PIONEER.

Row Width in Corn Grain Production

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SUMMARY

- The vast majority of corn acres in the U.S. and Canada are currently planted in 30-inch rows, with row spacings less than 30-inches used on less than 7% of corn acres.
- The primary rationale for narrow row spacings in corn is that by reducing the crowding of plants within a row, the crop will be able to better utilize available light, water, and nutrients by reducing competition among individual plants.
- Yield benefits with narrow row corn have been observed most frequently in the northern portion of the Corn Belt.
- Research has shown a correlation in narrow row corn between improved yields and increased light interception; however, light interception is typically not yield-limiting in 30-inch rows outside of the northern Corn Belt.
- University and Pioneer research has shown that optimum plant population is generally not greater in narrow or twin rows than in 30-inch rows.
- Many university row spacing studies have included multiple hybrids but generally have found no difference in their response to narrow rows.

INTRODUCTION

Optimum row width has long been a topic of interest among corn producers. Ever since the replacement of horse-drawn machinery allowed corn rows to be less than 40 inches apart, growers and researchers have looked to narrower row spacings to increase corn yield. Narrower row configurations increase the distance between plants in a row, potentially increasing yields by allowing more efficient use of available space and resources. Narrow row corn is generally (and for the purposes of this review) defined as any row spacing less than 30 inches. Yield benefits of narrow row corn have not been large or consistent enough thus far to motivate a large shift away from 30-inch rows in most areas of North America. However, interest persists, largely due to the belief that continuing increases in corn yield and changing agronomic practices may eventually favor narrow rows.

CURRENT PRACTICES

The vast majority of corn acres in the U.S. and Canada are currently planted in 30-inch rows (Figure 1). This percentage has increased over recent years, from 80% in 2007 to 86% in 2015, while the percent of corn acres in wider row spacings

Corn production in 30-inch rows

(36- and 38-inch) has declined (data not shown). Adoption of narrow row corn has been very limited, with row spacings less than 30 inches currently used on less than 7% of corn acres in the U.S. and Canada. The most common narrow row spacing is 20-inch, which was used on 3.0% of corn acres in 2012, followed by 22-inch (2.6%) and 15-inch (0.7%).

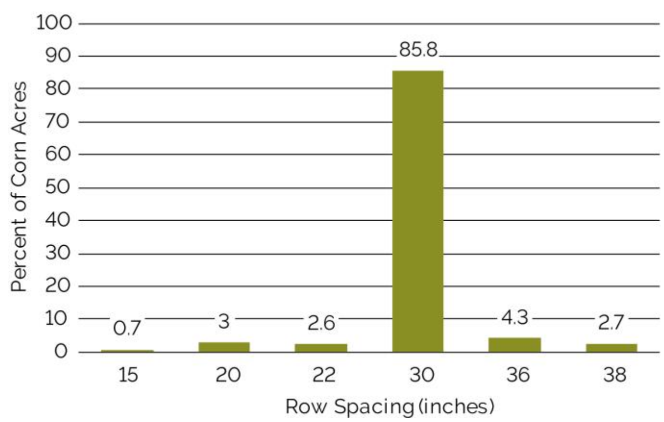

Figure 1. Corn row spacings (in inches) in North America as a percentage of total acres, 2015. Source: Pioneer Survey.

Corn acreage planted in narrow rows has increased slightly over the past several years, comprising a combined 4.2% of corn acres in 2010 and 6.3% in 2015 (Table 1). Regional adoption of narrow rows varies widely, with the highest adoption rate in the northern Corn Belt states of Minnesota, and South Dakota (Figure 2). Narrow row implementation remains less than 5% in most of the central Corn Belt states.

Table 1. Corn acreage planted to the most common narrow row spacings from 2010 to 2015 in North America. Source: Pioneer Survey.

Row Width	2010	2011	2012	2013	2014	2015
inches			——— acres (%) ———			
15	0.4	0.4	0.6	0.8	0.5	0.7
20	2.7	2.5	2.5	3.3	3.3	3.0
22	1.2	1.4	1.5	1.6	2.3	2.6
All Narrow	**4.2**	**4.3**	**4.6**	**5.7**	**6.1**	**6.3**

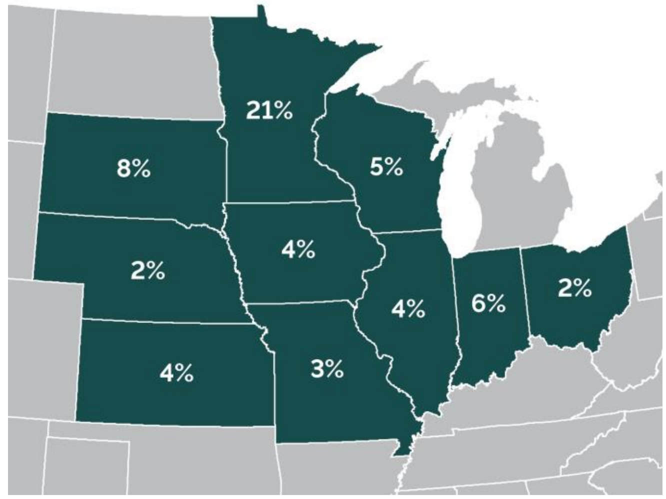

Figure 2. Narrow row corn adoption (15-, 20- and 22-inch) in the U.S. Corn Belt. Source: USDA-NASS farmer-reported row widths, 2013-2017.

RECENT ROW SPACING RESEARCH

University Research

Over the years, research on narrow row corn has produced variable results, which suggests that multiple factors likely influence corn yield response to row spacing. Yield benefits with narrow row corn have been observed more frequently in the northern portion of the Corn Belt in the area north of approximately 43°N latitude (line running roughly through Mason City, IA; Madison, WI; and Grand Rapids, MI) (Lee, 2006). In a survey of several recent university corn row studies comparing 15-, 20- or 22-inch rows to 30-inch rows, the greatest yield benefits with narrow rows were observed in experiments conducted in Minnesota and Michigan (Table 2). An average yield advantage of 2.8% with narrow or twin rows was observed in northern studies, compared to no advantage on average (-0.2%) for narrow rows in Iowa, Indiana and Nebraska (Figure 3).

Table 2. Yield advantage (%) of 15-inch, 20- or 22-inch, and twin rows compared to 30-inch rows observed in recent corn row spacing research studies in the Midwestern U.S.

							Yield Increase vs. 30-inch		
Study	Location	Years	Locs	Hybrids	Yield Level	Populations	15	20 or 22	Twin
					bu/acre	1000 plants/acre		——— % ———	
1	Minnesota	92-94	3	6	100-150	25, 30, 35, 40		7.7	
2	Minnesota	97-99	1	1	100-150	33		6.2	
3	Minnesota	98-99	1	2	150-175	30	5.9	2.8	
4	Minnesota	09-11	6	3	175-200	16.5, 22, 27.5, 33, 38.5, 44		4.5*	
5	Michigan	98-99	6	6	175-200	23, 26, 30, 33, 36	3.8	2.0	
6	Nebraska	09-11	1	3	200-225	28, 33, 38, 42			1.4
7	Iowa	00-02	1	3	150-175	20, 28, 36, 44	1.2		
8	N. Dakota	06-08	1	2	>225	25, 30, 35	0.0		2.0
9	Michigan	98-99	1	1	150-175	24, 30, 34	0.5	0.8	
10	Wisconsin	98-01	1	1	175-200	34.5**	0.0		
11	Iowa	97-99	1	3	150-175	20, 28, 36	0.0		
12	Iowa	95-96	1	3	150-175	20, 28, 36	-0.6		
13	Minnesota	09-10	2	3	150-175	16.5, 22, 27.5, 33, 38.5, 44		-1.0	
14	Indiana	09-11	1	3	>225	28, 33, 38, 42			-1.0
15	Iowa	97-99	6	6	150-175	24, 28, 32, 36	-1.9		

1: Porter et al., 1997; 2: Johnson and Hoverstad, 2002; 3: Sharratt and McWilliams, 2005; 4: Coulter and Shanahan, 2012; 5: Widdecombe and Thelen, 2002; 6: Novacek et al., 2013; 7: Pecinovsky et al., 2002; 8: Albus et al., 2008; 9: Tharp and Kells, 2001; 10: Pedersen and Lauer, 2003; 11,12: Pecinovsky et al., 2002; 13: Van Roekel and Coulter, 2012; 14: Robles et al., 2012; 15: Farnham, 2001.

*Average yield increase at 38,500 and 44,000 plants/acre. A significant row spacing by population interaction was observed.
**Approximate final stand, which differed from target populations.

Even among northern locations, however, yield benefits to narrow rows were inconsistent. For example, Van Roekel and Coulter (2012) found no yield advantage to narrow rows in research conducted during 2009 and 2010 at two southern Minnesota locations. Research at these same two locations in the early 1990's found an average 7.3% yield advantage for 20-inch rows over 30-inch rows (Porter et al., 1997).

Pioneer Research

Similar results were observed in Pioneer research. Results from 76 research studies conducted between 1991 and 2010 showed an average yield advantage of 2.7% with narrow or twin rows in the northern Corn Belt states of Minnesota, North Dakota, South Dakota, Wisconsin and Michigan, compared to a 1.0% advantage across studies in Illinois, Iowa, Indiana, Missouri, Nebraska, Ohio and the southern tip of Ontario (Figure 3).

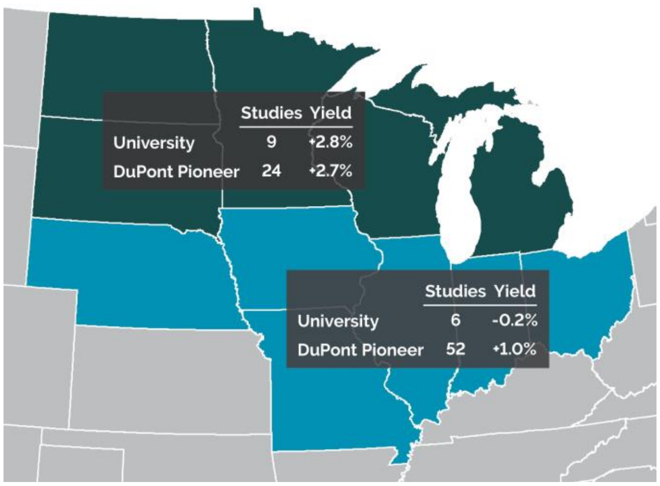

Figure 3. Average corn yield response to narrow rows in northern and central Corn Belt states observed in 20 years of university and Pioneer studies.

Pioneer also conducted numerous on-farm research studies from 2010 to 2012 comparing yield in twin and 30-inch rows. Most of the studies were conducted in Illinois, Iowa and Minnesota; although, side-by-side comparisons were also done

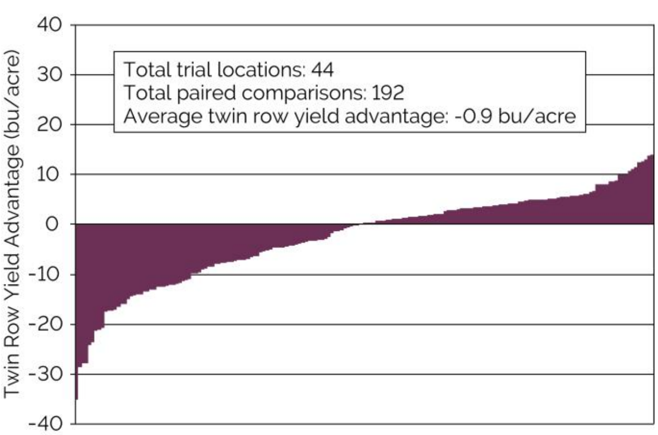

Figure 4. Yield advantage of twin rows compared to 30-inch rows in Pioneer on-farm research studies.

in Colorado, Indiana, Kansas, Missouri and Ohio. A total of 192 paired comparisons across 44 locations showed no overall yield advantage to twin rows over 30-inch rows (Figure 4). showed no overall yield advantage to twin rows over 30-inch rows (Figure 4).

RATIONALE OF NARROW ROW CORN

The primary rationale for narrow row spacings in corn is that by reducing the crowding of plants within a row, the crop will be able to better utilize available light, water, and nutrients by reducing competition among individual plants. However, the variability of corn yield response to narrow rows observed in research studies poses the question of why corn yield increases in narrow rows in some cases but not in others and particularly why narrow rows seem to provide a more consistent benefit in the northern Corn Belt. Identifying environmental and agronomic factors that tend to favor narrower rows can help determine the best fit for this practice in current and future corn production systems.

Light Interception

Research has shown a strong relationship between improved yields in narrow row corn and increased light interception (Andrade et al., 2002). In the absence of major water or nutrient limitations, corn yield is largely driven by the amount of solar radiation intercepted by the crop during the critical period for yield determination, immediately before and after silking. In order to maximize yield, the crop canopy needs to capture 95% or more of photosynthetically active radiation (PAR) during this period. Corn at a constant density can intercept a greater percentage of solar radiation when planted in narrow rows, which can increase yield in cases where corn in 30-inch rows does not meet this threshold (Andrade et al., 2002).

Despite the ability of narrow rows to increase interception of solar radiation, research has shown that corn in 30-inch rows can routinely capture over 95% of PAR in Midwestern production. Studies conducted in Illinois (Nafziger, 2006), Nebraska (Novacek et al., 2013), Indiana (Robles et al., 2012), Minnesota (Sharratt and McWilliams, 2005) and Michigan (Tharp and Kells, 2001) found that narrow and twin rows tended to increase light interception during vegetative growth stages, but this advantage diminished as the plants approached flowering. By the time the plants reached silking, there was little or no difference in light interception between 30-inch and narrow rows (Table 3).

Table 3. Light interception at V10 and R2 and yield of corn grown at 34,500 plants/acre in twin row, 30-inch and 15-inch rows in a University of Illinois study (Nafziger, 2006).

Row Type	Light Interception (%)		Yield (bu/acre)
	V10	R2	
Twin	79.5	98.9	187.4
30-inch	70.3	98.8	209.6
15-inch	83.3	98.5	199.3
LSD 0.10	6.2	0.8	8.5

Increased light interception is generally thought to be the reason that yield increases with narrow rows tend to be more frequent in the northern Corn Belt (Thelen, 2006). A research study conducted in Michigan, in which narrow rows significantly increased yields, found that differences in light interception between 30-inch and narrow rows were similar to those observed in other studies. Narrow rows intercepted more light during vegetative growth, but by flowering, there was no difference. However, the researcher hypothesized that the timing of the disparity in light interception may be the basis for the yield increase in narrow rows. The increased light interception in narrow rows coincided with the period of maximum daylength for northern latitudes; whereas light interception of corn further south in the Corn Belt would tend to be less affected by row spacing during this period due to its more advanced growth stage.

This is illustrated in Figure 5, which shows projected growth timelines relative to daylength for an 89 CRM hybrid planted May 5 at Moorhead, MN, compared to a 113 CRM hybrid planted April 15 at Champaign, IL. Daylength reaches its maximum at the summer solstice on June 21. At this point, the Moorhead crop is at a growth stage where narrow rows will increase light interception, whereas the Champaign crop is closer to silking and the light interception advantage with narrow rows has likely begun to diminish.

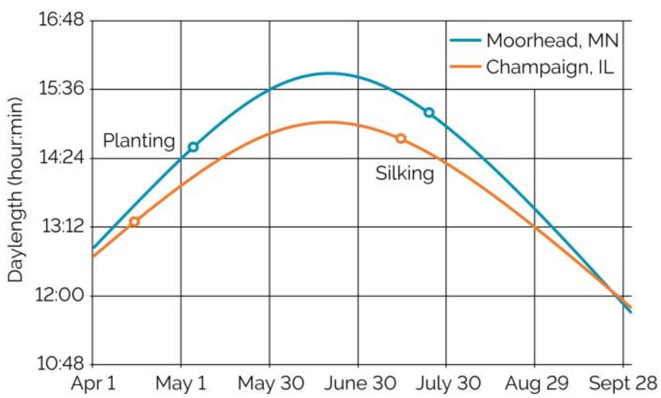

Figure 5. Projected silking date relative to daylength for corn at Moorhead, MN, and Champaign, IL.

Water and Nutrient Recovery

In addition to improving capture of solar radiation, narrow rows can also improve uptake of resources from the soil. The more equidistant plant spacing in narrow rows creates a more uniform distribution of roots within the soil profile which reduces competition among individual plants within a row for water and nutrients (Sharratt and McWilliams, 2005).

Research has shown that narrow rows can improve nitrogen use efficiency of corn by increasing the ability of the crop to recover nitrogen from the soil (Barbieri et al., 2008). This can improve yield in nitrogen-deficient conditions. Narrow rows have the added benefit of improving light interception when canopy development is limited by nitrogen deficiency. However, both of these advantages are reduced as nitrogen availability increases and may not result in increased yield when adequate nitrogen is available (Barbieri et al., 2000; Barbieri et al., 2008).

Pioneer nitrogen rate study showing nitrogen deficient corn in the foreground. Narrow rows may increase yield under nitrogen deficiency by improving uptake from the soil and increasing light interception.

The potential of narrow rows to increase yields by improving water uptake is less clear. Barbieri et al. (2012) found that narrow rows increased water uptake during the early stages of crop growth, likely due to deeper and more uniform distribution of roots in the soil profile, but this advantage diminished as the season progressed. Total seasonal crop evapotranspiration ultimately did not differ between row spacings. Conversely, Sharratt and McWilliams (2005) found that narrow-row corn did have greater total soil water extraction in one year of a two-year study.

The effect of corn row spacing on water use likely depends on moisture availability patterns during the growing season. In cases where drought stress persists during the growing season, increased water extraction early may reduce water that is available later in the season. Increased early water uptake may have the added effect of creating greater demand for water later in the season due to improved early crop growth. If water is not limited later in the season, the greater early uptake may be advantageous for the crop. However, research does not indicate any broad advantage to narrow-row corn under drought stress conditions.

POTENTIAL INTERACTING FACTORS

Plant Population

In examining the potential value of narrow-row corn production, it is important to consider not just current crop management systems but also factors that are likely to change in the future. One such factor is plant population density. Historic yield gains in corn have largely been driven by the continual improvements in stress tolerance, which have allowed corn to be planted at ever-increasing densities.

Average corn seeding rates in the U.S. and Canada have increased linearly over the last 20 years, from approximately 25,000 seeds/acre in 1992 to over 31,000 seeds/acre in 2017 (Figure 6). Extending this trend line 20 years into the future yields a predicted average seeding rate of over 37,000 seeds/acre in 2035. Whether or not the increases in optimum seeding rates over the last 20 years will continue at the same rate over the next 20 years remains to be seen; however, it raises the question of how agronomic practices may need to adapt to maximize production in the future.

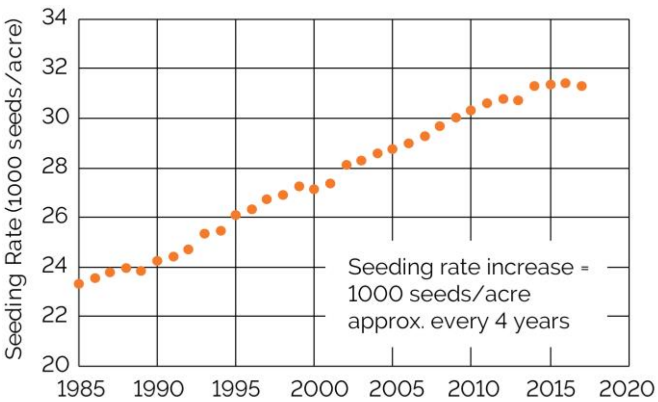

Figure 6. Average corn seeding rates reported by growers in North America, 1985 to 2017. Source: Pioneer Survey.

As corn population density increases, plants are crowded closer together within the row. At a density of 30,000 plants/acre, corn plants are spaced 7 inches apart within a row when planted in 30-inch rows. This spacing drops to 5.8 inches at 36,000 plants/acre and 5.0 inches at 42,000 plants/acre. There has been some speculation that crowding within the row can be yield-limiting at higher populations, in which case narrow rows could serve to alleviate this effect by increasing space between plants (Figure 7).

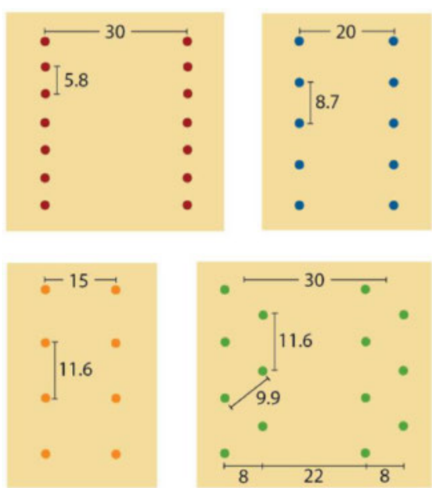

Figure 7. Across- and within-row spacing (in inches) in various row configurations at 36,000 plants/acre.

Row spacing studies in corn have routinely tested for interactions with plant population and specifically, whether or not narrow rows have a higher optimum density than 30-inch rows. Several university studies have included plant populations in excess of 40,000 plants/acre and have found little evidence that narrow rows have a higher optimum population (Table 2). Pioneer research on twin-row corn also found no difference between row spacings at high populations (Figure 8).

One notable exception was a University of Minnesota/ Pioneer research study in northwestern Minnesota which found significantly greater yield with 22-inch rows than 30-inch rows at the two highest plant populations tested (38,500 and 44,000 plants/acre) (Coulter and Shanahan, 2012). However, for growers outside of the northern Corn Belt, current research does not indicate that yields at higher plant populations will increase with narrow rows.

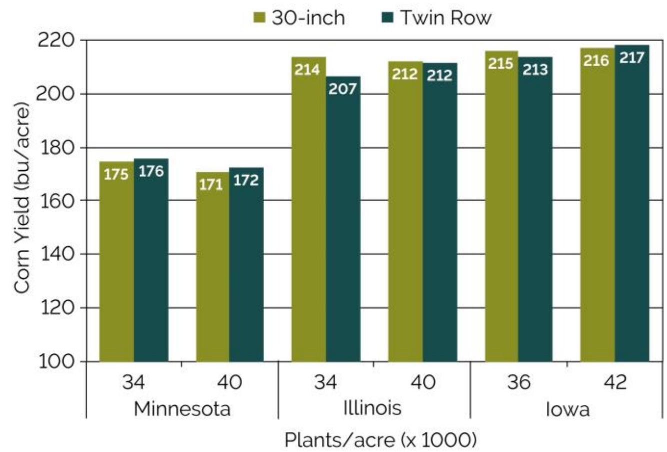

Figure 8. Corn yield in 30-inch rows and twin rows among plant populations included in Pioneer studies conducted in Minnesota, Illinois and Iowa in 2010.

Hybrids

A common question regarding narrow-row corn is whether certain hybrids are more suited to this system than others and also if future improvements in corn genetics may eventually produce hybrids specifically optimized for narrow rows.

Many university row spacing studies have included multiple hybrids but generally have found no difference in response to narrow rows. Of the twelve studies summarized in Table 2 that included more than one hybrid, only one (Study 15) reported a significant hybrid by row spacing interaction (Farnham, 2001). Out of six hybrids tested in this study, one yielded better in 15-inch rows, one yielded better in 30-inch rows, and four did not differ.

Pioneer on-farm twin row studies conducted in 2010 included several locations with multiple hybrids, some locations with as many as 10 hybrids. Among 14 hybrids that were tested at three or more locations, no significant differences in yield between twin rows and 30-inch rows were observed nor were any hybrid by row spacing interactions observed among hybrids compared at multiple locations (data not shown). Yield response to row configuration often appeared to differ among hybrids at individual locations; however, these differences diminished as the number of testing locations increased.

It has been suggested that improvements to stress tolerance in high population environments may yield new hybrids particularly suited to a high-density narrow-row or twin-row configuration. Decades of breeding corn for higher yield has resulted in modern hybrids with very different leaf architecture than those of 50 years ago, so it is not unreasonable to suppose that future breeding efforts could further alter the morphology of corn plants.

The idea of optimizing hybrids for narrow-row production has typically focused on leaf architecture, specifically that plants with narrower and more upright leaves may be more suited to narrow rows. Research thus far, however, has not shown a relationship between leaf architecture and yield response to row spacing among contemporary hybrids.

Research conducted in Michigan compared performance of six hybrids with differing leaf architecture in narrow rows (Widdicombe and Thelen, 2002). Of these hybrids, two were characterized as having erect leaf orientation, three with semi-upright leaves and one with wide leaves. Average corn yield was significantly higher in narrow rows, but performance did not differ among hybrids. A study in Minnesota comparing two hybrids of differing leaf architecture also found no difference in yield response to narrow rows (Sharratt and McWilliams, 2005).

There is some indication that modern hybrids may actually be more suited to maximize yield in 30-inch rows than those of the past. Van Roekel and Coulter (2012), in noting the lack of yield response to narrow rows at two Minnesota locations where similar research had found a significant yield response in the early 1990's, hypothesized that selection by plant breeders for increased tolerance to stress associated with high plant densities may have also resulted in improved performance in 30-inch rows relative to older genetics. Analysis by Hammer et al. (2009) tends to support this hypothesis. Their modeling studies indicated that historic improvements in corn yield were likely more related to changes in root architecture than leaf architecture, specifically roots systems that grow deeper in the soil at a steeper angle. Plants with more vertical, downward-growing root systems would seem less likely to be affected by competition with neighboring plants and therefore, less sensitive to differences in row spacing.

CONCLUSIONS

The extensive history of research on corn row spacing has repeatedly shown that it is a very complex issue with many interacting factors. Yield results have often been inconsistent and highly variable across environments, making it difficult for growers to determine the best solution for their individual farms. However, the accumulated body of Pioneer and university research conducted over the past 20 years does not indicate that the current standard 30-inch row spacing is limiting to corn productivity for most of the Corn Belt. This research also provides little evidence to suggest that narrow rows will consistently increase yield relative to 30-inch rows on productive soils under current agronomic practices. Yield results in the northern Corn Belt have tended to be more positive for narrow rows but still have shown a high degree of variability.

Many Pioneer and university corn row spacing studies have included multiple hybrids and have generally found no difference in hybrid performance among row spacings, indicating that growers currently in narrow row systems are not limited in their choice of corn products for maximum performance. Consult your local Pioneer sales professional for information on the best products for your specific management system and growing environments.

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