growth stage, and extended leaf height) no evidence was detected of effects by load level. Plant dry matter weight was slightly increased at the V3 growth stage with low load levels in moist soils, but only at a reduced 85% confidence level.

Acknowlegements

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