Evaluate Planter Meter and Seed Tube Systems for Seed Spacing Performance of Confection Sunflower Seed to Improve Plant Spacing in the Field

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Introduction

The quality of confection sunflower seed harvested, specifically seed size and uniformity of size, is dependent on plant population and uniformity of plant spacing within the row. Examples of studies conducted to determine the effect of plant population on seed quality include projects by Robinson, et al. (1980) in Minnesota; and by Johnson et al. (1999) in North Dakota. Both studies found that specific plant populations provided maximum yield depending on test location. Both studies also showed that seed size generally decreased as plant population increased. Thus, plant population is directly related to sunflower seed size and yield.

In a separate study, Robinson et al. (1981) in Minnesota studied the effect of uniformity of plant spacing within the row on sunflower yield and quality. They found that uniformity of plant spacing within the row affected yield, seed size, and consistency of seed size in some of the sites and years of their study. Thus, both seed population and seed spacing at planting time have effects on harvested seed yield and seed size.

Several researchers have published results from comparisons of planter models and field speeds for several sunflower seed sizes for seed spacing accuracy as delivered by the planter. Mollanen et al. (1987) in North Dakota compared four planter models on a grease belt test stand, each with several options, at three field speeds with three seed sizes, for a ‘planter index’. They found seed spacing accuracy differences among planter models, among options within models, among field speeds, and among seed sizes. Allen et al. (1983) in Texas planted sunflower seed on a test track and in the field using four seed sizes using a mechanical plate planter and an early version pneumatic planter. They also found differences in seed spacing accuracy caused by planter model, seed size, and field speed.

Since these planter comparison tests were conducted, producers are using different planter models, different seed sizes, more accurate seed spacing measuring equipment is available, and improved parameters for describing seed spacing accuracy have been developed. There is more demand for larger sized confection seed and for more consistent seed size. Confection sunflower (and oilseed sunflower) producers are still having problems with planter seed spacing in the field. New research on planter performance will provide needed information to address these issues.

Objective

Evaluate seed spacing accuracy of selected sunflower planters on a planter test stand to determine if there are planter designs and seed metering issues that likely cause field stand problems with confection sunflowers.

Materials and Methods

Planter models.

Three basic planter models, each with several options and adjustments, were tested — the Case-IH 1200 series; the Deere MaxEmerge vacuum planter series; and the Deere finger pickup series. The meter unit was paired with a seed tube on the test stand. Only one seed tube is offered by Case-IH. Both Deere meter units used the current 'curved' seed tube typically used for corn planting (Deere part no. A56784). The seed tubes included seed sensors. Unless noted, the seed tubes and meter units were new or nearly new. Optional components for the Deere planters were acquired and tested from Precision Planting (23207 Townline Road, Tremont, Il 61568) and Kinze Manufacturing (Ladora, IA).

Seed tested.

The large, narrow confection sunflower seed used for all tests, unless noted otherwise, was Seeds 2000 (Breckenridge, MN 56520) variety Jaguar, with Cruiser and Apron applied (3265 seeds/lb). The 'seed size sensitivity' test for each planter model also included large, wide confection seed (Seeds 2000 variety Panther with Cruiser and Apron applied, 2735 seeds/lb); small confection seed (Seeds 2000 variety Jaguar with Cruiser and Apron applied, 6094 seeds/lb); and #2 oil seed (Seeds 2000 variety Defender Plus with Apron and Maxim applied, 4464 seeds/lb).

Planter test stand.

The planter test stand includes an electronic seed spacing measuring system developed at the University of Nebraska and a conventional 'grease belt' for visual observation of seed spacings. This state-of-the-art test stand uses electronic seed sensing instrumentation to 'sense' seeds dropped from the planter seed tube through a photogate that contains 24 sensor pairs in the direction of planter travel and 24 sensor pairs in the direction perpendicular to planter travel. This sensor system measures the time between seeds that pass through the photogate, and with a calibration factor that includes planter speed and seed spacing, calculates an actual equivalent distance between seeds. Each seed spacing is also adjusted by the position it traveled through the photogate to compensate for any seeds that do not follow the intended path from the end of the seed tube. Thus, the calculated seed spacing will be equivalent to the seed spacing that would appear on a grease belt. The two dimensional feature of this seed sensing system provides information on seed spacing in the direction of planter travel and also side-to-side positioning of the seed, important when evaluating seed drop tubes. The photogate sensors are positioned below the planter seed tube at a distance that is equivalent to the bottom of the planter seed furrow in the field. The electronic seed sensing system used with the University of Nebraska planter test stand, including hardware and software, is described by Lan, et al. (1999) and Kocher, et al. (1998).

Seed spacing accuracy parameters.

Four parameters are used in this project to numerically quantify seed spacing accuracy results: "CP3"; "precision"; "close spacings"; and "wide spacings".

CP3: This is a parameter used in some European planter testing to quantify the percentage of 'desirable spacings'. Within this project CP3 is defined as the percentage of all seed spacings within the test that are ±1.5 cm. (about ±5/8 in.) of the most frequent spacing. In general, with the 9 in. target spacing used in this study, a CP3 value above 70% would appear visually as very good spacing. A CP3 value of 55% would have some noticeable deviations from the average spacing but would still be very acceptable spacing in the field. A CP3 value below about 40% appears as noticeably inconsistent spacing and would probably be considered as unacceptable or undesirable seed spacing accuracy in the field.

Precision: The standard deviation of the spacings not defined as "close spacings" or "wide spacings", divided by the mode spacing, and multiplied by 100.

Close Spacings: The percentage of seed spacings whose lengths are less than half the mode spacing based on the total number of spacings. This will include doubles, triples, and close spacings.

Wide Spacings: The percentage of seed spacings whose lengths are greater than 1.5 times the mode spacing, based on the total number of spacings. This will include skips, and long spacings.

The parameters "precision"; "close spacings"; and "wide spacings" are further defined in ISO standard 7256/1 (1984). Together, these four parameters provide a very complete numerical picture of seed spacing accuracy. Further description and discussion of these parameters is provided by Kachman et al. (1995).

The planter testing was designed to compare seed spacing accuracy of options and adjustments within a planter model and not to directly compare planter models. Each planter model was tested with relevant meter component options; field speed (3, 4½, and 6 mph); sensitivity to vacuum level and singulator adjustment where applicable; sensitivity to seed size; and influence with a used seed tube. The Deere vacuum and finger pickup planter models both use the same seed tube design, so only the vacuum model was tested with a used seed tube. The used seed tubes were acquired from producers who had planted approximately 3000 acres of corn (eight row planters) with the seed tube, and the inside front contact surface was no longer very smooth to the touch. Otherwise, these used seed tubes were intact and not damaged.

Initial vacuum and singulator settings for seed plate comparisons of the vacuum planter models were determined by visual observations of seed spacing accuracy on the grease belt. Then single runs with electronic measurements were made of that setting and compared to higher and lower adjustments of both singulator and vacuum settings to verify a best vacuum and singulator setting for each seed plate.

Unless noted, all tests were conducted at 4½ mph equivalent field speed and 9 in. seed spacing. The 9 in. seed spacing was chosen to duplicate a final sunflower plant stand of 18,000 plants/A at 75% emergence with 30 in. row spacing. Each individual test run included spacings between 500 consecutive seeds and was replicated four times. Thus reported values for each treatment are the average of four replications and a total of 2000 seed spacings.

Results and Discussion

<u>Case-IH 1200 Series</u>

Comparisons within the Case-IH 1200 series planter meter unit included seed plates, field speed, vacuum, singulator, seed size, and worn seed tube. Results for each of these comparisons are contained in Tables 1 - 6.

Table 1. Seed plate comparison for the Case-IH planter. All at 4½ mph with large, narrow confection sunflower seed and at the best vacuum and singulator setting for each seed plate.

Seed Plate	Vacuum (in. water)	Singulator Setting	Close Spacings (% of total)	Wide Spacings (% of total)	Precision	CP3 (%)
2455	18	2	2.8	0.7	9.0	56.9
2440	26	2	1.7	1.6	9.3	57.1
2423	40	2	2.3	12.1	8.7	50.1
lsd (p=0.05)			*0.8*	*3.2*	*ns*	*6.1*

Seed plate 2440 was the overall best plate for the large, narrow confection sunflower seed, although plate 2455 was nearly as good. The holes in plate 2423 were too small, required excessive vacuum pressure, and had higher number of wide spacings (skips).

Table 2. Sensitivity of field speed on seed spacing accuracy for the Case-IH planter when all other meter settings were held constant. All three speeds used the 2440 seed plate, 26 in. water vacuum, singulator setting 2, and large, narrow confection sunflower seed.

Field Speed (mph)	**Close Spacings (% of total)**	**Wide Spacings (% of total)**	**Precision**	**CP3 (%)**
3	3.3	0.8	6.7	71.1
4½	1.7	1.6	9.3	57.1
6	3.2	2.8	11.5	44.9
lsd (p=0.05)	*1.0*	*0.6*	*0.7*	*3.7*

Increasing field speed from 3 through 6 mph decreased seed spacing accuracy and generally increased the combination of wide or close spacings. Fine tuning of vacuum and/or singulator setting would likely improve seed spacing accuracy at 3 and 6 mph.

Table 3. Sensitivity of vacuum setting on seed spacing accuracy for the Case-IH planter when all other settings were held constant. All three vacuum levels were tested with the 2440 plate, 4½ mph, singulator setting 2, and large narrow confection sunflower seed.

Vacuum Level (in. of water)	**Close Spacings (% of total)**	**Wide Spacings (% of total)**	**Precision**	**CP3 (%)**
26	2.7	1.0	9.4	56.3
31	3.0	1.0	9.2	56.2
21	2.3	2.2	9.2	55.1
lsd (p=0.05)	*ns*	*0.7*	*ns*	*ns*

Changing vacuum setting from 21 to 31 in. water made little change in seed spacing accuracy.

Table 4. Sensitivity of singulator setting on seed spacing accuracy for the Case-IH planter when all other settings were held constant. All three singulator settings were tested with plate 2440, 4½ mph, 26 in. water vacuum, and large, narrow confection sunflower seed.

Singulator Setting	**Close Spacings (% of total)**	**Wide Spacings (% of total)**	**Precision**	**CP3 (%)**
1	1.9	6.7	9.5	52.5
2	1.7	1.6	9.4	57.1
3	4.6	0.7	9.8	52.8
lsd (p=0.05)	*1.2*	*3.9*	*ns*	*ns*

Singulator setting was critical to minimizing close and wide spacings for plate 2440.

Table 5. Sensitivity of seed size to seed spacing accuracy for the Case-IH planter when other meter settings were held constant. All treatments used seed plate 2440, 4½ mph, 26 in. water vacuum, and singulator setting 2.

Seed Size	Close Spacings (% of total)	Wide Spacings (% of total)	Precision	CP3 (%)
Large, narrow confection seed	2.7	1.0	9.4	56.3
Large, wide confection seed	2.8	9.5	9.6	50.6
#2 oil seed	2.2	0.3	6.7	70.4
Small confection seed	9.2	0.7	9.0	53.3
lsd (p=0.05)	*1.4*	*0.8*	*0.9*	*3.6*

Table 5 data show that some combination of changes in seed plate, vacuum, and singulator setting must be made when changing sunflower seed size and shape.

Table 6. Effect of “used” seed tube on seed spacing accuracy of the Case-IH planter. Both seed tubes were compared with seed plate 2440, 4½ mph, 26 in. water vacuum, singulator setting 2, and large narrow confection seed.

Seed Tube	Close Spacings (% of total)	Wide Spacings (% of total)	Precision	CP3 (%)
New seed tube	4.4	1.0	9.3	56.1
“Used” seed tube	6.6	1.4	12.3	45.0
Statistically Different (p=0.05)?	*no*	*no*	*yes*	*yes*

The used or worn seed tube did not cause more close or wide spacings but did cause reduced precision of seed spacing as compared to a new seed tube.

Deere MaxEmerge Vacuum Series

Comparisons within the Deere MaxEmerge vacuum series planter meter unit included seed plates, field speed, vacuum, singulator position, seed size, and worn seed tube. Results for each of these comparisons are contained in Tables 7 - 13.

Table 7. Seed plate comparison for the Deere MaxEmerge series planter. All at 4½ mph with large, narrow confection sunflower seed and at the best vacuum and singulator settings for each seed plate.

Seed Plate	Vacuum (in. water)	Singulator Setting (% of hole covered)	Close Spacings (% of total)	Wide Spacings (% of total)	Precision	CP3 (%)
A52391 (flat plate)	12	¾	6.1	2.7	14.6	35.9
A52390 (flat plate)	12	½	7.5	7.2	13.7	36.7
A50617 (cell plate)	6	---	22.1	182.0	16.0	23.5
H136478 (cell plate)	12	---	19.3	24.0	16.6	19.1
H138722 (cell plate)	1 ½	---	32.6	6.2	20.9	17.7
H136092 (cell plate)	1 ½	---	17.1	14.5	19.9	21.1
lsd (p=0.05)			*3.2*	*2.7*	*1.6*	*4.1*

Only flat plate A52391 (with accompanying 'doubles eliminator' properly adjusted) was close to being acceptable for planting the large, narrow confection sunflower seed. The 6.1% close seed spacings were primarily caused by two seeds dropped from one plate cell. The planter operator's manual recommends plate A52391 for confection sunflower seed. However, Deere generally does not recommend this planter model for planting the large, narrow confection sunflower seed. Perhaps fewer cells in this A52391 plate would improve performance because this long sunflower seed does not have space to line up end-to-end on the plate cells.

Table 8. Comparison of seed spacing accuracy with the best Deere seed plate (A52391) and with three seed plates (and associated meter accessories) manufactured by Precision Planting. All at 4½ mph field speed and with large, narrow confection sunflower seed.

Seed Plate	Vacuum (in. water)	Singulator Setting (part of hole covered)	Close Spacings (% of total)	Wide Spacings (% of total)	Precision	CP3 (%)
7200035 (Precision Planting eSet)	10.0	¾	3.5	2.9	11.2	36.9
7200034 (Precision Planting eSet)	12.0	---	3.4	3.1	11.8	44.3
720003 (Precision Planting eSet	8.0	---	3.7	2.0	13.1	41.3
A52391 (Deere flat plate)	12.0	---	6.5	2.6	14.1	38.4
lsd (p=0.05)			*1.3*	*ns*	*1.3*	*ns*

The Precision Planting 'eSet' meter components improved seed spacing accuracy compared to the Deere seed plates. Additional fine tuning of the Precision Planting options would likely improve performance even further.

Table 9. Sensitivity of field speed on seed spacing accuracy for the Deere MaxEmerge vacuum planter when all other meter settings were held constant. All three speeds with A52391 seed plate, 12 in. water vacuum, singulator setting at ¾ hole closed, and large, narrow confection sunflower seed.

Field Speed (mph)	Close Spacings (% of total)	Wide Spacings (% of total)	Precision	CP3 (%)
3	4.4	1.0	11.1	49.8
4 ½	6.5	2.6	14.1	38.4
6	4.7	1.3	15.9	32.8
lsd (p=0.05)	*1.3*	*1.2*	*1.2*	*4.0*

Although increasing field speed did not make a consistent change in close or wide spacings, precision steadily and substantially decreased with increased field speed.

Table 10. Sensitivity of vacuum setting on seed spacing accuracy for the Deere MaxEmerge vacuum series planter when all other settings were held constant. All three vacuum levels with flat plate A52391, 4½ mph, singulator setting at ¾ hole closed, and large narrow confection sunflower seed.

Vacuum Level (in. of water column)	Close Spacings (% of total)	Wide Spacings (% of total)	Precision	CP3 (%)
10	4.5	1.8	13.6	41.1
12	6.5	2.6	14.1	38.4
14	5.0	0.9	13.9	38.5
lsd (p=0.05)	*ns*	*1.1*	*ns*	*ns*

Changing vacuum between 10 and 14 in. water made little difference in seed spacing performance.

Table 11. Sensitivity of singulator setting on seed spacing accuracy for the Deere MaxEmerge vacuum planter when all other settings were held constant. All three singulator settings with flat plate A52391, 4½ mph, 12 in. water vacuum, and large, narrow confection sunflower seed.

Singulator Setting	Close Spacings (% of total)	Wide Spacings (% of total)	Precision	CP3 (%)
½ hole covered	8.4	1.2	13.3	38.3
¾ hole covered	6.5	2.6	14.1	38.4
Hole almost completely (>90%) covered	3.3	6.4	13.9	38.7
lsd (p=0.05)	*2.4*	*0.9*	*ns*	*ns*

Singulator setting (‘doubles eliminator’) was critical for minimizing close (doubles) and wide (skips) spacings. With this particular planter model there is no scale or setting number to adjust all units the same, a disadvantage of this model.

Table 12. Sensitivity of seed size to seed spacing accuracy with the Deere MaxEmerge vacuum planter when other meter settings were held constant. All treatments used flat plate A52391, 4½ mph, 12 in. water vacuum, and singulator setting with ¾ hole closed.

Seed Size	**Close Spacings (% of total)**	**Wide Spacings (% of total)**	**Precision**	**CP3 (%)**
Large, narrow confection seed	6.5	2.6	14.1	38.4
Large, wide confection seed	3.5	1.0	13.1	41.5
Small confection seed	14.4	2.9	17.0	26.9
#2 oil seed	5.1	0.6	12.9	44.0
lsd (p=0.05)	*2.0*	*0.9*	*1.2*	*4.4*

Without making any planter meter changes, changing seed size or shape had a substantial effect on seed spacing performance.

Table 13. Effect of "used" seed tube, and a seed tube with a lodged seed, on seed spacing accuracy of the Deere MaxEmerge vacuum planter. All three seed tubes were compared with flat seed plate A52391, 4½ mph, 12 in. water vacuum, and singulator setting of ¾ hole closed.

Seed Tube	**Close Spacings (% of total)**	**Wide Spacings (% of total)**	**Precision**	**CP3 (%)**
New seed tube	6.5	2.6	14.1	38.4
"Used" seed tube	12.9	3.3	17.4	27.7
Example of a seed tube with one seed lodged within the seed tube	46.3	22.4	27.0	7.6
lsd (p=0.05)	*1.50*	*2.10*	*1.30*	*2.1*

The "used" seed tube had a front contact surface that was slightly rough, similar to used sandpaper. This rough surface caused some seed to take a different speed or path down the seed tube, resulting in reduced seed spacing accuracy. We suspect this rough surface is caused by planting corn. When we began testing the Deere vacuum planter we noted that seed spacing changed during one test. After considerable checking the instrumentation and the test stand we finally discovered that one seed had lodged side-to-side in the front of the seed tube just above the location of the seed sensor. This repeated continually during the testing with this vacuum planter and the finger pickup model since it used the same seed tube. The average frequency was about one lodged seed in every 5,000 seeds tested. In all but one instance, only one seed lodged at a time. We never had a complete blockage of the seed tube. When one seed lodged in the seed tube, then every seed would make contact with it, and seed spacing was extremely irregular. The planter still delivered the correct number of seeds but at very poor spacing. We have heard reports from growers who have told us this happens frequently in the field with the very long, narrow confection seed.

Deere Finger Pickup Series

Comparisons within the Deere Finger Pickup series planter meter unit included main meter component combinations, backing plate seed exit hole size, field speed, and seed size. Results for each of these comparisons are contained in Tables 14 - 17.

Table 14. Seed meter component combination comparison within the Deere Finger Pickup planter. All at 4½ mph with large, narrow confection sunflower seed.

Fingers	Backing Plate	Backing Plate Hole Size	Brush	Close Spacings (% of total)	Wide Spacings (% of total)	Precision	CP3 (%)
Long Deere	Deere	Large	Deere	8.4	23.3	12.8	35.3
Short Deere	Deere	Large	Deere	6.6	35.5	13.7	26.4
Long P.P.*	P.P. "A"	Small	P.P. Blank	4.1	12.3	8.2	55.8
Long P.P.	P.P. "A"	Small	P.P. No. 1	3.9	16.5	9.2	49.7
Long P.P.	P.P. "A"	Small	P.P. No. 5	3.6	17.2	8.8	51.0
Long P.P.	P.P. "C"	Small	P.P. No. 1	4.4	13.2	8.5	54.8
Long P.P.	P.P. "C"	Small	P.P. No. 5	2.9	14.9	7.9	55.2
Long P.P.	P.P. "C"	Enlarged	P.P. No. 5	3.9	13.8	8.2	52.6
lsd (p=0.05)				*2.3*	*2.5*	*1.1*	*4.6*

* Precision Planting

All combinations of components used in this test were considered unacceptable for planting the large, narrow confection seed. Some combinations provided good close spacing values and good precision, but all had excessively high percentage of wide spacings (skips). Observation of the seed passing through the finger mechanism path when the meter was opened, suggests that this long, narrow shape does not function properly within this type of metering mechanism. Long fingers performed better than the short fingers, and some options by Precision Planting performed better than the original Deere components.

Table 15. Effect of seed exit hole size in backing plate on seed spacing accuracy of the Deere Finger Pickup planter. Both backing plate hole sizes were compared with Deere long fingers, Deere brush, 4½ mph, and large narrow confection sunflower seed.

Size of Seed Exit Hole in Backing Plate	**Close Spacings (% of total)**	**Wide Spacings (% of total)**	**Precision**	**CP3 (%)**
Large (Kinze backing plate part no. GR0664)	10.7	14.5	13.9	37.3
Small (Kinze backing plate part no. GR1569)	9.2	35.6	14.6	27.3
Statistically Different (p=0.05)?	*no*	*yes*	*no*	*yes*

The large seed exit hole in the backing plate performed much better than the small seed exit hole in the Kinze backing plate.

Table 16. Sensitivity of field speed on seed spacing accuracy with the Deere Finger Pickup planter when all other meter settings were held constant. All three speeds with the long Deere fingers, Deere backing plate with large seed exit hole, Deere brush, and large, narrow confection sunflower seed.

Field Speed (mph)	**Close Spacings (% of total)**	**Wide Spacings (% of total)**	**Precision**	**CP3 (%)**
3	6.0	24.5	12.7	31.8
4 ½	9.5	18.3	12.9	37.1
6	14.4	20.3	16.8	27.4
lsd (p=0.05)	*ns*	*4.4*	*2.7*	*7.8*

Seed spacing performance of this finger pickup metering mechanism significantly deteriorated as field speed was increased from 3 mph through 6 mph.

Table 17. Sensitivity of seed size on seed spacing accuracy within the Deere Finger Pickup planter when all other settings were held constant. All seed sizes used the Deere long fingers, Deere backing plate with large seed exit hole, Deere brush, and 4½ mph field speed.

Seed Size	**Close Spacings (% of total)**	**Wide Spacings (% of total)**	**Precision**	**CP3 (%)**
Large Wide	1.9	7.6	8.8	56.6
#2 Oil Seed	9.5	1.9	8.1	55.6
Small Confection	7.5	26.6	10.9	33.1
Large Narrow	9.5	18.3	12.9	37.1
lsd (p=0.05)	*2.5*	*2.5*	*1.1*	*4.0*

The finger pickup meter mechanism was very sensitive to seed size/shape for seed spacing accuracy.

Conclusions

This study was conducted on the premise that confection sunflower seed must be accurately spaced within the row to in-turn provide consistently spaced sunflower plants with uniform head and seed size. The increasingly popular large, narrow confection sunflower seed is difficult to accurately meter in some row crop planter models. This study compared meter options within the Case-IH 1200 series planter; the Deere MaxEmerge vacuum planter series; and the Deere Finger Pickup planter series for seed spacing accuracy on an electronic planter test stand.

The large diameter, flat plate, multiple element singulator design of the Case-IH 1200 series planter provided very good seed spacing performance with the large, narrow confection sunflower seed. Although the experimental design of this study was not intended to compare basic planter models, the magnitude of differences in results are large enough that we would consider the standard Deere MaxEmerge vacuum planter model to be 'marginally' acceptable for planting confection sunflower seed, and the standard Deere Finger Pickup model to be unacceptable for planting confection sunflower seed.

The only minor concern with the Case planter unit was the possibility of having a seed part lodge in the seed plate hole, since there is no hole cleanout mechanism. A hole never plugged during this test, although we have seen holes plugged very infrequently in grower's planters during field operation.

The Deere vacuum planter unit with best seed plate had higher than preferred close spacings and wide spacings, and a lower (higher value) seed spacing precision than the Case-IH planter. The Deere finger pickup planter unit, with appropriate options, had acceptable close spacings and spacing precision, but excessive seed skips (wide spacings). An even larger concern for both Deere planter models, was the too frequent occurrence of seed lodging in the seed tube which created very erratic and unacceptable seed spacing distribution. This has been reported by operators of these planters in the field while planting the large, narrow confection sunflower seed. An additional danger of this problem is that, unless the seed tube plugs completely, typical planter monitors will indicate the planter is delivering the correct number of seeds per acre (which it would be) but will provide no information that the individual seed spacing is unacceptable.

All three basic planter metering systems tested were sensitive to adjustments such as vacuum, singulator setting, seed plate or finger option, seed size/shape, and field speed.

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