CORN STAND UNIFORMITY IN WISCONSIN

Mike Rankin[1/] and Joe Lauer[2/]

Introduction

As you drive down the road in early summer, most corn fields appear uniform. However, a closer examination often reveals a wide variation in how evenly plants are spaced within the row. When planters are not operated or functioning properly, a high number of doubles or gaps may occur. Some researchers have suggested using standard deviation (SD) as a measure of in-row corn stand uniformity (Nielson, 1991). At Purdue University, Nielson (1991) has suggested that corn grain yield declines about 2.5 bu/acre for each 1 inch increase in standard deviation above a value of 2 inches. Conversely, many researchers have seen very little impact of corn spacing SD on final grain yield (Butzen, 1998). Nafziger (1996) has suggested that SD alone is not a good means of predicting yield responses to stand variability because of the differing and interactive effects of row skips, doubles, and plant density.

Few studies have been done in the upper Midwest to quantify in-row stand uniformity of production corn fields and measure its effect on grain yield. To investigate this question, a research project was initiated in 1998.

Methods

Stand uniformity in production fields

County UW-Extension faculty were asked to select fields for stand uniformity evaluations. Forty-two fields were evaluated in 1998 and 45 fields were evaluated in 1999. The 87 total fields represented at least one field from 16 different Wisconsin counties. Plant to plant spacing was measured between 30 consecutive corn plants for each row unit of the planter at two different locations of each field evaluated. Fields and areas of fields were selected that had good emergence so that factors other than planter performance (e.g. diseases, insects, and environmental conditions) would not confound final results. Stand uniformity was characterized by determining SD, plant density, average plant spacing, row gaps per 50 ft., and seed doubles per 50 ft. using a Microsoft Excel® spreadsheet program. Plant doubles were defined as any plants within 2 inches of each other and gaps for 30, 36 or 38-inch row spacings were defined as spaces of 12 inches or more without an emerged plant. For 20-inch row spacings, gaps were defined as 18 inches or more without a plant. Data was summarized for both individual fields and in total. Each cooperating corn grower was given a summary sheet with data derived from their individual field (see Attachment 1).

Interactions of planting speed, stand uniformity, and grain yield

In 1998, corn was planted at 4, 6, and 8 MPH on two Fond du Lac County farms (Lamartine and Eden locations) in an effort to force differences in stand uniformity. Similar field plots were established in 1999 on two Fond du Lac County farms (Byron and Malone locations) and at the Arlington Agricultural Research Station in Columbia County. Field plots were established using a randomized complete block design with three or four

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1/ Crops and Soils Agent, University of Wisconsin-Extension, Fond du Lac County
2/ Extension Corn Agronomist, Dept. of Agronomy, University of Wisconsin-Madison

replications. After corn emergence, the distance between 30 consecutive plants was measured for each row of every plot. Stand uniformity was characterized by determining SD, plant density, average plant spacing, row gaps per 50 ft., and seed doubles per 50 ft. using a Microsoft Excel® spreadsheet program. Grain yields were measured in the fall. Statistical analysis was done using AgStats2 (Karow, 1990). At four other locations (Malone, Two Rivers, Mason, and Saxon) in 1998 and three other locations (Brownsville, Gillett, and Saxon) in 1999, the same treatments were imposed and data was collected with the exception of grain yield. Planting information for all plot locations is presented in Table 1.

Table 1. Planter and field information for 1998 and 1999 corn stand uniformity trials

Location	**Year**	**Planter Make/model**	**Seed Delivery System**	**Row number/ width**	**Planting Date**	**Planting Rate**
				(#/in.)		(seeds/acre)
Lamartine	1998	IH Cyclo 800	air	6/30	6 May	32,000
Eden	1998	JD 7000	finger	6/30	21 May	35,600
Malone	1998	JD 7200	finger	6/30	11 May	30,900
Two Rivers	1998	JD 7200	air-vac	6/30	14 May	28,500
Mason	1998	JD 1770	air-vac	12/30	15 May	30,000
Saxon	1998	White 5400	air	4/30	16 May	26,000
Malone	1999	JD 7200	finger	6/30	11 May	30,200
Byron	1999	Kinze 2000	finger	6/30	4 May	31,000
Brownsville	1999	JD 7200	finger	6/30	2 May	29,600
Gillett	1999	JD 7000	finger	6/30	13 May	27,000
Saxon	1999	White 5400	air	4/30	28 May	26,000
Arlington	1999	Kinze	finger	4/30	10 May	30,000

Standard Deviation Primer

SD is a mathematical measure of variability within a group of measurements. For example, a "perfect" corn stand with every plant exactly the same distance away from the next plant would have a SD of 0 inches. This of course never happens even with the best of planter maintenance programs and operation. The more variability that exists among plant-to-plant measurements, the higher the SD value. Effectively, SD describes how close all measurements cluster around the sample average. Nielson (1991) suggested that a SD of 2 inches is about the best a producer can obtain in actual production fields because of planter performance limitations and the fact that a small percentage of seed will not germinate.

A Survey of Stand Uniformity in Wisconsin Corn Fields

Eighty-seven Wisconsin corn fields have been evaluated for in-row stand variation during the 1998 and 1999 growing seasons. It is again important to emphasize that fields with good to excellent emergence were targeted in an effort to measure corn planter performance rather than other variables inhibiting germination and emergence. Success in accomplishing this goal is indicated by the fact that actual stands averaged 97.1% of farmer-reported planting rates. Corn planter characteristics and planting rates for these fields are presented in Table 2.

Table 2. Overview of corn planters and planting rates for fields evaluated (n=87)

Planter Type	**# fields**	**Row Spacing** (in)	**# fields**	**Target Planting Rate** (seeds/acre)	**# fields**
Finger	57	20	2	<25,000	3
Air	16	30	67	25,000 – 29,999	25
Vacuum	9	36	8	30,000 – 35,000	58
Plate	5	38	10	>35,000	1

Average SD for all fields was 3.3 inches with a range of 1.9 to 5.9 (Table 3). Doubles per 50 ft. ranged from 0.1 to 25.9 with an average value of 5.1. Gaps per 50 ft. averaged 7.3 with a range of 1.0 to 16.9. Gaps had more of an impact and were a better predictor of SD than doubles (Figures 1 and 2). This is in agreement with previous research done by Nafziger (1996). Some fields with a relatively large number of doubles but few gaps still had very respectable SD values. This was especially (and perhaps not surprisingly) true of fields planted in 38-inch row spacings at relatively high plant densities. Conversely, the two fields planted in 20-inch rows had the lowest frequency of both gaps and doubles. Hence, it appears that SD alone is not a perfect indicator of stand uniformity by which to make comparisons unless other factors such as row spacing and plant density are similar. It was encouraging to note that most Wisconsin producers with fields in this study were planting seed at rates much higher than would have been the case ten years ago. Average planting rate for the 87 fields was 30,311 seeds per acre. Actual plant counts ranged from 22,264 to 35,501 plants per acre with an average of 29,377.

Table 3. Stand characteristics of 87 Wisconsin corn fields evaluated for stand uniformity

	All-farm Average	**All-farm Range**
Standard Deviation (in)	3.3	1.9 – 5.9
Doubles per 50 ft. of row	5.1	0.1 – 25.9
Gaps per 50 ft. of row	7.3	1.0 – 16.9
Average spacing (in)	7.2	5.4 – 10.1
Planting rate (seeds/acre)	30,311	21,000 – 35,600
Actual plant density (plts/acre)	29,377	22,264 – 35,501
Stand as % of planted	97.1%	77.8% - 113.5%

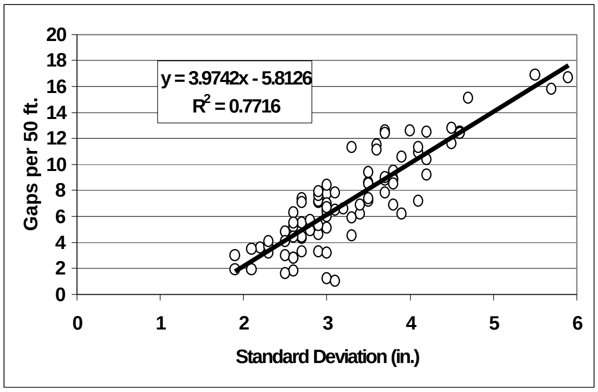

Figure 1. Relationship between row gaps per 50 ft. and standard deviation of in-row plant spacings in 87 Wisconsin corn fields (1998-99)

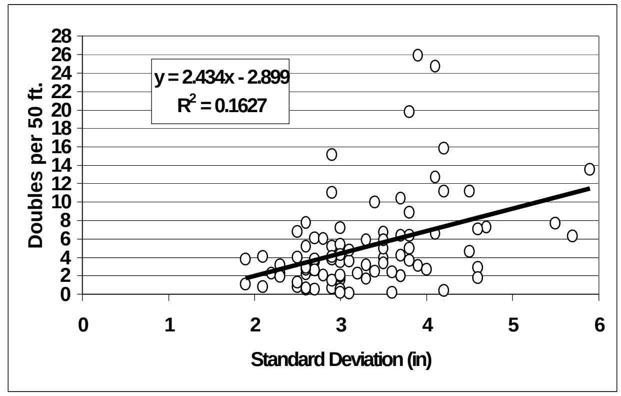

Figure 2. Relationship between seed doubles per 50 ft. and standard deviation of in-row plant spacings in 87 Wisconsin corn fields (1998-99)

Planting speed, stand uniformity, and grain yield

We've determined that a large range of in-row plant-to-plant stand variability exists in Wisconsin corn fields. The next logical question is: "Does this variability impact corn grain yield?" Planting speed was used as a mechanism to force differences in stand variability and measure the effects on grain yield with field scale equipment. Nielson (1995), in a series of on-farm strip trials conducted in Indiana, showed that planting speed can have negative effects on stand uniformity.

At the 5 locations where yield measurements were taken, yields tended to decline as planting speed increased (Figure 3). When averaged across all locations, a significant yield loss from 183 bu/acre at the 4 MPH planting speed to 176 bu/acre at the 8 MPH speed occurred (Figure 4). Along with this decline in grain yield, there was a significant increase in SD from 3.3 inches at 4 MPH to 4.2 inches at 8 MPH (Figure 4).

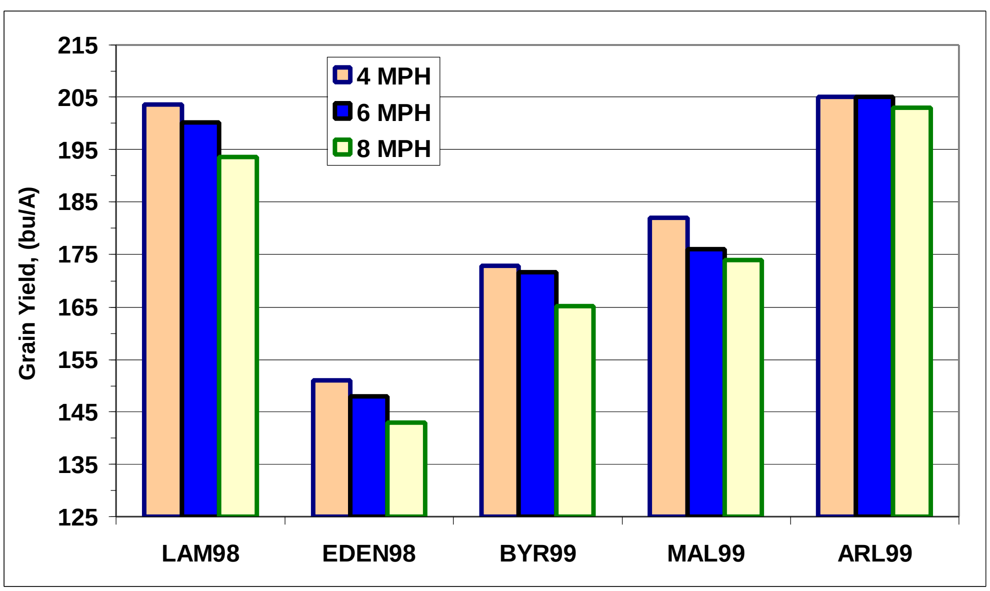

Figure 3. Effect of planting speed on corn grain yield at five Wisconsin locations (1998-99)

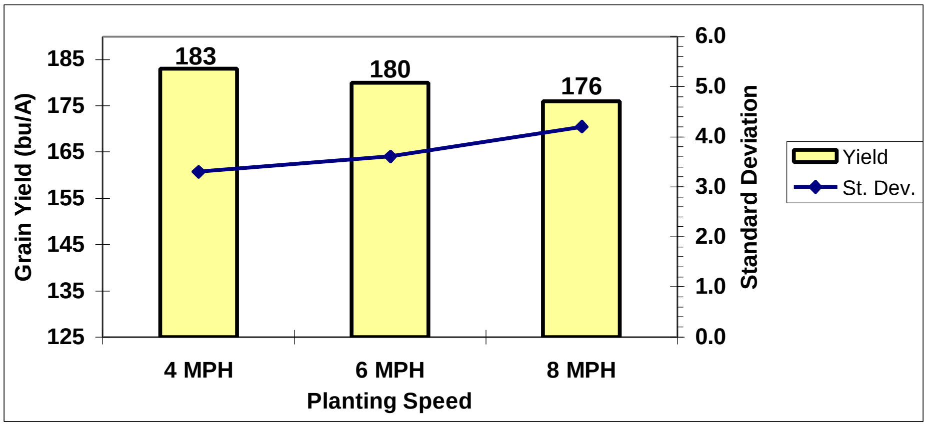

Figure 4. Effect of planting speed on corn grain yield and standard deviation of plant-to-plant in-row spacing. Average of five locations . Yield $LSD_{(0.05)}$ = 2.7 SD $LSD_{(0.05)}$ = 0.44 (1998-99)

Because these fields had good initial emergence, and changes in plant population were not large enough to explain the yield reductions (Table 4), it can be assumed that yield declines were primarily attributed to differences in plant-to-plant spacing. A fair question to ask is why did we see a larger response in yield decline relative to increased SD (about 4% for a 1-inch increase in SD) than has been documented in other Midwestern states? Perhaps it is simply a function of the type of growing seasons we had. Both 1998 and 1999 were exceptional years in Wisconsin for growing corn. Another possible reason is that we may see more response to uniform stands in the northern states where growing seasons are shorter. Certainly it appears this is the case with narrowing corn row spacing to attain more equidistant plant spacing (Lauer, 1996). Small plot, replicated research is currently being conducted at the University of Wisconsin to evaluate a wider range of stand variability with different frequencies of doubles and row gaps. Until more data is collected, we will reserve further judgment other than it appears growers would be well served to strive for uniform stands.

<u>A closer look at planting speed and stand variables</u>

Stand uniformity data was collected on a total of 12 planting speed trials during the 1998-99 growing seasons. Of these, 7 were finger-type planters and 5 were air planters (either positive or negative pressure). Stand uniformity data for the 12 sites is presented in Table 4. Although there were differences in results depending on location and year, some trends are apparent. It is important to note here that it is the trends that are important rather than the performance of a specific planter make, model, or type of seed delivery system. These trials were done over a range of different field conditions, target plant densities, and planter maintenance schedules.

Regardless of seed delivery system and site-year, SD always increased as planting speed increased from 4 to 8 MPH (Table 4). Finger-type seed delivery systems had higher plant densities at faster planting speeds (Table 5). In some cases (Malone-99 and Byron-99), the increase in plant density was over 5,000 plants per acre. Air systems had lower densities at faster planting speeds. Interestingly, even though the trend in plant density was different for finger and air planters, each type had increased numbers of doubles and row gaps with faster planting speeds. Especially significant is the trend for more seed doubles from 2.8 to 14.3 per 50 ft. of row with the finger-type planters as

Table 4. Effect of planting speed on stand uniformity variables at 12 Wisconsin locations (1998-99)

Location / Year	Planting Speed	Stand Variable: St. Dev.	Plant Density	Average Spacing	Doubles	Gaps
		(in)	(plts/acre)	(in)	(per 50 ft.)	(per 50 ft.)
Malone - 98	4 MPH	3.5	27,814	7.7	1.3	12.4
	6 MPH	3.5	28,524	7.5	3.2	9.5
	8 MPH	5.0	27,814	7.8	6.8	12.4
Eden - 98	4 MPH	3.1	32,597	6.6	3.8	6.4
	6 MPH	4.0	34,049	6.3	16.7	7.7
	8 MPH	4.6	34,403	6.2	19.9	10.6
Lamartine - 98*	4 MPH	4.1	28,902	7.6	7.7	12.2
	6 MPH	4.4	29,169	7.4	8.1	11.6
	8 MPH	5.4	27,298	8.0	11.5	16.8
Saxon - 98*	4 MPH	5.6	26,814	7.9	13.4	16.4
	6 MPH	6.2	27,007	7.8	16.3	17.8
	8 MPH	7.4	25,262	8.5	15.3	21.5
Two Rivers - 98*	4 MPH	3.5	28,911	7.4	4.3	8.7
	6 MPH	4.2	28,459	7.6	5.5	10.3
	8 MPH	4.5	27,814	7.7	6.7	11.4
Mason - 98*	4 MPH	3.9	28,064	7.9	2.8	10.5
	6 MPH	4.3	27,104	8.0	3.9	11.1
	8 MPH	4.8	27,072	8.1	5.4	13.1
Malone - 99	4 MPH	2.8	30,653	7.0	3.2	7.4
	6 MPH	3.2	32,409	6.6	7.0	6.1
	8 MPH	3.6	35,829	5.9	18.4	6.8
Byron - 99	4 MPH	3.0	30,847	6.9	4.6	7.7
	6 MPH	3.1	32,738	6.6	7.2	5.9
	8 MPH	3.7	39,256	5.6	22.3	7.8
Brownsville – 99**	4 MPH	2.7	29,330	7.2	2.6	7.1
	6 MPH	3.4	31,363	6.8	8.6	7.6
	8 MPH	4.7	29,911	7.2	13.7	14.8
Gillett - 99	4 MPH	2.8	27,878	7.7	2.0	6.5
	6 MPH	4.4	28,524	7.6	7.0	10.9
	8 MPH	4.2	28,988	7.5	6.8	12.5
Saxon - 99*	4 MPH	5.3	26,426	8.4	7.6	15.8
	6 MPH	5.7	26,330	8.2	13.8	19.2
	8 MPH	6.7	23,522	8.9	10.3	19.1
Arlington - 99	4 MPH	3.5	30,590	7.2	1.8	8.0
	6 MPH	3.1	32,358	6.7	5.0	6.2
	8 MPH	3.7	33,340	6.4	12.0	6.9

* Designates air system planter (positive or negative pressure). See Table 1 for make and model of planter.

** Actual planting speeds were 5, 6, and 7 MPH at Brownsville location.

planting speed increased from 4 to 8 MPH (Table 5). The locations with the highest target planting rates often were those where increased planting speed had the greatest negative impact on stand uniformity. Planting speed and planter maintenance may be more critical for establishing uniform stands where producers are trying to optimize yields with higher corn populations (28,000 to 32,000). This is especially true where 36 and 38-inch planters are used and seed delivery systems are working at an exceptionally fast speed to deliver the desired plant density.

Table 5. Effect of planter seed delivery system (finger or air) and planting speed on stand uniformity variables. Average of 7 finger planters and 5 air planters. (1998-99)

Planting	St. Dev.		Plant Density		Avg. Spacing		Doubles		Gaps	
Speed	Finger	Air*	Finger	Air*	Finger	Air*	Finger	Air*	Finger	Air*
	(inches)		(plants/acre)		(inches)		(per 50 ft.)		(per 50 ft.)	
4 MPH	3.1	4.5	29,958	27,823	7.2	7.8	2.8	7.2	7.9	12.7
6 MPH	3.5	5.0	31,424	27,614	6.9	7.8	7.8	9.5	7.7	14.0
8 MPH	4.2	5.8	32,792	26,194	6.7	8.2	14.3	9.8	10.3	16.4

* Positive or negative pressure air planters.

Summary

A survey of 87 Wisconsin corn fields in 1998-99 showed a wide variation of in-row stand uniformity. In general, SD did a good job of sorting out relatively uniform stands from those that had a high degree of variability. However, the term does not always convey a meaningful assessment of stand uniformity problems. Row gaps influence calculated SD more than doubles. SD will also be inherently higher as row spacing and/or target plant density decreases. Thus, comparing calculated SD's of stand variability may only be useful where row spacing and plant densities are similar. Initial results from on-farm comparisons indicate that an increase in stand variability (higher SD) has a negative impact on grain yield. Averaged over 5 sites where stand variability was increased with faster planting speeds, corn grain yields decreased by about 4% with a 1-inch increase in SD. From these studies we were not able to determine the specific effects of seed doubles and gaps on grain yield or over what range of SD values the relationship exists. Small plot research currently being conducted by the University of Wisconsin and continuing this project in the 2000 growing season will help to answer some of these questions. Finally, it is clear that planter maintenance and planting speed have a large impact on stand uniformity. The degree of impact will vary with individual corn planters and field conditions. Corn producers in Wisconsin looking to maximize corn yields will need to make monitoring of stand variability a part of their management routine and take appropriate actions where problems exist.

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Acknowledgements

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Attachment 1: Sample of individual sheet given to cooperating producers.

Quantifying Stand Uniformity in Wisconsin Corn Fields

Agent: Mike Rankin
County: Fond du Lac

Cooperator: D. Boelk

Field Location: County B
Previous Crop: Soybean
Soil Series/Texture: Beecher Silt Loam

Planting Date: 5/8/98
Planting Rate: 29,616
Hybrid: Spangler 3044
Row Spacing: 30
Row Number: 12
Planter Make/Model: JD 7000
Planter Type: Finger pick-up

~~Stand Uniformity Analysis~~

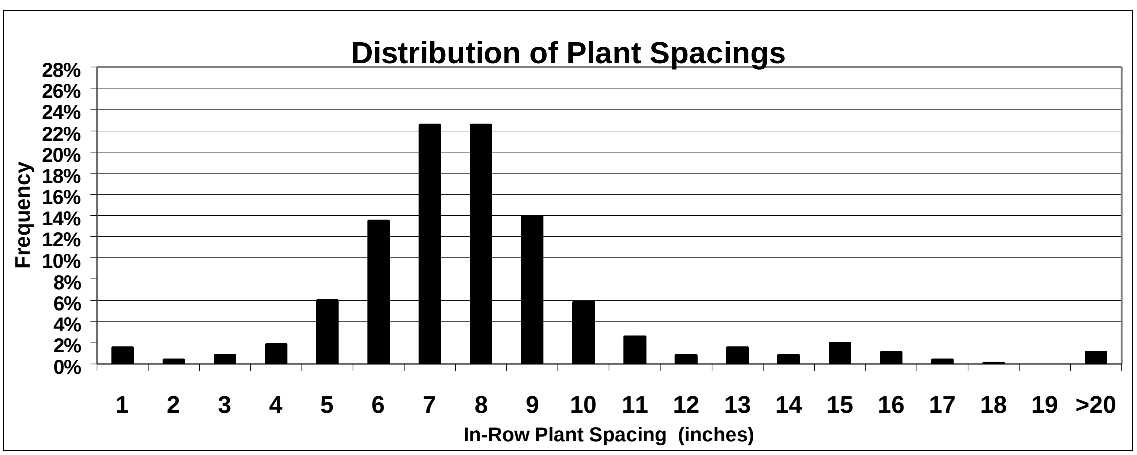
Standard Deviation x Row Unit

	Loc. 1	Loc. 2	Mean
Row 1	3.4	2.8	3.1
Row 2	2.3	2.6	2.4
Row 3	3.0	1.9	2.4
Row 4	2.1	2.7	2.4
Row 5	3.2	4.4	3.8
Row 6	2.7	2.7	2.7
Row 7	2.2	1.9	2.1
Row 8	4.9	2.5	3.7
Row 9	3.2	1.8	2.5
Row 10	3.6	4.8	4.2
Row 11	3.6	2.1	2.8
Row 12	1.9	4.7	3.3
Mean	3.0	2.9	3.0

Plant Population x Row Unit

	Loc. 1	Loc. 2	Mean
Row 1	30202	27878	29040
Row 2	29040	30202	29621
Row 3	25555	30202	27878
Row 4	29040	30202	29621
Row 5	30202	26717	28459
Row 6	27878	26717	27298
Row 7	26717	29040	27878
Row 8	25555	26717	26136
Row 9	27878	27878	27878
Row 10	25555	24394	24974
Row 11	26717	27878	27298
Row 12	29040	24394	26717
Mean	27782	27685	27733

	Your Farm	1998 All-Farm Mean	1998 All Farm Range
Standard Deviation:	**3.0**	3.4	1.9 - 5.9
Doubles per 50 ft. of Row:	**1.6**	4.1	0.2 - 13.5
Gaps per 50 ft. of Row:	**6.0**	8.0	1.9 - 16.7
Average Plant Spacing:	**7.8**	7.3	6.1 - 9.3
Target Planting Rate:	**29,616**	30,216	24,000 - 35,600
Actual Plant Population:	**27,733**	28,719	22,264 - 35,195



Notes:

1. Standard deviation is a measure of stand spacing uniformity. A "perfect" stand would have a SD of "0" but in reality the best we can hope for is a SD of "2".
2. Doubles are defined as plants within 2 inches of each other.
3. Gaps are defined as spaces of more than 12 inches without a plant.

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