Long-Term Corn, Soybean, Oats, and Alfalfa Yields as Affected by Rotations and Nitrogen Fertilization for Corn in Northern Iowa – 1985-2023 Summary

July 2024

Antonio P. Mallarino, professor emeritus, Department of Agronomy, and Matthew Schnabel, farm superintendent. Iowa State University

Introduction

Crop rotations often influence crop yield by changing the availability of several nutrients and water, soil physical properties, and incidence of diseases, pests, or weeds. Including legumes in a rotation increases soil nitrogen (N) supply for corn and reduces needed N fertilization rates. A long-term rotation study was initiated in 1954 at the Iowa State University Northern Research and Demonstration Farm to assess the effects of various crop rotations and N rates for corn on yield of several crops. There were rotation and N rates changes over time until 1984. This article summarizes average yields from 1985 to 2023 and from 2020 to 2023.

Summary of Methods

The predominant soil at the site is Webster, and the tillage system has been moldboard plowing in the fall and disking in the spring. Seven rotations have been evaluated since 1985: (1) continuous corn with spring N, (2) a 4-year sequence of corn-corn-corn-oat/alfalfa (alfalfa is undersown with oat, only oat grain is harvested, and alfalfa not continued), (3), corn-soybean, (4) a 4-year sequence of corn-soybean-corn-oat/alfalfa (oat/alfalfa is managed as for Rotation 2), (5) a 4-year sequence of corn-corn-oat/alfalfa-alfalfa (hay is harvested in the alfalfa second year), (6) a 4-year sequence of corn-oat/alfalfa-alfalfa-alfalfa (hay is harvested in the alfalfa second and third years), and (7) continuous corn with fall N application. The N rates applied only to corn since 1985 have been 0, 80, 160, and 240 lb N/acre by broadcasting granulated urea in spring before disking, except for Rotation 7 (broadcast in the fall before plowing). Grain yield was adjusted to 15% moisture for corn, 13% for soybean and oat, and dry matter for alfalfa and corn silage.

Table 1 shows soil organic matter from 6-inch samples taken in spring 2015 from selected rotations and N rates. Organic matter was the lowest for continuous corn and the highest for the rotation with three years of alfalfa. Long-term N application slightly increased organic matter over the nonfertilized control for most rotations.

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 (%) ----			
1. CC	5.31	5.46	6.00	5.60
3. C-S	5.71	5.69	6.13	5.72
2. C-C-C-O	5.54	-	-	6.05
4. C-S-C-O	5.75	-	-	6.13
5. C-C-O-A	6.04	-	-	6.08
6. C-O-A-A	5.70	-	-	6.81

† A, alfalfa; C, corn; CC, continuous corn; O, oat undersown with alfalfa; S, soybean.

Yield Results

Corn grain yield.

Figure 1 shows average corn yields for all rotations from 1985 to 2023. There are five distinct groups of corn "crops" with roughly similar yield levels without N fertilization and yield responses to N according to the rotation and position in the crop sequence. (1) First-year corn after a second or third year of alfalfa (Rotations 5 and 6) with maximum yield by the 160-lb and 240-lb N rates (187 bu/acre on

average) and 7 bu/acre less with the 80-lb rate. (2) First-year corn after one year of oat/alfalfa (Rotations 2 and 4) with maximum yield by the 240-lb rate (185 bu/acre) but 3 bu/acre less with the 160-lb rate. (3) First-year corn after soybean (Rotations 3 and 4) and second-year corn after a second year of alfalfa (Rotation 5) with average maximum yield of 183 bu/acre with the 240-lb rate and 7 bu/acre less than the 160-lb rate. (4) Second-year corn after one year of oat/alfalfa (Rotation 2) with maximum yield of 181 bu/acre by the 240-lb rate and 10 bu/acre less than the 160-lb rate. (5) Third-year corn after one year of oat/alfalfa (Rotation 2) and continuous corn with fall or spring N with average maximum yield of 168 bu/acre by the 240-lb rate and 10 bu/acre less than the 160-lb rate. Yield of continuous corn with fall N was 6 to 15 bu/acre lower than with spring N.

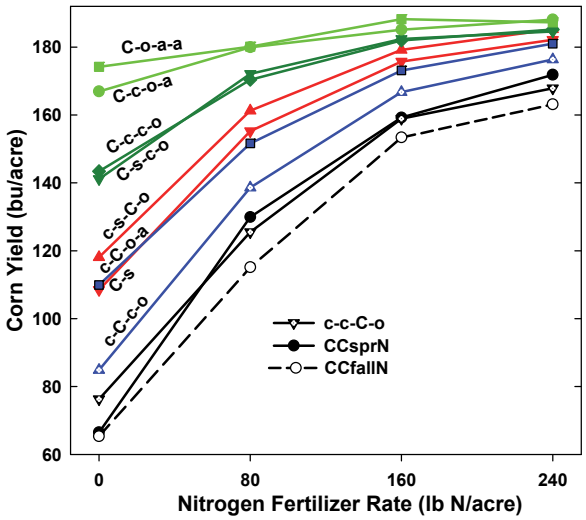

Fig. 1. Average corn yields from 1985 to 2023. Capital letters specify the crop for shown yield (a, alfalfa; C or c, corn; CC, continuous corn; o, oat with undersown alfalfa; s, soybean).

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 high temporal yield variation due to weather. Yields were much higher than for the averages for the entire period due to advances in crop genetics, but the same five corn groups are obvious. The most remarkable result for the last 4 years is there were no clear differences between fall and spring N application for continuous corn. In the past, yield with spring N was higher in about 70% of the years (that explains averages for the entire period in Table 1), which was attributed to less nitrate leaching with the spring N application. The recent average results might be explained by similar amounts of nitrate leaching due to drier than normal rainfall between the fall and spring N applications in the last three years (not shown).

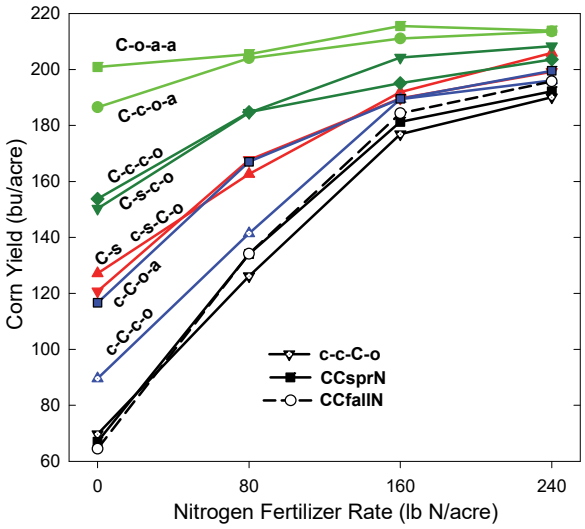

Fig. 2. Average corn yields from 2020 to 2023. Capital letters specify the crop for shown yield (a, alfalfa; C or c, corn; CC, continuous corn; o, oat with undersown alfalfa; s, soybean).

Both figures show that the 240-lb rate was not sufficient to attain maximum yield of second or third corn of the rotation with only one year of oat/alfalfa and for continuous corn.

Oat, soybean, and corn silage yields

Averages since 1985 in Table 2 show a very large residual effect of N applied for corn on yield of oat grown after corn. Increases for the 240-lb N rate over the nonfertilized treatment were the largest (21 bu/acre) for Rotations 2 and 4 each having only the seeding year of alfalfa, 14 bu/acre for Rotation 5 having a

second year of alfalfa, but only 3.5 bu/acre for Rotation 6 having a third year of alfalfa. The N applied for corn had no effect on yield of alfalfa or soybean. Soybean yield was 5 bu/acre higher for Rotation 4 (having two years of corn and one year of oat/alfalfa) than for Rotation 3 (corn-soybean rotation).

Table 2. Yield of alfalfa, oats, and soybean from 1985 to 2023.

Rotation and Crop †		Nitrogen Rate (lb N/acre)			
		0	80	160	240
		--- Oats Grain Yield (bu/acre) ---			
2	cccO	50.2	58.8	65.6	70.3
4	cscO	51.8	60.7	66.6	72.6
5	ccOa	59.0	65.7	69.3	73.1
6	cOaa	73.8	74.4	77.6	77.4
		-- Soybean Grain Yield (bu/acre) --			
3	cS	49.6	49.3	49.6	48.9
4	cSco	54.6	55.0	54.2	54.6
		------- Alfalfa Yield (ton/acre) -----			
5	ccoA	3.76	3.80	3.82	3.80
6	coAa	3.85	3.50	3.83	3.61
6	coaA	3.99	3.81	4.05	3.94

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

Table 3 shows that during the last four years of the study oat yields were slightly lower than averages for the entire period but also benefited from N applied only for corn. Oat yield increases for the 240-lb rate over the nonfertilized treatment were 11 to 23 bu/acre across Rotations 2, 4, 5, and 6. In contrast to the entire period (Table 2), and for unclear reasons, in the last 4 years oat yield increases were the largest for Rotations 5 and 6 which included two or three years of alfalfa. As was observed for the entire period, N applied for corn had no effects on yields of soybean and that soybean yield for Rotation 4 (having two corn years and one year of oats/alfalfa) was 9 bu/acre higher than for Rotation 3 (the corn-soybean rotation). The N applied for corn did not affect alfalfa yield in Rotation 5, which has only one year of oat/alfalfa but the 240-lb rate for corn slightly decreased yield of both second- and third-year alfalfa in Rotation 6.

Table 3. Yield of alfalfa, oats, and soybean from 2020 to 2023.

Rotation and Crop †		Nitrogen Rate (lb N/acre)			
		0	80	160	240
		--- Oats Grain Yield (bu/acre) ---			
2	cccO	40.0	44.9	46.3	50.7
4	cscO	41.2	47.2	50.8	57.1
5	ccOa	37.6	41.4	45.3	60.5
6	cOaa	52.6	64.0	68.5	75.6
		-- Soybean Grain Yield (bu/acre) --			
3	cscS	52.6	52.2	52.7	50.9
4	cSco	60.5	61.1	60.8	60.2
		------- Alfalfa Yield (ton/acre) -----			
5	ccoA	3.73	3.98	4.18	3.74
6	coAa	4.65	4.10	4.21	3.83
6	coaA	4.52	4.63	4.52	4.31

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

Conclusions

Including soybean or alfalfa in rotations increased corn yield and greatly reduced the need for N fertilizer. The yield of continuous corn with spring N was higher than with fall N for averages for the entire study period. Recently, however, there were no differences probably due to less than normal rainfall between the fall and spring applications that may have resulted in similar nitrate leaching. There was a large benefit of N applied for corn on yield of oat but not for soybean or alfalfa yield. Higher corn yield and lower N need in rotation with legumes must be considered in the context of economic benefits from all crops and sustainability issues.

Acknowledgements

We appreciate support by the College of Agriculture and Life Sciences of ISU and contributions of seed by Monsanto/Bayer and fertilizers by PCS Corp/Nutrien Ltd.