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N-Use Efficiency Improves In Ecological Intensification Project

Management systems designed to preserve the integrity of the environment are proving profitable in yields and more efficient use of inputs.

Summary: *Average yields approaching 80 percent of the yield potential of corn have been routinely achieved in the Ecological Intensifi cation project at the University of Nebraska in Lincoln. We have observed a trend toward improvement in nitrogen (N) use efficiency that in part is due to a gain in soil C and N storage as a result of intensive management. Closing the yield gap requires higher plant populations and improved nutrient management to maintain efficient and profi table improvement in corn production. Soil quality improvements and higher residue inputs under intensive management should make this task easier with time.*

Average corn grain yields in the U.S. have increased linearly at the rate of 1.7 bu/A over the past 35 years with a national yield average of 140 bu/A. However, results of yield contest winners and data from well-designed field experiments, as well as simulation models, indicate that the actual yield potential of corn in our temperate climate exceeds 300 bu/A. Given the apparent yield gap that exists in the US Corn Belt, there are most probably significant changes in management practices that can be adopted to close this yield gap. However, there is a need to develop management systems that also preserve the integrity of the environment and that are profitable in practice. Given the lack of new agricultural lands to exploit and the ever-growing need for increased productivity on existing land, intensification strategies must be developed that improve soil nutrient supply, nutrient-use efficiency as well as soil nutrient supply.

Input management

Nutrient management consisted of two strategies during the period of the study (1999-2003):

M1 (recommended) for a yield goal of 200 bu/A using N at 107 to 123 lbs/A for corn after soybeans and 161 to 181 lbs/A for corn aftercorn. No P or K was applied due to high soil test values. N was applied preplant and at V6 stage.

M2 (intensive) for a yield goal of 300 bu/A using N at 193 to 266 lbs/A for corn after soybeans and 223 to 324 lbs/A for corn after corn. P_2O_5 was applied at 92 lbs/A, K_2O at 93 lbs/A, and S at 10 lbs/A. N was applied preplant and at V6, V10, and VT stages.

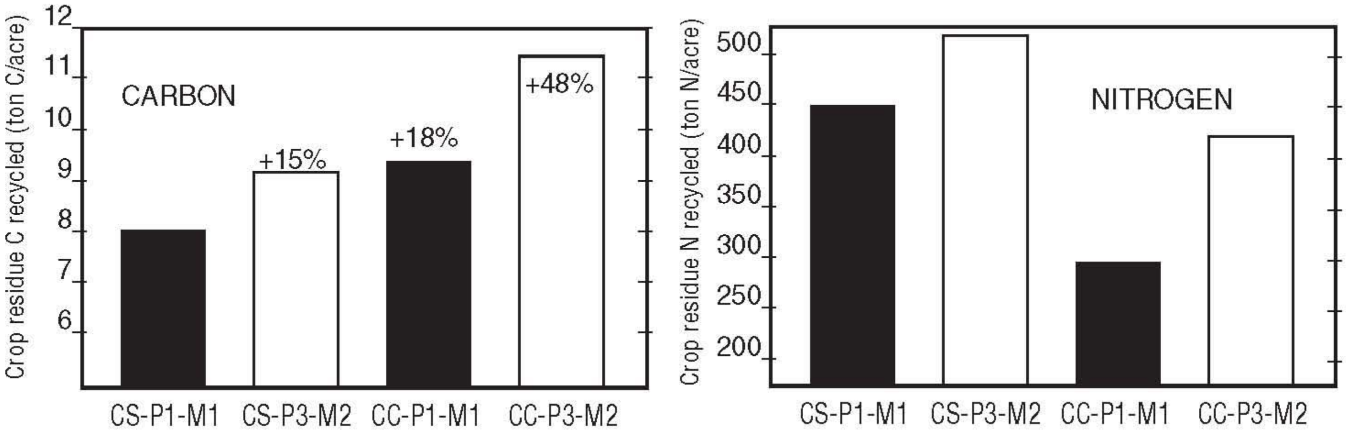

Figure 1. Cumulative carbon and nitrogen inputs to soil in aboveground crop residues as affected by crop rotation, plant density, and nutrient management, 1999-2002.

Table 1. Corn grain yield (15.5 percent moisture) trends as affected by crop rotation, fertility management, and plant population density. Yields for M2 treatment refer to the plant density with the highest yield in the given year; Ecological Intensification Study.

Treatments*	N rate--lbs/A					
	Average	**1999**	**2000**	**2001**	**2002**	**2003**
Continuous Corn						
M1	170		181	179	161	161
M2	268		324	268	258**	223**
Corn after Soybeans						
M1	116	116	123	116	107	116
M2	224	201	266	214	193	223

* M1: preplant and V6; M2: preplant, V6, V10, V12-VT.
** Continuous corn includes M2 fall N application of 65 lbs/A (2001) and 45 lbs/A (2002) on residue prior to tillage.

Table 2. History of N fertilizer application to continuous corn and corn following soybeans for the M1 (recommended) and M2 (intensive) fertilizer management treatments.

Treatments		Corn grain yield--bu/A					
Density*	**Fertilizer**	**Average**	**1999**	**2000**	**2001**	**2002**	**2003**
Continuous Corn							
P1	M1	217		241	223	178	255
P2 P3	M2	247		229	252	242	265
Corn after soybeans							
P1	M1	236	219	225	230	221	268
P2 P3	M2	256	257	248	249	243	285

* M2 treatment with highest yielding plant density; P2 in 2000 and 2003; P3 in 1999, 2001, and 2002.

Plant population consisted of three strategies:

P1 (recommended) at 33,000 plants per acre for all years.

P2 (intensive) at 37,000 plants/A in 2000 and 2003.

P3 (intensive) at 44,000 plants/A in 1999, 2001, and 2002.

Results

Grain yield. Table 1 shows the trend in grain yield over the period 1999 to 2003. Maximum grain yields were achieved with P2 and P3 plant populations under intensive fertilizer management. When averaged over crop rotation, the M2 treatment resulted in an average yield gain of 11 percent and this gain was manifest at higher plant populations. Although soils test values for P and K were in the very high range, current fertilizer recommendations (M1) were insufficient to supply the demand of higher biomass under the P2 and P3 plant populations.

Yield loss at the P2 population in 2000 was due to severe heat stress in that year and a reduced period of grain fill. In 2003, the hybrid Pioneer P31N28 was unresponsive to population density under the M2 treatment. This may be attributed to an excellent growing season (coolest in 30 years) where full

Table 3. Trend in NUE as influenced by crop rotation, population density, and fertility management.

Treatments		Average			NUE				
Density*	Fertilizer	N rate lbs/A	Yield bu/A	NUE bu/lbN	'99	'00	'01 bu/lbN	'02	'03
Continuous Corn									
P1	MI	170	217	1.28		1.18	1.25	1.11	1.59
P2 P3	M2	268	247	0.94		0.71	0.94	0.94	1.18
Corn after soybeans									
P1	M1	116	236	2.04	1.89	1.83	1.98	2.06	2.31
P2 P3	M2	224	256	1.16	1.28	0.93	1.16	1.26	1.28

* M2 treatment with highest yielding plant density: P2 in 2000 and 2003; P3 in 1999, 2001, and 2002.

expression of yield potential was realized regardless of population density. This could also be an artifact of the general characteristics of this hybrid, which has very erect leaf structure. We are using this same hybrid in 2004.

N rates. N application rates are adjusted as a function of projected yield potential, previous crop and spring residual soil NO_3-N (Table 2). Application rates have remained more consistent for the corn/soybean rotation owing in part to the impact of soybeans on reducing residual soil NO_3-N. Beginning in 2002, prior to plowdown in the fall, we began the practice of applying fluid N at the rate of 45 to 65 lbs/A to the residue of the corn M2 treatment. This was meant to facilitate decomposition and humification of the high amounts of residue we have experienced under this treatment with the intent of decreasing the competition of decomposers for N sources during the early growing season. The elevated NO_3-N levels in the spring following these applications have resulted in a significant reduction in fertilizer rate (Table 2).

NUE. The impact of these management changes on N–use efficiency (NUE) is given in Table 3. Average farm NUE in the U.S. is 1.03 bu/lb of N. Although average NUE for the continuous corn M2 treatment is below this level, we have experienced a steady increase in NUE over the course of the study. This indicates the potential that exists for increasing NUE in cornbased systems. We hypothesize that the increase in NUE we are observing is due to improvement in both soil quality from greater carbon inputs to the soil and concomitant sequestration of N with this carbon.

Cumulative carbon/N. The cumulative effect of crop residue carbon (C) and N recycled in these systems is summarized in Figure 1. Over the four-year period, 7.5 tons C/A were recycled in the recommended CS-P1-M1 treatment, which is the most widespread rotation in the Corn Belt. This amount increased to 9.1 tons C/A in the intensified corn/ soybean system (CS-P3-M2). Net C recycling in all of the continuous corn treatments was larger than in any of the corn/soybean treatments, reaching 9.3 tons C/A in continuous corn P1 M1 and a maximum of 11.7 tons C/A in continuous corn P3 M2. This increase represents a 48 percent gain in residue C inputs to soil over this four-year period.

N recycled in crop residues was highest in the corn/soybean rotation with an average of 481 lbs/ A vs. 356 lbs/ A in the continuous corn treatment. Increased C inputs to soil can only build organic matter if there are not elevated losses of CO_2-C from soil respiration. We have been monitoring soil CO_2-C respiration since 1999 and have noted that fertility treatments have had a minor impact on CO_2-C losses. Although CO_2-C losses during the 2003 growing season were higher for continuous corn (owing to higher residue C input), fertility management did not result in CO_2-C losses equivalent to C inputs. This suggests that increases in soil C and N should result.

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