Corn Plant Population Response and Risk in the Northern Corn Belt

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Introduction

The production practices of corn (*Zea mays* L.) have been intensely researched and constantly improved during the last century. Plant population has been one of the most closely studied crop management practices dealing with corn production because of improved hybrids. Before 1930, Morrow and Hunt (1889, 1891) and Morrow (1891) found, with open-pollinated corn in Illinois, that the grain:stover ratio increased as plant population rose from low rates up to a maximum, which coincided with the highest grain yield. However, average grain yields were static because no yield gains were realized from breeding advances or changes in management practices. Since 1930, steady grain yield increases have occurred due to the use of improved hybrid cultivars, increased use of fertilizers, better weed control, higher plant populations, and improved management (Cardwell, 1982).

In 1930, farmers used check-row planting with 107 cm between rows and hills with three or four plants per hill^{-1}. This management system resulted in populations of 11,700 to 15,700 plants A^{-1} (Cardwell, 1982). Plant population increases first occurred in the 1940s and early 1950s as a result of adopting hybrids with greater stalk strength and switching from hand to mechanical harvesting. In addition, replacing horsepower with tractor power to aid in timely weed control encouraged drilling and the advantages of more uniform plant spacing within the row (Cardwell, 1982). Rounds et al. (1951) found that drilled corn yielded 7% better than did corn planted in hills. They reported that drilling corn allowed higher plant populations than utilized under previous hill planting systems. According to Rossman and Cook (1966), higher plant population was found to have a greater effect on yield than row width or planting pattern.

A second increase in plant population occurred in the late 1960s. According to Prior and Russell (1975) and Duvick and Cassman (1999), this significant change occurred because farmers grew cultivars at higher plant populations to take advantage of higher rates of fertilizer, earlier planting dates, narrower row spacing, and improved hybrids that exhibited increased stalk strength and tolerance to augmented plant population. Plant populations increased rapidly from 1964 through 1974, but leveled off some in the mid 1970s because of increased energy costs of fertilizer, and also because of drier weather that decreased subsoil moisture at planting time, thus lowering optimum plant populations (Troyer and Rosenbrook, 1983). Following the drier weather period, corn populations were again rising. According to Cardwell (1982), population increased from 13,700 to 22,200 plants A^{-1}, which resulted in 21% of the gain in average grain yield during those 50 years.

Numerous reasons have been proposed as to why newer corn hybrids are better than the old varieties. According to Tollenaar and Wu (1999), a large proportion of yield improvement in maize may be attributable to the capacity of newer hybrids to better tolerate stress conditions.

Newer hybrids have a better level of resistance to barrenness under stress whether from high plant population, drought, or other causes (Troyer and Rosenbrook, 1983). Tollenaar (1989) suggested that modern hybrids do not produce barren plants at high populations because of increased tolerance to plant stress. Stalk lodging is a major deterrent to using high plant populations because of its often dramatic effect on grain yield. Duvick (1984) showed that differences in grain yield between older and newer hybrids were a function of plant population. Differences between hybrids were small at low plant population and became greater as plant population increased. The increasing stress tolerance of commercial maize hybrids allows effective use of intensive agronomic practices, such as higher plant population and greater nutrient inputs. These intensive practices place greater competitive pressure on individual plants for water and light (Duvick and Cassman, 1999). Plant distribution in the field, as affected by plant population, has been one area that has received a great deal of attention over the last several decades (Farnham, 2001).

So how do producers know that they are reaching the optimum population for maximum yield for their environmental conditions? Optimum plant populations vary with factors such as moisture stress, hybrid, soil fertility, and yield goal (Benson, 1982). Olson and Sander (1988) found that ear size is one simple method of estimating whether plant population is optimum. In most studies, an ear size of 220g (~0.5 lb) is associated with maximum yields. However, there is some evidence that optimum ear size may be slightly less in the northern Corn Belt, indicating again that optimum plant populations are higher in the northern than southern Corn Belt. Increasing population affects the number the kernels ear^{-1} and not the kernel weight (Norwood, 2001).

So why do we seek to know what the maximum population is? Wouldn't it be safer to plant at lower populations and play it safe? Cox (1997) found that populations less than 74 100 plants ha^{-1} result in more of a yield loss than that of plant populations above 74 100 plants ha^{-1}. It is a bigger risk not planting to the environment's maximum potential.

Guidelines

Recently, corn seed costs have dramatically increased due to technology fees. It is not unheard of for seed of high-performing premium hybrids to cost $160-$200 per bag, whereas 10 years ago, premium seed would cost about $80-$120 per bag. Understanding what the true value of transgenic hybrids mean to farm profitability is challenging.

The following guidelines help growers adjust their plant densities and maintain or enhance farm profitability depending upon their farm situations. Not only has the economics of seed cost been changing, but the yield response of corn to plant density has been increasing over time. But ultimately, *optimum plant density is affected by both seed cost and corn price***.**

Placing a value on seed is relatively easy since the price of seed is known at the time of purchase and the amount used is known after a field is planted. The realistic value of grain will vary depending upon the producer’s ability in marketing the grain. Corn grain that will be used on farm as livestock feed should be valued at the price it would cost to purchase if feedstocks run short.

Table 1. Price ratio of seed:corn (i.e. $/1000 seeds ÷ $/bu corn).

Price of seed		Price of corn ($/bu)						
$/80 K bag	$/1000 seeds	$1.00	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00
$40	$0.50	0.50	0.33	0.25	0.20	0.17	0.14	0.13
$60	$0.75	0.75	0.50	0.38	0.30	0.25	0.21	0.19
$80	$1.00	1.00	0.67	0.50	0.40	0.33	0.29	0.25
$100	$1.25	1.25	0.83	0.63	0.50	0.42	0.36	0.31
$120	$1.50	1.50	1.00	0.75	0.60	0.50	0.43	0.38
$140	$1.75	1.75	1.17	0.88	0.70	0.58	0.50	0.44
$160	$2.00	2.00	1.33	1.00	0.80	0.67	0.57	0.50
$180	$2.25	2.25	1.50	1.13	0.90	0.75	0.64	0.56
$200	$2.50	2.50	1.67	1.25	1.00	0.83	0.71	0.63
$220	$2.75	2.75	1.83	1.38	1.10	0.92	0.79	0.69

Table 1 describes seed:corn price ratios for seed costs ranging from $40 to $220 per bag and corn prices ranging from $1.00 to $3.50/ bu. As seed costs increase and/or corn prices decrease the seed:corn price ratio increases. Conversely, as seed cost decreases and/or corn price increases the seed:corn price ratio decreases. Currently, most seed:corn price ratios range from 0.33 to 1.50. For example, the seed: corn price ratio at $2.00/bu corn ranges from 0.50 to 1.13 for $80 to $160 per bag of seed.

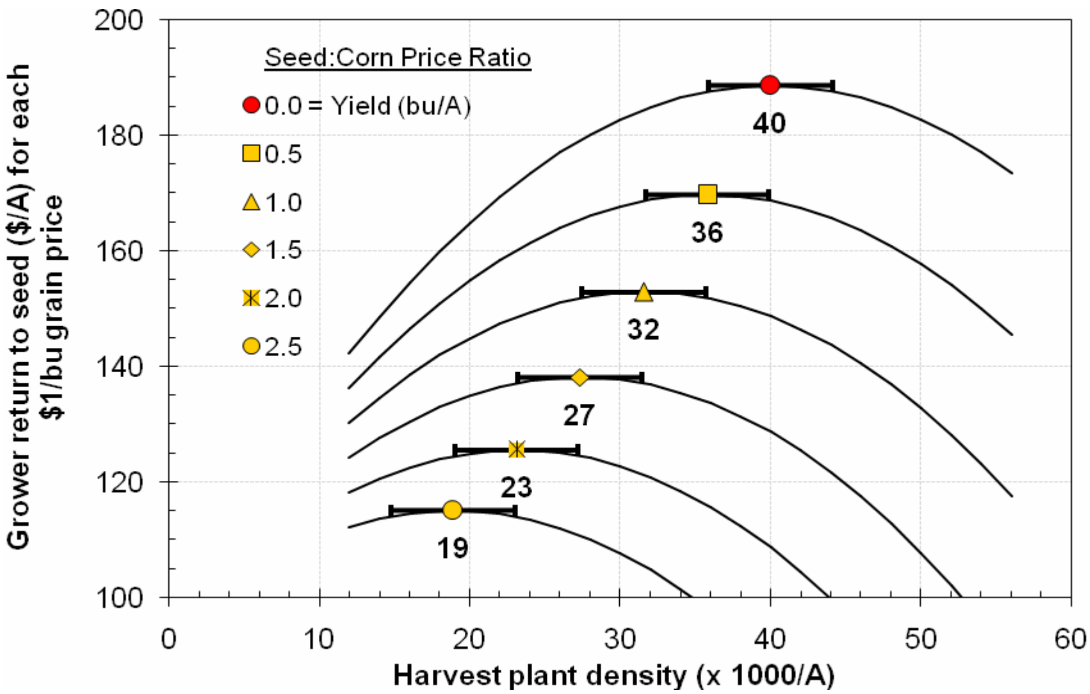

Figure 1. Profitable harvest plant densities for seed:corn price ratios of 0.0, 0.5, 1.0, 1.5, 2.0, and 2.5. Symbols represent the economic optimum return to plant density (EOPD) and error bars are the low and high ends of the range of profitability (within $1/A of EOPD) at each seed:corn price ratio.

For a seed:corn price ratio of 1.0, the economic optimum plant density (EOPD) is 33,000 plants/A and grower return is at a maximum of $159/A for each $1.00 of corn price (Figure 1). If $1.00 is subtracted from the maximum grower return ($159 - $1 = $158), the range in plant density is 29,500 to 36,600 plants/A (error bars). As corn price increases, grower return increases proportionally, but the EOPD of each ratio does not change. For example, if the seed:corn price ratio is 1.0, the EOPD is 33,000 plants/A resulting in a grower return of $159/A at a $1.00 corn price. If the corn price = $2.50 then grower return = $159 x $2.50 = $398/A.

As seed costs increase and/or corn prices decrease, the optimum harvest plant density decreases, (i.e., EOPD for ratio of 1.50 = 29,800 plants/A). As seed cost decreases and/or corn price increases (ratio = 0.50), the EOPD increases to 36,200 plants per acre. If seed cost is not considered (ratio = 0.0), then the EOPD estimates yield and is 39,400 plants/A.

An Example: Bt-ECB Corn Seed

Lodging is a major constraint to maximizing grain yields in modern corn production. Lodging is one of the hazards of increasing plant densities to get maximum yields. Current UW recommendations for harvest plant densities range between 26,000 and 30,000 plants/A.

Bt corn hybrids resist European corn borer (ECB) damage and lodge less. From 2002 to 2004, Bt and non-Bt corn hybrids were planted at plant densities ranging from 25,000 to 50,000 plants/A in 5,000 to 6,000 plants/A increments at 10 locations in Wisconsin.

The plant density maximizing yield for Bt hybrids was 42,300 plants/A, while for non-Bt hybrids was 40,000 plants/A. If plant densities were increased from 30,000 plants/A to 41,400 plants/A, yields increased 4.2%.

At the same plant density, Bt corn hybrids yield more than non-Bt corn but seed costs of Bt corn are often greater than non-Bt seed. The seed:corn price ratio is higher for Bt corn.

For Bt and non-Bt corn where the seed:corn price ratios are the same, as seed costs increase and/or corn prices decrease the economic optimum plant density (EOPD) decreases (Figure 2). For example, the EOPD for a ratio of 1.50 is 29,600 plants/A for Bt corn and 27,300 plants/A for non-Bt corn. As seed cost decreases and/or corn price increases (ratio = 0.50) the EOPD increases to 38,100 plants/A for Bt corn and 35,800 plants/A for non-Bt corn.

Corn management systems must be justified on the basis of economic returns, rather than on crop yield alone. Overall, Bt corn hybrids in this study yielded 6.6% greater and had 22% less lodging than non-Bt hybrids. However, the yield and lodging benefits for Bt hybrids were offset by the higher seed and harvest costs associated with Bt corn, adding no economic benefit. This study determined the EOPD to be 33,900 plants/A (regardless of hybrid trait) or 3900 plants/A more than the current recommendation in Wisconsin. Even though no economic benefit was measured for Bt corn due to higher seed costs, other benefits such as safety (pesticide handling), insurance (potential for ECB outbreaks), and “peace of mind” might be important for growers to consider when using Bt corn.

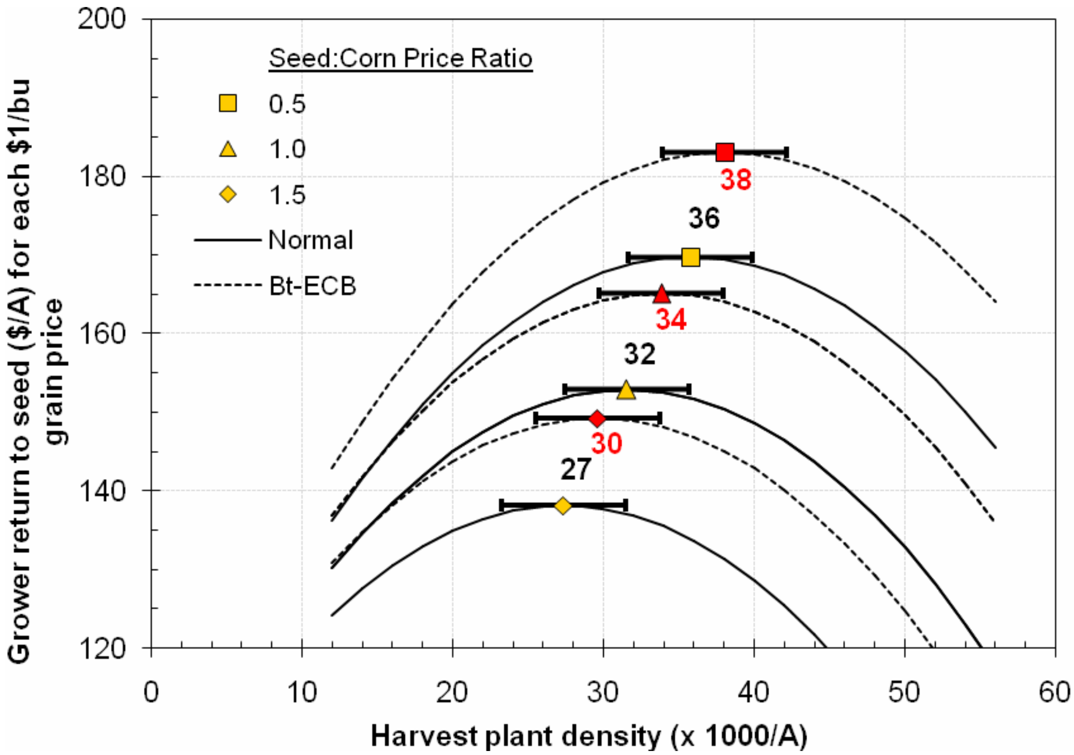

Figure 2. Profitable harvest plant densities of Bt and non-Bt corn hybrids for seed:corn price ratios of 0.5, 1.0, and 1.5. Symbols represent the economic optimum return to plant density (EOPD) and error bars are the low and high ends of the range of profitability (within $1/A of EOPD) at each seed:corn price ratio.

Guidelines for choosing an appropriate plant density for corn

1. Currently, seed:corn price ratios range from 0.33 to 1.50.
2. Grain yield continues to increase through plant densities of 39,400 plants/A.
3. The EOPD for seed:corn price ratios between 0.5 and 1.5 is 29,800 to 36,200 plants/A. The plant density of 32,700 plants/A is within $1.00 of the EOPD for ratios between 0.5 and 1.5.
4. In general, silage yield continues to increase as plant density increases. However, a trade-off exists as measured by Milk2006 where quality decreases with increasing population. Thus, the EOPD is the same for corn grown for silage or grain. Corn silage is often more valuable than grain and so the EOPD follows more closely seed:corn price ratios less than 1.0.

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