

ON-FARM EVALUATION OF WITHIN-ROW PLANT SPACING UNIFORMITY¹

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SUMMARY

- On-farm split-planter tests in 2000 revealed a positive, but weak relationship between yield and improved within-row plant spacing (WRPS) standard deviation. On average, grain yield increased 4.1 Bu/ac for every one inch improvement in WRPS standard deviation.
- Individual plant spacing measurements and ear samples were taken from over 6,000 plants at four diverse locations in Missouri, Iowa and Minnesota during the 2001 growing season. Individual plant grain yield improved by 1.1 to 6.1 Bu/ac for every inch improvement in within-row plant spacing standard deviation with an average improvement of 3.4 Bu/ac/in.
- Perfect plant spacing uniformity was not required to achieve maximum yields at any of the four locations. In general, maximum grain yields were achieved when WRPS standard deviations were no more than 2 to 3 inches.
- There was no evidence for increased barrenness with closely-spaced plants at any location. In fact, these “extra” plants showed the greatest individual plant yield (per planted area).
- Plants growing next to gaps were the least productive plants (per planted area) despite high “ear flex” ratings for all of the hybrids used.

INTRODUCTION

Agronomists have long suspected that within-row plant spacing uniformity has an impact on corn grain yield, but research and anecdotal evidence has been inconsistent at demonstrating this benefit. There is renewed interest in the concept of “picket-fence” plant spacing for several reasons. The first reason is the popularity of several planter calibration services that are currently being promoted across the Corn Belt. A second reason for this attention is the testimonials of corn yield contest winners that often insist that both adequate plant population and uniform spacing are necessary for top yields.

University research on the benefits of within-row plant spacing uniformity have produced inconsistent results (Lauer, 2001). Erbach et al. (1972), Johnson and Mulvaney (1980), Edmeades and Daynard (1979), Muldoon and Daynard (1981), and Daynard and Muldoon (1983) found no significant improvement in corn yields with improved plant spacing uniformity from small plot research in Iowa, Illinois and Ontario respectively. Liu et al. (2001) looked at a combination of spatial and temporal variation in plant emergence in small plot research conducted in Ontario. They concluded that corn was more responsive to plant emergence variability than plant spacing variability. In contrast, Krall et al. (1977) and Vanderlip et al. (1988) reported that small plot research conducted in Kansas indicated a beneficial effect of

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improved plant spacing uniformity on corn grain yield. Krall et al. (1977) reported a 3.4 Bu/ac decrease in yield for each inch increase in standard deviation of inter-plant spacing. Vanderlip et al. (1988) found that grain yields decreased when plant spacing standard deviation values exceeded 2.4 inches. In one of very few studies conducted in commercial fields, Nielsen (2001) reported that corn grain yields decreased an average of 2.5 Bu/ac for every inch increase in plant spacing standard deviation above 2 inches. He also reported that the rate of yield loss with increasing standard deviation was not constant but varied at eight Indiana locations from 1.2 to 4.5 Bu/ac yield loss per inch increase in plant spacing standard deviation.

Because of the inconsistency of the small plot research findings, and the near-absence of results under typical producer conditions, a two-year on-farm study was undertaken with the following objectives, 1) determine the relationship between within-row plant spacing standard deviation and corn grain yield from field-length strip plots and 2) develop a spatial analysis tool to document the influence of within-row plant spacing uniformity on individual plant yield.

SPLIT-PLANTER STUDY – 2000

Pioneer Hi-Bred conducted an on-farm survey in 2000 to investigate the relationship between plant spacing uniformity and corn grain yield (Doerge and Hall, 2000). This survey was conducted across the major corn-growing regions of North America and included trials at 96 locations in 11 states and two provinces. At each location, cooperators were asked to use a split-planter technique to compare adjusted and unadjusted planter meters in field-length strips. With this method, half of the meters on the planter were serviced and calibrated using the MeterMax™ System and the remaining meters were left unadjusted. Planting one or more passes through the field resulted in alternating strips of the two planter “treatments” as shown in Figure 1. This method of establishing planter treatments results in strips that differed only in plant spacing uniformity. All other cultural practices and environmental conditions were the same in the two strips. A combination of finger pickup and vacuum planter meters were used in the survey.

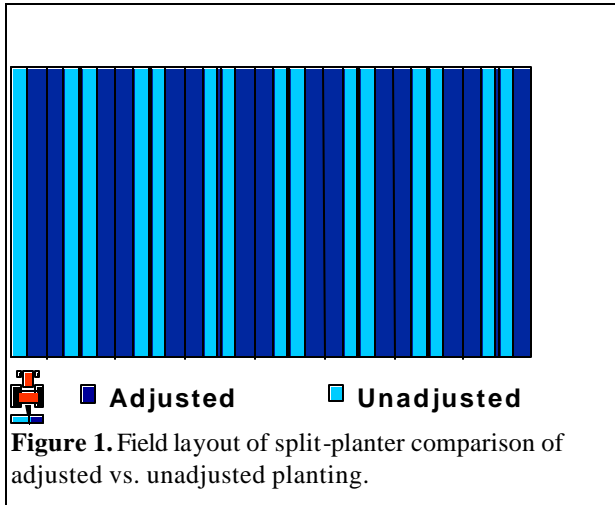


Figure 1. Field layout of split-planter comparison of adjusted vs. unadjusted planting.

Cooperators were asked to collect in-season measurements consisting of the plant spacing for 30 consecutive plants in four randomly-selected areas. In addition, grain yield was measured at harvest for both planter treatments. Any difference in grain yield between the two strips was attributed to the difference in plant spacing uniformity, as estimated by the standard deviation of the inter-plant spacings.

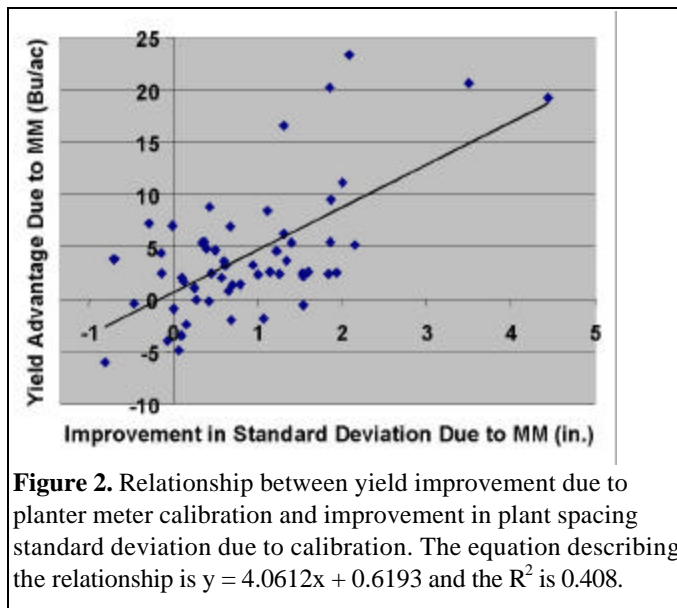
Virtually all researchers looking at the effects of within-row plant spacing uniformity have used plant spacing

standard deviation as the preferred index of spatial uniformity. The main advantages of using this index are that it is easy to measure and it is quantitative. The main potential disadvantages are that standard deviation is not mechanistic and is not a measurement that is specific to individual plants.

Definition of Standard Deviation: Standard deviation is a statistic that describes the variation in plant spacing uniformity, expressed as variation from the mean, or average. In a perfectly planted corn field where all the plants were 7.0 inches apart, the average spacing would be 7.0 inches and the standard deviation would be zero. If 50% of the spacings were 6.0 inches and 50% were 8.0 inches, the average spacing would still be 7.0 inches but the standard deviation would be 1.0 inch. An extreme example with 50% of the plant spacings at 2.0 inches and 50% at 12.0 inches would again result in an average spacing of 7.0 inches but the standard deviation would be 5.0 inches, and so on.

In corn fields, a standard deviation in plant spacing of below 3 inches would be considered low, 3-5 inches, moderate and above 5 inches, high. Surveys have shown that commercial corn fields rarely have a plant spacing standard deviation below two inches (Nielsen, 2001).

Yield Results: Figure 2 shows the relationship between improvement in plant spacing standard deviation due to meter calibration and the improvement in yield due to calibration. As expected, the trendline drawn through the data points indicates a positive, linear relationship between these two variables.



As plant spacing improves due to meter calibration, grain yields increase about 4.1 bu/acre per one inch improvement in standard deviation. This is somewhat higher than the findings of other researchers, such as Nielsen (2001) who reported a 2.5 bu/acre increase in yield per inch of standard deviation improvement. Also note that there is considerable scatter in the data around the trendline. This suggests that decreasing standard deviations are only associated with improved yields but may not directly cause yield

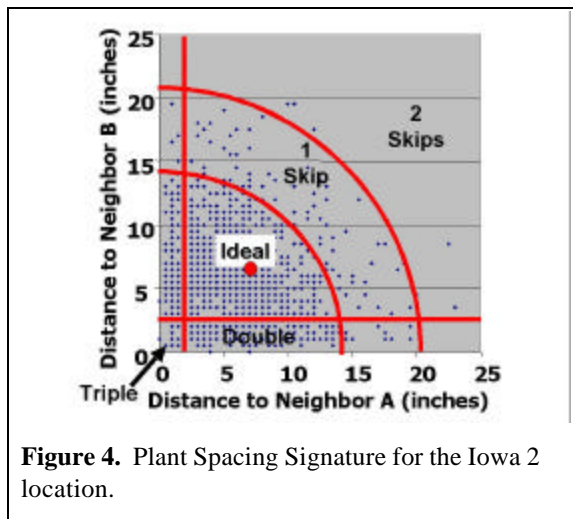
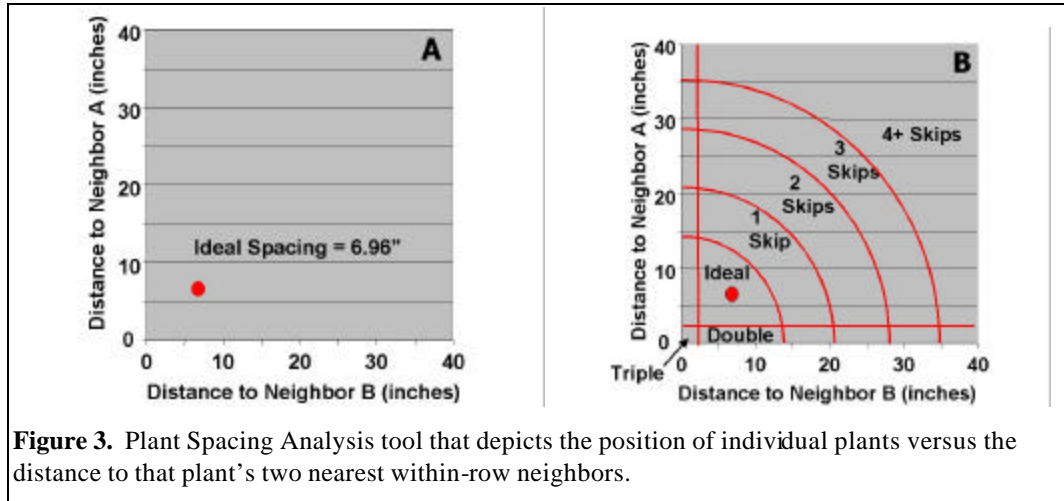
improvement.

INDIVIDUAL PLANT RESPONSE TO WITHIN-ROW SPACING UNIFORMITY – 2001

Plant spacing non-uniformity can arise from several causes, including misplaced plants, missing plants (skips) and extra plants. There is general agreement that plant spacing standard deviation due to missing plants will result in a yield loss, compared to a perfectly planted stand. This is because the two plants bordering a skip will not be able to fully adjust their ear size to fully compensate for the loss of grain that would have come from the missing plant (Nafziger, 1996). There is less agreement on the effect of very closely-spaced “extra” plants. Some argue that these plants are so crowded that they will go barren (produce no ear) and will simply act as a weed by competing for light, water and nutrients with neighboring productive plants. Others suggest that closely spaced plants that produce grain will result in at least equal grain production per unit area compared to a stand with plants all at the desired spacing (Nafziger, 1996).

From an agronomic standpoint, plant response to within-row plant spacing occurs at the level of the individual plant, not at the scale of a research plot or field-length strip. For this reason, continued on-farm testing was conducted in 2001 to better understand the reason for the positive, but weak relationship between improved plant spacing uniformity and improved grain yield. Plant spacing measurements and individual ear sampling were conducted to determine the grain yield response per acre for single plants.

corn fields. The sub-regions of this coordinate system that correspond to different plant spacing outcomes are shown in Figure 3B. Finally, the within-row distances to the two nearest neighbors of hundreds or even thousands of plants can be plotted on these axes to give a visual representation of plant spacing uniformity within a whole field; or “Plant Spacing Signature”. This is depicted in Figure 4 which comes from the Iowa 2 location.



Yield Maps Based on Plant Spacing:

This Plant Spacing Analysis tool can also be used to create yield contour maps that graphically show the effect of within-row plant area and plant spacing uniformity on individual plant yield. Geographical Information System (GIS) software is used to create these maps. Plant Spacing yield maps are similar to regular yield maps developed from yield monitor data. The difference is that in this case, the coordinate system is based on the distances to a plant’s two nearest neighbors, not on latitude and longitude. Figure 5 is a Plant Spacing yield map for the Iowa 1 location.

On these yield maps, as one moves along the dotted diagonal line from the origin [0,0] to the upper right hand corner, Within-Row Plant Distance increases from zero to >22 inches in this example. As expected, individual plant yield decreases continuously as we move along this diagonal path. This is nothing more than a simple plant population response. However, the remarkable finding is that plants at very close spacing (nearest the origin) are the highest yielding plants per planted area. For these occasional closely-spaced plants, there was no evidence of increased barrenness at any of the four locations. These findings indicate that

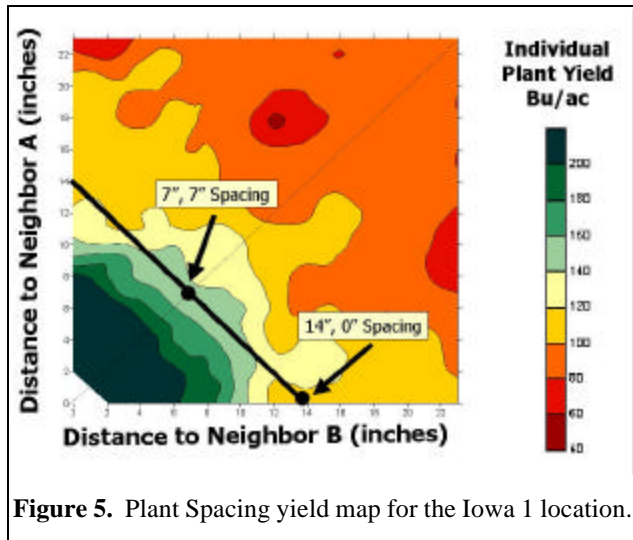


Figure 5. Plant Spacing yield map for the Iowa 1 location.

“do plants at perfect 7 X 7 inch spacing yield more than plants at 14 X 0 inch spacing”, for example. For this location, the answer is clearly, “yes”. At perfectly uniform spacing, the expected yield is 143.4 Bu/ac. At the [14,0] point, spacing is at its worst, and the expected yield per plant is 108.8 Bu/ac. This analysis can be displayed graphically as shown in Figure 6. This figure plots the change in the predicted individual plant yield (in Bu/ac) as the distance to its two neighboring plants varies. In this example, the Within-Row Plant Distance is held constant at 7.0 inches. In all cases, the lowest yields are from the plants with the poorest plant spacing uniformity. Individual plant yield increased with improving plant spacing uniformity, but only up to a point. In general, individual plant yields did not increase further if plant spacing was within 2-3 inches of perfect 7-inch spacing. This same pattern was observed for all WRPD’s and across all locations.

Estimated Benefits of Improved Plant Spacing Uniformity: These Plant Spacing yield maps can also be used to estimate the potential benefits of improved plant spacing uniformity in commercial corn fields. It’s a simple matter of comparing the actual yield measured at a location to the predicted yield if all of the plants were at perfectly uniform spacing. These

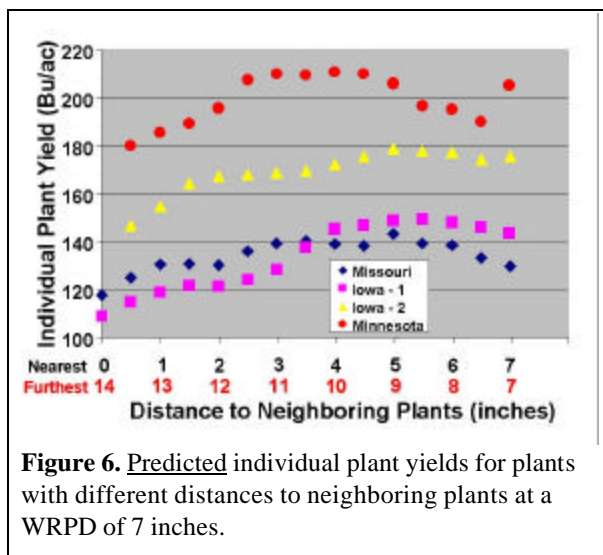


Figure 6. Predicted individual plant yields for plants with different distances to neighboring plants at a WRPD of 7 inches.

estimations are summarized in Table 2 for these four locations. Improving the plant spacing standard deviation from its original level down to zero improved yields by 7 to 19 bushels per acre. For these four sites, the change in yield per inch of improvement in plant spacing standard deviation ranged from 1.1 to 6.1 with an average of 3.4 Bu/ac/in. This is very similar to the findings of Nielsen’s (2001) extensive on-farm survey. Many investigators have stated that a plant spacing standard deviation of below 2.0 is quite unusual and is generally unattainable under most

increases in plant spacing standard deviation due to occasional closely-spaced plants may actually improve grain yields.

Effect of Plant Spacing Uniformity on Grain Yield: These Plant Spacing yield maps also provide information on the effects of plant spacing uniformity at a constant plant population. In Figure 5, plants falling on the solid diagonal line connecting the [0,14] and the [14,0] points would all have the same within-row plant distance (7 inches), but would have quite different plant spacing uniformity. This type of yield map can answer the question,

Location	Original Spacing		Perfect Spacing		Yield Improv.	
	Ave. Spacing	S.D. Yield (actual)	S.D. Yield (predicted)	Yield		
	in.	in.	Bu/ac	in.	Bu/ac	Bu/ac/in
Missouri	10.8	6.9	102	0	109	1.1
Iowa 1	6.2	3.2	139	0	158	6.1
Iowa 2	7.1	3.6	163	0	174	2.9
Minnesota	7.1	3.8	193	0	206	3.3
Average	--	4.4	149	0	162	3.4

Table 2. Estimated yield improvement due to improved plant spacing at four on-farm locations in 2001.

commercial conditions. These results suggest that even if standard deviations are improved by only one inch, the resulting yield benefit would be about 3.4 Bu/ac. The yield increase needed to just offset the cost of planter meter calibration for a 600-acre corn grower using a 12-row planter is only 0.5 Bu/ac. When one considers the amount a producer invests in their planter, seed, and other inputs, this modest investment in planter meter calibration every 1 to 2 years is an inexpensive way to manage risk.

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