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Are You Approaching Yield Thresholds?

Nebraska researchers suggest the answer is "no." Increased plant populations and nutrients can bring higher corn yields, plus the added benefit of increased carbon sequestration.

Summary: *Current fertilizer recommendations that are based on a yield goal that is well below the yield potential threshold do not allow expression of full attainable yield that is possible at higher plant densities and more intensive nutrient management. Compared to current recommendations, high corn yields require higher plant density (40,000 to 44,000 plants/A) and greater N and K uptake per unit yield. High-yielding maize systems significantly increased the amount of crop residue added to the soil. The resulting increase in the amount of carbon added to the soil is likely to improve soil quality in future years. The potential to increase carbon sequestration is greatest in continuous corn systems with intensive management that supports high yield levels.*

Crop yield improvement must continue unabated well into the 21st century, not only to meet food and fiber needs of the nine billion people on earth in the year 2050, but also to minimize the conversion to agriculture of land now spared for nature. Globally important intensive agricultural systems such as rainfed and irrigated continuous corn or corn/soybeans will play a key role in sustaining the future global food supply because present acreage corn and soybean yields are only about 50 percent of the estimated climatic-genetic yield potential of these crops. This yield gap will not be closed by genetic technology. Intensified crop

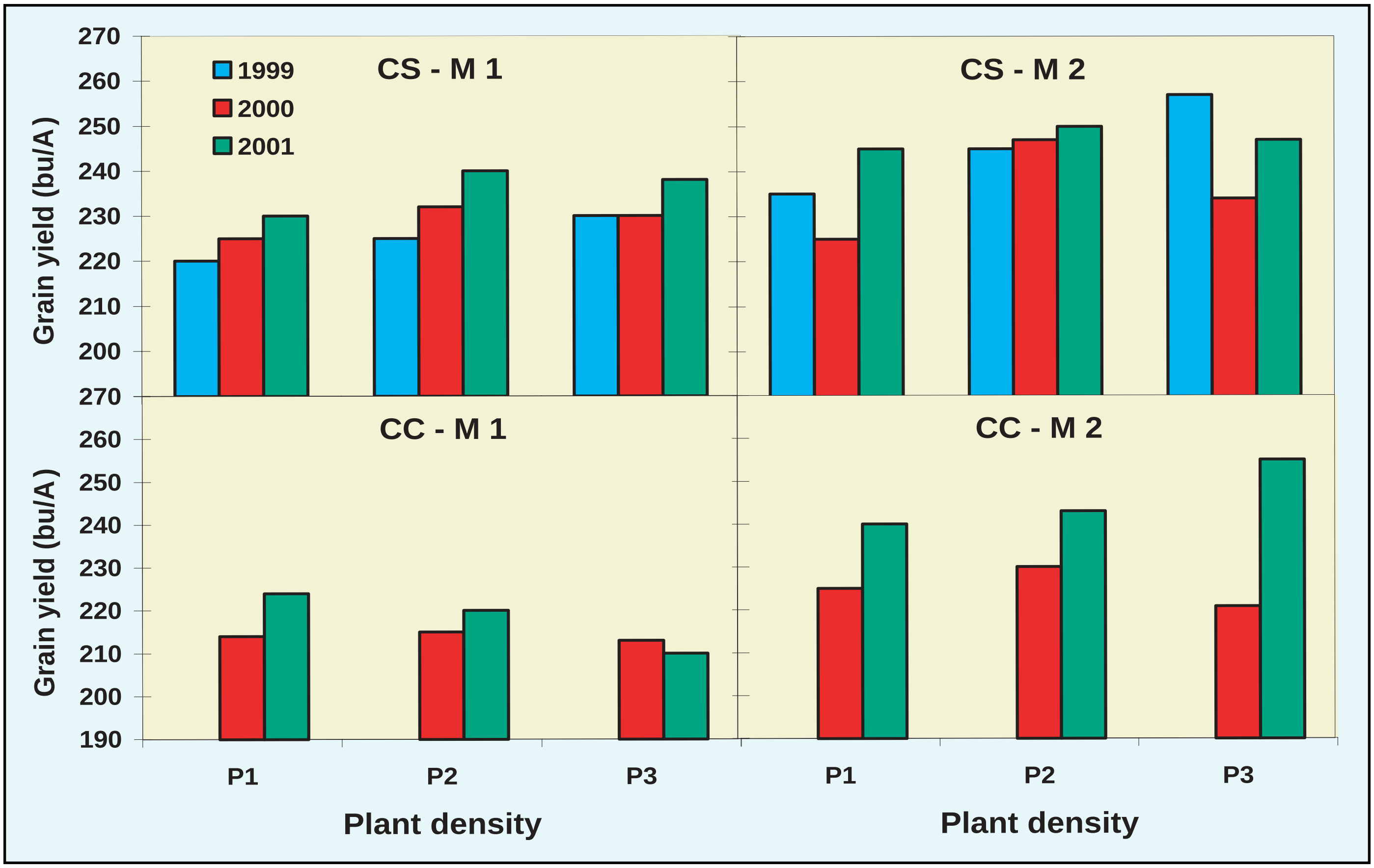

Figure 1. Corn grain yield as affected by crop rotation, fertility management, and final plant population density. CC = continuous corn, CS = corn/soybean, M1 = recommended, M2 = intensive, P1 = 28-30,000 pl/A, P2 = 36-41,000 pl/A, P3 = 44-47,000 pl/A.

and soil management will be necessary to coax more out of the crop biomass potential.

In this article, focus will be on a more detailed understanding of corn yields, as well as soil processes regarding carbon sequestration at different cropping intensity.

Yields improved

Plant density and nutrient management levels significantly affected yield, harvest index, stover yield, components of yield, and nutrient uptake requirements of corn. Intensive fertilizer management (M2) significantly increased yield in all three years over the recommended fertility regime (M1) as shown in Figure 1. Maximum grain yields ranged from 249 to 257 bu/A in all three years of the study. In all three years, treatment CS-M2-P2 produced consistently high yields of 245 to 252 bu/A that were close to the simulated yield potential for this plant density (Figure 1). Continuous corn yields were below those obtained in the corn/soybean rotation at the recommended level of nutrient management (M1), but the differences diminished for M2 nutrient management.

1999. Corn was planted late (May 13) and grain yield increased with both increasing population density and management intensity, with a high of 258 bu/A for the CS-M2-P3 treatment. At the M2 level of nutrient management, the harvest index of maize decreased with increasing plant density due to greater vegetative biomass accumulation. Sink size (number of kernels/m^2) and nutrient uptake also increased with increasing plant density and nutrient management level. The 100-seed weight was about 4 percent larger in M2 treatments than in M1, but decreased with increasing plant density.

2000-2001. Corn was planted in late April and growth was much affected by hot temperatures during grain filling. Highest yield was 249 bu/A in 2000 (CS-M2-P2 treatment) and 252 bu/A in 2001 (CS-M2-P2 and CC-M2-P3 treatments). In 2000, at all population and nutrient management levels, grain yield in continuous corn was below that of corn grown after soybeans, but the difference was smallest in M2 treatments. Similar observations were made for M1 treatments in 2001, but corn yield in M2 treatments with high plant density was similar in the CC and CS rotations (Figure 1). Increasing plant density beyond the P2 level did not significantly increase yield and plant nutrient accumulation in 2000 and 2001, or even lead to the decrease observed in 2000. Actual plant densities in the P3 treatment were about 5 percent greater than in 1999 (P3: average of 46,500 plants/A in 2000 and 2001 vs. 44,200 plants/A in 1999), which may have further accelerated crop stress under high temperatures during grain filling. Biomass x temperature interactions on crop respiration losses may explain why in 2000 and 2001 yields did not increase in the highest density treatment because the actual plant density in P3 was probably excessive, whereas it was already near optimal (37-41,000 plants/A) in the P2 treatment.

Table 1. Nutrient accumulation per unit grain yield as affected by fertility management (M) and plant density (P). Averages of 1999 and 2000, corn after soybean.

Plant population	NPK—lbs/A	Yield bu/A	N	P_2O_5	K_2O	Mg	S
			lbs nutrient/bu/A yield				
			Aboveground nutrient uptake				
P1	M1 UN-L-rec (120-0-0)	224	1.06	0.43	1.55	0.10	0.12
P2	M2 intensive (234-92-93)	247	1.08	0.42	1.76	0.10	0.11
P3	M2 intensive (234-92-93)	247	1.12	0.41	1.84	0.10	0.11
			Nutrient removal with grain				
P1	M1 UN-L-rec (120-0-0)	224	0.69	0.32	0.22	0.05	0.06
P2	M2 intensive (234-92-93)	247	0.68	0.32	0.23	0.05	0.06
P3	M2 intensive (234-92-93)	247	0.67	0.31	0.22	0.05	0.05

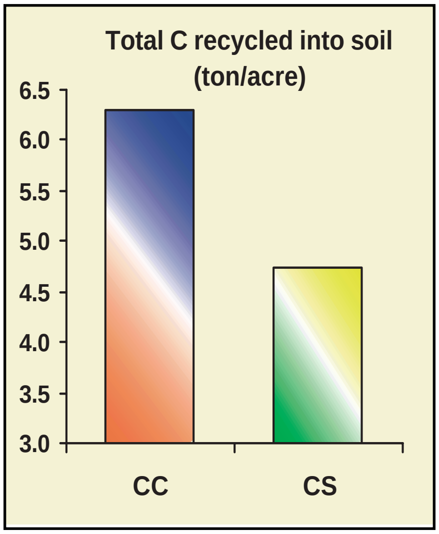

Figure 2. Comparison of estimated total C input to soil from 1) aboveground crop residues after grain harvest and 2) roots, after two years (1999 to 2000) in continuous corn (CC) and corn/soybean (CS) in M2 nutrient management and P2 plant densities.

At the intensive level of nutrient management, harvest index of maize decreased with increasing plant density due to greater vegetative biomass accumulation. Stover yield (stalks, leaves, cobs, tassels) increased with increases in both population and fertility management. For example, averaged over three years, stover yield was 6.8 tons/A dry matter in corn after soybeans at the currently recommended plant density (P1, 30,000 plants/A) and fertilizer management level (M1). By contrast, stover yield at very high density (P3) and intensive fertilizer management (M2) averaged 7.9 tons/A. In continuous corn, annual stover yield averaged 6.5 tons/A for the M1-P1 treatment vs. 7.8 tons/A under very intensive management (M2-P3).

Plant nutrient accumulation

Higher plant density and intensive nutrient management resulted in greater plant accumulation of N and K per unit of grain yield, whereas no differences were observed for P, Ca, Mg, and S (Table 1). Average crop nitrogen accumulation in aboveground biomass (corn after soybeans) was 1.06 lbs N/bu yield in M1 treatments at normal plant density (P1), but 1.10 lbs N/bu under M2-P2/P3 management. Average crop potassium accumulation in aboveground biomass was 1.55 lbs K/bu in M1, but increased to 1.84 lbs K/bu under M2 management at high plant density. By contrast, nutrient removal with grain alone did not differ significantly among the nutrient management and plant density levels, except for a slight decrease in grain N removal with increasing cropping intensity (Table 1).

As yields approach existing ceilings, internal plant nutrient requirements increase to sustain the physiological functions of a vastly increased amount of aboveground biomass. This is particularly true for nutrients such as potassium, which has both non-specific and specific plant functions and can be stored in large amounts in the vacuole. However, more work is needed to verify whether the increased K uptake represents a true increase in crop K requirements for achieving yield potential under non-stress conditions.

Carbon Sequestration

Other justifications for interest in optimal soil productivity are low commodity prices, and the need for mitigating local and global environmental effects of human activities.

Corn production systems can contribute to solving environmental problems rather than being perceived to be the source of such problems.

One such example is the potential of corn systems to fix atmospheric carbon dioxide (CO_2) in crop biomass through the process of photosynthesis and to sequester a portion of this fixed carbon (C) in soil organic matter. Once in place, this C sequestration would contribute to reducing the rate of increase in greenhouse gases. In fact, international negotiations are under way that may create markets for such C storage.

The annual C storage potential of corn production systems may range from 0.25 to 1.5 tons/A of C, depending on soil management and yield level. However, no studies have been conducted to quantify this at near-optimal yield levels.

Soil samples collected after the first year indicated no significant differences in soil C and N stocks among treatments. As a baseline, average total soil C stored in the top foot was 26.1 tons/A, and average total soil N was 2 tons/A. Average concentrations were 14.8 g C kg^{-1} and 1.14 g N kg^{-1}. However, depending on the nutrient management and plant density levels, total C input over two years (1999 to 2000) was 15 to 30 percent greater in continuous corn than in a corn/soybean rotation (Figure 2), mainly due to less vegetative biomass production in soybeans compared to corn. Total C input from recycled crop biomass was 1.5 tons/A greater in continuous corn than in a corn/soybean rotation. We expect the difference in C sequestration to be even greater because soybean residue decomposes much more rapidly than corn stover.

It remains to be seen how the different levels of C input will affect soil stocks over the medium and long term, and whether potentially greater C sequestration can be achieved without increases in CO_2 emissions and other greenhouse gases. Preliminary data indicate that intensive management schemes do not appear to cause increased soil surface CO_2 flux that would offset increased soil carbon sequestration potential. However, efforts to increase sequestered carbon through high N applications may lead to other problems such as increased nitrous oxide (N_2O) emissions, which must be mitigated through more detailed forms of N management.

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