NITROGEN AND WATER REGIME EFFECTS ON CORN YIELDS DETERMINED BY N-15 TRACER TECHNIQUE

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Abstract

This investigation was carried out to determine the relationships between fertilizer nitrogen leaching and N fertilizer application time, method and irrigation rate by using ^{15}N methodology. Therefore, in the field experiments, the effects of three factors namely; a) irrigation rates (optimum 240 mm, high 360 mm), b) N application times (all at planting, 1/2 at planting and 1/2 after planting when plant heights were 50 cm), c) N application methods (sidedress and broadcast) were investigated. The field experiments were conducted using randomized block desing as split-split plot with 4 replications. As the test plant hybrid corn (TUM-82-2) was sowed on a 0.80 m row spacing and 0.25 m seed spacing. Nitrogen was applied 120 kgN/ha to the all treatments as urea fertilizer (46 % N). In addition, to the sub-plots (which received half of N at planting and the other half when plant heights were 50 cm) ^{15}N labelled urea (2.63 % ^{15}N atom excess as 120 kgN/ha) was applied. After harvesting, total N and ^{15}N analyses were done for different plant parts and soil samples.

The results showed us that the seed and total yields were increased with higher (360 mm) irrigation. When N application was sidedressed the availability of N was increased, and also its' loss by leaching from the active root zone was decreased. In conclusion, it was observed that at high irrigation rate was saved about 84 kgN/ha by sidedressing rather than broadcasting of the applied N fertilizer.

Introduction

Main objective of the research on soil and fertilizer N is to maximize the efficiency of N use in crop production. Increase of N use efficiency will increase the value of N as a crop production factor, increase farmer's profits and minimize any adverse effects on the environment that result from inefficient N use. Increase use of N fertilizer may result in large input of N fertilizer to soil from year to year and a corresponding increase in soil N may occur in well aerated fine textured soils (Gass, et.al., 1971. Herron, et. al., 1971). This residual N, while beneficial as a plant nutrient reservour, also may represent a potential loss and health hazard if it leaches beyond the root zone and pollutes ground water when heavy irrigation is done. Little attention has been paid in Çukurova Region (southern part of Turkey) to the possible leaching aspects of N fertilizer, although heavy irrigation and N fertilization practices are being performed by the farmers. Therefore, it is necessary to investigate the factors effecting the efficiency of applied N fertilizer. Isotopically labelled fertilizers provide a unique and valuable tool for this kind of investigation (Paltineanu,et.al.,1980). This investigation was carried out to determine the relationship between corn yields, fertilizer N leaching, fertilizer N application times, methods and applied water regimes using ^{15}N labelled fertilizer.

Material and methods

The field experiments were carrried out at the experimental field of Tarsus Agricultural Research Institute at Cukurova Region in 1985 and 1986. The soil at the experimental site was clay loam with medium organic matter content and alkaline soil reaction. It had low N and P contents, high cation exhange capacity and high K, Na, Ca, Mg contents. In the field experiments the effects of three factors namely; a.) Irrigation rates (240mm for optimum and 360mm for high rate) b.) N application times (all at planting; 1/2 at planting + 1/2 after planting when plants reached to 50 cm height) c.) N application methods (sidedress and broadcast) were investigated by using a randomized block design as split-split plot arrangement with four replications for each treatment. The irrigation rates were arranged as the main plots, N application times as the sub-plots and N application methods as the sub-sub plots.The size of the sub-sub plots were 7m x 4m = 28 m^2. Corn variety TUM-82-2 was planted on April 24, 1985, with a row spacing of 0.80 m and the seed spacing of 0.25 m. Nitrogen (120 kgN/ha) was applied to all treatments as urea (46 % N). Phosphorous (35 kg P_2O_5/ha) was applied to all treatments as triplesuperphosphate (43 % P_2O_5) before sowing. Isotopic plots with the dimension of 1.6 m x 1.25 m = 2.00 m^2 were established in each sub-sub plot which received half of N at planting and the other half when plant heights were 50 cm. Labelled nitrogen fertilizer with an atom excess of 2.63 % N-15 labelled urea were applied to the isotopic plots as 120 kg N/ha. For all treatments irrigation water was applied at two different times, i) at sidedressing (80 mm for optimum rate; 120 mm for high rate), ii) at tasseling (160 mm for optimum rate; 240 mm for high rate), and the amount of applied water to every treatment was measured with a water-meter. The plants were harvested on August 20, 1985. The plants were separated into seed, leaf and stover parts. Also from each treatment, soil samples were taken from the 0-30, 30-60, 60-90 and 90-120 cm depths. Total N analyses in seed, stover and soil samples were done by micro-Kjeldahl and also NO_3-N determination were done for the soil samples. ^{15}N determinatoins for plant and soil samples were done by ^{15}N Jasco emmision spectrometer (Faust, 1981).

The equation used in ^{15}N calculations were;

$$\% \, Ndff = \frac{\% \, ^{15}N \text{ atom excess (plant)}}{\% \, ^{15}N \text{ atom excess (fertilizer)}} \times 100$$

Where Ndff = Nitrogen derived from fertilizer ,

$$\% \, NUE = \frac{(\% \, Ndff)\,(N \text{ yield, kg N/ha})}{\text{Applied N Fertilizer Rate (kg N/ha)}} \times 100$$

All statistical analysis were done by using Mstat-C statistic programme.

Results and discussion

1.) Results related to plant:

a) Yields. The highest seed yield (5680 kg/ha) was obtained from the high irrigation rate when fertilizer was sidedressed at two different growth stages, meanwhile the lowest seed yield (3914 kg/ha) was obtained from the optimum irrigation rate when all of the N fertilizer was broadcasted at planting (Table 1).

Table 1. Yields of Corn Plant (kg/ha)

Irrigation Rate	N Application Time	N Application Method	Average Yields (kg/ha) *		
			Seed (15.5 % Moisture)	Stover (Dried at 65°C)	Total
Optimum irrigation rate (240 mm)	All at Planting	Sidedress	4006 d**	6374 e	10380 f
		Broadcast	3914 d	6666 c	10580 e
	½ at Planting + ½ at 50 cm heigth	Sidedress	4048 d	6690 c	10738 d
		Broadcast	4003 d	6907 b	10910 c
High irrigation rate (240 mm)	All at Planting	Sidedress	4757 b	7163 a	11920 a
		Broadcast	4346 c	6534 d	10880 c
	½ at Planting + ½ at 50 cm heigth	Sidedress	5680 a	6212 e	11892 a
		Broadcast	4783 b	6677 c	11460 b

* Values are the average of 4 replications.

** Values shown with the same letter in each column are not significantly different at 0.01 level

However, the highest seed and stover yields (11920 kg/ha) were obtained from the high irrigation rate when all of N was sidedressed at planting, and the lowest seed and stover yields (10380 kg/ha) were obtained from the optimum irrigation rate when all of N was sidedressed at planting. The increases obtained in seed , stover and seed and stover yields when higher irrigation water applied were found to be significant at 0.01 level. Although there were no significant influences of N application time and method on yields at optimum irrigation rate, significant (at 0.01 level) differences were found at high irrigation rate.

b) % N and N Uptake. Nitrogen contents (% N) of both seed and stover were lower at optimum compared to high irrigation rate,however these differences were not found to be significant (at Table 2). At both irrigation rates, lower % N for seed and stover were obtained when N fertilizer was broadcasted rather than sidedressed. However, these differences in % N were also not found to be significant. Therefore, significantly (at 0.01 level) higher N uptakes at high compared to optimum irrigation rate were resulted due to higher yields obtained at high irrigation rate. Higher total N uptakes were found when N was split applied compared to when all of N applied at planting.Parallel to this trend, N uptakes were higher when N fertilizer was sidedressed rather than broadcasted.

Table 2. % N, Total N yields (kg N/ha) of Corn Plant

Irrigation Rate	N Application Time	N Application Method	Average N * (%)		Total N * Yield (kg N/ha)
			Seed	Stover	
Optimum irrigation rate (240 mm)	All at Planting	Sidedress	1.65	0.77	115.2 e**
		Broadcast	1.68	0.70	112.4 f
	½ at Planting + ½ at 50 cm heigth	Sidedress	1.65	0.77	118.3 d
		Broadcast	1.59	0.70	115.2 e
High irrigation rate (240 mm)	All at Planting	Sidedress	1.66	0.72	130.5 b
		Broadcast	1.56	0.77	118.1 d
	½ at Planting + ½ at 50 cm heigth	Sidedress	1.66	0.66	135.3 a
		Broadcast	1.63	0.65	121.4 c

* Values are the average of 4 replications.

** Values shown with the same letter in each column are not significantly different at 0.01 level

c) % ^{15}N atom excess, % Ndff and % FUE

Different irrigation rates had no significant effect on % ^{15}N a.e. of seed, leaf and stover,however different N application methods had significant (at 0.01 level) effects. Significantly higher % ^{15}N a.e. were obtained when N was sidedressed at both irrigation rates. Calculated % Ndff, and % FUE values showed similar trends, which indicate clearly that plant benefits more from N fertilizer when it is sidedressed rather than broadcasted, and thus leaching of N beyond the plant root zone will be lessened.

2) Results related to soil:

Percent N and total N values in the soil profile to a depth of 120 cm, for years 1985 and 1986 are given in Table 3.

Table 3. % N-15 atom excess of Corn Plant

Irrigation Rate	N Application Time	N Application Method	Average % N-15 a.e. *		
			Seed	Stover	Leaf
Optimum irrigation rate (240 mm)	All at Planting	Sidedress	-	-	-
		Broadcast	-	-	-
	½ at Planting + ½ at 50 cm heigth	Sidedress	0.834	0.879	0.768 b**
		Broadcast	0.766	0.699	0.652 c
High irrigation rate (240 mm)	All at Planting	Sidedress	-	-	-
		Broadcast	-	-	-
	½ at Planting + ½ at 50 cm heigth	Sidedress	0.868	0.814	0.752 a
		Broadcast	0.754	0.677	0.659 d

* Values are the average of 4 replications.

** Values shown with the same letter in each column are not significantly different at 0.01 level

Generally, at similar irrigation rate and N application time, nitrogen moved deeper within the soil profile when it was broadcasted rather than sidedressed. As a fact, for both N application time treatments the average % N at 30 - 60 cm soil depth was found to be % 0.180 and % 0.170 in 1985 and 1986, respectively when N was sidedressed. However they were % 0.193 and % 0.208 when N was broadcasted in 1985 and 1986, respectively. On the other hand, at high irrigation rate when N was sidedressed, % N values were % 0.140 in 1985 and % 0.135 in 1986; but they were % 0.190 and % 0.192 in 1985 and 1986, respectively when N was broadcasted. Similar results were obtained when N was split applied (half at planting and the other half later during the growth stage). Similar trends in total N (t/ha) values were found in both years, and these results all indicated that in order to restrict the movement of N beyond the plant root zone and thus more economical use by the plants, N fertilizer must be applied as sidedressing to corn plant.

In both years, $\%^{15}N$ a.e. and % Ndff values showed differences according to irrigation rate and N application method (Table 4, Fig.1 and 2). Significantly lower $\%\ ^{15}N$ a.e. values were found for optimum irrigation rate in comparison to high irrigation rate, in all depths except 0-30 cm in both years. This result showed clearly that with high irrigation rate N was leached up to 120 cm depth in our experimental conditions. On the other hand $\%\ ^{15}N$ a.e. and % Ndff values for all soil depths were also influenced by N application method. Other researchers also found similar results mainly under high irrigation rates (Bauder and Schneider,1979; Moustafa and Khadr, 1983). Generally, the root distribution of the corn plant is most extensive in 0-60 cm of soil depth (active root zone), although some roots can reach far below 120 cm depth. Therefore it will be more meaningful to discuss the residual N in the soil profile at 0-60 cm depth. The results of the residual N (t/ha) for both years in the soil profile can be summarized as follows:

		Residual N (t/ha)	
	Soil Depth(cm)	1985	1986
Broadcasted			
Opt. Irr. Rate	0 - 60	0.465 b	0.188 a
(240 mm)	60 - 120	0.373 c	0.128 b
High Irr. Rate	0 - 60	0.365 c	0.191 a
(360 mm)	60 - 120	0.546 a	0.208 a
Sidedressed			
Opt. Irr. Rate	0 - 60	0.446 b	0.152 ab
(240 mm)	60 - 120	0.311 c	0.112 b
High Irr. Rate	0 - 60	0.449 b	0.177 a
(360 mm)	60 - 120	0.430 b	0.215 a

Table 4. % Ndff and NUE of Corn Plant

Irrigation Rate	N Application Time	N Application Method	Average % Ndff *			NUE *** (%)
			Seed	Stover	Leaf	
Optimum irrigation rate (240 mm)	All at Planting	Sidedress	-	-	-	-
		Broadcast	-	-	-	-
	½ at Planting + ½ at 50 cm heigth	Sidedress	31.71 a**	33.41 a	29.21 a	30.99 a
		Broadcast	29.13 b	26.57 c	24.78 b	25.75 b
High irrigation rate (240 mm)	All at Planting	Sidedress	-	-	-	-
		Broadcast	-	-	-	-
	½ at Planting + ½ at 50 cm heigth	Sidedress	33.00 a	30.95 b	28.59 a	34.78 a
		Broadcast	28.65 b	25.74 c	25.03 b	20.09 b

* Values are the average of 4 replications.

** Values shown with the same letter in each column are not significantly different at 0.01 level

*** These values are obtained by taking the averages of % Ndff of seed, stover and leaf.

Table 5. Average of Total N (%) and Total N (t/ha) in the soil profile after harvesting (1985, 1986)

Irrigation Rate	N Applicatio n Time	N Application Method	Soil Depth (cm)	1985 Aveg. Total N *		1986 Aveg. Total N *	
				(%)	(t/ha)	(%)	(t/ha)
1	2	3	4	5		6	

1	2	3	4	5		6	
Optimum irrigation rate (240 mm)	All at Planting	Sidedress	0-30	0.195	3.90	0.200	4.00
			30-60	0.180	3.60	0.170	3.40
			60-90	0.150	3.00	0.170	3.40
			90-120	0.138	2.75	0.135	2.70
		Broadcast	0-30	0.198	3.95	0.220	2.40
			30-60	0.193	3.85	0.208	4.16
			60-90	0.160	3.20	0.160	3.20
			90-120	0.138	2.75	0.152	3.04
	½ at Planting + ½ at 50 cm heigth	Sidedress	0-30	0.160	3.20	0.141	2.85
			30-60	0.180	3.60	0.164	3.28
			60-90	0.143	2.85	0.140	2.80
			90-120	0.145	2.90	0.148	2.96
		Broadcast	0-30	0.158	3.15	0.170	3.40
			30-60	0.193	3.85	0.183	3.66
			60-90	0.183	3.65	0.177	3.54
			90-120	0.150	3.00	0.134	2.68
High irrigation rate (360 mm)	All at Planting	Sidedress	0-30	0.165	3.30	0.153	3.06
			30-60	0.160	3.20	0.148	2.96
			60-90	0.165	3.30	0.150	3.00
			90-120	0.140	2.80	0.135	2.70
		Broadcast	0-30	0.155	3.10	0.149	2.98
			30-60	0.175	3.50	0.164	3.28
			60-90	0.185	3.70	0.180	3.60
			90-120	0.190	3.80	0.192	3.84
	½ at Planting + ½ at 50 cm heigth	Sidedress	0-30	0.175	3.50	0.181	3.62
			30-60	0.180	3.60	0.186	3.72
			60-90	0.205	4.10	0.213	4.26
			90-120	0.125	2.50	0.138	2.76
		Broadcast	0-30	0.167	3.34	0.190	3.80
			30-60	0.165	3.30	0.185	3.70
			60-90	0.217	4.34	0.209	4.18
			90-120	0.160	3.20	0.165	3.30
LSD (0.01)				**0.015**	**0.47**	**0.011**	**0.35**

* Values are the average of 4 replications.

Discussion

As it can be seen from the above data, the highest residual N in both years was found in the 60-120 cm soil depth (below the active root zone of corn plant) at high irrigation rate when N was sidedressed. If we compare the residual N found at high irrigation rate when N broadcasted versus N sidedressed we see that 84 kg more of nitrogen per hectare can be available or saved for the next crop in 0-60 cm soil depth by sidedressing the N fertilizer. Similar trends of N movement with high irrigation treatments in the soil profile under corn were observed by Cassel et. al.(1974) and Singh and Sekhan (1976), Herron, et. al.(1971), Gass, et. al.(1971).

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