Nitrogen Fertilizer Movement in Wheat Production, Roll

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Abstract

Labeled nitrogen fertilizer (N-15) was applied to wheat to determine fertilizer nitrogen movement in the soil at harvest. Most of the labeled fertilizer recovered in the soil was found in the surface few feet. The amount of nitrogen fertilizer detected below 5 feet was minimal.

Introduction

Nitrate pollution of groundwater is a growing public concern. Half of our nation's population relies on groundwater as a source of drinking water. Agriculture is being scrutinized as a source of nitrate pollution of groundwater. Nitrogen fertilizer is a potential source of groundwater pollution. Best management practices (BMP's) for nitrogen fertilizer applications have been mandated in an effort to limit nitrogen pollution of groundwater. BMP's for nitrogen management in wheat are based on soil testing, plant analysis, and efficient irrigation. The purpose of this investigation is to relate best management practices and nitrogen fertilizer movement in a commercial wheat field.

Materials and Methods

A commerial wheat field in Roll was monitored during the 1991-92 wheat growing season. The soil type of the field was a silt loam consisting of 3 to 4 feet layer of silt on top of sand. The chemical properties of the soil are: pH=8.4, electrical conductivity (ECe)=0.48 mmhos/cm, Na=3.83 meq/L, Ca+Mg=1.4 meq/L, sodium adsorption ratio (SAR)=1.7, exchangeable sodium percentage (ESP)=1.2, NO_3-N=3 ppm, P=1 ppm, K=220 ppm. The soil holds approximate 10 inches of plant available water in the top 5 feet of soil. Irrigation water was applied in level basins.

The hard red spring or bread wheat cultivar 'Yecora rojo' was drilled in dry soil and irrigated on 18 December 91. The seeding rate was 135 lbs seed/A and the row spacing was 6 inches. A summary of the irrigation and fertilization is presented in Table 1.

Labelled nitrogen fertilizer (^{15}N) was applied at rate of approximately 5% of the intended grower fertilizer rate preplant and before each fertigation. Ten 1 meter x 1 meter plots were established in two level basins 9 acres each. Ammonium sulfate with a 99% enrichment of ^{15}N was used as the labelled nitrogen fertilizer. Before planting, labelled nitrogen was applied to each 1 m2 plot in a 20 x 20 grid pattern of 5 cm x 5 cm squares. Each 5 cm x 5 cm square received 1 ml of solution. Potassium bromide was included in the ^{15}N solution applied preplant at a rate of 150 lbs Br/A. After planting, the 1 ml of solution was dispensed between rows every 5 cm. The rate of ^{15}N for each fertilization is presented in Table 1.

The lower portion of the wheat stem was sampled and analyzed for nitrate content before each irrigation until flowering. Soil moisture was monitored using a neutron probe until mid-jointing. Crop water use was estimated using weather data from the AZMET weather station in the north Gila Valley near Yuma. Rainfall data was obtained from a location near the experimental site and obtained from the Wellton-Mohawk Irrigation District. On May 21, the crop was near physiological maturity, and entire wheat plants were removed from a 2 ft x 2 ft area within each of ten microplots. A plant sample was also removed outside the plot areas for background ^{15}N calculation. The plants were air-dried, weighed, and threshed for grain. The grain was weighed and kernel weight, head number, and yellow berry were determined. Total nitrogen and ^{15}N content of the grain and straw will be determined.

Soil was also sampled on 21 May. A single, 2 inch diameter auger hole was dug in the center of each microplot and in one area outside the plots. The soil was sampled in 1 foot increments to a depth of 13 feet. Nitrate and bromide content of the soil at harvest was determined. Total nitrogen and ^{15}N content of the soil and plant at harvest is currently being determined.

Results and Discussion

Nitrogen Fertilizer Management

The nitrogen fertility program of the grower was very similar to that recommended according to the BMP's of preplant soil testing and in-season tissue analysis. The recommended nitrogen rate based on preplant soil nitrate concentration of 3 ppm is 65 pounds of nitrogen per acre and the grower applied 73 pounds. The stem tissue nitrate concentrations were low, but the grower applied close to recommended rates of nitrogen (Table 2). Large differences in stem tissue concentrations reflect soil heterogeneity and point out difficulties encountered in selecting an "optimum" fertilizer program.

Irrigation Management

Irrigation water was managed well in this particular field. The months of January and February were relatively wet. The first two post-plant irrigations were applied while the soil was fairly moist to supply nitrogen fertilizer and water to a developing root system unable to fully utilize soil resources (Table 3). The irrigation on March 4 may have been applied too late and the May 3 irrigation could have been delayed or, possibly, not applied altogether. Potential for leaching may exist at the first two post-plant irrigations and at the last irrigation.

Yield

The average grain yield for the entire field was 3.4 T/A. The grain yield averaged over the ten microplots was also 2.8 T/A (Table 4). This grain yield will probably be above average for this year, which was not particularly favorable. The total plant yield averaged 6.4 T/A and straw yield was 3.6 T/A. The average harvest index of 46.5% is considered normal. The kernel weights are high for this cultivar and can be attributed to favorable conditions during grain fill.

Nitrogen Fertilizer Movement

Bromide and nitrate amounts in the soil at harvest are presented in Tables 5 and 6. Bromide was applied before the first irrigation and ^{15}N was applied at each fertilization.

Soil bromide concentration was usually greatest near 7 feet. Bromide was very low or not detectable on plots 2, 4, and 6 and may have been detected below 13 feet if we had sampled deeper. Plot 6 was on an unusually sandy spot in the field.

The nitrate concentration in the soil profile at harvest averaged less than 2 ppm, although some individual plots contained much higher levels than this (Table 6). The nitrate levels are considered very low. Appreciable nitrate was detected on two plots only, plots 9 and 10, between 5 and 6 feet below the surface. The nitrate levels at harvest are difficult to assess by themselves, since the initial nitrate values at the beginning of the season are not available for comparison.

Most of the ^{15}N detected in the soil was found in the top 2 feet (Table 7) in non-nitrate form. Approximately 20% of the ^{15}N was found in the top 2 feet of soil, while depths below 3 feet averaged less than 1% recovery. The amount of ^{15}N detected at these lower depths is small and near natural abundance of ^{15}N.

The amount of ^{15}N recovered in the plant averaged 27%, 5% in the straw and 22% in the grain (Table 8). Our plant and soil analyses have accounted for approximately 54% of the applied labelled nitrogen. Some ^{15}N was undoubtedly recovered in the plant crowns, which were not sampled. The applied ^{15}N could also have been lost in the gaseous form due to ammonia volatilization, denitrification, or evolution from the plant.

Acknowledgements

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Table 1. Schedule of irrigation, fertilization, and ^{15}N application.

Date	Stage	Irrigation	Fertilizer	^{15}N
		(inches)	(lbs N/A)	(lbs N/A)
Dec 14	Preplant	—	73	—
Dec 16	Postplant	—	—	3.6
Dec 18	Postplant	6.0	—	—
Jan 31	5-leaf	—	—	1.8
Feb 01	5-leaf	5.9	36	—
Mar 02	3 nodes	—	—	2.5
Mar 04	3 nodes	4.8	55	—
Mar 23	Flower	—	—	1.8
Mar 24	Flower	4.9	36	—
Apr 13	—	5.4	—	—
Apr 25	—	5.4	—	—
May 03	—	4.8	—	—
ALL		37.2	200	9.7

Table 2. Stem nitrate concentrations.

Date	Jan 31	Mar 2	Mar 23
Stage	5-leaf	3 nodes	Flower
Plot	---------- Stem Nitrate (ppm NO_3-N) ----------		
1	563	594	283
2	964	2810	1742
3	2161	3189	1885
4	1182	1486	1050
5	902	901	1323
6	596	278	138
7	2111	328	314
8	2029	221	297
9	3785	1018	325
10	2570	300	582
Recommended N Rate (lb/A)	58	49	36
Actual N Rate (lb/A)	36	55	36

Table 3. Irrigation amounts and rainfall and estimated crop water use since the previous irrigation.

Date	Irrigation Amount	Rain	Water Use
	(inches)		
18 Dec	6.0	—	—
01 Feb	5.9	1.55	1.7
04 Mar	4.8	2.49	1.8
24 Mar	4.9	0.23	7.2
13 Apr	5.4	0.86	4.6
25 Apr	5.4	0.00	3.7
03 May	4.8	0.00	2.0
03 Jun	—	0.33	2.7
Sum	37.2	5.46	24.8

Table 4. Yield and kernel characteristics.

Plot	Total Yield (T/A)	Grain Yield (T/A)	Harvest Index (%)	Kernel Weight (mg)	Spike Size kernels	Spike Density ft^{-2}	Yellow Berry (%)
1	7.9	3.4	42.9	45.6	33.2	46.5	0
2	6.5	2.8	42.5	46.4	31.4	39.5	0
3	7.1	3.2	44.4	45.4	30.4	47.7	0
4	7.3	3.2	44.5	47.2	30.9	46.2	0
5	7.1	2.9	40.2	50.0	25.5	46.7	0
6	4.8	2.2	46.9	48.2	33.2	29.0	0
7	3.9	1.6	41.6	55.8	17.3	35.5	0
8	6.4	3.1	48.3	48.6	30.4	43.5	0
9	5.3	2.5	46.8	50.0	30.3	34.2	0
10	7.1	3.2	44.8	47.2	30.5	46.2	0
ALL	6.4	2.8	44.3	48.4	29.3	41.6	0

Table 5. Bromide concentration (ppm Br^-) in the soil at harvest.

Depth	Plot										
	1	2	3	4	5	6	7	8	9	10	AVG.
ft	Bromide (ppm Br^-)										
1	0.0	0.0	0.0	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.1
2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.3	0.1
3	0.2	0.1	0.1	0.1	0.0	0.1	0.3	0.5	0.3	0.7	0.2
4	0.2	0.1	1.1	0.1	0.1	0.1	0.2	0.4	7.0	0.4	1.0
5	0.7	0.1	1.1	0.1	0.3	0.0	0.3	3.2	4.5	0.2	1.1
6	2.9	0.0	0.2	0.1	2.1	0.1	0.2	4.0	0.7	1.1	1.1
7	4.0	0.3	0.8	0.0	1.6	0.0	2.1	6.5	0.3	0.3	1.6
8	1.3	0.1	0.1	0.0	0.5	0.2	0.4	1.1	0.9	0.3	0.5
9	0.5	0.5	0.5	0.5	0.4	0.0	0.0	0.1	0.0	0.0	0.3
10	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0
11	0.4	0.1	0.2	0.2	0.3	0.3	0.1	0.3	0.4	0.3	0.2
12	0.3	0.1	0.1	0.2	0.5	0.1	0.2	0.4	0.2	0.2	0.2
13	0.1	0.0	0.4	0.2	0.9	0.3	0.4	0.5	0.4	0.1	0.3

Table 6. Nitrate concentration (ppm NO_3-N) in the soil at harvest.

Depth	Plot										
	1	2	3	4	5	6	7	8	9	10	AVG.
ft	Nitrate (ppm NO_3-N)										
1	1.5	2.2	3.2	2.5	2.9	2.8	2.6	2.4	1.9	3.3	2.5
2	0.9	0.9	1.1	0.1	0.8	0.8	0.5	0.6	0.5	0.8	0.7
3	0.1	0.2	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.2
4	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	2.2	0.2	0.3
5	0.2	0.6	0.3	0.5	0.9	0.9	0.5	0.8	10.1	0.8	1.6
6	0.3	0.1	0.4	1.0	2.2	0.8	0.9	0.5	5.4	9.3	2.1
7	0.7	0.3	0.7	2.5	2.9	1.1	0.7	1.1	1.1	4.5	1.6
8	2.6	0.6	0.5	0.7	1.7	1.7	1.1	0.1	0.7	1.3	1.1
9	2.3	1.5	0.7	1.1	1.5	1.3	0.0	0.1	0.0	1.6	1.0
10	0.3	3.4	0.6	0.9	0.1	1.0	0.7	0.5	0.8	1.6	1.0
11	0.0	0.5	0.8	1.9	0.6	0.5	1.5	1.1	0.1	1.4	0.8
12	0.2	0.7	0.5	1.0	0.4	1.0	1.8	0.6	0.0	0.7	0.7
13	0.0	0.7	0.0	1.6	0.3	0.1	0.0	0.1	0.0	0.0	0.3

Table 7. Labeled nitrogen in the soil at harvest.

Depth	Plot										
	1	2	3	4	5	6	7	8	9	10	AVG.
ft	Soil ^{15}N (% of ^{15}N applied)										
1	14.2	6.3	14.0	12.5	19.7	7.8	21.8	15.1	19.5	42.5	17.3
2	2.1	1.3	2.5	1.5	1.1	2.6	4.5	1.9	3.2	2.4	2.3
3	1.4	0.6	0.6	1.9	0.5	0.7	1.2	0.7	0.8	4.1	1.3
4	0.9	0.5	1.0	1.7	0.7	0.8	0.6	1.4	1.3	1.5	1.0
5	0.6	0.5	-0.1	2.0	1.6	0.5	1.0	1.9	1.3	2.4	1.2
6	0.5	0.0	0.5	1.5	1.4	0.7	0.1	0.5	2.8	2.1	1.0
7	0.3	0.7	1.1	0.8	0.9	0.7	0.6	0.3	0.3	2.0	0.8
8	0.7	-0.1	0.7	0.7	0.8	0.5	0.9	0.2	0.3	0.6	0.5
9	0.8	-0.4	0.5	0.9	0.6	1.1	1.9	0.2	0.5	0.9	0.7
10	0.0	-0.1	0.3	1.0	0.1	0.4	0.4	0.6	0.3	0.8	0.4
11	0.2	0.2	0.2	0.9	0.2	0.2	-0.3	0.2	0.1	0.2	0.2
12	0.2	0.2	0.1	0.2	0.1	0.9	-0.2	0.1	0.2	0.5	0.2
13	0.4	0.3	0.1	1.3	0.1	1.1	0.4	0.1	0.3	0.2	0.4
SUM	22.2	10.0	21.6	26.8	27.6	17.9	32.7	23.3	31.0	60.2	27.3

Table 8. Labeled nitrogen in the grain and straw at harvest.

Plant Part	Plot										
	1	2	3	4	5	6	7	8	9	10	AVG.
	Soil ^{15}N (% of ^{15}N applied)										
Grain	23.0	22.1	25.3	24.7	25.3	17.2	16.2	19.6	19.7	24.1	21.7
Straw	6.3	6.2	5.5	5.2	5.5	3.1	6.5	4.1	1.9	5.4	5.0
Total	29.3	28.3	30.9	29.9	30.8	20.2	22.7	23.7	21.6	29.5	26.7