IRRIGATED CORN RESPONSE TO NITROGEN FERTILIZATION IN THE COLORADO ARKANSAS VALLEY

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ABSTRACT

High levels of residual NO_3-N are present in the soils in the Arkansas River Valley where alfalfa, grains, and vegetable crops are produced. Nitrogen requirements to optimize yield potential of crops, such as corn, following vegetables needs to be evaluated to reduce NO_3-N leaching potential in the Valley where high NO_3-N levels have been reported in the ground water. The effects of N source (urea and Polyon®[3]) and fertilizer N rate on corn yields were evaluated for 4 years. Corn grain yields were not significantly increased by N fertilization the 1st year following watermelon, but increased with increasing residual soil NO_3-N levels the 2nd year without additional N fertilization, and increased by N fertilization in the 3rd and 4th years. Averaged over years, N source did not significantly affect corn yields. Averaged over years, corn grain yields were near maximum with an average application of 75 to 100 lb N/a per year. Silage yields increased with increasing N rate each year, except for the 2nd yr. Soil residual NO_3-N levels were increased with increasing N rate the 1st year. Residual soil NO_3-N levels declined following the 2nd corn crop with no additional N fertilizer applied. Irrigation water was limited and became unavailable due to drought conditions the first week of August for the 3rd crop. Therefore, the 3rd corn crop suffered from severe drought stress and reduced yields. The 3-year average N fertilizer use efficiency was 64% at the lowest fertilizer N rate and less than 40% at the higher N rates. Residual soil NO_3-N levels declined with each additional corn crop in the check (no N added) treatment. Nitrogen application to corn in Arkansas River Valley produced in rotation with vegetable crops and alfalfa may need to be reduced to prevent NO_3-N contamination of groundwater in this area. Based on this study, it appears that a minimal amount (75 to 100 lb N/a) of N fertilizer may be needed to maintain high grain and silage corn yields in the Valley in rotation with vegetable crops and alfalfa. Fertilizer N appears to be moving out of the root zone with downward movement of irrigation water.

INTRODUCTION

High 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

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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.

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 (Halvorson et al., 2001, 2002a, 2002b).

Application of slow-release fertilizers to crops in the Arkansas Valley could potentially increase N fertilizer use efficiency (NFUE) and reduce NO_3-N leaching potential. Improved N management practices for crops in the Arkansas River Valley should optimize crop yields while minimizing N fertilizer impacts on ground water quality.

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 NFUE by corn, and evaluate the influence of N fertilizer rate on residual soil NO_3-N and potential for groundwater contamination.

METHODS AND MATERIALS

A N source and rate study was initiated under conventional till, furrow irrigated corn on a calcareous Rocky Ford silty clay loam soil at the Arkansas Valley Research Center (AVRC) in 2000. The plot area 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 added 64 lb N/a during the five years of alfalfa production. Watermelon was produced on the plot area in 1999 with 21 lb N/a added with the P fertilizer (Halvorson et al., 2001). Six N rates (0, 50, 100, 150, 200, and 250 lb N/a or N1, N2, N3, N4, N5, N6, respectively) were established in 2000. Due to only a minimal response to N fertilization in 2000, no additional N was applied to the 2001 crop. In 2002, N rates of 0, 25, 50, 75, 100, and 125 lb N/a were applied to the original 2000 N treatments, respectively. In 2003, the N rates were increased slightly to 0, 30, 60, 90, 120, and 150 lb N/a, respectively. Two N sources, urea and Polyon® (a slow-release urea fertilizer), were applied at each N rate. The N fertilizer was broadcast and incorporated with a harrow before corn planting. In the fall of 2000, 2001, and 2002, 11 lb N/a was applied with the P fertilizer (11-52-0) just prior to plowing, and no P was applied to the 2003 crop. A split-plot, randomized complete block design with 4 replications was used.

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. Corn (Garst 8559 Bt/RR) was planted on April 23, 2002 and April 29, 2003 at a seeding rate of about 39,000 seeds/acre. Herbicides were applied for weed control, with the plots being essentially weed free during the study period. Soil NO_3-N levels in the 0-6 ft profile have been monitored since the spring of 1999, and were measured before fertilization and after harvest of each crop.

Due to severe drought conditions and lack of irrigation water in 2002, the last irrigation occurred on August 2nd, shortly after pollination was completed. Therefore, the 2002 crop suffered from water stress during grain fill which reduced yield potential. 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, 2.8 ppm NO_3-N in 2001, and 2.4 ppm NO_3-N in 2002. 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, about 15 lb N/a in 2000, about 14 lb N/a in 2001, and about 14 lb N/a in 2002 while irrigating the corn crops. In 2003, N level in the water was not monitored, but was assumed to be similar to previous years. Assuming a 50% irrigation efficiency, about 7 to 8 lbs of N may have entered the soil each year.

RESULTS

In April 1999, 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 181 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 amount of N in the watermelon tops and unharvested melons in 1999, with a C/N ratio of about 12, potentially contributed up to 184 lb N/a to the 2000 corn crop (Halvorson et al., 2001). This might explain the unexpected high level of soil NO_3-N (181 lb N/a) at corn planting in 2000. In 2001, soil NO_3-N levels had declined following the second corn crop. At corn planting in 2002, soil NO_3-N levels had increased slightly compared with levels after harvest in 2001. Planting soil NO_3-N levels in 2003 were similar to those in 2002. The check plot (no N fertilizer applied) has had sufficient residual soil N to produce 718 bu of corn per acre in 4 years. The mineralization of available N from the soil organic matter in this soil appears to be quite high, as evidenced from the corn yields obtained from the check plots and removal of 395 lb N/a in the grain in 4 years (using an estimated N removal for 2003 crop).

Residual soil NO_3-N levels after corn harvest for each N rate in 2001 and 2002 are reported in Table 2. Residual soil NO_3-N levels were approaching more normal levels after

Table 1. Average soil NO_3-N levels in the non-fertilized check plots before and after the 1999, 2000, and 2001 crops, and before planting the 2002, and 2003 crops.

Soil Depth	1999 Watermelon		2000 Corn		2001 Corn		2002 Corn	2003 Corn
	Apr. 1	Nov. 8	Apr. 10	Oct. 25	Mar. 20	Nov. 5	Apr. 1	Apr. 1
feet	Soil NO_3-N, lb/a							
0-1	82	41	79	42	72	20	47	62
1-2	13	23	33	22	15	6	16	8
2-3	6	26	24	32	14	5	5	4
3-4	4	25	18	20	11	6	4	3
4-5	5	24	15	17	7	8	2	2
5-6	4	17	11	7	6	6	2	2
Total	114	157	181	140	125	52	76	82

Table 2. Soil NO_3-N levels with soil depth on 5 November 2001 and 24 September 2002 for each N rate treatment.

Soil Depth	2000 Fertilizer N Rate (lb N/a)						2002 Fertilizer N Rate (lb N/a)					
	0	50	100	150	200	250	0	25	50	75	100	125
	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6
	5 November 2001						24 September 2002					
Ft	Soil NO_3-N, lb N/a											
0-1	20	22	20	18	21	45	25	29	40	43	51	42
1-2	6	7	8	7	13	20	17	9	14	19	16	16
2-3	5	6	9	10	20	40	13	12	11	18	16	18
3-4	6	6	5	14	16	14	9	9	18	15	21	20
4-5	8	6	5	14	20	16	9	10	10	18	14	20
5-6	6	9	7	12	17	14	14	9	15	29	16	19
Total	52	55	54	76	107	149	87	78	99	142	134	135

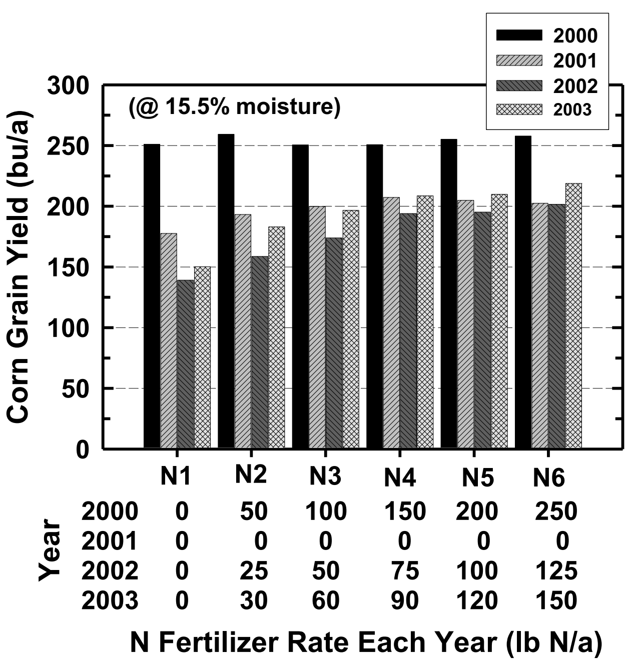

Figure 1. Corn grain yield each crop year as a function of N applied.

harvest of the 2001 corn crop which was not fertilized. Residual NO_3-N levels in the 6 ft soil profile on 24 September 2002 still increased with increasing rates of N fertilization. The increase in residual soil NO_3-N levels in 2002 over those following the 2001 crop were probably due to the reduced N use by the 2002 corn crop due to drought and water stress. Yields, grain and biomass, were reduced from the previous two years due to the drought in 2002.

Corn grain yields were increased significantly ($\alpha = 0.05$) by N fertilization each year, except in 2000 (Figure 1). The lower yields in 2001 than in 2000 were partially caused by insect damage to the corn ear during ear development. The low yields in 2002 were the result of water stress due to lack of irrigation water during grain fill. Drought stress in 2003, although not as severe as in 2002, resulted in a severe ear smut problem, which may have reduced yield potential.

Averaged over years, the Polyon® N source (207 bu/a) did not have a significant yield advantage over urea (205 bu/a). However, if a slow release fertilizer becomes available at a

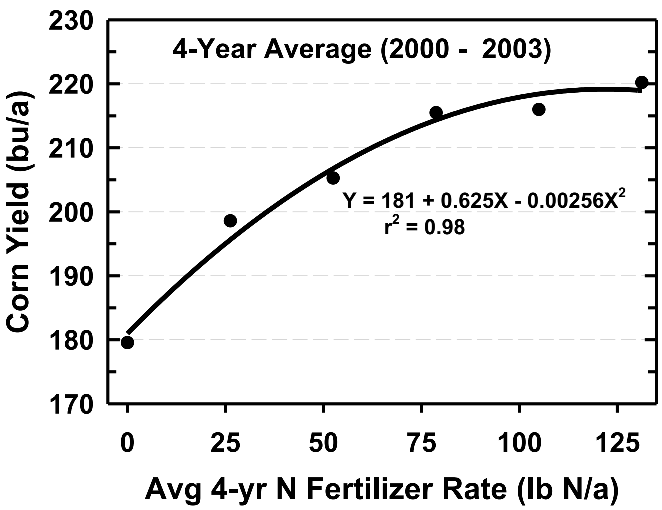

Figure 2. Four-year average corn yield as a function of average annual N rate.

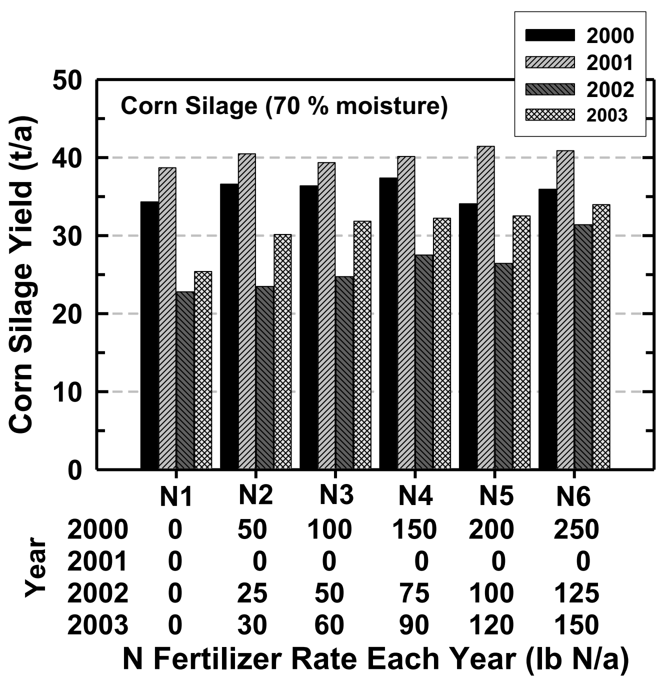

Figure 3. Corn silage yield each year as a function of N rate.

competitive cost with urea, its use may improve NFUE and reduce NO_3-N leaching potential in the Arkansas Valley in Colorado.

Grain yields averaged 254 bu/a in 2000, 198 bu/a in 2001, 177 bu/a in 2002, and 195 bu/a in 2003 when averaged over all N rates and N sources. The higher grain yields in 2000 compared to the other years may reflect the rotational benefits of corn following watermelon rather than corn following corn. The average 4-yr grain yield increased with increasing N rate (Figure 2), with N rate expressed as a 4-yr average for the N1, N2, N3, N4, N5, and N6 treatments.

Corn silage yields (70% moisture) in 2000 increased significantly ($\alpha = 0.05$) with increasing N rate up to 150 lb N/a (Figure 3). Silage yields in 2001 did not increase significantly ($\alpha = 0.05$) with increasing residual soil NO_3-N levels. Silage yields in 2002 and 2003 increased significantly ($\alpha = 0.05$) with increasing N rate, but did not vary with N source.

Crop N fertilizer use efficiency (NFUE) based on total biomass 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. The two year NFUE's based on total biomass N uptake for the combined 2000 and 2001 crops were 71, 39, 34, 25, and 25 % for these same respective N treatments. The three year (2000-2002) NFUE was 64, 41, 42, 32, and 38 % for the N2, N3, N4, N5, and N6 fertilizer N treatments, respectively. Based on total N removal by grain in 3 years, the NFUE was 42, 24, 25, 25, and 23 % for the N2, N3, N4, N5, and N6 fertilizer N treatments respectively. The 2003 samples are currently being analyzed, so the 2003 data was not included in the NFUE analysis.

Based on the corn N uptake data, an average of 0.7 lb N/bu was removed in the corn grain in 2000, 0.68 lb N/bu in 2001, and 0.63 lb N/bu in 2002. Nitrogen removal in the grain increased with increasing N rate when averaged over 3 years. An average total N requirement of 1.09 lb N/bu was required to produce the 2000 corn crop, 1.19 lb N/bu in 2001, and 0.87 lb N/bu in 2002 with a 3 year average of 1.05 lb N/bu with no influence of N rate or N source on the amount of N required to produce a bushel of corn. These total N requirement values from AVRC are in agreement with total N needs of irrigated corn of 1.1 to 1.2 lb N/bu reported in the literature and used by the fertilizer industry to estimate N fertilizer needs.

Although the irrigation water contributed some N to the cropping system, it does not appear to be a major contributor to the high levels of NO_3-N found in the soils at AVRC. Based on corn yields and N uptake of the check plots (no N fertilizer applied), soil N mineralization potential was very high in this soil.

The plot (Figure 2) of average corn grain yield as a function of the average (annual) N fertilizer application rate for the 4 years shows a curvilinear increase in grain yield with increasing rate of N fertilizer application. Grain yields start to level off above an annual rate of 75 lb N/a and are near maximum at 100 lb N/a. This would indicate that N fertilizer rates applied to corn could potentially be reduced in the Arkansas Valley while maintaining high yield potential when rotating with vegetable crops and alfalfa, which would reduce NO_3-N leaching potential.

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 appears to have been 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. (2002a), 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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