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ABSTRACT

An on-farm survey was conducted in Nebraska to determine factors affecting corn seed spacing uniformity. Statistical analysis indicated that relative surface roughness, amount of residue present, amount of preplant tillage, and tillage system were important factors affecting uiformity. Subsequently, replicated tillage plots at eight locations were used to evaluate seed spacing uniformity with different planters and tillage systems. Seed spacing coefficient of variation and a planter index developed showed conservation tillage does not significantly reduce seed spacing uniformity.

INTRODUCTION

With increased emphasis on soil and water conservation and the need to save fuel and labor, corn producers are changing to reduced tillage and no-tillage planting systems. However, questions have been raised by producers concerning proper seed spacing and placement which may be influenced by the residue left by alternate tillage systems. Griffith et al. (1977) stated that many farmers report poor stands with conservation tillage. Poor seed placement was listed as a possible cause of this problem.

Uniform plant spacing allows more efficient use of soil moisture, nutrients and light (Donald, 1963). Krall et al. (1977) showed that increasing planting uniformity by decreasing the standard deviation of within-row variability could increase corn yields from 200 to 1,200 kg/ha (3.2 to 19.2 bu/ac) without changing planting rates. Pinter et al. (1978) also showed that corn yields could be related to spacing uniformity. The coefficient of variation of the seed spacing (Pinter et al., 1979) and a numerical scale value from one to five (Pinter et al., 1978) were used to develop relationships of spacing to yield. The numerical scale, which was visually subjective, was based on one representing uneven spacing and five representing uniform spacing. Agness and Luth (1975) warned that because of metering errors, statistical values could be misleading when applied to spacing data. They developed an acceptable space index that indicated the percentage of seeds dropped within 0.5 and 1.5 times the mean spacing. Horne (1973) evaluated planter performance by presenting the percentage of seeds within a specific distance of ideal spacing.

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SURVEY AND RESEARCH PROCEDURES

Planters are designed to plant seeds uniformly when operated, maintained, and adjusted properly. But planter features and field conditions, such as soil moisture and texture as well as type and amount of residue, can affect actual seed spacing uniformity. Although plant populations are often observed to judge planter performance, variations in plant spacing can be caused by several factors. For example, a dead seed may be accurately planted, but the loss of viability and thus, lower plant spacing uniformity, is not the result of planter performance.

To ascertain actual field performance of row crop planters, a survey including 100 planters located on farms in eastern and south central Nebraska was conducted in 1979. Planter operators were selected at random and occasionally, county extension agents were contacted to locate additional operators.

The planter operator was interviewed regarding tillage and planting operations on the field he was currently planting. The planter make, model, features, options, number of rows, and row spacing were recorded. The technician measured the planting speed; made estimates of the type and amount of residue on the surface, the soil type, and the surface roughness and took soil samples for moisture determination.

In order to evaluate the preplant field operations, each was subjectively assigned a score which represented the relative amounts of tillage performed, fuel and labor required, and residue covered. Point breakdown was one for harrowing, two for disking and field cultivating, three for rotary tilling, and four for chisel plowing and moldboard plowing. Points were not assigned to shredding, fertilizing, spraying, planting, and other non-tillage operations. The points were totaled for each field to yield a number representative of the amount of tillage. For example, shredding, moldboard plowing, disking, harrowing, and planting would score a total of seven points.

After the plants had emerged two to four weeks later, the plant and seed spacing uniformity was measured. The plant spacing measurements were obtained by laying out a tape measure and recording the number on the tape at which a plant occurred, to the nearest 1.27 cm (0.5 in.) for a distance of 3.05 m (10 ft) in each row. Apparent skips or large gaps were checked for seeds or plants which had not emerged and their locations were also recorded. Six adjacent rows on six- and twelve-row planters or eight adjacent rows on four-, eight-, and sixteen-row planters were measured to obtain the spacing uniformity data for each planter.

In 1980 and 1981, replicated plots at eight sites in eastern Nebraska were planted to measure the influence of various tillage systems on corn seed spacing uniformity. The replicated sites were at the University of

TABLE 1. SITE AND PLANTER DESCRIPTIONS

	Site							
	1	2	3	4	5	6	7	8
Year	1981	1981	1981	1980	1981	1980	1980	1980
Planter*	I-H[a]	J.D.	I-H[a]	Buffalo	J.D.	A-C[b]	A-C[b]	J.D.
Model	800	7000	800	4550	7000	333	333	7000
Name	Early Riser	Max-Emerge Conservation	Early Riser	Slot	Max-Emerge Conservation	No-Til Special	No-Til Special	Max-Emerge Conservation
Rows x spacing, cm	6 x 76	6 x 76	6 x 76	6 x 76	6 x 91	6 x 91	6 x 91	2 x 76
Coulters	Narrow Rippled	Narrow Rippled	Narrow Rippled	Smooth	Narrow Rippled	Wide Fluted	Wide Fluted	Narrow Rippled
Residue type	Soybeans	Soybeans	Corn	Corn	Corn	Corn	Corn	Oats
Slope, %	3	3	5	5	1	1	1	10
Soil type	Silt-loam	Silt-loam	Silty Clay loam	Silty Clay loam	Silty Clay loam	Silty Clay loam	Silty Clay loam	Silt-loam

*Planters with same letters are the same planter

Nebraska Rogers Memorial Farm, Northeast Station, and Mead Field Laboratory (Table 1). Each of the eight sites had four tillage systems; plow-disk-disk, chisel-disk, disk-disk, and no-till. The plots were replicated a minimum of three times and one planter was used at each site without changing speed or adjustments among the tillage treatments. Six standard production planters were used in the study.

As with the 1979 survey, approximately two to four weeks after planting, spacing measurements were taken. The same method of measuring was used except that the locations of the plants or seeds were recorded to the nearest 0.64 cm (0.25 in.) rather than 1.27 cm (0.5 in.) and each row of the planter was measured once and then averaged to obtain a single observation. One or more observations were made on each of the replicated plots.

PLANTER INDEX

In order to evaluate seed spacing uniformity, an index was developed to indicate planter performance. An average seed spacing was calculated for each observation based on the total number of growing plants and ungerminated seeds in all of the rows measured. This average, called the "ideal spacing," was based upon the seeds actually planted and not necessarily what the operator desired, thus removing operator adjustment errors. The percent miss from the ideal spacing was calculated for each seed dropped in the two based upon the distance from the previous seed as shown in the equation:

$$\text{Percent Miss from Ideal Spacing} = \left| \frac{\text{Actual Distance} - \text{Ideal Spacing}}{\text{Ideal Spacing}} \right| \times 100$$

The percent miss value was then assigned an interger value from zero to five with five meaning less than a 10 percent error in seed placement. An error of more than 50 percent was assigned a value of zero. A double seed drop and a skip or large gap had a value of zero. The index assignment is summarized in Table 2. Within an observation, each individual seed index value was averaged with all other seed index values to obtain an average planter index for that observation. The index, being independent of plant population, can be used to compare planter performance for different row widths and seed spacing within rows.

This planter index is an indicator of the average percent of miss from ideal spacing for each seed dropped by the planter. For example, a planter index value of 2.8 would represent an average placement error for each seed of about 32 percent. The planter index is similar to the percent acceptable space index developed by Agness and Luth (1975) in that no points are given for seeds misplaced by 50 percent or more. Also, the planter index is similar to the one to five point scale developed by Pinter et al. (1978) because both indexes use five points for even spacing and lower values for uneven spacing. Unlike the visually subjective Pinter scale, the planter index is mathematically defined.

RESULTS AND DISCUSSION

Spacing data was gathered from 100 different corn fields during the 1979 survey. Nine different brands of planters, including over 35 models, were observed. The most common brands were John Deere, International, and Allis-Chalmers totaling nearly 80 percent of the planters observed. The percent distribution by brand is given in Table 3.

About 42 percent of the fields used a four-row planter, the most common size observed (Table 4). The most common row spacing, found in 40 percent of the fields, was 76 cm (30 in.). The remaining 60 percent of the fields were planted in wide rows ranging from 91 to 102 cm (36 to 40 in.).

The planter indexes were calculated for each field based upon the seed and plant spacing data. The mean

TABLE 2. SEED INDEX ASSIGNMENT

Percent error in seed placement	Index
0 to 10.0	5
10.1 to 20.0	4
20.1 to 30.0	3
30.1 to 40.0	2
40.1 to 50.0	1
More than 50	0

TABLE 3. MAKES OF PLANTERS OBSERVED IN THE 1979 PLANTER SURVEY

Make	Percent of total
John Deere	44
International	25
Allis-Chalmers	10
White	6
Buffalo	6
Ford	4
Dempster	1
Burch	1
Case	1
Farmer combinations	2

TABLE 4. PLANTER SIZE BY NUMBER OF ROWS AND ROW SPACING

Row spacing cm (in.)	Number of rows 4	6	8	12	16	Totals
76 (30)	6	17	9	4	4	40
91 (36)	11	10	4	—	—	25
97 (38)	21	1	7	—	—	29
102 (40)	4	—	1	—	—	5
Totals	42	28	21	4	4	99*

*One 2 row, 102 cm (40 in.) was also observed.

planter index was 2.41 for the 100 fields, ranging from 1.21 to 4.22 (Fig. 1). The 2.4 index indicates that on the average, each corn seed planted had a placement error of about 36 percent. Only 14 percent of the fields had a planter index of more than three. Even the best performing planter had about a 15 percent error. Although not the same index, the average Pinter et al. (1978) index ranged from 2.3 to 4.5 for their experiments with spacing uniformity. Horne (1973) concluded that any seed placed within 5 cm (2 in.) of ideal spacing, a 30 percent placement error, would be considered acceptable for the population being studied.

Potential factors affecting seed spacing uniformity for the fields in the 1979 survey were analyzed using one way analysis of variance with Duncan's test of the means at the 10 percent level. The analysis indicated that a main factor affecting corn seed spacing uniformity was the tillage and planting system used.

The disk system was used in 60 percent of the fields surveyed, making this the most common tillage system. Fifteen percent of the fields were tilled with the chisel tillage system and 11 percent with the moldboard plow system. The remaining 14 percent of the fields used the no-till, rotary-till, or till-plant systems. In the comparison of the planter indexes for the various tillage systems, fields using the no-till system had a statistically higher mean index (3.53) than those using chisel (2.48), plow (2.45), disk (2.32), rotary-till (2.42), or till-plant (2.76) for seedbed preparation. Analysis of the points for preplant field operations showed that no-till fields had statistically more uniform spacing than fields with tillage. Analysis of the surface roughness also indicated that fields with no-till surface conditions were statistically more uniform in spacing (3.34) than those with well tilled conditions (2.46). Also, fields with a well tilled surface were significantly more uniform than fields with a cloddy surface (2.25). Fields with residue levels of 0 to 2,250; 2,250 to 4,490; or 4,490 to 6,740 kg/ha (0-2000; 2000-4000; or 4000-6000 lb/ac) had significantly less uniform spacing (2.36, 2.51, and 2.18, respectively) than fields with over 6,740 kg/ha (6000 lb/ac) residue (3.36). This trend of better spacing uniformity in fields with no-till conditions, high amounts of residue, and an untilled surface is contrary to the findings of Griffith et al. (1977) and to popular opinion that it is difficult to achieve uniform spacing with reduced and no-till systems.

The type of residue and soil texture did not significantly affect seed spacing uniformity. Also, seed spacing uniformity was not affected by the 4.8 to 11.2 km/h (3 to 7 mi/h) range of ground speeds observed in the survey. However, when more than 74,100 seeds/ha (30,000 seeds/ac) were planted, spacing was less uniform than for lower populations. Analysis of the planter features indicated that planters having a coulter in front of the planting unit tended to have more uniform seed spacing. The type of seed furrow opener, double disk or runner, or the seed covering device had no affect on seed spacing uniformity. Surprisingly, the Duncan's multiple range analysis indicated that press wheel shape had an affect on seed spacing uniformity. Closer examination of the press wheel indicated that rather than shape, the use of press wheels to drive the seed metering mechanism may result in lower seed spacing uniformity as compared to other drive mechanisms. The analysis also indicated that planters which used the press wheel to control seed depth had a statistically lower spacing uniformity planter index (2.34) than planters which used depth bands or gauge wheels to control seed depth (2.85 and 2.59, respectively). As with press wheel shape, using press wheels for depth control appeared to have an interaction with the type of drive for the seed metering mechanism. Therefore, it was concluded that the press wheel may not influence spacing uniformity as much as the drive for the seed metering mechanism. This topic needs further investigation.

The 1979 survey results of the tillage affects on seed spacing uniformity was the basis of the 1980 and 1981 experiment. The planter index for seed spacing uniformity was calculated for each of the replicated tillage plots in the experiment. Also calculated was the coefficient of variation of seed spacing for each observation. Meaningful between site comparisons were not made because of site variations. In addition, no planter was used as a standard at each site. Consequently, valid comparisons between planters could not be made.

The one way analysis of variance with the Duncan's test of the means at the 10 percent level was applied to the data from each site. The planter indexes and the coefficient of variation for each tillage system at each site

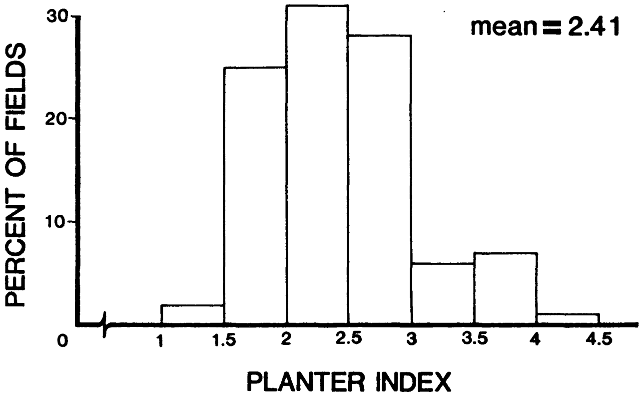

FIG. 1 Planter index distribution from the 1979 survey.

TABLE 5. PLANTER INDEX FOR EACH SITE

Site	Tillage system Plow-Disk-Disk	Chisel-Disk	Disk-Disk	No-Till
1	2.86	2.68	2.53	2.53
2	3.92	3.74	3.83	4.03
3	2.95[b]	2.51[a]	2.57[ab]	2.86[ab]
4	2.38[a]	2.17[a]	2.40[a]	2.99[b]
5	2.55	2.40	2.50	2.32
6	1.85	1.91	1.94	1.93
7	1.62[a]	1.61[a]	1.60[a]	1.80[b]
8*	3.35	3.23	3.41	3.19

a,b — indexes with different subscripts, when present, are significantly different at the 10 percent level at each site.
*Sweep plow undercut substituted for chisel plowing

TABLE 6. COEFFICIENT OF VARIATION OF SEED SPACING FOR EACH SITE

Site	Tillage system Plow-Disk-Disk	Chisel-Disk	Disk-Disk	No-Till
1	0.38	0.40	0.43	0.40
2	0.26	0.30	0.30	0.26
3	0.40	0.44	0.45	0.55
4	0.49[a]	0.50[a]	0.46[a]	0.35[b]
5	0.47	0.48	0.45	0.47
6	0.62	0.61	0.61	0.60
7	0.67[a]	0.68[a]	0.65[ab]	0.62[b]
8*	0.36	0.45	0.35	0.38

a,b — coefficients of variation with different subscripts, when present, are significantly different at the 10 percent level at each site.
*Sweep plow undercut substituted for chisel plowing

are summarized in Tables 5 and 6, respectively. Except for chisel-disk at Site 3, the planter index indicated that adoption of conservation tillage systems did not significantly reduce seed spacing uniformity from that obtained in moldboard plow systems. At all sites, the coefficient of variation indicated again that adoption of conservation tillage systems did not reduce seed spacing uniformity. Based upon the planter index, the no-till system had a statistically better spacing uniformity at Sites 4 and 7. Similar results were shown by the coefficient of variation at Sites 4 and 7. All sites showed that no-till planting can provide seed spacing as uniform, if not more uniform, as other tillage systems.

The planters at sites 4 and 7, which had statistically better uniformity in no-till conditions, had seed metering mechanisms driven by either a press wheel or a rolling coulter. This and similar findings in the 1979 survey analysis indicate that loose soil created by tillage implements may tend to decrease seed spacing uniformity when the planting mechanism is driven by press wheels or coulters. In the 1980-1981 experiment, the presence of either loose soil or untilled soil did not appear to influence seed spacing uniformity with planters having other types of drive for seed metering.

SUMMARY AND CONCLUSIONS

A planter index was developed to evaluate seed spacing uniformity. Five points were used for less than a 10 percent error and a score of zero was given for more than a 50 percent error in seed placement. The mean planter index measured was 2.41 and ranged from 1.21 to 4.22. Even the best planters in the survey had a 20 to 30 percent error in seed placement.

An analysis of factors affecting seed spacing uniformity indicated that relative surface roughness, amount of residue present and amount of preplant tillage were important factors affecting uniformity. Somewhat contrary to popular opinion, better seed spacing uniformity was achieved with no-till planting.

Subsequently, an experiment was designed to evaluate seed spacing uniformity in four tillage systems. A total of six planters were evaluated at eight sites with one planter used at each site. Analysis of the planter index and coefficient of variation of seed spacing showed that adoption of tillage systems other than the moldboard plow does not lower seed spacing uniformity. All sites showed that no-till planting can provide seed spacing as uniform, if not more uniform than other tillage systems.

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