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# STAND ESTABLISHMENT VARIABILITY IN CORN

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A wise agriculturalist once told me that "the sins of planting will haunt you all season." By that he meant that mistakes made during the planting operation are usually permanent, unless you decide to replant the field at a later date. The effects of uneven or variable stand establishment on the yield potential of corn are also permanent and begin very early in the growing season.

A field of young corn plants can be a beautiful sight from the window of a pickup truck moving rapidly down a country road. However, a closer inspection sometimes reveals that the stand is not as uniform as it appeared from the road. There may be tall corn and short corn, long gaps within the row, and groups of crowded plants. Indeed, stand establishment variability is composed of both emergence variability and within-row plant spacing variability.

How important is it for producers to establish as uniform a stand of corn as they possibly can? What effect does uneven plant spacing or uneven seedling emergence have on grain yield? What causes variability in stand establishment? How can stand establishment variability be prevented?

Read on for some answers...

## Plant Spacing Variability

Modern corn planters have the capability to uniformly singulate individual kernels from the seed hopper or drum and deliver them uniformly to the seed furrow. In reality, the actual spacing between plants within rows is often quite uneven.

Variability among plant-to-plant spacings within the row usually consists of some combination of crowded plants (doubles, triples, or worse) and long gaps. While it is true that plants next to a gap may compensate and produce larger ears, they generally cannot compensate enough for the smaller ears of the crowded plants that are competing for sunlight, water, and nutrients.

### Measuring & Quantifying Plant Spacing Variability

To evaluate the effects of plant spacing variability (PSV) on yield, it is first necessary to measure a number of actual plant-to-plant spacings throughout a field and quantify the variability among those spacings. While it may be more appropriate to measure the variability among SEED spacings (relative to planter accuracy concerns), measuring the spacings among PLANTS requires less effort and time. The result of measuring PLANT spacings rather than SEED spacings will be discussed later in this publication.

The act of measuring the spacings is simple. You measure as many plant-to-plant spacings as you think it takes to adequately describe the PSV situation in your field. Typically, I measure plant spacings in two or three locations throughout a field. Within each location, I measure all of the individual plant-to-plant spacings (inches between pairs of plants) that occur in 30 feet (nine meters) of row and repeat this for each row of the planter unit.

The variability among the plant spacings is then quantified by calculating what is called the ***standard deviation*** of the plant-to-plant spacings. A standard deviation is a common statistical measure of the spread or variation of a group of individual measurements. The larger the value, the greater the variability among the measurements. The standard deviation can be calculated by hand, using formulas available in any standard statistics reference, but is better suited to the use of statistical calculators or computer spreadsheets[1].

## Understanding Standard Deviation

If you do not have prior experience with using standard deviation to describe variability, it can be confusing. One way to visualize a standard deviation of a group of plant spacing measurements is that it describes how close the majority of the plant spacings occur around the sample average. The standard deviation is calculated in the same units of measure as the plant spacings.

Examples of two hypothetical standard deviations are illustrated in **Figure 1**. The average plant spacing for both examples is identical (i.e., same plant density), but the distribution of the spacings is quite different.

In Example 1, all the plant spacings are identical (8 inches), meaning the standard deviation is equal to zero (perfection). In Example 2 the standard deviation is equal to 3 inches, meaning the majority of the plant spacings are within plus or minus 3 inches from the average.

## PSV In Commercial Corn Fields

Actual examples of standard deviations measured in two commercial corn fields are illustrated in **Figure 2**. The plant populations in the two fields were identical (about 24,000 plants per acre), thus the average plant-to-plant spacing in each field was also identical (8.7 inches). The variability of plant spacing in one field, however, was almost twice as large as the other (standard deviations of 6.8 versus 3.5 inches). **Figure 2** also illustrates that a greater number of crowded plants (double seed drops) and large gaps occurred in the more variable field, even though the plant population was identical to the more uniform field.

My colleagues and I have measured PSV in more than 350 commercial fields of corn throughout Indiana and Ohio (**Figure 3**). Among those sampled fields, standard deviation of plant spacing was three inches or less in only about 16 % of the fields. About 60 % of the sampled fields exhibited standard deviations of plant spacing between

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1 Most computer spreadsheet programs can calculate the standard deviation of a group of values (i.e., a given range of data cells) with the use of a built-in mathematical function. For example, in Microsoft™ Excel™ the formula would be: **=STDEV(cell range)**

four and five inches, while plant spacing variability in about 24 % of the fields was six inches or greater (to as great as 12 inches).

## Effect of PSV on Grain Yield

Field studies (small- and large-scale plots) evaluating the effect of PSV (treatment standard deviations from 2 to 12 inches) on grain yield were conducted across Indiana (Purdue research farms and commercial farms) from 1987 through 1993. The results of that field research (Table 1) indicated that about 2½ bushels per acre are lost for every 1 inch increase in the standard deviation of the plant-to-plant spacings[2].

The threshold or target PSV to aim for is a standard deviation of about 2 inches (5 cm) rather than zero because the variability is calculated for PLANT spacings, not SEED spacings. The reason for this threshold value is that typical emergence in commercial fields is 90 - 95 % of the seeding rate. At typical seeding rates (26 - 30 thousand seeds per acre) and assuming random occurrence of non-emergers, a standard deviation of PLANT spacings equal to 2 inches can easily occur even if SEED spacing were perfect.

With a 2-inch standard deviation as a goal, the results of the field research suggest that the potential yield gain for a field with a 5-inch standard deviation of plant spacings is about 7½ bushels per acre[3]. Similarly, the results of the survey of commercial corn fields (Figure 3) suggest that 60 % of those fields could improve yield from 5 to 7½ bushels per acre by improving the uniformity of plant-to-plant spacing to a standard deviation of 2 inches.

## Causes of Plant Spacing Variability

Do not forget that small gaps will always occur due to the fact that less than 100 percent of the kernels planted actually germinate. Warm germination percentage of seed corn typically ranges from 90 to 95 percent, thus perfect final stands are rare. More importantly, plant spacing variability is typically related to misadjusted or malfunctioning planter mechanisms.

With finger-pickup seed metering systems, double or triple seed drops may occur from worn finger-pickup mechanisms, misadjusted finger tension, worn knockoff brushes, or from driving too fast. Aged seed conveyor belts may not deliver kernels properly to the seed chute.

Misadjusted air pressure, leaks in the system, worn knockoff brushes, or wrong disc sizes may cause uneven seed drop with air planters.

Keep in mind that stand reductions caused by weather- or pest-related damage may also result in unevenly spaced plant survivors within the rows. Perhaps replant decisions should take this additional yield loss into considerations.

## Tips for Preventing PSV

Adjustment instructions and service schedules provided in the planter operation manual should be read and followed religiously during the off-season as well as during the planting season. Here are a few pointers:

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[2] The metric equivalent is about 62 kg/ha loss for each 1 cm increase in standard deviation of plant-to-plant spacing.

[3] Equal to 2½ bushels per acre per inch difference in standard deviation (5 - 2 =3).

- ✓ With plate-type planters, match the seed grade with the correct planter plate.
- ✓ Planters with finger pick-ups should be checked for wear on the back plate and brush. Use a feeler gauge to check tension on the fingers, then tighten them correctly.
- ✓ Check for wear on double-disc openers and seed tubes.
- ✓ Make sure the sprocket settings on the planter transmission are correct.
- ✓ Check for worn chains, stiff chain links, and improper tire pressure.
- ✓ Lubricate all chains and grease fittings.
- ✓ Make sure seed drop tubes are clean and clear of any obstructions.
- ✓ Clean seed tube sensors if you have a planter monitor.
- ✓ Make sure coulters and disc openers are aligned properly.
- ✓ With air planters, match the air pressure to the weight of the seed being planted.

## Plant Emergence Variability

Another component of stand establishment variability is delayed emergence. While it is not common for every plant in a field to emerge on the same day, farmers intuitively desire such uniform emergence. Until recently, though, the effects of delayed emergence on grain yield of corn were unknown.

Research conducted at the universities of Illinois and Wisconsin (Carter & Nafziger, 1989; Nafziger et al., 1991) were designed to determine the effect of delayed emergence on corn grain yield. Differing lengths of delays, different patterns and proportions of delayed and normal plants, and two hybrids differing in ear-size flexibility were all evaluated in these field experiments.

Emergence delays of about 10 days scattered throughout the field reduced yield 6 to 9% compared to full stands of normal emergence. Emergence delays of about 21 days reduced yield 10 to 22 percent compared to a full stand of normal emergence, depending on the proportion of delayed emergers to normal emergers.

The reason for the detrimental effect of delayed emergers is that they simply cannot compete with older, more established plants for sunlight, moisture and nutrients. The delayed emergers will typically become stunted in their growth and rarely produce a harvestable ear.

The exact dates of emergence in every field of a farming operation are rarely monitored by farmers or their consulting agronomists. So, another way to determine the severity of the problem in your field is to compare growth stages of normal and delayed emergers. From my observations in the field, a growth stage difference of two leaves or greater between adjacent plants will almost always result in the smaller (younger) of the two being barren at the end of the season.

### Causes of Delayed Emergence

All you need for perfect emergence in a corn field are 1) adequate soil moisture, 2) adequate soil temperature, and 3) adequate seed-to-soil contact. Pretty simple, right? In practice, however, one or more of these factors is limiting and the resulting germination or emergence is uneven.

The **primary causes** of delayed seedling emergence in corn include 1) soil moisture variability within the seed depth zone and 2) poor seed to soil contact due to cloddy soils, inability of no-till coulters to slice cleanly through surface residues, worn disc openers, and misadjusted closing wheels.

**Other causes** include soil temperature variability within the seed zone, soil crusting prior to emergence, occurrence of certain types of herbicide injury, and variable insect and/or soil-borne disease pressure.

## Tips for Preventing Delayed Emergence

Remember your goal in planting corn should be to achieve rapid and uniform kernel germination and seedling emergence. Time spent before and during planting to ensure uniform stand establishment is time well spent.

Determining the correct seeding depth may be one of the biggest decisions a corn grower makes in the field during planting. Notice I said "**in the field**" and "**during planting**."

Your seeding depth decision should be made in the field, not in the shop or from last year's records. The correct seeding depth for any given field should be based on its current soil moisture conditions and the 5 to 10-day weather forecast.

For example, if the soil is dry down to 1½ inches and the short-term forecast calls for continued dry weather, do not hesitate to plant at 2 or 2½ inches. With such dry soil conditions, the risk of germination problems is greater for shallow planting than for deeper planting. Germination may be uneven at shallower depths if some seeds encounter sufficient moisture and others do not. Corn can easily emerge from depths of 2 or 2½ inches, even deeper if necessary.

Also check that the depth control settings on your planter are accurate. Check the manual's theoretical depth with actual depth for the settings you commonly use. Remember, too, that actual depth will likely change as soil conditions change. Check it every time you pull into a new field or start a new day.

If your planter has rocker arm assemblies to "smooth" the effects of surface rocks on depth, make sure the assemblies are well lubricated and are operating as they should.

Inspect the condition of the double-disc openers before planting. As each disc wears, its diameter decreases and the two discs slowly "move" apart where they meet at their bottoms. Such worn disc openers may slice a "W" shaped seed furrow rather than a "V" shaped one. The closing wheels may not be able to adequately firm a "W" shaped furrow, leaving pockets of air around or near the seed. Remember, you want good seed-to-soil contact, not good seed-to-air contact!

Coulter down-pressure and depth for no-till planting should be adjusted for each field's soil and residue situation. Make sure the coulters slice cleanly through the residue, rather than pinning residue inside the seed furrow. Remember, you want good seed-to-soil contact, not good seed-to-residue contact!

If your single coulters just cannot cut through residue no matter what you do, then maybe it is time to consider one of the many types of planter attachments that move, sweep, brush, incorporate, or otherwise manage residue.

It is my contention that the value of these zone preparation gadgets lies primarily in their potential for moving the residue away from the planter units so that the units can do what they were built to do; that is to open the furrow, drop the seed, and firm soil (not residue) around the seed for optimum germination and emergence conditions.

Adjust the tension of the closing wheels according to the soil conditions you will be planting in. Make sure the seed furrow is being closed and firmed adequately.

On the other hand, be aware that too much tension on the closing wheels may lead to troubles in itself. For example, too much tension on true-V press wheels in loose soil may decrease the uniformity of seeding depth by occasionally squeezing kernels upward. In wet soils, excessive tension on the closing wheels may compact the surface soil of the furrow and restrict emergence.

Finally, if you are using reduced tillage practices and especially if you are planting on the early side, be aware of soil temperature variability. Temperatures under heavy residue areas may be several degrees lower than more bare areas in the field.

While corn will germinate at soil temperatures of 45 to 50 degrees F, minor drops in temperature below this range may significantly decrease the uniformity of germination.

If crop residues are not spread evenly throughout the field, avoid planting until average soil temperatures are closer to 55 or 60 degrees.

## Summary

The bottom line is that uneven stand establishment in corn can reduce a field's yield potential from the first day you place seed in the ground. Yield losses can easily be as much as 7 to 15 bushels per acre due to combinations of uneven within-row plant spacing or uneven seedling emergence. Once you have identified the nature and extent of the problem, the tips I have identified in this publication should help you improve the uniformity of stand establishment in your farming operation.

If you have further questions on this topic, please contact me via phone at 765/494-4802, via FAX at 765/496-2926, or via electronic mail at *rnielsen@purdue.edu*.

**For more information on corn, check out the Corn Growers Guidebook on the World Wide Web at:**

http://www.kingcorn.org

## References

Carter, Paul, and Emerson Nafziger. 1989. Uneven Emergence in Corn. NCR-344.

Nafziger, E.D., P.R. Carter, and E.E. Graham. 1991. Response Of Corn To Uneven Emergence. Crop Sci. 31:811-815.

# Figures

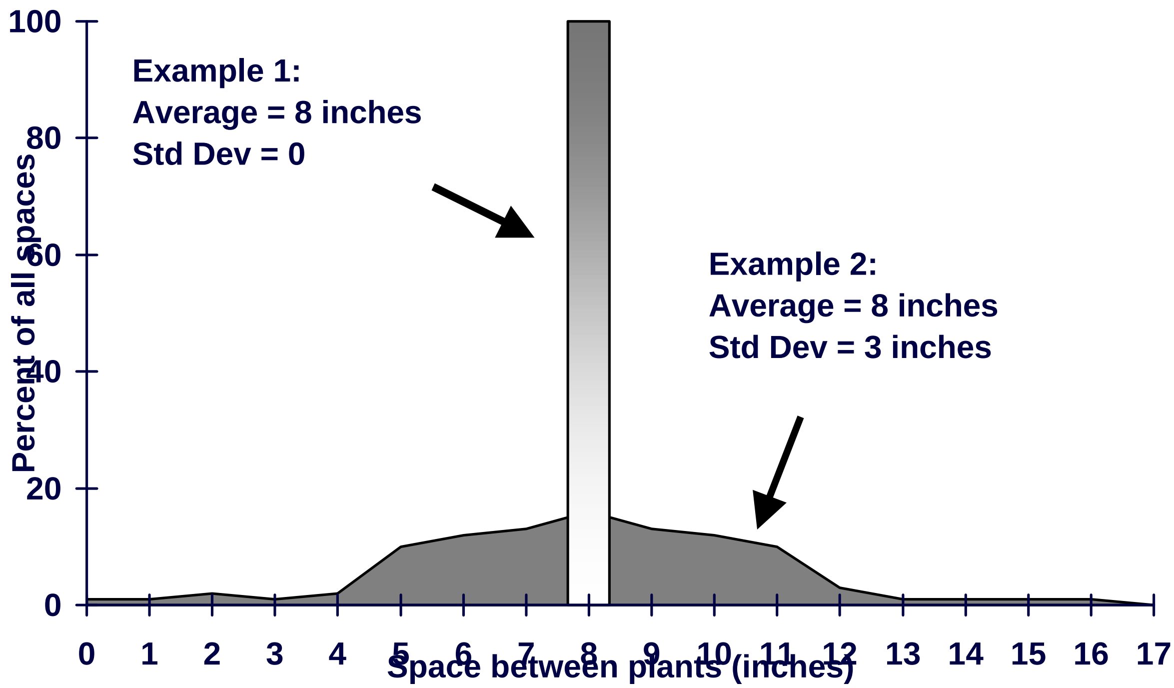


**Figure 1. Illustration of standard deviation of plant spacing with two hypothetical examples.**

# Figures

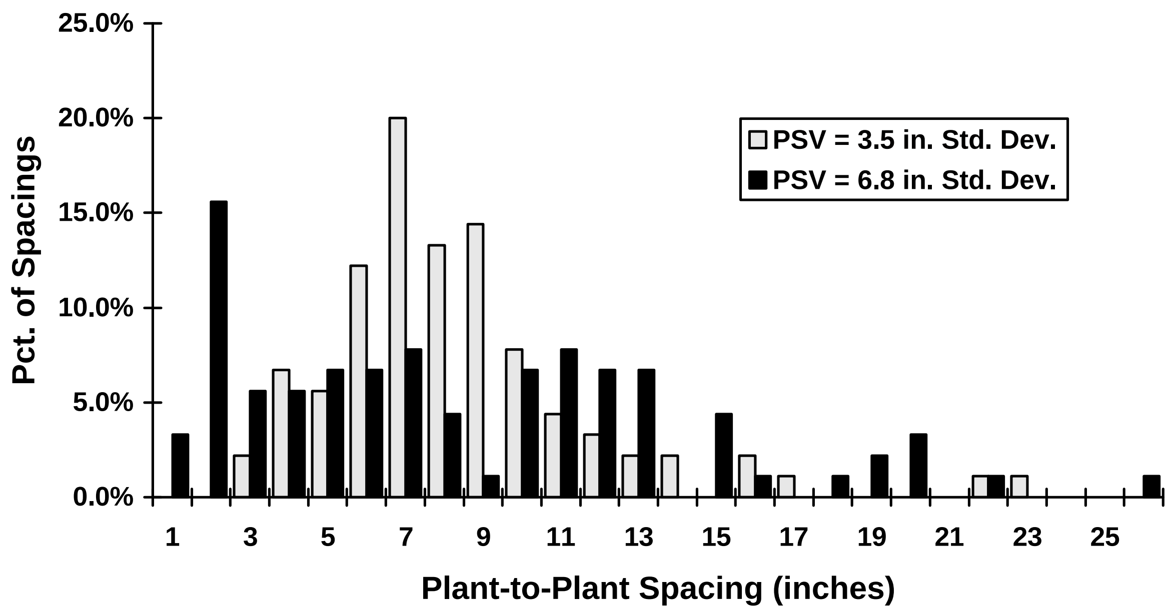


**Figure 2. Plant spacing distribution within two commercial fields of corn in Wells Co., Indiana, 1987.**

# Figures

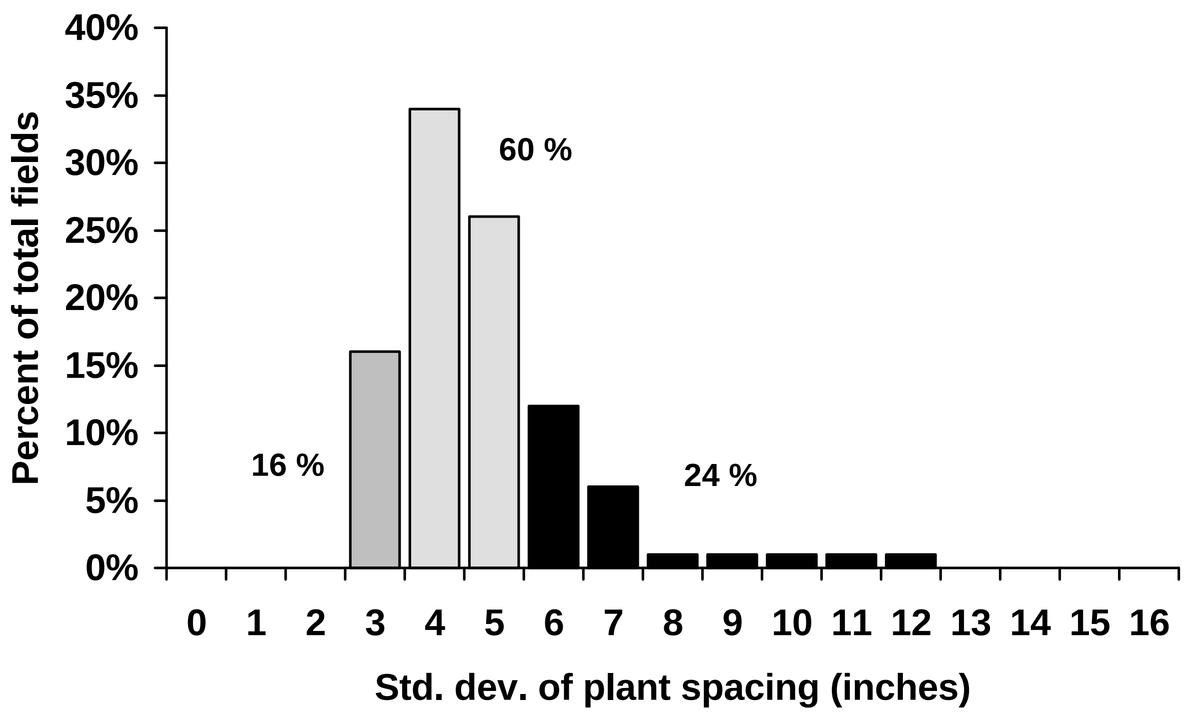


**Figure 3. Range of plant spacing variability measured in 354 fields throughout Indiana and Ohio, 1987 - 96.**

# Tables

**Table 1. Yield loss due to plant spacing variability in corn. 1987-93.**

| Year | Indiana Location | Harvested Population | Yield Level | Rate of Yield Loss (bu/in. of Std. Dev.) |
|---|---|---|---|---|
| 1987 | Westcentral | 28,500 ppa | 200 bu./ac. | -3.7 |
| 1987 | Southcentral | 26,000 ppa | 145 bu./ac. | -4.5 |
| 1990 | Eastcentral | 24,500 ppa | 125 bu./ac. | -2.0 |
| 1991 | Northeast | 27,500 ppa | 150 bu./ac. | -2.3 |
| 1992 | Northeast | 27,000 ppa | 165 bu./ac. | -2.7 |
| 1992 | Northwest | 26,000 ppa | 150 bu./ac. | -1.4 |
| 1992 | Southeast | 26,000 ppa | 185 bu./ac. | -1.2 |
| 1993 | Northwest | 20,500 ppa | 130 bu./ac. | -2.0 |
| | | | Average = | -2.5 |

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