Corn, Soybean, Oat, and Alfalfa Yields as Affected by the Rotation and Nitrogen Fertilization for Corn in Northeast Iowa – 1979-2023 Summary

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Introduction

A long-term rotation study was initiated in 1979 at the Iowa State University (ISU) Northeast Research and Demonstration Farm to assess effects of various crop rotations and N fertilization for corn on the yield of several crops. Crop rotations often influence crop yield by changing the availability of several nutrients and water, some soil physical properties, and incidence of diseases, pests, or weeds. Including legumes in a rotation usually increases soil nitrogen (N) supply for corn and reduces needed N fertilization. This article summarizes average yields from 1979 to 2023 and from 2020 to 2023.

Summary of Methods

The dominant soils at the site are Kenyon loam and Readlyn loam. Since 1979, seven rotations have been (1) continuous corn with grain harvest, (2) continuous corn for silage, (3) corn-soybean, (4) corn-corn-soybean, (5) corn-corn-corn-soybean, (6) corn-corn-oat/alfalfa-alfalfa, and (7) continuous soybean. Alfalfa for 2 years is undersown with oat, only oat grain is harvested the first year, and hay is harvested the second year. There are three replications and all crops of the rotations are included each year in plots with similar management. The tillage practices are chisel-plowing in the fall only for cornstalks residue and disking in the spring for all crops. The N rates for corn are 0, 80, 160, and 240 lb N/acre using granulated urea. The urea is broadcast in the spring before disking. Since 2007 similar annual N rates have been applied for continuous soybean. Grain yield was adjusted to 15% moisture for corn, 13% for soybean and oat and to dry matter for corn silage and alfalfa.

Table 1 shows soil organic matter results from 6-inch samples taken in spring 2015 from selected rotations. Long-term N application slightly increased soil organic matter, except for continuous soybean. Soil under continuous corn harvested for grain and the rotation corn-corn-oat/alfalfa-alfalfa had the highest soil organic matter levels whereas the lowest levels were for continuous soybean and continuous corn harvested for silage.

Table 1. Soil organic matter for selected rotations and N treatments (6-inch depth).

	N Rate (lb N/acre)			
Rotation†	0	80	160	240
	--- Organic Matter (%) ---			
CC for grain	3.69	3.79	3.90	3.91
CC for silage	3.35	3.49	3.76	3.65
C-Soybean	3.64	3.51	3.79	3.74
C-C-O-A	3.77	-	-	3.86
Cont. Soybean	3.47	3.38	3.56	3.48

† A = Alfalfa; C, corn; CC, continuous corn; O, oat with undersown alfalfa.

Yield Results

Corn grain yield

Figure 1 shows average corn yields of all rotations for the entire 1979-2023 period. There are four corn "crops" with roughly similar yield levels without N fertilization and yield increases from N that were (1) first corn after alfalfa has the highest yield (185 bu/acre), which was attained with the two highest rates (160 and 240 lb N/acre) but yield with the 80-lb rate was only one bu/acre lower; (2) yield for first, second or third corn after soybean with average maximum yield

attained with the 240-lb rate (282 bu/acre) but yield with the 160-lb rate was only 5 bu/acre lower; (3) yield for second-year corn after alfalfa of the rotation having oat and alfalfa, with a maximum yield of 172 bu/acre attained with the 240-lb rate but yield with the 160-lb rate was only 5 bu/acre lower; and (4) yields of continuous corn with grain harvest and second- or third-corn crops after soybean. The increases were the largest of all rotations and the average maximum (162 bu/acre) was attained with the 240-lb rate but probably would have been higher with a higher N rate.

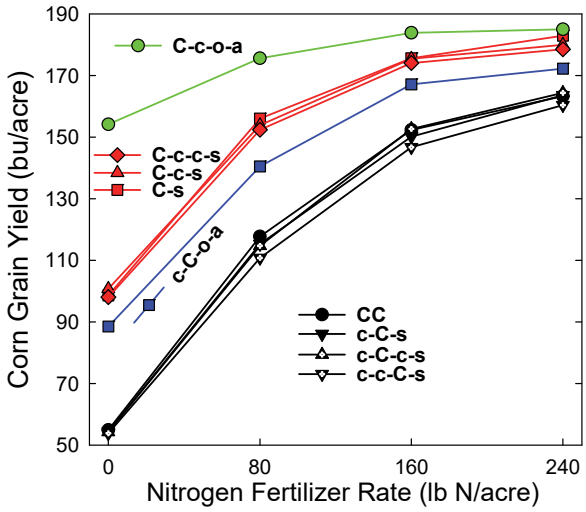

Fig. 1. Average corn yields from 1979 to 2023. Capital letters specify the crop for shown yield (a, alfalfa; C or c, corn; CC, continuous corn; o, oat with undersown alfalfa; s, soybean).

Figure 2 shows average corn yields from 2020 to 2023. Averaging yields for a 4-year period is the best estimate of recent results because all crops repeat at least every 4 years and smooths temporal yield variation due to weather. Yields were much higher than for the averages for the entire period due to advances in crop genetics. For the recent period there are only three distinct groups of corn crops mainly because yield for the second corn after alfalfa of the rotation having oat and alfalfa was almost identical to yield of corn after soybean. Two other results from the recent period are noteworthy. One is that yields of corn after alfalfa and corn after soybean were similar and was the highest for N rates of 160 and 240 lb N/acre. The other is that corn yield differences among rotations for the 240-lb N rate were smaller than for the entire period. Still, it is obvious that including legumes in the rotation reduced the N need of corn. The response of corn after alfalfa only up to the 80-lb rate observed for the entire study period (Fig. 1) and the last 4-year period (Fig. 2) is reasonable because years of alfalfa in this study are fewer than in production agriculture (a seeding year with oat and a second year).

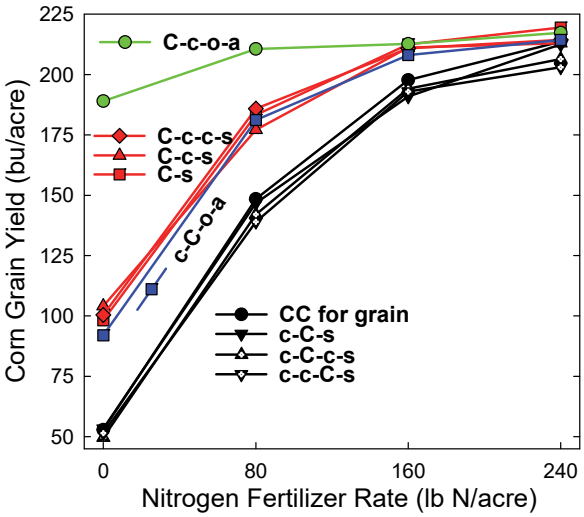

Fig. 2. Average corn yields from 2020 to 2023. Capital letters specify the crop for shown yield (a, alfalfa; C or c, corn; CC, continuous corn; o, oat with undersown alfalfa; s, soybean).

The long-term averages (Fig. 1) show that the 240-lb N rate was not enough to maximize yield of second-year corn after alfalfa and second-or third-year corn after soybean, but this was not clear for the last 4-year averages (Fig. 2).

Oat, soybean, and corn silage yields

Averages for the entire study period in Table 2 show a very large residual effect of N applied for corn on yield of oat grown after two corn crops. Oat yields were 61.2, 65.9, 72.3, and 76.2 bu/acre for N rates of 0, 80, 160, and 240 lb/acre that had been applied only for corn.

However, N applied for corn had no effect on yield of soybean grown in rotation or continuously. Soybean yield was the lowest for continuous soybean (49.3 bu/acre on average across N rates) and increased a little with increasing number of corn years in the rotation (on average 54.1, 56.9, and 58.5 with one, two and three corn years). Table 2 also shows large corn silage yield increases from N fertilization. The two highest N rates applied for corn slightly reduced alfalfa yield.

Table 2. Yield of alfalfa, oat, soybean, and corn silage from 1979 to 2023.

Rotation and Crop †		N Rate for Corn (lb N/acre)			
		0	80	160	240
		-- Grain Yield (bu/acre) --			
6	ccOa	61.2	65.9	72.3	76.2
3	cS	53.6	54.9	54.1	54.0
4	ccS	57.3	56.4	57.1	56.8
5	cccS	59.2	58.8	58.3	57.8
7	SS	48.9	49.3	49.7	49.5
		- Forage Yield (ton/acre) -			
2	CCsil	4.37	7.55	8.63	8.90
6	ccoA	4.27	4.25	4.11	3.95

† Capital letters specify the crop for shown yield (A or a, alfalfa; c, corn; CCsil, continuous corn for silage; O or o, oat with undersown alfalfa; S or s, soybean; SS, continuous soybean).

Table 3 shows that during the last four years oat yields were higher than averages for the entire period. Oat benefited greatly from N applied for corn, with a yield increase of 22 bu/acre for the 240-lb rate. The N applied for corn had no effect on yield of soybean grown in rotation or continuously and the higher two N rates reduced yield of alfalfa. Continuous soybean yield was 10 bu/acre lower than for soybean grown in rotation. Another significant result in Table 3 is that the 160-lb N rate maximized yield of corn silage whereas the 240-lb N rate was needed for continuous corn harvested for grain (Fig. 2). This happened despite reduced soil organic matter over time with corn silage harvest compared with only grain harvest for all N rates (Table 1).

Table 3. Yield of alfalfa, oat, soybean, and corn silage from 2020 to 2023.

Rotation and Crop †		Nitrogen Rate (lb N/acre)			
		0	80	160	240
		-- Grain Yield (bu/acre) --			
6	ccOa	64.5	73.5	82.8	86.7
3	cS	62.0	62.6	60.4	62.3
4	ccS	64.8	62.5	64.2	64.1
5	cccS	66.3	65.1	64.4	64.3
7	SS	55.5	55.4	54.8	56.8
		- Forage Yield (ton/acre) -			
2	CCsil	4.75	9.32	11.87	11.70
6	ccoA	4.58	4.54	4.42	4.29

† Capital letters specify the crop for shown yield (A or a, alfalfa; c, corn; CCsil, continuous corn for silage; O or o, oat with undersown alfalfa; S or s, soybean; SS, continuous soybean).

Conclusions

Including soybean or alfalfa in rotations increased corn yield and greatly reduced the need for N fertilizer. The yield and response to N of continuous corn and second- or third-year corn after soybean were similar. Increasing the frequency of corn in rotation slightly increased soybean yield. There was a large benefit of N applied for corn on yield of oat but not for soybean or alfalfa. Continuous soybean did not respond to directly applied N and yield was lower than for soybean grown in rotation. The higher yield and lower N need of corn in rotation with legumes must be considered in the context of economic benefits from all crops and sustainability issues.

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