Comparison of Residual Nitrate and Fertilizer Nitrogen Efficiency in Basin Irrigated Wheat

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ABSTRACT

The relative efficiencies of residual soil NO_3-N and fertilizer N in basin-irrigated wheat production are not well defined. A two-year field study was conducted at the Safford Agricultural Center to investigate what these N efficiencies are under optimum yielding conditions. 'Aldura' durum wheat was grown on the same field site two years in succession. In 1987 a wide range of fertilizer N (0 to 419 lbs/A) applications resulted in residual NO_3-N accumulations of 36 to 140 lbs/A in the surface four feet of soil. Residual N plots were split in 1988 with one subplot receiving no additional N while the other was treated with 145 lbs of fertilizer N/A. Grain yield response curves for the -N and +N subplots were used to estimate the marginal rate of substitution (MRS) of soil NO_3-N for fertilizer N. The marginal efficiency of residual NO_3-N was a constant 16.7 lbs. grain produced/lb. of N across the range of profile N values in this study, while the marginal efficiency of fertilizer N varied from over 17 to below 6 lbs. grain/lb. N. When basin-irrigated wheat is supplied with adequate, but not excessive N, the MRS of soil vs. fertilizer N is about 1:1 although absolute N efficiencies under basin irrigation are considerably lower than those achieved in other grain production systems.

INTRODUCTION

The imposition of Best Management Practices for nitrogen (N) fertilizers in 1989 has focused much attention on the fate of N in agricultural systems. The importance and relative efficiency of residual soil nitrate (NO_3-N) compared to fertilizer N is a crucial, but very poorly understood, component of overall N management in irrigated agriculture. Research in non-irrigated small grains revealed that residual soil NO_3-N was only about 30% as effective in producing grain yield as was fertilizer N applied during the growing season (Haby et al., 1983). Additional work under sprinkler and furrow irrigated conditions revealed that the marginal rate of substitution (MRS) of residual N for fertilizer N varied considerably, depending on such factors as method and frequency of irrigation, soil physical properties, yield level of the crop to be grown and the absolute value of the residual NO_3-N present in the soil (Onken et al., 1985).

Information detailing the MRS of residual NO_3-N for fertilizer N under basin or flood-type irrigation, which is common in Arizona, is much needed, but largely unavailable. A two-year field study was conducted at the Safford Agricultural Center to investigate the relative efficiency of residual NO_3-N and fertilizer N used in durum wheat production under optimum yielding conditions.

MATERIALS AND METHODS

The two phases used in this experiment were: 1) to establish field plots with a wide range of residual soil NO_3-N; and 2) to quantify the response of durum wheat to both types of N, namely residual N and fertilizer N.

In the fall of 1986, unfertilized Sudan grass was planted uniformly over the entire plot area to be used in this study to provide a uniformly low base level of residual soil NO_3-N. The soil used was a Pima clay loam (fine silty, mixed, thermic, Typic Torrifluvents). The chemical characteristics of this site were pH, 8.1; bicarbonate extractable P, 9.5 ppm; and electrical conductivity, 2.9 dS/m. On 23 December 1986, 'Aldura' wheat was drilled into flat borders at the rate of about 200 lbs/A and irrigated. Five levels of N fertilizer, from 0 to 419 lbs N/A were imposed in a randomized complete block design with 4 replications. Individual plots were 24 x 45 feet in size.

The plots were harvested on 20 June 1987, using a commercial combine. Additional details of this field experiment can be found in Doerge et al. (1987). The soil in each plot was then sampled to a depth of 4 feet in one-foot increments to permit analysis of residual soil NO_3-N still present in the rooting zone for wheat. Soil samples were air-dried, ground to pass a 2mm mesh screen and analyzed for NO_3-N content, using a water extraction and Kjeldahl steam distillation.

For the 1987-88 crop season, each original plot was split, resulting in two 12 x 45 foot subplots. The experimental area was uniformly seeded to 'Aldura' durum wheat on 9 December, using similar seeding rates and irrigation techniques as in the preceding year. One subplot within all the main plots was designated as a -N subplot and received no additional N fertilizer. The other +N subplots received a uniform application of 145 lbs N/A, including split treatments of 20 lbs N/A prior to planting and 45, 55 and 25 lbs N/A at the 5-6 leaf, joint and flowering stages, respectively. These rates of N were based on soil + stem NO_3-N tests and were chosen to provide adequate N for plots containing moderate to high levels of residual NO_3-N. A uniform application of 40 lbs P_2O_5/A as triple super phosphate was banded near the seed at planting.

The experimental area was uniformly irrigated six times with a total of 33 inches of water which contained about 15 lbs N/A. The rainfall for the growth period was 4.5 inches. Weeds were controlled by an application of 2, 4-D just prior to the jointing stage. No other pesticides were applied.

Grain yields were estimated for all subplots on 22 June using a small plot combine with a swath of 4.0 feet. The relationships between grain yield and total residual NO_3-N in the soil profile were determined for the -N and +N subplots using standard polynomial curve fitting techniques. The first derivative of the -N response curve was used to estimate the relative efficiency of residual NO_3-N across the range of those values present in this experiment. The relative efficiency of fertilizer N was estimated by dividing the yield response to the application of N by the quantity of N fertilizer applied, or:

$$\text{Relative Efficiency of Fertilizer N} = (\text{+N yield minus -N yield})/145 \qquad (1)$$

The MRS of residual NO_3-N for fertilizer N can then be estimated by dividing the relative efficiency of residual NO_3-N by the relative efficiency of fertilizer N.

RESULTS AND DISCUSSION

Table 1 summarizes the 1987 N treatments and the residual NO_3-N levels resulting from these fertilizer applications. The range of total profile NO_3-N of 36 to 140 lbs N/A is not excessive and probably encompasses the conditions expected in most Graham County grain fields. Figure 1 depicts the response curves of the -N and +N subplots. The grain yields measured in the -N subplots increased linearly with increasing profile NO_3-N, reaching a maximum of about 5300 lbs. grain/A or 82% of highest yields achieved in the +N plots. The yield response of wheat to the application of N was greatest at low residual NO_3-N levels and decreased markedly as profile N increased.

Table 1. Nitrogen fertilizer rates applied to field plot on a Pima clay loam in 1986-87 and the resulting soil NO_3-N levels at the conclusion of that season.

N Rate	Soil NO_3-N content				Total NO_3-N
in 1987	0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft	in profile
lbs/a	ppm				lbs/A
0	3.5	2.3	2.0	1.2	36.0
107	8.7	3.5	2.7	1.7	66.4
186	11.2	5.0	3.0	1.7	83.6
263	15.4	6.0	3.4	2.5	109.2
419	19.8	7.6	5.0	2.6	109.2

Figure 1. Yield responses curves for durum wheat grown over a range of residual soil NO_3-N. The -N plots received no N fertilizer while the +N plots received a total of 145 lbs. N/A.

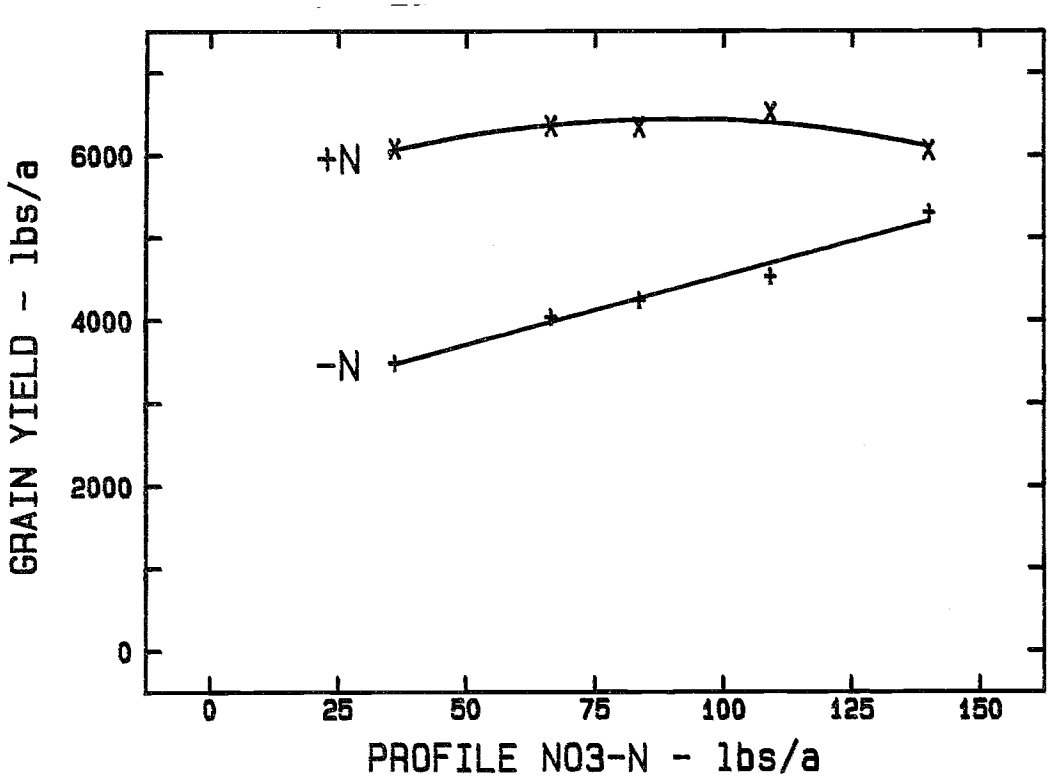
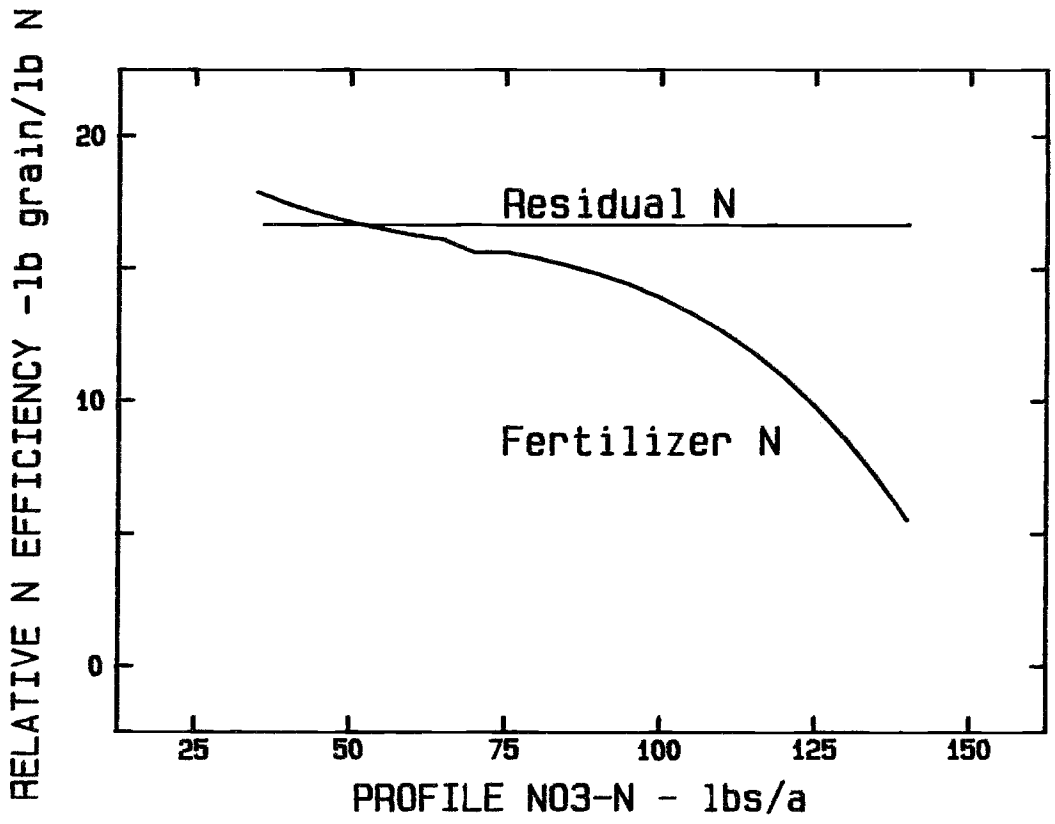


Figure 2 diagrams the estimated efficiencies of both residual and fertilizer N over the range of profile N values present in this study. The efficiency of residual NO_3-N was constant over this range, with a value of 16.7 pounds of grain produced per pound of residual N present in the soil profile. The efficiency of fertilizer N was highest when residual soil N was very low but decreased very rapidly as profile N increased. This emphasizes the long known principle that N fertilizer use efficiency decreases significantly when excessive applications of N are made.



The MRS for soils of moderate or lower residual N content is approximately 1:1 for the conditions present in this study. The MRS values for soils with higher levels of profile N would be somewhat greater. This apparently high value for MRS needs to be put into perspective with the absolute efficiencies of N recorded here under basin irrigation compared to those achieved under other production systems. A relative N efficiency of 17 pounds grain/pound of N is equivalent to about 3.5 pounds of N needed for each bushel of grain produced. This is well above the N requirement of grain produced under rain-fed conditions, which routinely average 2.0 to 2.5 lbs N/bushel of grain.

Considerable additional field research is needed to better describe the relative efficiencies of various types of N under basin-type irrigation as practiced in Arizona. However, the results of this study do suggest that when the N supplied to a wheat crop is adequate but not excessive, the relative efficiencies of both residual and fertilizer N are approximately equal but are considerably lower than those achieved in other more efficient grain production systems.

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