IRRIGATING CORN WITH HIGH NITRATE WATER

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INTRODUCTION

Nitrate contamination of groundwater is a growing problem in some irrigated regions across the Great Plains. In general it is the result of the leaching of nitrate-nitrogen from the root zone of irrigated corn. Except in a few locations with exceptional soil conditions, it is practically impossible to produce corn without some nitrate leaching. However, excess application of either nitrogen fertilizer or irrigation water usually results in losses much greater than the "minimum". Nitrogen lost in this way is carried to the groundwater by water draining from the root zone. In locations where this has been a problem for many years, very large quantities of nitrate-nitrogen may be "stored" in the groundwater.

Keeping applications of production inputs to the minimum necessary is good management practice any time. In this period of low grain prices and high operating costs, it is imperative to limit expenditures on inputs such as nitrogen, as much as possible. In areas where nitrate-contaminated groundwater is being used for irrigation, the opportunity exists to use the nitrate already in the irrigation water to meet part of the crop's nitrogen needs. For most producers the adjustments required to take advantage of this "free" N source may be minimal.

For every acre-inch of water applied, each ppm of nitrate-nitrogen in the water contains 0.23 lb of N. Thus, a seasonal application of 15 inches of water with a concentration of 20 ppm of nitrate-nitrogen would contain 15 x 20 x 0.23 = 69 lb/ac of N. The question is, "How much of this N is effective?" Before addressing this question we need to know when the water was applied, how much other nitrogen was available to the crop, and the stage(s) of growth when water was applied. In general, over 80 percent of corn's N uptake is completed within 2-3 weeks after pollenation, although a small amount of uptake will continue later into the season. Thus, nitrate in water applied during the rapid N uptake period is likely to be more useful than nitrate in water applied later. If excess irrigation is applied, even during the rapid N uptake period, some of the mineral N already in the root zone will be leached out, along with some of the nitrate in the water just applied.

At the Nebraska MSEA Project research site in the Central Platte Valley, University of Nebraska and USDA/ARS researchers have been studying this problem. The goal of the work is to develop practical management strategies that producers can use to take advantage of the N already in the water. The information which follows is a progress report on this research. We still have a lot of questions.

Field Experiments With High- and Zero-Nitrate Waters

<u>Site location and conditions</u>

The MSEA research site is located near the town of Shelton, in Buffalo County, NE. The predominant soil is a Hord silt-loam. It is 3-4 ft deep and is underlain by sand. The research field was laser graded in 1990, with a longitudinal slope of 0.15%.

There are two aquifers at the research site. The upper aquifer is the one that supplies the irrigation water in the area. It consists of alluvial sands and gravel. The bottom of the aquifer is at a depth of about 60 ft, and is separated from the Ogallala formation below by 12-15 feet of silty clay. The depth to the water table in the upper aquifer varies from 10-20 ft, depending on rainfall and pumping. The nitrate-N concentration in the upper aquifer is 30 ppm. Each acre-inch of water contains about 6.9 lbs of nitrate-nitrogen. In contrast, the deep, Ogallala aquifer is free of nitrate, containing only 0.1 ppm of nitrate-N. Apparently, there is little or no interchange of water between the upper and lower aquifers.

Irrigation research has been conducted at the MSEA site since 1991, using high-nitrate water from the upper aquifer. In the spring of 1997, we drilled a well into the Ogallala formation, adjacent to the existing well in the upper aquifer. At the interface between the two aquifers we sealed around the outside of the well casing to prevent any flow of water between the two aquifers. This dual well arrangement let us run experiments with side-by-side treatments using either high-nitrate or zero-nitrate water.

<u>Experiment on land with "uniform" residual nitrate.</u>

In 1997, we installed an experiment with irrigated corn to evaluate the value of the "extra" nitrogen in the contaminated upper aquifer. The work was continued in 1998. In both years, the experiment was placed on land that had been planted to corn for over 10 years. Nitrogen fertilizer applications of 150-170 lb/ac had been uniformly applied across the field during the previous two years. Field preparation consisted of a double disking before planting.

Irrigation was applied to the experiment by surge irrigation in quarter mile rows. We followed local practice and blocked the lower end of the furrows with a dike to prevent runoff from leaving the field. Irrigations were scheduled using the checkbook method, supplemented with field checks with a hand soil probe and with the neutron probe at a few locations. Irrigation began in late June to early July, when water was needed and the field was prepared. The following treatments were applied:

Irrigation

W_1 = Careful irrigation with every-other-row irrigation with high-nitrate water; timing dictated by irrigation scheduling procedure; amount usually 2 inches or less per irrigation.

W_2 = Excess irrigation with every-row irrigation with high-nitrate water; irrigation weekly in absence of rain; irrigation at least every second week until end of the rapid N uptake period, regardless of rainfall.

W_3 = Same as W_1 except with zero-nitrate water.

Table 1 summarizes the irrigation amounts during the 2 years of operation.

Table 1

Total Yearly Irrigation Depths

Irrig. Tmt	1997	1998
	----------------inches----------------	
W_1	11.0	9.0
W_2	18.7	17.7
W_3	12.4	4.6

Nitrogen

Except for the small amount of N applied in the liquid starter, N fertilizer was applied as anhydrous ammonia both years. In 1997, application was made as a sidedress when the crop was about a foot tall. In 1998, a preplant application was made, and included a nitrification inhibitor. In both years nitrogen fertilizer was applied at 4 different rates under each irrigation treatment.

Table 2 provides a summary of both the N fertilizer amounts and the gross N application from the irrigation water. Based on our results in 1997, nitrogen fertilizer rates were moderately reduced in 1998.

The experiment was organized in the field so that there were 4 replications of each irrigation treatment, and 8 replications of each fertilizer treatment within each irrigation treatment. This was done so that we could see if there was any difference in yield between the upper and lower halves of the field. We found no difference between halves in either year, so the data from both halves were grouped together for analysis.

Table 2 Nitrogen Amounts from Fertilizer and Irrigation							
1997 Results							
N Tmt	N Fert	N from Irrigation Water			Total N Applied		
		W_1	W_2	W_3	W_1	W_2	W_3
	-----lb/ac-----						
N_1	10	76	129	0	86	139	10
N_2	80	76	129	0	156	209	80
N_3	125	76	129	0	201	254	125
N_4	170	76	129	0	246	299	170
1998 Results							
N Tmt	N Fert	N from Irrigation Water			Total N Applied		
		W_1	W_2	W_3	W_1	W_2	W_3
	-----lb/ac-----						
N_1	3	62	122	0	65	125	3
N_2	53	62	122	0	115	175	53
N_3	98	62	122	0	160	220	98
N_4	143	62	122	0	205	265	143

1998 experiment to evaluate crop response to different residual N levels

In 1998 we installed an additional experiment over the plots used in 1997, to look at yield response to the residual N from the previous year. We put the same three irrigation treatments in the same locations that had been used in 1997. The irrigation amounts and the resulting N amounts from the irrigation water were the same as shown in Table 2 for the other 1998 experiment. Two N fertilizer rates were used: 0 and 80 lb/ac on plots that received the different N rates in 1997. We had 4 replications of each N and irrigation treatment over each level of residual N.

RESULTS

1997 experiment on land with "uniform" residual nitrate.

The spring of 1997 was relatively warm and dry, resulting in favorable conditions for early, rapid plant growth and for rapid mineralization of mineral N from soil organic matter. Irrigation requirements were about average across the growing season.

The average yields for the various water and N fertilizer treatments are presented in Figure 1. For the W_1 treatment (careful irrigation with high-nitrate water) there was no statistical difference in yield across any fertilizer treatment. That is, we got the same yield with or without N fertilizer beyond the 10 lb/ac of starter. The 76 lb/ac of N in the water, plus the 50 lb/ac residual nitrate-N (0 - 4 ft), plus mineralization of plant-available N from organic matter provided enough N to yield an average 193 bu/ac.

The W_2 treatment (excess irrigation with high-nitrate water) had a 12 bu/ac lower yield with starter only. We are not sure why. The wetter root zone conditions may have resulted in more denitrification, lower oxygen levels, etc. With 80 lb/ac of N or greater, there was no statistical difference between the W_1 and the W_2 irrigation treatments except at the 170 lb N rate. At this N level, the combination of high N and excess irrigation resulted in more stalk rot and stalk breakage in the W_2 treatment.

The W_3 water treatment (careful irrigation with zero-nitrate water) had a 27 bu/ac yield loss in comparison to the W_1 treatment when only starter fertilizer was applied. Effectively, the high-nitrate water provided enough extra N to produce an additional 27 bushels in comparison to the "clean" water. However, with 80 lbs or more of N fertilizer, there was no statistical difference between W_3 and W_1.

For practical purposes, 80 lb/ac of N fertilizer was enough to produce full yield under any irrigation treatment, including the zero-nitrate water.

1998 experiment on land with "uniform" residual nitrate.

In 1998 the experiment of 1997 was repeated on adjacent land that had been uniformly cropped and fertilized in previous years. As previously indicated, N rates were moderately reduced during the second year of the study (Table 2). The spring of 1998 was quite different from 1997, with lower temperatures and excessive rain up to planting time and again till the latter part of May. There was considerable leaching of residual nitrate. Because of the below normal temperatures, mineralization was slower than normal until mid-June.

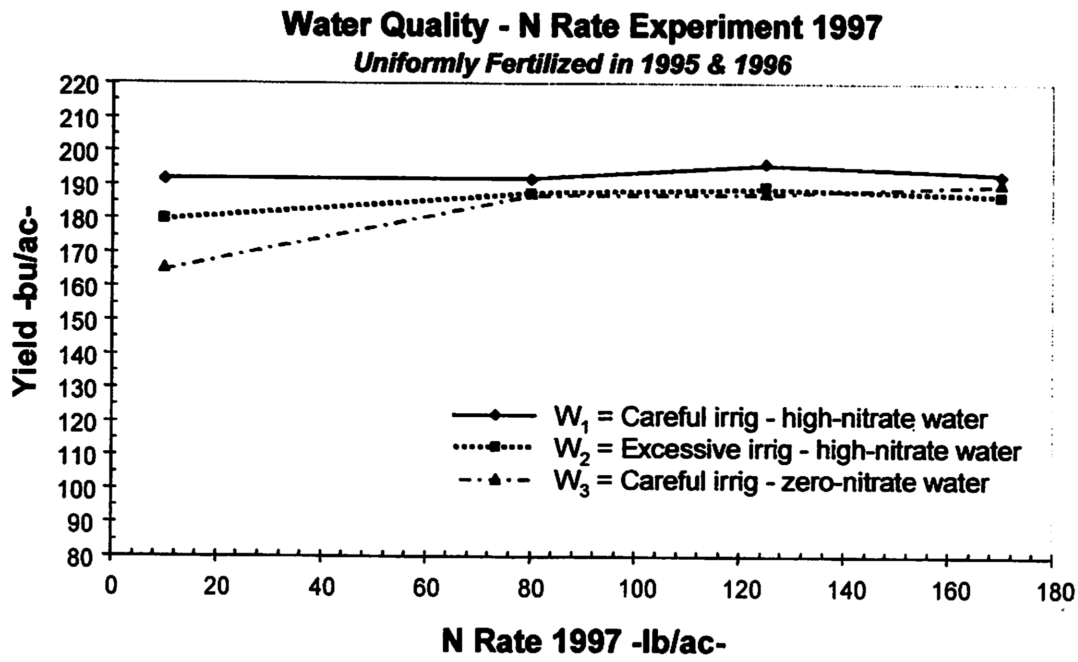

Figure 1. Corn yield from irrigation treatments using high-nitrate and zero-nitrate irrigation water, with 4 levels of N fertilizer, 1997. Treatments applied to land with history of uniform N application.

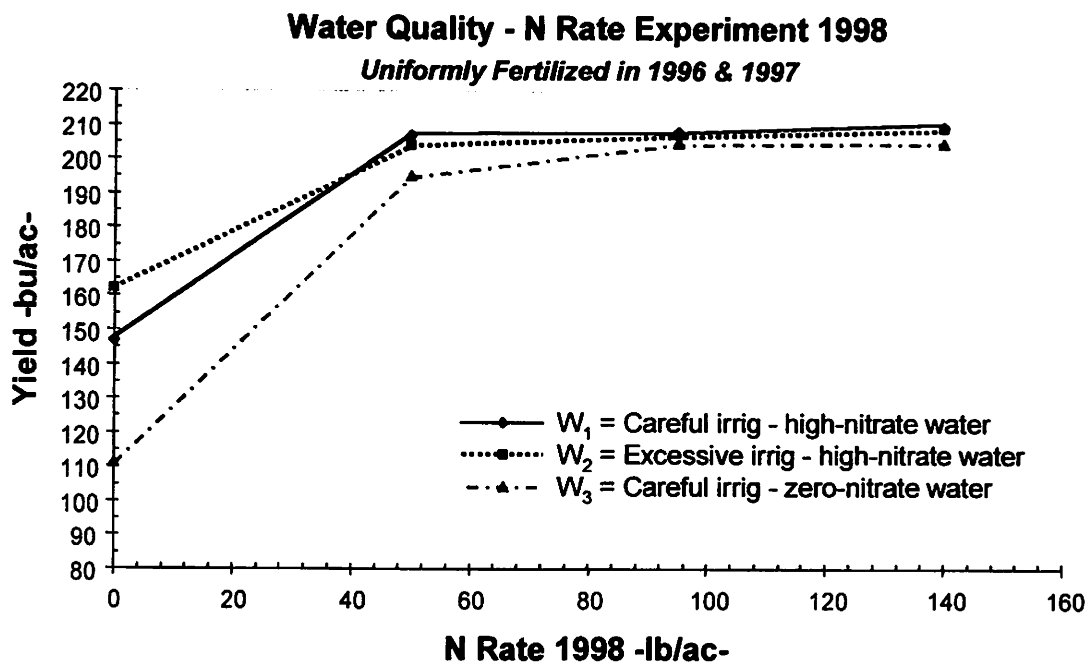

Figure 2. Corn yield from irrigation treatments using high-nitrate and zero-nitrate irrigation water, with 4 levels of N fertilizer, 1998. Treatments applied to land with history of uniform N application.

In theory, the W_1 and W_3 irrigation amounts in 1998 should have been about the same. The plan was for W_3 to be irrigated the day following the irrigation of W_1. In 1998 the W_1 irrigation total was larger than that for W_3 because rain interrupted the scheduled W_3 irrigation on at least two occasions on the day after the W_1 treatment had been watered.

Yields from the experiment are presented in Figure 2. In contrast to 1997, the crop suffered a quite visible, early season N shortage in the N_1 (starter only) treatment. This resulted in an 84 bu/ac yield loss for the W_3 (zero-nitrate water) treatment, and an average of 51 bu/ac for the W_1 and W_2 (high-nitrate water) treatments in comparison to yields for the N_2, 50 lb/ac preplant application. In spite of the early season N stress on the N_1 treatment, the high-nitrate water added sufficient N later in the growing season to increase the yield by 33 bu/ac in comparison to the clean water. However, extra nitrogen from the irrigation water in July could not fully compensate for the N stress resulting from lack of N early in the season.

There was no statistical difference between any of the irrigation or nitrogen treatments for an N amount of 50 lb/ac or greater. We had expected a lower yield from the zero-nitrate water. However, soils such as the Hord, which have been in corn for many years, seem to have a very substantial mineralization potential after the soil warms up. Mineralization may supply 60-100 lb/ac or more of plant-available nitrogen.

These results do not mean that we can expect to achieve the same yields year after year with such low N rates. The more interesting question for the producer is, "What yield response to fertilizer can be expected in the second and third years of cropping on the same land where low N rates have previously been applied?" Under low N rates, residual N is lower. Mineralization may gradually decline as plant residues with lower N contents are returned to the soil. To look at this issue in relation to the high and low nitrate waters, we began an experiment in 1998 which will continue through 1999.

1998 experiment to evaluate crop response to different residual N levels

After the 1997 harvest, the plots in that experiment were sampled to a 4 ft depth to determine the amount of residual nitrate-N. Results of the sample analysis are shown in Figure 3. Residual N tended to increase with increasing N fertilizer amounts in 1997. Residual amounts were about the same under either irrigation treatment with high-nitrate water, and were consistently lower under the W_3, zero-nitrate treatment. This is not too surprising, since continued irrigation with the high-nitrate water after the crop had completed most of its N uptake resulted in an accumulation of the N contained in the late-season irrigation water.

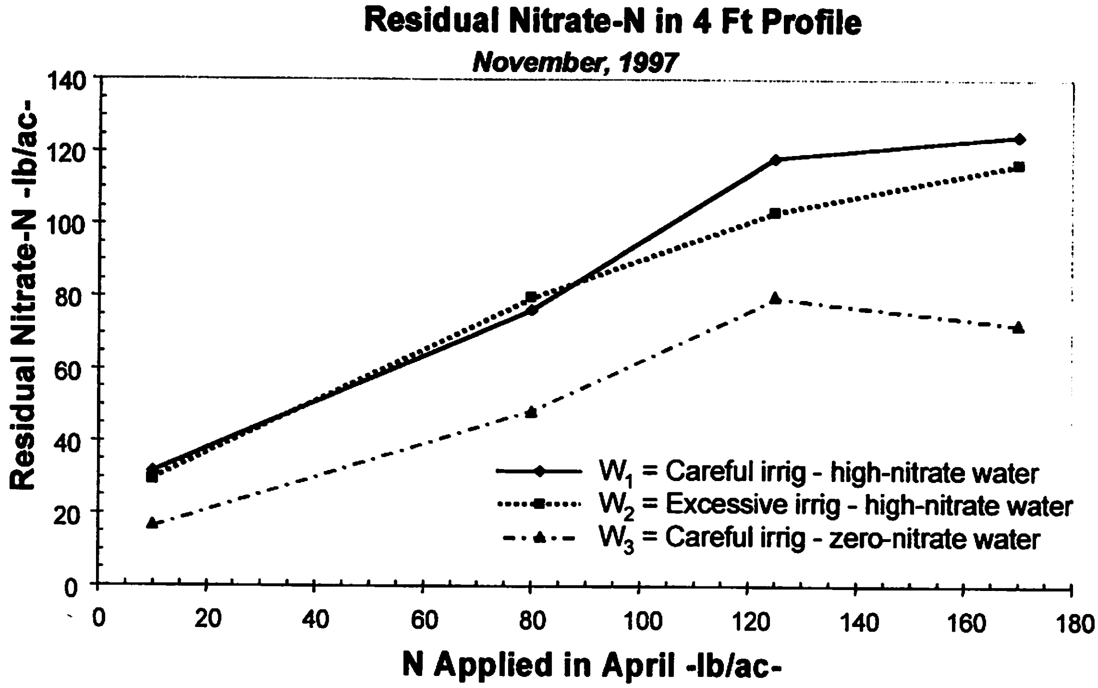

Figure 3. Residual nitrate-N in 4 ft. profile, following the 1997 water-N experiment of Figure 1.

Figure 4 shows the yield response where we applied no additional N in 1998 (except 3 lb/ac as starter). There is a clear and substantial difference in yield response among the three irrigation treatments, with yield increasing as more N was supplied by the water. The excessive irrigation with high-nitrate water had a greater yield than did careful irrigation with the same water quality, which had a much greater yield than did irrigation with zero-nitrate water. Response to residual N was found only for 1997 N rates of 120 lb/ac or greater. The relatively low response to residual N was, at least in part, the result of leaching loss during the spring. We do not know how much N was lost, but the amounts were undoubtedly substantial. However, another major factor was the early season N stress suffered by the zero fertilizer treatment. Yield potential was permanently lost when this stress occurred.

The value of early N in 1998 is shown by the results from the 80 lb/ac N application. While yields from the "clean" water irrigation treatment appear to fall slightly below those for the high-nitrate water (Figure 5), there was no statistical difference among any of the treatments. Application of 80 lb/ac of N was enough to provide a full yield, regardless of 1997 residual N amount or 1998 irrigation treatment. As was the case for the other 1998 experiment, the preplant anhydrous application allowed the crop to avoid the early-season N stress during May and early June. The early N together with mineralization through early August provided enough N to meet the crop's needs.

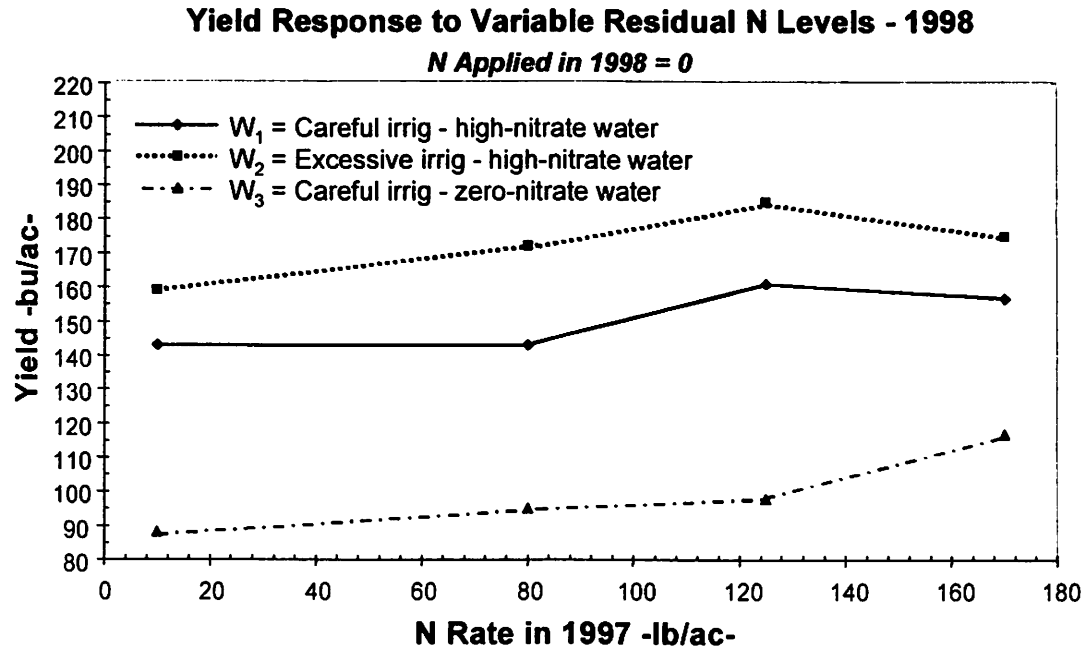

Figure 4. Yield response in 1998 to residual N plus 3 lb/ac of starter N on the plots of the 1997 experiment; irrigation with high-nitrate and zero-nitrate water.

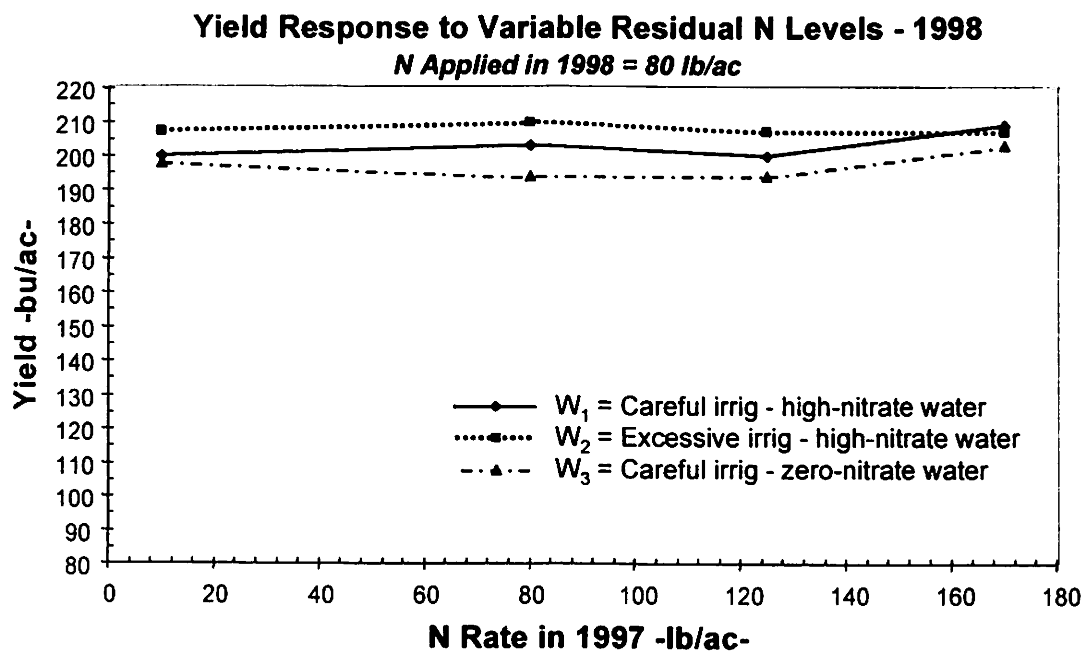

Figure 5. Yield response in 1998 to residual N plus 83 lb/ac of preplant N fertilizer on the plots of the 1997 experiment; irrigation with high-nitrate and zero-nitrate water.

What can you do in 1999 if you are irrigating with high nitrate water?

If funds are short:
- ---Use a healthy dose of starter N to minimize early season stress.
- ---Apply a modest amount of sidedress N (50 - 80 lb/ac).

OR

- ---Apply 50-80 lb/ac preplant.
- ---Use a modest amount of starter N.

Also

- ---Check residual N.
- ---Pray for a warm spring without excess precipitation.

SUMMARY

It is difficult to clearly define the value of the nitrogen contained in high-nitrate groundwater at the MSEA research site in the Central Platte Valley of Nebraska. Under the "normal" springtime conditions of 1997, mineralization and residual nitrate in the soil provided enough N so that there was no response to fertilizer under irrigation with high-nitrate water (30 ppm nitrate-N). In contrast, irrigation with zero-nitrate water resulted in a 27 bu/ac yield reduction when only 10 lb/ac of N as starter was applied. With 80 lb/ac or more of N fertilizer, there was no yield difference between the irrigation treatments with the high and zero nitrate waters.

In 1998, the spring was cold and wet. N stress was apparent on plots that received no preplant N. Using starter only (3 lb/ac N), irrigation with zero-nitrate water resulted in a 33 bu/ac yield reduction in comparison to irrigation with high-nitrate water. With 50 lb/ac or more of preplant N fertilizer, there was no yield difference between the irrigation treatments with the high- and zero-nitrate waters.

A second experiment in 1998 provided information about response to zero and high-nitrate water under variable residual N amounts resulting from the experiment of 1997. With starter only, the high-nitrate water with careful irrigation provided an average yield increase of 51 bu/ac in comparison to the zero-nitrate water. Excess irrigation with high-nitrate water gave an additional increment of 22 bu/ac or 73 bu/ac more than the zero-nitrate water. However, when 80 lb/ac of N were applied preplant, full yield was obtained under all irrigation treatments. There was no yield benefit obtained from the high-nitrate water. Mineralization was apparently sufficient to meet the remaining N requirements of the crop.

We expect the response to the high-nitrate water to increase over time, particularly where low N amounts are applied. The supply of rapidly mineralizable N in the organic pool will decline with the result that more N will have to come from other sources to meet crop needs.