Effect of Tillage and Nitrogen Rate on Corn Response in a Corn-Soybean Rotation

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Introduction

Soil tillage has significant impact on soil, water, and nutrient extraction by crop plants. In the short-term, tillage can improve soil aeration, the mineralization of organic matter, and availability of N and P in the soil system. However, long-term no-tillage systems enhance greater mineralizable C and N pools in the soil system contrary to conventional tillage systems. Thus, the uptake of N by crop plants is potentially changed with different tillage systems and their interactions with different N rates and N application timing. An understanding of the effect of different tillage systems and their interactions with N rate on the availability of N and P uptake by crop plants at different growth stages is essential to the efficient management of N and P in crop production system. The objective of this research was to investigate the effect of three tillage systems (no-tillage, NT; strip-tillage, ST; chisel plow, CP) and four N rates of two sources of N on corn responses and N and P use efficiencies.

Materials and Methods

This study was conducted on a 40-acre site at the Iowa State University Northeast Research Farm near Nashua, IA, from 2002 to 2004. The 40-acre site was divided into two 20-acre areas for corn and soybean rotations.

The focus of this study was to investigate corn response to three tillage systems and four N rates of the two N sources of liquid swine manure and anhydrous ammonia fertilizer in a corn-soybean (C-S) rotation. In 2002, the 20-acre area to the east of the site was divided into two 10-acre areas north and south and planted with corn with the application of liquid swine manure and anhydrous ammonia fertilizer to the north and to the south areas, respectively. The experimental design for each corn experiment during each corn year was a randomized complete block with split-plots arranged in three replications. The three tillage systems of NT, ST, and CP were assigned as the main plot treatments and the four N rates were randomly assigned as the subplot treatments. Each tillage treatment plot measured approximately 185 ft long and 69 ft wide with subplots for each N rate measuring approximately 185 ft long and 17 ft wide. Each tillage system was maintained at the same plot for the duration of the study with timely use of pre-emergence and post-emergence herbicides for weed control. The soybeans were planted in a 30-in. row spacing at a seeding rate of 168,000 plants/acre using the same tillage treatments for the previous corn experiment. After harvest each year in the mid-November, CP and ST treatments were applied to both the corn and soybean plots.

In 2002, 2003, and 2004, manure was injected 3 to 4 in. below the soil surface on November 15 and 23, respectively, at the rates of 0, 75, 150, and 225 lb/acre in each corn experiment in the same direction and location of previous rows in all tillage systems. There was no manure application after harvesting corn during the soybean season. Anhydrous ammonia was also injected 4 to 6 in. below the soil surface in early April each year. In May of each year during planting, 25.9 lb P_2O_5/acre ($NH_4H_2PO_4$) and 31.3 lb K_2O/acre (KCL) were applied as starter fertilizers to the anhydrous ammonia plots at 2 in. deep and 2 in. from the center of the row.

In the spring of each year, the CP tillage treatment plots were field cultivated before planting corn. Dekalb 537 BT-corn was planted in all tillage treatments in early May of each year at a seeding rate of 33,600 plants/acre in a 30-in. row spacing. At maturity, corn grain yield was adjusted to 15% moisture and grain dry matter, N and P uptake were determined.

Corn plant samples were collected at the sixth-leaf (V6), 12th-leaf (V12), tassel (VT), and at physiological maturity (R6) or black layer growth stages for each split plot to determine dry matter production, N and P uptake. Plant and corn grain N and P uptake were estimated as products of total plant dry matter or grain yield and their respective total N and total P concentrations. The data was analyzed using a statistical analysis system (SAS) package.

Results and Discussion

The main effect of tillage on grain yield was not statistically significant for all N rates of both N sources (Table 1). It was observed that regardless of tillage system or N source, increasing the N rate above 75 lb N/acre had no effect in increasing grain yield. The corn response to different tillage systems and N management showed that type of tillage system has little effect on corn yield.

Grain N and P uptake showed no differences between tillage systems for all N rates with manure (Table 2). In the manure source plots, the grain N and P uptake increased with additional N application regardless of tillage system and the greatest N and P uptake was achieved with 225 lb N/acre of manure. In the fertilizer source plots, ST grain N uptake was greater compared with NT and CP, especially at 0 and 75 lb N/acre (Table 2). However, grain P uptake with different tillage systems was not different regardless of N rate. The only difference in P uptake with fertilizer source was observed between 0 and other N rates across all tillage systems.

At the V6 to R6 growth stages of corn, plant N uptake was significantly greater with the CP system compared with NT at 75 lb N/acre and 150 lb N/acre N rates of manure source (Table 3). The plant N uptake at the 225 lb N/acre N rate was inconsistent during all growth stages. The differences in plant N uptake between N rates within each tillage system showed generally greater plant N uptake with the increase in N rate up to 150 lb N/acre for manure source. The plant P uptake was generally not different for all tillage systems at 0 kg N/acre rate during all growth stages with manure source (Table 3). Increasing the manure application rate that led to a greater amount of P application did not cause differences in plant P uptake between tillage treatments. These findings are expected due to high soil-P test of the site. In the fertilizer plots, the tillage effect on plant N uptake with different N rates was highly variable during all growth stages (Table 4). At the V6 to R6 growth stages, the difference in plant N uptake was only statistically different between 0 and high N rates across all tillage systems. It was noticeable at the VT growth stage that a maximum N accumulation was reached and greater plant N uptake was observed at all fertilizer N rates for the CP tillage system, except at the 225 lb N/acre (Table 4). Generally, at the V6 to R6 growth stages, plant P uptake was not different between 0 and high N rates of fertilizer source regardless of the tillage system (Table 4). Plant P uptake exhibited a similar pattern, where corn plant P uptake in the CP tillage system was greater at the VT growth stage than ST and NT for all N rates (Table 4).

Conclusions

The findings of this research showed that regardless of N source and tillage system, corn yield did not increase with increasing N rate application above 75 lb N/acre. The effect of tillage system on grain-N uptake at different N rates with both N sources was generally insignificant, except with fertilizer source, where ST had improved N uptake compared with NT and CP for the 0 and 75 lb N/acre rates. Across all tillage systems and N rates, plant N and P uptake percentages at the V12 growth stage represent 44% and 39% of total plant + grain N uptake, respectively, with manure source, and 43% and 34%, respectively, with fertilizer source.

However, the most dominant interaction effect on plant N and P uptake was N rate × year from V6 to R6 growth stages. This statistically significant interaction effect on plant N and P uptake was consistent with both N sources at the V6 and R6 growth stages. This indicates that seasonal variability has more effect on N availability than the type of tillage system. The results suggest that both N sources have a similar effect on yield and N and P uptake regardless of tillage type. Additional N application from both N sources did not increase N uptake or yield for one particular tillage system over another. The results of this study also indicate that the most effect a tillage system can have on plant N and P uptake was early in the growing season with both N sources, and it had a limited effect on plant N and P uptake later in the growing season. It was always believed that NT might have a disadvantage in nutrient availability and the need for additional N and P applications compared with conventional tillage systems. However, these findings showed the limited effect of increased N or P application has on increasing the utilization of these two nutrients by corn grown with all tillage systems. Another interesting observation from these results is the similarity of nutrient value of both N sources and corn response to these two N sources across all tillage systems.

Acknowledgements

We would like to thank Ken Pecinovsky for his time and labor in helping with the experiment setup, planting, and harvesting.

Table 1. Effect of tillage systems and N rates of two N sources on corn grain yield in 2002-2004.

		N rate lb/acre			
N source	Tillage systems†	0	75	150	225
		grain yield, bushel/acre			
Manure	NT	99.8Ab‡	138.6Aa	156.5 Aa	159.4 Aa
	ST	104.3Ab	144.5Aa	155.0 Aa	160.9 Aa
	CP	119.2Ab	159.4Aa	163.9 Aa	168.4 Aa
Fertilizer	NT	96.9Ab	150.5Aa	157.9 Aa	156.5 Aa
	ST	128.1Ab	150.5Aa	153.5 Aa	153.5 Aa
	CP	117.7Ab	149.0Aa	156.5 Aa	157.9 Aa

†NT, no-tillage; ST, strip-tillage; CP, chisel plow.

‡Means in a column within each N rate with the same uppercase letter are not statistically different according to least square means for tillage and N rate interactions adjusted for multiple comparisons as $P \leq 0.05$. Means in rows within each tillage system with the same lowercase letter are not statistically different according to least square means for tillage and N rate interaction adjusted for multiple comparisons at $P \leq 0.05$.

Table 2. Grain N and P uptake with different tillage systems and N rates of manure and fertilizer in 2002-2004.

N source	Tillage system†	N rate lb/acre 0	75	150	225	N rate lb/acre 0	75	150	225
		total N uptake, lb/acre				total P uptake lb/acre			
Manure	NT	71.2Ad‡	90.9Ac	109.0Ab	122.6Aa	10.4Ab	15.2Ab	15.3Ab	19.2Aa
	ST	73.7Ab	100.3Ab	112.5Aa	120.0Aa	11.7Aa	16.7Aa	15.2Aab	17.8Aa
	CP	73.9Ab	101.6Ab	103.2Ab	127.7Aa	10.4Aa	17.6Aa	16.0Aa	17.6Aa
Fertilizer	NT	68.4Bc	109.3Aa	129.0Aa	127.3Aa	9.1Ab	14.6Aa	14.9Aa	14.8Aa
	ST	88.8Ab	120.6Aa	116.5Ba	124.2Aa	9.8Ab	12.6Aab	14.3Aa	13.1Aab
	CP	77.6Bb	104.1Ba	112.5Ba	126.0Ba	10.7Aa	14.9Aa	13.8Aab	14.2Aab

†NT, no-tillage; ST, strip-tillage; CP, chisel plow.
‡Means in a column within each N rate with the same uppercase letter are not statistically different according to least square means for tillage and N rate interactions adjusted for multiple comparisons as $P \leq 0.05$. Means in rows within each tillage system with the same lowercase letter are not statistically different according to least square means for tillage and N rate interaction adjusted for multiple comparisons at $P \leq 0.05$.

Table 3. Corn plant N and P uptake with three tillage systems and four N rates of <u>manure</u> at four growth stages in 2002-2004.

Growth stage†	Tillage system‡	N rate lb/acre 0	75	150	225	N rate lb/acre 0	75	150	225
		N uptake, lb/acre				P uptake lb/acre			
V6	NT	4.3Ad§	11.1ABb	7.9Bc	14.7ABa	0.5Ac	0.9Ab	1.0Bb	1.4Aa
	ST	4.7Ac	9.6Bb	9.5Bb	16.7Aa	0.5Ab	0.8Ab	1.3Aa	1.2Aa
	CP	6.7Ab	12.7Aa	13.8Aa	13.6Ba	0.6Ac	1.1Ab	1.5Aa	1.3Aa
V12	NT	47.5Ab	64.6Bb	104.4Ba	87.2Aa	6.3Ac	8.1Bbc	9.0Bab	10.6Aa
	ST	49.6Ab	97.5Aa	111.6Aa	105.7Aa	6.5Ab	9.3ABa	10.9Aa	11.4Aa
	CP	61.9Ac	109.3Aa	113.3Aa	92.2Ab	6.8Ab	10.6Aa	11.3Aa	9.8Aa
VT	NT	73.0Bc	123.1Bb	149.6Ca	108.7bb	11.2Ab	15.0Aa	15.5Ba	16.2Aa
	ST	68.6Bc	135.2Bb	168.3Ba	129.9Ab	10.8Ab	16.0Aa	17.9ABa	15.4Aa
	CP	90.9Ad	153.4Ab	189.0Aa	125.9Ac	12.9Ac	17.8Ab	20.6Aa	15.9Ab
R6	NT	62.4ABb	93.8Ba	99.1Ba	97.2ABa	10.3Ab	20.9Ba	18.0Ba	21.2Aa
	ST	68.8Ab	98.8Ba	96.4Ba	104.7Aa	12.9Ac	24.4Aa	17.6Bb	20.3Ab
	CP	47.3Bb	111.2Aa	123.8Aa	83.5Bc	12.3Ac	24.6Aa	22.0Aa	16.7Bb

†V6, sixth-leaf stage of corn; V12, 12th-leaf stage of corn; VT, tassel stage of corn; R6, physiological maturity stage of corn.
‡NT, no-tillage; ST, strip-tillage; CP, chisel plow.
§Means in rows within each tillage system with the same lowercase letter are not statistically different according to least square means for tillage and N rate interaction adjusted for multiple comparisons at $P \leq 0.05$.

Table 4. Corn plant N and P uptake with three tillage systems and four N rates of <u>fertilizer</u> at four growth stages in 2002-2004.

Growth stage†	Tillage system‡	N rate lb/acre 0	75	150	225	N rate lb/acre 0	75	150	225
		N uptake, lb/acre				P uptake lb/acre			
V6	NT	6.3Bb§	11.4Ba	10.9Aa	10.0Ba	0.4Ac	0.9Aa	0.7Ab	0.9Ba
	ST	6.9ABb	10.5Ba	10.4Aa	9.3Ba	0.4Ab	0.8Ba	0.7Aa	0.7Ca
	CP	8.5Ac	14.7Aa	11.4Ab	15.6Aa	0.5Ad	1.0Ab	0.8Ac	1.2Aa
V12	NT	46.6Ab	63.2Bb	98.9Aa	73.9Aa	4.6Ab	6.6Aa	6.8Aa	6.9Aa
	ST	58.1Ac	103.5Aba	116.5Aa	88.9Ab	4.7Ab	7.4Aa	8.4Aa	7.1Aa
	CP	63.0Ab	99.4Aa	102.0Aa	95.4Aa	5.6Ab	8.1Aa	8.6Aa	8.1Aa
VT	NT	78.2Bc	131.5Bb	165.0Ba	135.6Bb	8.7Bb	13.1Ba	13.0Ba	12.2Ba
	ST	66.1Bc	133.5Bb	154.5Bb	181.1Aa	9.2Bb	13.2Ba	13.6Ba	13.3Ba
	CP	104.6Ac	170.9Aba	190.8Aa	142.8Bb	11.6Ab	15.6Aa	17.2Aa	16.4Aa
R6	NT	47.2Ac	83.9Aab	101.3Ba	69.4Ab	5.4Ab	14.1Aa	11.5ABa	10.9Aa
	ST	37.8Ab	81.4Aa	86.4Ba	80.3Aa	5.2Ab	12.4Aa	7.4Bb	12.1Aa
	CP	47.5Ac	70.9Ab	111.1Aa	66.3Ab	4.3Ab	7.9Bb	14.6Aa	8.2Ab

†V6, sixth-leaf stage of corn; V12, 12th-leaf stage of corn; VT, tassel stage of corn; R6, physiological maturity stage of corn.

‡NT, no-tillage; ST, strip-tillage; CP, chisel plow.

§Means in column within each N rate with the same uppercase letter are not statistically different according to least square means for tillage and N rate interactions adjusted for multiple comparisons as $P \leq 0.05$. Means in rows within each tillage system with the same lowercase letter are not statistically different according to least square means for tillage and N rate interaction adjusted for multiple comparisons at $P \leq 0.05$.