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

H. M. Hanna, B. L. Steward, L. Aldinger

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, 180 to 490 N (40 to 110 lb); medium, 490 to 890 N (110 to 200 lb); and heavy, over 890 N (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-gauge 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.*

Soil compaction, soil moisture, tillage procedures, and surface organic matter impact both early development and crop yield (Hill, 2000). Increasing early growth and development rates of corn plants are desirable (Erbach, 1982). 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 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 4-year study (Erbach et al., 1991). Conversely a comparison of effects of various tires and tracks on the planter tractor found no significant effects on corn yield in a single-year study (Gelder et al., 2007).

Four different depth wheel control configurations were evaluated for their effects on corn and grain sorghum seed depth placement and emergence in no-till wheat and sorghum stubble by Morrison and Gerik (1985). They found depth control from wheels mounted on the side of a double-disc seed opener to produce less seed depth variation than from depth wheels mounted only on the rear or front of the seed opener in no-till stubble. More down-pressure force, however, was required of the side-mounted depth wheels to maintain limited seed depth variation than down-pressure for a similar minimal depth variation when both front- and rear-mounted wheels were linked to provide depth control.

Effects of using or omitting the use of depth-gauge and press wheels on no-till corn, soybean, and wheat seedings with an offset double-disc seed opener were investigated by Chen et al. (2004). Seed depth, emergence rate, and yields were measured. Removing the press wheel reduced the speed of emergence and final stand in normal and dry soil, however in wet soil, speed of emergence increased without the press wheel [not all crops were used in all soil moistures (normal, dry, wet)].

During planting, the depth-gauge wheels, which are wheels rolling on the soil surface to establish seed release depth, 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

Submitted for review in October 2009 as manuscript number PM 8249; approved for publication by the Power & Machinery Division of ASABE in March 2010. Presented at the 2008 ASABE Annual Meeting as Paper No. 08-3968.

This journal paper of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, was supported by Hatch Act and State of Iowa Funds. Trade and company names are included in this article for the benefit of the reader and do not infer endorsement or preferential treatment of the product named by Iowa State University.

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spring-type planters, down-pressure is adjusted manually on individual row units. Cylinder-type systems apply down-pressure using pneumatic cylinders and allow load adjustment of multiple row units at one time.

Depth control mechanisms on planting equipment must be compatible with needs of high-residue conservation-tillage systems (Erbach et al., 1983). 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.

Objectives

The objectives of the research were:

- To determine the optimal contact force between planter depth-gauge wheels and the soil to maximize seed emergence rate, final stand, and early plant growth.
- To determine the effects of various contact force levels on uniformity of seed depth and seed spacing.
- 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, Iowa), 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, Iowa) 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

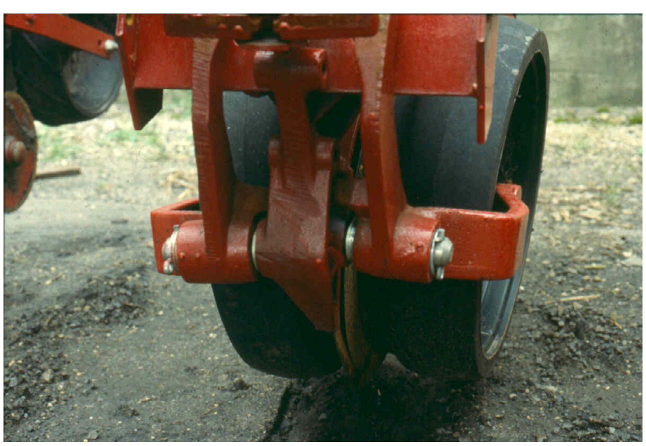

Figure 1. Depth-gauge wheels adjacent to seed opener.

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

depth adjustment and the upper contact point of the depth wheel assembly and row unit.

Load cells measured contact force at 0.131-s 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-gauge 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 experimental purposes, the 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-gauge wheels on the soil surface, a customary guideline for optimal planting. A load cell on the control row measured soil contact force during operation similar to the other three rows. During planting all seed hoppers carried a small amount of seed for planting as well as one unopened bag of seed weighing approximately 270 N (60 lb) to simulate a partially full seed hopper.

Load Ranges Tested

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 as each row unit traveled along the seed furrow varied considerably, sometimes over distances of just 1 to 2 m (3 to 6 ft). To increase the chances of creating suitable lengths of row receiving light, medium, or heavy load, exposed rod length of the hydraulic cylinder on each of the three non-control 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 be slightly changed after 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

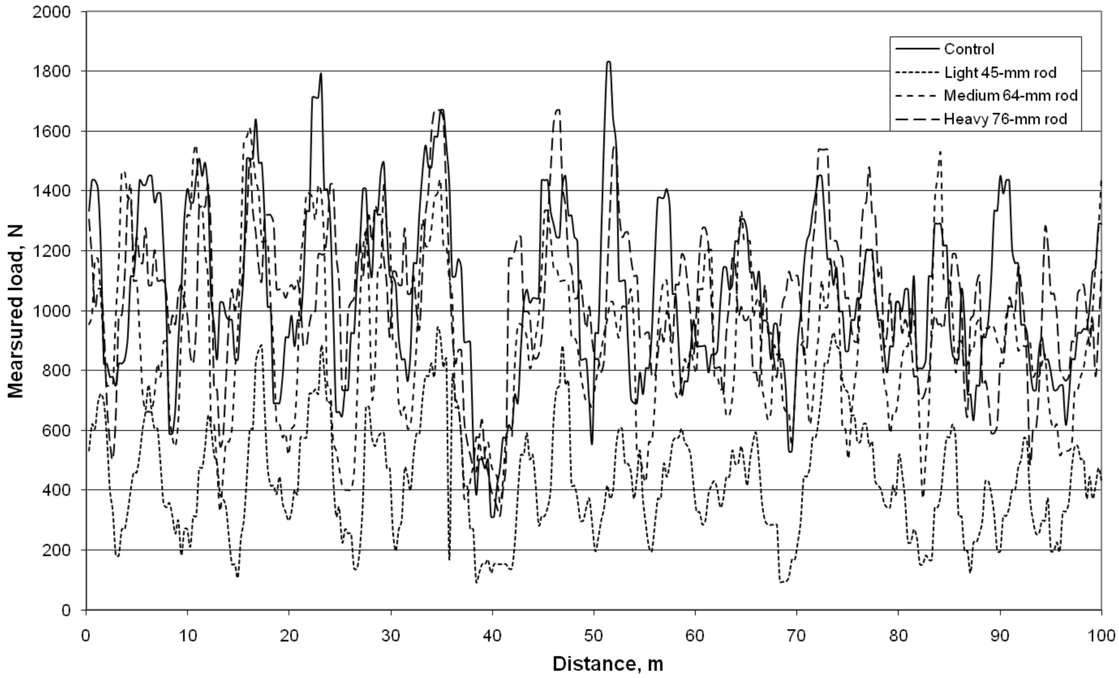

Figure 3. Depth-gauge wheels contact load on soil vs. distance during one planter pass on the first planting date.

four 64 mm (2 ½ in). Typical load variation is shown for a single planter pass during the first planting in figure 3. Initial amount of seed carried and other row unit adjustments such as closing wheel down-pressure and seed-depth adjustment were held constant across row units to minimize variation.

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-gauge 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 180 N (40 lb, slightly more than the weight of the depth-gauge wheels) and the greatest loads were in excess of 890 N (200 lb). After these preliminary observations the following load ranges were selected: 180 to 490 N (40 to 110 lb), low; 490 to 890 N (110 to 200 lb), medium; and greater than 890 N (200 lb), high.

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 at 8 km/h (5 mi/h), 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- to 51-mm (0- to 2-in.) depth. The first planting occurred on 17 May 2005 at 17.5% d.b. soil moisture content, the second planting on 1 June 2005 at 20.8% d.b. soil moisture, and the final of the three plantings was on 15 July 2005 at a soil moisture content of 13.9% d.b. On the first date of planting, field conditions were judged to be nearly too wet for planting (i.e. avoiding plastic soil plugging the seed opener), 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- to 51-mm (0- to 2-in.) depth at which the soil moisture samples were taken.

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. Because of significant in-field load variations (fig. 3), segments could come from any of the three rows with down-pressure spring length adjusted by hydraulic cylinder. 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. Plot stakes bounded individual row sections used for measurement after the identification of suitable row segments (fig. 4).

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), speed of emergence index (SEI), 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.

$$\text{ERI} = \sum_{n=first}^{last} \frac{\%n - \%(n-1)}{n} \quad (1)$$

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 of days after planting when emergence was considered complete (last counting day).

SEI, speed of emergence index, is an additional measurement of how rapidly plants emerged taking into account growing degree days during the emergence process. Similarly to ERI, a series of terms are calculated using the total number of newly emerged plants each day. This sum described by Siemens et al. (2007) equals SEI.

$$\text{SEI} = \sum_{n=first}^{last} \frac{N_i}{A \times AHU_i} \quad (2)$$

where N_i is the number of newly emerged plants on day i, A is the area (m^2) of plant count, and AHU_i is the accumulated heat units (4.4°C base) on the i^{th} day after planting.

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 60°C (140°F) for 72 h (ASAE Standard 358.2; *ASAE Standards,* 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.

Figure 4. Row measurement areas bounded by plot stakes after evaluating depth-gauge wheels load on soil along rows.

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.

Emergence Rate Index

Emergence rate index, ERI, was significantly affected with the varying load levels (table 2). 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 in the control row without a selected load was less than in a row with 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.

Speed of Emergence Index

The speed of emergence index, SEI, also indicated that plants emerged more quickly with lighter down-pressures in wetter soils (table 2). Although not statistically significant,

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

	Plants/ha (Plants/acre)		
Load	17 May	1 June	15 July
Low	71,200 (28,800)	79,600 (32,200)	83,300 (33,700)
Medium	73,100 (29,600)	74,900 (30,300)	78,100 (31,600)
High	68,900 (27,900)	74,600 (30,200)	80,300 (32,500)
Control	71,400 (28,900)	74,900 (30,300)	83,500 (33,800)
$LSD_{0.05}$[a]	NS	NS	NS

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

Table 2. Emergence rate and speed of emergence indices at different load levels of planter depth-gauge wheels on the soil surface.

	Emergence Rate Index			Speed of Emergence Index		
Load	17 May	1 June	15 July	17 May	1 June	15 July
Low	12.7	18.6	22.5	0.0369	0.0509	0.0540
Medium	11.6	16.6	22.9	0.0362	0.0440	0.0517
High	10.9	16.0	25.1	0.0326	0.0439	0.0566
Control	10.9	16.0	21.0	0.0339	0.0430	0.0509
$LSD_{0.05}$[a]	0.6	1.9	1.6	0.0027	0.0057	NS

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

the numerical value of SEI was greatest with higher down-pressure in drier soil. Occasional missing plants in the drier mid-summer soil, perhaps due to seed consumed by ground squirrels, caused more variability in total final plant stand among replications for the last (dry) soil planting. This may be partially responsible for the higher contact pressure SEI values not being statistically greater than other treatments.

Plant Spacing Mean and Standard Deviation

The mean plant spacing and standard deviation were not significantly affected by down-pressure (table 3). Unemerged seeds (not contributing to early corn growth) were not included in spacing measurement. 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.

Plant Dry Matter

Although there was a trend toward greater plant weight with lower loads in wetter soil conditions (first two planting dates, table 4), this was statistically significant only at a reduced (85%) level of confidence.

Seed Depth

Significant differences in seed depth were detected across down-pressure levels (table 4). Greater down-pressure resulted in greater seed depths. This is a somewhat expected result, as more pressure exerted on 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 2).

Extended Leaf Height and Growth Stage

Extended leaf height and corn vegetative growth stage (table 5) were not significantly different at the 95% level for the different loads. Although for some loads plants had emerged more quickly (table 2), plant response was not different for these measurements a few weeks later in the season.

Uniformity of emergence and seed depth

In addition to speed of emergence, some growers are interested in uniformity of plant emergence. Variation in days to plant emergence and seed depth (as measured by standard deviation, table 6) was generally not statistically significant in as many cases as were emergence indices (table 2) or average seed depth (table 4).

Discussion

Effects observed were either directly related to pressure of the depth-gauge wheels on the soil surface (seed depth placement) or early plant response to the seeding environment created by wheel loading (speed of emergence). Seed placement depth and speed of emergence may be related somewhat in that although shallower seeds may emerge more quickly in moist soils, deeper placement to reach soil moisture may be advantageous in dry conditions.

Table 3. 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 June	15 July	17 May	1 June	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.

Table 4. 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 June	15 July	17 May	1 June	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.

Table 5. 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 June	15 July	17 May	1 June	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.

Table 6. Standard deviation of emergence date and seed depth at different load levels of planter depth-gauge wheels on the soil surface.

	Standard Deviation					
	Emergence, days			Seed Depth, mm (in.)		
Load	17 May	1 June	15 July	17 May	1 June	15 July
Low	0.77	0.48	0.92	6.6 (0.26)	5.8 (0.23)	7.6 (0.30)
Medium	1.32	0.67	0.78	6.1 (0.24)	5.3 (0.21)	6.1 (0.24)
High	1.61	0.50	0.80	5.1 (0.20)	5.6 (0.22)	5.1 (0.20)
Control	1.47	0.70	1.07	6.6 (0.26)	7.1 (0.28)	8.4 (0.33)
$LSD_{0.05}$[a]	0.36	NS	NS	NS	NS	2.0 (0.08)

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

After the growing season progressed several weeks, later indicators of plant response (final stand, growth stage, and extended leaf height) were not affected by load of the depth-gauge wheels on the soil surface, however there may have been a slight effect on plant dry matter accumulation at the V3 growth stage. Ultimate grain yield results from many factors (e.g., fertility, weather conditions during the growing season, pest pressure, etc.). Other factors can mask early season planter effects. Nevertheless, growers seeking to optimize practices for highest yield potential may impact early plant growth by planter adjustment.

Seed spacing, although primarily affected by the metering system can also be affected by seed bounce in the seed drop tube or during placement in the seed furrow. At moderate speed (8 km/h; 5 mi/h) and in these no-till field conditions, load on depth-gauge wheels was not observed to affect seed spacing or spacing variability and so did not contribute to uneven spacing by soil conditions within the seed furrow.

Conclusions

Within the range of field conditions tested and load levels of the depth-gauge planter wheels on the soil surface [low, 190 to 490 N (40 to 110 lb); medium 490 to 890 kg (110 to 200 lb); high, over 890 kg (200 lb)] data support the following conclusions:

With the same depth setting (relative position of depth-gauge 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-gauge 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

Support for this project by the Duello Ag Group, Vinton, Iowa is gratefully acknowledged.

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