Nitrogen Fertilization Of Irrigated Corn In A High Residual Soil N Environment In The Arkansas River V Alley

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NITROGEN FERTILIZATION OF IRRIGATED CORN IN A HIGH RESIDUAL SOIL N ENVIRONMENT IN THE ARKANSAS RIVER VALLEY

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ABSTRACT

High levels of residual soil NO_3-N are present in the soils in the Arkansas River Valley where melons and other vegetable crops are produced. The amount of N fertilizer required to optimize the yield potential of crops, such as corn, following vegetables needs to evaluated to reduce NO_3-N leaching potential in the Valley where high NO_3-N levels have been reported in the ground water. This study evaluated the effects of N fertilizer rate (0, 50, 100, 150, 200, and 250 lb N/a) and N source (urea and Polyon®[3]) on corn yields following 5 years of alfalfa and one year of watermelon production. Corn grain yields were not increased by N fertilization in 2000 and were not influenced by N source. Corn plant stands were reduced by urea broadcast, incorporated application rates above 150 lb N/a in 2000, but were maintained when Polyon® was used. Silage yields increased with increasing N rate up to about 150 lb N/a, then decreased with increasing N rate. Soil residual NO_3-N levels increased with increasing N rate in 2000. In 2001, corn grain and silage yields did not increase with increasing residual soil NO_3-N levels (no N fertilizer applied). Based on this study, it appears that a minimal amount (<50 lb N/a) of N fertilizer needs to be applied to corn to maintain grain and silage yields in the Valley in rotations with a vegetable crop like watermelon. Fertilizer N appears to be moving out of the root zone with downward movement of irrigation water.

INTRODUCTION

High nitrate-N (NO_3-N) levels have been reported in groundwater in the Arkansas River Valley in Colorado, which is a major producer of melons, onions, and other vegetable crops grown in rotation with alfalfa, corn, sorghum, winter wheat, and soybeans. Relatively high rates of N fertilizer are used to optimize crop yields and quality, generally without regard to soil testing. Vegetable crops generally have shallow rooting depths and require frequent irrigation to maintain market quality. High residual soil NO_3-N levels, high N fertilization rates to shallow-rooted crops, shallow water tables, and excess water application to control soil salinity all contribute to a high NO_3-N leaching potential.

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[3]Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product by the authors or the USDA, Agricultural Research Service.

Application of slow-release fertilizers to crops in the Arkansas Valley could potentially increase nitrogen use efficiency (NUE) and reduce nitrate-N leaching potential. Nitrogen management research is needed to develop improved NUE and N management practices for furrow irrigated crops in this area. Improved N management practices for crop rotations in the Arkansas River Valley should optimize crop yields while minimizing N fertilizer impacts on ground water quality.

The objectives of this research were to determine N fertilizer needs for optimizing furrow-irrigated corn yields in a high residual soil N environment in Arkansas River Valley, evaluate the effects of a slow-release N fertilizer on N fertilizer use efficiency by corn, and evaluate the influence of N management on residual soil NO_3-N and potential for groundwater contamination.

MATERIALS AND METHODS

A N fertilizer rate and source study on corn was initiated under conventional tillage and furrow irrigation on a calcareous (soil pH of 7.8) Rocky Ford silty clay loam soil at the Colorado State University, Arkansas Valley Research Center (AVRC) at Rocky Ford in 2000. Based on previous soil tests, soil organic matter (SOM) ranged from 1.5 to 1.8%. The study was initiated on a plot area that had previously been in alfalfa for 5 years, before being plowed up on 20 October 98. Two applications of 150 lb P_2O_5/a as 11-52-0, which added 64 lb N/a, were applied during the five years of alfalfa production. Watermelon was produced on the plot area in 1999 with 100 lb P_2O_5/a applied as 11-52-0 which contained 21 lb N/a. Corn was produced in 2000 with 50 lb P_2O_5/a applied over the entire plot area as 11-52-0 which contained 11 lb N/a. Six broadcast N rates were established (0, 50, 100, 150, 200, and 250 lb N/a) in 2000. Two N sources, urea and Polyon® (a slow-release urea fertilizer), were applied for each N rate. The N fertilizer was broadcast applied by hand and incorporated with a harrow before ridging for corn planting. A randomized block, split-plot design was used with N rate as main plot and N source (urea or Polyon®) as subplots with 4 replications.

Corn (Pioneer 33A14 hybrid) was planted on April 27, 2000 at a seeding rate of about 28,400 seeds per acre. The 2001 corn (DeKalb 642RR hybrid) crop was planted on April 24 at a seeding rate of about 40,000 seeds per acre.

Soil NO_3-N levels have been monitored in the plot area since the spring of 1999. Soil samples were collected for NO_3-N analysis in spring 1999 before watermelon planting, fall of 1999 after watermelon harvest, spring of 2000 before N fertilizer was applied to corn crop, fall of 2000 after corn harvest, spring 2001 before corn planting, and fall 2001 after corn harvest (samples currently being analyzed). The N fertilizer rates were not reapplied in 2001 because of high levels of residual soil NO_3-N following harvest of the 2000 corn crop, due to lack of response by corn to N fertilization. In the fall of 2000, 11 lb N/a was applied with the application of 100 lb/a of 11-52-0 just prior to fall plowing the plot area. The 2001 corn crop was produced with the residual soil NO_3-N remaining from the 2000 N fertilizer application.

Total corn biomass production, grain yield, plant N uptake, and residual soil NO_3-N were determined. Plant samples were collected in September both years for biomass yield. Grain yields were measured when the corn was mature (black layer had formed) at about 20% moisture both years.

The N level in the irrigation water was monitored by AVRC throughout each growing season. The irrigation water contained an average of 2.5 ppm NO_3-N in 2000 and 2.8 ppm NO_3-N in 2001.

We used this information along with number of irrigations and amount of irrigation water applied to calculate an estimate of N added to the cropping system by irrigation. The N contribution from the irrigation water to the plot area would have amounted to about 6 lb N/a in 1999 while irrigating the watermelon and about 15 lb N/a in 2000 and 14 lb N/a in 2001 while irrigating the corn. The corn crop was irrigated 7 times from May 3rd to Sept 19th in 2000 with approximately 4.5 inches applied per irrigation except for the Sept 19th irrigation, when about 1.6 inches was applied. In 2001, five irrigations were applied to the corn. Assuming a 50% irrigation efficiency, about 7 to 8 lbs of N may have entered the soil each year. Corn growing season (May through September) precipitation totaled 4.77 inches in 2000 and 8.68 inches in 2001.

RESULTS AND DISCUSSION

Analysis of soil samples collected in April 1999 from the plot area shows that the soil NO_3-N in the profile was concentrated in the 0-2 ft soil depth, with low levels of NO_3-N at deeper depths (Table 1). The total amount of NO_3-N in the 6-ft profile was 114 lb N/a. Following the watermelon crop, soil NO_3-N levels in November 1999 had decreased in the top 2 ft but increased in the deeper soil depths. The total amount of NO_3-N in the 6-ft profile was 157 lb N/a in November of 1999. In April 2000, soil NO_3-N levels in upper part of the soil profile had increased, with a total level of 180 lb N/a in the 6-ft profile. Thus soil NO_3-N levels just prior to N fertilization and corn planting was relatively high, despite the fact that little N fertilizer had been applied during the previous 6 years. The question is, what is the source of this high level of residual soil N?

Table 1. Average soil NO_3-N levels in the non-fertilized N plots before and after the 1999 watermelon crop, before and after the 2000 corn crop, and before the 2001 corn crop.

Soil Depth	1 Apr 99 Before Watermelon	8 Nov 99 After Watermelon	10 Apr 00 Before 2000 Corn Crop	25 Oct 00 After 2000 Corn Crop	20 Mar 01 Before 2001 Corn Crop
feet	Soil NO_3-N, lb/a				
0-1	81.8	41.1	78.9	42.3	72.3
1-2	13.1	23.1	33.0	21.5	14.8
2-3	5.6	26.4	24.4	32.1	13.8
3-4	4.4	25.4	18.1	19.6	10.7
4-5	5.2	23.7	14.9	16.7	7.3
5-6	3.7	16.7	11.2	7.3	6.2
Total	113.7	156.5	180.5	139.5	124.9

Watermelon was planted May 18, 1999 on the plot area and harvested in late August and early September. By August 25, 1999, the total oven dry biomass produced (tops + melons) was 12,094 lb/a with the tops contributing 4,098 lb/a of this total. About 124 lb N/a was returned to the soil in the tops, which had a C/N ratio of 13. At this C/N ratio, the tops would decompose rather rapidly when incorporated into the soil, with a release of N to the following corn crop. At harvest on August 25th, the watermelon rinds made up 29.5% of the oven dry melon weight. Assuming that 50% of the melons were of harvestable size (>18 lbs), the rinds on the unharvested melons left in the field could have contributed 35 lb N/a back to the soil. With a C/N ratio of 14, the rind was expected to decompose rather rapidly. Assuming that the fruit or meat part of the unharvested melons contained about 1% N, an additional 30 lb N/a could possibly have been returned to the soil. When the unharvested melons and tops were destroyed by disking, microbial decomposition of the melon biomass was initiated. This could explain the increase in soil NO_3-N measured in the profile from November 1999 to April 2000. The amount of N in the watermelon tops and unharvested melons could potentially contribute up to 184 lb N/a to the next crop. This might explain the unexpected high level of soil N at corn planting in 2000 (Table 1). Residual soil NO_3-N levels after corn harvest in 2000 and 2001 are reported in Table 2.

Table 2. Soil NO_3-N levels with soil depth on 25 October 2000 and 20 March 2001 for each of the 2000 N rate treatments.

Soil Depth	Fertilizer N Rate (lb N/a) Applied to 2000 Corn Crop											
	0	50	100	150	200	250	0	50	100	150	200	250
	25 October 2000						20 March 2001					
ft	Soil NO_3-N, lb N/a											
0-1	42	64	90	118	157	206	72	133	125	134	200	231
1-2	22	21	17	21	79	62	15	13	17	20	23	34
2-3	32	41	48	73	36	145	14	8	15	18	14	23
3-4	20	16	17	34	35	83	11	7	10	19	18	21
4-5	17	22	50	43	69	52	7	34	14	16	24	21
5-6	7	15	21	15	25	23	6	11	8	16	20	21
Total	140	180	244	304	401	570	125	206	189	222	299	350

Corn plant stands in 2000 were affected by fertilizer N source and N rate. Plant populations decreased as N rate increased for urea (Fig. 1). Plant populations were greater with Polyon® than with urea. The N rate x N source interaction was significant ($P = 0.077$). The data show that as the rate of urea-N increased above 150 lb N/a, the corn plant population was reduced. These data would suggest that if high rates of urea are to be applied to the corn crop, a split application would be recommended to avoid a negative effect on plant population. Corn population was uniform over all plots in 2001 at 39,313 plants/a.

Corn grain yields were not significantly increased by N fertilization in this study in 2000 or by increasing residual N levels in 2001 (Tables 2 and 3). Nitrogen fertilizer source had no significant effect on grain yield either year (Table 3). The overall average grain yields were 254 bu/a in 2000 and 198 bu/a in 2001. The lower yield in 2001 was caused partially by insect damage to the corn ear during ear development. The lack of response to N fertilization in 2000 and to increasing residual soil NO_3-N levels in 2001 was unexpected. Residual soil NO_3-N was 136 lb N/a in the 0 to 3 ft soil depth prior to N fertilization in April 2000. Assuming a yield goal of 250 bu/a and a N requirement of 1 lb N/bu, about 250 lb/a of available N would be needed to produce this high yielding crop. Assuming that about 30 lb N/a is produced from each 1% soil organic matter, about 45 lb N/a may have been mineralized from SOM. It is estimated that less than 200 lb N/a was available to the corn crop without N fertilization, yet the non-fertilized plot produced 251 bu/a in 2000.

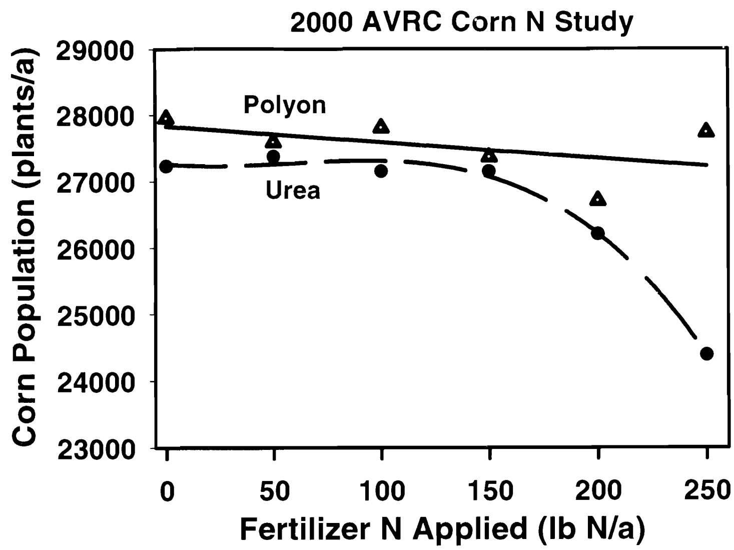

Figure 1. Corn stand as a function of N fertilizer rate and N source in 2000.

Corn silage yields (70% moisture) on 9 September 2000 increased significantly with increasing N rate up to 150 lb N/a then declined with increasing N rate (Table 3). The 2001 silage yields did not increase with increasing residual soil NO_3-N levels. The decrease in plant population at the 200 and 250 lb/a N rates, especially with urea, explains the decrease observed in corn silage yields at these N rates. In contrast, corn grain yields were maintained at these high N rates despite the lower population. Thus, the corn plants at the high N rates compensated with larger ears and two ears were produced on some plants. Crop N fertilizer use efficiency (NFUE) based on total N uptake in 2000 decreased with increasing N rate with NFUE of 41, 21, 15, 2, and 7% for the 50, 100, 150, 200, and 250 lb N/a treatments, respectively.

Based on the 2000 plant N uptake data, 0.7 lb N/bu was removed in the corn grain. An average total N requirement of 1.09 lb N/bu was required to produce the 2000 corn crop. Data for the 2001 crop were not available when this paper was prepared.

Although the irrigation water contributes some N to the cropping system, it does not appear to be the major contributor to the high levels of NO_3-N found in the soils at AVRC. Soil N mineralization potential needs to be assessed on this soil to evaluate the contribution of soil organic matter to the supply of available N to the crop.

Table 3. Corn grain and silage yields for 2000 and 2001 as a function of the fertilizer N rates applied only to the 2000 corn crop at Rocky Ford, CO.

2000 Fertilizer N Rate lb N/a	2000 Grain Yield		2000 Silage Yield		2001 Grain Yield		2001 Silage Yield	
	Urea	Polyon®	Urea	Polyon®	Urea	Polyon®	Urea	Polyon®
	bu/a (15.5% moist.)		t/a (70% moist.)		bu/a (15.5% moist.)		t/a (70% moist.)	
0	248	254	33.3	35.3	170	185	37.5	39.9
50	260	258	36.8	36.3	193	194	39.6	41.4
100	248	253	36.5	36.3	198	201	39.9	38.9
150	254	247	37.7	37.0	214	201	42.2	38.1
200	250	260	32.7	35.4	205	204	40.4	42.5
250	256	259	33.9	36.0	209	196	39.7	42.1
$LSD_{0.05}$	N.S.		2.3		N.S.		N.S.	

This corn N study will be continued on the same plots in 2002. Nitrogen fertilizer will be applied, but lower N rates than in 2000 will be used. Nitrogen fertilization effects on residual soil nitrate-N levels will continue to be monitored. Based on the soil NO_3-N data in Table 2, the addition of N fertilizer increased the level of soil NO_3-N throughout the 6 ft profile. Assuming an effective rooting depth of 3 to 4 ft, some of the fertilizer N was leached beyond the corn root zone in this study. This observation is supported by an adjacent ^{15}N fertilizer study with onion and corn by Halvorson et al. (2002), who found fertilizer N leached to a 6-ft depth the year of application to an onion crop and was still present after harvest of the following corn crop with no additional fertilizer N applied.

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