Effects of Crop Rotation and Nitrogen Fertilization for Corn on Yields of Corn, Silage Corn, Soybean, and Oats

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Introduction and Methods

Crop rotation influences crop yield by changing the availability of nutrients and water, several soil properties, and incidence of pests and weeds. A crop rotation study was initiated in 1979 to assess the effects of various crop sequences and nitrogen (N) fertilization for corn on crop yield. The crop rotations are continuous corn for grain and for silage, continuous soybean, several corn-soybean sequences with one to three corn crops for every soybean crop, and corn-corn-oats/alfalfa. Alfalfa is undersown with oats and only oats grain is harvested the first year. The tillage practices are chisel-plowing of cornstalks in the fall and disking of other crop residues in spring. The N treatments are 0, 80, 160, and 240 lb N/acre only for corn using granulated urea, which is spread in spring and is incorporated into the soil by disking. Grain yield was adjusted to 15 percent moisture for corn and 13 percent for soybean and oats. Biomass yield (corn for silage and alfalfa) is expressed as dry matter yield. The corn harvested for total biomass was cut 6 to 8 in. above the ground at about the black layer stage, and both weight and moisture content were determined for the whole plant.

Results and Discussion

Yield of corn after corn. The corn grain yield response to N fertilization has been greatly affected by the crop rotation. Analysis of data in Table 1 shows four groups of corn crops each with approximately similar yields without N fertilization and yield response to N fertilizer: first corn after alfalfa, first corn after soybean, second corn after alfalfa, and corn after corn. A significant result that has been consistent over time is that both the overall yield level and the response to N fertilizer has been similar for continuous corn and second or third year corn after soybean. Corn after corn has shown a very large yield response up to 160 lb N/acre, and a moderate additional response to the 240-lb rate. The additional response to the 240-lb rate was 9 bushels/acre for the 30-year averages and 13 bushels/acre for the last four years. Response equations fitted to the yield averages for these corn crops suggest that the N fertilizer rate needed to maximize yield would have been 225 lb N/acre for the 30-year averages and 235 lb N/acre for averages across the last four years.

Yield of corn harvested for biomass. An additional result of this study is that the N fertilizer rate needed to maximize yield of corn harvested for total biomass (silage) has been similar or lower than for corn harvested only for grain even after 30 years of cropping (Table 1). Total biomass yield showed a very large response up to 160 lb N/acre, and a moderate additional response to the 240-lb rate. Calculations based on a response equation fitted to the yield averages in Table 1 indicated that the N fertilizer rate needed to maximize biomass yield would have been 193 lb N/acre for the 30-year long-term averages and 210 lb N/acre for the yield averages for the last four years. This has been a consistent result in most years, even though soil analyses in 2008 showed that N fertilizer increased soil organic matter in both systems but total biomass harvest decreased it. Organic matter (6-in. depth) was 3.57, 3.75, 3.76, and 3.85 percent for N rates of 0, 80, 160, and 240 lb N/acre with grain harvest, but was 3.45, 3.46, 3.53, and 3.60 percent for total biomass harvest.

Yield of corn after soybean or alfalfa. The yield response to N fertilizer of first year corn after soybean has been similar for sequences with one, two, or three corn crops. Yields were highest for the 240-lb rate, but the difference for the 160-lb rate was only 2 bushels/acre for the 30-year averages and 7 bushels/acre the last four years. Moreover, in several years yield was maximized by rates of 80 and 160 lb N. Calculations from response equations showed that rates of 166 and 187 lb N/acre would have maximized grain yield for the 30 years of the study and for the last four years, respectively.

The response of first-year corn after alfalfa to N fertilizer has been small, mostly to the 80-lb N rate and small or no additional increase from the 160-lb rate. Although the overall corn yield level has increased over time, the relative size of the yield response has decreased, probably due to cumulative effects of many years of rotation with alfalfa on soil N. Both the yield level and the response to N of second year corn after alfalfa have been intermediate between those for corn after soybean and corn after corn.

Results of soil testing for nitrate in late spring from previous years have demonstrated a higher soil N supply in corn after legumes than corn after corn, with the largest supply after alfalfa. For example, average soil nitrate-N levels from 1994 to 2004 for plots receiving no N were 6 ppm for corn after corn, 9 ppm for first corn after soybean, and 17 ppm for first corn after alfalfa.

Corn grain yield differences between rotations for the largest N application rates have been small between corn after alfalfa and corn after soybean, but have been large between these rotations and for corn after corn. Averages from data in Table 1 for the highest N rate showed that yield of corn after alfalfa was 3.5 bushels/acre for 30-year averages and 4.5 bushels/acre for the last four years. However, the difference between corn after alfalfa and corn after corn was 17 and 21 bushels/acre, respectively, even though new corn hybrids with Bt and rootworm resistant traits were planted during the last few years. This yield gap could be explained partly by improved soil physical properties or less incidence of pests for corn in rotation. However, the difference also could be partly explained by insufficient N for corn after corn in some years because the responses suggested that the 240-lb rate not always maximized yield.

Yield of oats, soybean, and alfalfa. Table 2 shows that yield of oats was significantly increased by N fertilizer applied before corn. The oats response was linear up to the highest N rate applied. Soybean yield has not been affected by N fertilizer applied to the previous corn crop, but it increased with the frequency of corn in the rotation. The difference has been similar (4.5 bu/acre) for long-term averages and for recent years. The yield of continuous soybean (which received no fertilizer N) as expected was the lowest for the 30-year averages (43 bu/acre). This result might be explained by a lower incidence of soybean diseases or pests after corn. Unexpectedly, however, averages for the last four years showed similar yield for continuous soybean and soybean after one year of corn (63 bu/acre). Alfalfa yield has not been affected by N fertilizer applied to the first year corn.

Conclusions

Including soybean or alfalfa in rotations with corn increases corn yield and reduces the need for N fertilizer. Increasing the frequency of corn crops in corn-soybean rotations slightly increases yield of soybean. Similar results have been shown by other studies in the Midwest, but assessing the magnitude of the differences for Iowa is useful as soils, climate, hybrids, and management practices change. However, this study also has been providing other very significant results. One is that the yield level and response to N of continuous corn has been similar to those of second or third year corn after soybean. Another significant result is that even after 30 years of harvesting continuous corn for total biomass (silage), it did not increase the N rate required to maximize yield compared with corn harvested only for grain, although it reduced soil organic matter slightly.

The differences in response to N application rates used in this study should be interpreted with caution because the increments between the N rates are large and also because four rates are too few to estimate optimum N rates with certainty. Also, the benefits of higher corn yield and lower N need for corn grown in rotation have to be considered in the context of economic benefits from all crops in the rotation and sustainability issues that are beyond the scope of this report.

Table 1. Rotation and N fertilizer effects on corn yield across 30 years and the last 4 years of the study.

Corn crop and	1979-2008 average yield				2005-2008 average yield			
sequence*	0 N	80 N	160 N	240 N	0 N	80 N	160 N	240 N
	------------------------------ Grain yield (bu/acre) ------------------------------							
First of C-C-O-A	139	158	164	165	185	202	207	208
First of C-S	100	148	160	164	102	177	195	202
First of C-C-S	101	143	159	161	104	157	184	193
First of C-C-C-S	101	142	158	159	104	165	190	195
Second of C-C-O-A	81	126	149	153	103	158	187	189
Continuous corn	54	109	136	144	55	122	165	170
Second of C-C-S	52	110	137	146	44	125	165	180
Second of C-C-C-S	54	110	138	146	45	121	168	180
Third of C-C-C-S	54	105	132	143	46	114	153	173
	---------------------- Total dry matter yield (tons/acre) ----------------------							
Cont. corn silage	4.3	7.2	7.6	8.0	4.4	8.3	9.6	10.2

* A, alfalfa; C, corn; and S, soybean.

Table 2. Effects of crop rotation and residual effects of N applied before corn on yield of soybean, oats, and alfalfa across 30 years and the last 4 years of the study.

	1979-2008 average yield				2005-2008 average yield			
Crop and sequence*	0 N	80 N	160 N	240 N	0 N	80 N	160 N	240 N
	------------------------------ Grain yield (bu/acre) ------------------------------							
Soybean of C-S	47.7	48.8	48.4	47.7	63.3	63.3	63.1	62.4
Soybean of C-C-S	51.0	50.9	51.3	51.1	65.7	66.8	66.4	66.4
Soybean of C-C-C-S	53.0	52.7	52.6	52.2	68.1	67.4	67.3	67.6
Oats	60.2	65.6	71.8	76.3	64.5	71.4	77.3	81.6
	------------------------- Dry matter yield (tons/acre) -------------------------							
Alfalfa (2nd year)	4.2	4.2	4.2	4.0	5.8	5.7	5.7	5.3

* A, alfalfa; C, corn; O, oats; and S, soybean.