Corn, Soybean, Oat, and Alfalfa Yields as Affected by the Crop Rotation and Nitrogen Fertilization for Corn in Northeast Iowa

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Introduction

Crop rotation may influence crop yield by changing the availability of several nutrients and water, several soil physical properties, and incidence of diseases, pests, or weeds. Including grain legumes (such as soybean) or forage legumes in a rotation, usually increases soil nitrogen (N) supply for corn in subsequent years. A long-term crop rotation study was initiated in 1979 at the Iowa State University Northeast Research and Demonstration Farm, Nashua, Iowa, to assess the effects of various crop rotations and N fertilization of corn on crop yield.

Materials and Methods

The soil series at the site are Kenyon and Readlyn. The rotations are continuous corn for grain or silage, corn-soybean sequences with one to three corn crops for every soybean crop, corn-corn-oats/alfalfa, and continuous soybean. Alfalfa is undersown with oats and only oat grain is harvested the first year. The tillage practices are chisel-plowing in the fall and field cultivation in spring. The N treatments are 0, 80, 160, and 240 lb N/acre for corn using granulated urea. Since 2007, similar N treatments have been applied for continuous soybean. The urea is broadcast in the spring before field cultivation. Grain yield was adjusted to 15 percent moisture for corn and 13 percent for soybean and oats. Corn silage and alfalfa yields are expressed as dry matter yield.

Summary Results

Soil organic matter. Table 1 shows soil organic matter results from 6-inch samples taken in spring 2015 from selected rotations and N treatments. Long-term N application did not affect or slightly increased soil organic matter compared with not fertilized treatments. Plots of continuous corn harvested only for grain and of the rotation corn-corn-oat-alfalfa had the highest soil organic matter levels. The lowest observed organic matter values were for plots having continuous corn harvested for silage, but the difference decreased with increasing N rates, or continuous soybean.

Yield of corn after corn. The corn grain yield response to N fertilization has been greatly affected by the crop rotation. Table 2 shows four groups of corn crops, each with approximately similar yield level without N fertilization (0N) and yield response to N fertilizer: (1) first year corn after alfalfa, (2) first year corn after soybean, (3) second year corn after alfalfa, and (4) corn after corn. 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 large yield response up to 160 lb N/acre, and a moderate additional response to the 240-lb rate.

A significant result of this study is the N rate needed to maximize yield of corn harvested for total biomass (as for silage) has been similar for corn harvested only for grain even with 36 years of cropping (Table 2).

This happened in spite of reduced soil organic matter over time with silage harvest (Table 1).

Yield of corn after soybean or alfalfa. The yield response to N fertilizer of first year corn after soybean has been similar for the rotations with one, two, or three corn crops (Table 2). Yields were the highest for the 240-lb rate, but the difference with the 160-lb rate was very small for both the 36-year averages and for averages across the last four years. Moreover, in several years yield was maximized by the 80-lb or 160-lb N rates (not shown).

The response of first-year corn after alfalfa to N fertilizer has been smaller than for corn after soybean, and on average has responded up to the 160-lb rate. However, the additional yield response over the 80-lb rate has been small and was not observed in several years. It must be remembered the number of years of alfalfa production for this study are fewer than in normal agricultural settings (the seeding year with oats and one more year).

Corn grain yield differences between rotations for the highest N application rate have been small or nonexistent between corn after alfalfa and corn after soybean, but have been large between these rotations and corn after corn. The difference can be partly explained by insufficient N for corn after corn in some years because the 240-lb rate did not always maximize yield. However, most of the yield gap for corn after corn should be explained partly by improved soil physical properties and/or less incidence of diseases or pests for corn in rotation.

Yield of oat, soybean, and alfalfa. Table 2 shows oat yield was significantly increased by N fertilizer applied before corn, and the response was linear up to the highest N rate applied. This result has been consistent over time, and clearly shows the value of oats to utilize and recover carryover N applied to corn.

Soybean yield has not been affected by N fertilizer applied to the previous corn crop or to continuous soybean, but the yield level has increased with the frequency of corn in the rotation. The yield of continuous soybean (which received fertilizer N only since 2007) was the lowest both in the long-term and in the last four years. This result may be explained by a lower incidence of diseases or pests for soybean after corn.

Alfalfa yield has been slightly lower for the highest N rates applied for corn. We have no clear explanation for this result at this time because alfalfa stands or weed pressure have not been clearly affected by the highest N rates applied to corn.

Conclusions

Including soybean or alfalfa in rotations with corn increased corn yield and reduced the need for N fertilizer. Increasing the frequency of corn in rotation with soybean slightly increased soybean yield. The study also showed other important results. One is the yield level and response to N of continuous corn has been similar to those of second or third year corn after soybean. Another result is even after 36 years of harvesting continuous corn for total biomass (as for silage) and decreased soil organic matter, the N rate required to maximize yield has been similar to the rate needed to maximize yield of corn harvested for grain.

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 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 has 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. Soil organic matter for selected rotations and N treatments (6-in. sampling depth).

Rotation	N Rate†			
	0	80	160	240
	---------- % ----------			
Continuous corn for grain	3.7	3.8	3.9	3.9
Continuous corn for silage	3.3	3.5	3.8	3.6
Corn-Soybean	3.6	3.5	3.8	3.7
Corn-Corn-Oat‡-Alfalfa	3.8	-	-	3.9
Continuous soybean	3.5	3.4	3.6	3.5

†N applied only for corn since 1979 and for continuous soybean since 2007.
‡Oat always was undersown with alfalfa.

Table 2. Long-term crop yield as affected by the rotation and N fertilization†.

Rotation‡	Crop	1979-2015 average yield				2012-2015 average yield			
		0 N	80 N	160 N	240 N	0 N	80 N	160 N	240 N
		--- bu/acre (15.5% moisture) ---				--- bu/acre (15.5% moisture) ---			
C	Continuous corn, grain	54	113	142	151	58	122	157	169
cCs	2nd corn after soybean	54	111	141	152	59	107	147	168
cCcs	2nd corn after soybean	54	111	144	153	59	114	149	166
ccCs	3rd corn after soybean	53	106	137	149	53	103	143	161
Cs	Corn after soybean	100	151	167	173	92	150	180	196
Ccs	Corn after soybean	101	148	167	170	94	154	185	197
Cccs	Corn after soybean	98	145	164	169	85	149	177	196
Ccoa	Corn after alfalfa	147	166	174	175	161	179	199	199
cCoa	2nd corn after alfalfa	87	134	157	161	112	151	171	180
		----- bu/acre (13% moisture) ----				----- bu/acre (13% moisture) ----			
ccOa	Oat	61.0	65.4	71.7	75.8	70.9	70.3	76.3	78.3
cS	Soybean	51.1	52.3	51.7	51.5	62.1	63.2	61.1	63.5
ccS	Soybean	54.7	54.2	54.6	54.1	67.2	65.6	64.5	62.8
cccS	Soybean	56.6	56.3	56.1	55.4	68.2	67.7	66.5	64.2
S	Continuous soybean	46.1	46.7	47.3	46.9	63.7	65.6	62.3	63.6
		-------- ton/acre dry matter -------				-------- ton/acre dry matter -------			
ccoA	Alfalfa	4.2	4.2	4.1	4.0	3.5	3.6	3.3	3.1
C	Continuous corn, silage	4.3	7.3	8.0	8.3	4.6	7.4	9.2	9.3

†The N fertilizer was applied as urea in the spring and incorporated into the soil by disking before planting corn, and since 2007 for continuous soybean.
‡A capital letter indicates the crop for which yield is shown. A, alfalfa; C, corn; O, oat undersown with alfalfa; S, soybean.