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Effect of Various Nitrogen Carriers and Irrigation Regimes on Translocation of Nitrogen forms in Maize (*Zea mays* L.) with Two Different Growth Periods: A Column Study

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A column study was conducted during *summer*-2012 at Anand. The treatments comprised each of three levels of nitrogen carriers (prilled urea, urea super granule and neem coated urea) and irrigation regimes (8.0, 6.0 and 4.0 cm depth) as well as two growth periods (40 and 80 days after sowing) in soil column under completely randomized design keeping two repetitions. The soil (loamy sand) belongs to the soil order Inceptisols (*Typic Ustochrept*) with 7.8 pH, 0.35 % OC, low in available N and S, medium in available P_2O_5 and K_2O. Results from this study suggested that NH_4^+-N due to different nitrogen carriers were decreased while NO_3^--N was increased with increase in depth of soil. The NH_4^+ and NO_3^- nitrogen were found higher in soil column under application of USG followed by NCU and prilled urea. The amount of NH_4^+-N was progressively increased but NO_3^--N was decreased with increase in depth of irrigation. The NH_4^+ and NO_3^- nitrogen throughout the column was significantly higher when analyzed during later growth stage as compared to that of early growth period of 40 DAS. Looking to the significant interactions between nitrogen carriers and irrigation regimes in case of N forms in root indicated that use of NCU and/or USG under different irrigation regimes were benefited. Thus present study conclude that use of either slow released nitrogenous fertilizer like USG or nitrification inhibitor materials like NCU enhanced the biological yield and nutrients uptake by maize. They also provide NO_3^--N during crop growth period. The effect of limited use of irrigation water was more pronounced on reduction of transport of NO_3^--N in lower depth of soil.

Keywords: USG, NCU, irrigation regime, Nitrate & Ammonical content.

The increasing global population is now confronted by a major shortage of plant products. In achieving improved and sustainable agriculture in the world, increased productivity from existing farm land is absolutely essential, since additional land is limited, unavailable, and very fragile or must remain in its natural state for strategic purposes and environmental preservation. Soils rarely contain enough nitrogen for optimum plant growth and development for instance most of the Indian soils are low in N. N, which is generally taken up by the plant in NO_3^- and NH_4^+ forms, plays an important role in plant metabolism. Galloway *et al.* (1995) estimate that global N fertilizer production will increase 60–90% by the year 2025, and two-thirds of the total will be applied in the developing world. If efficiency of fertilizer use is not increased, these N fertilizer applications will result in increased N losses as leachate to freshwater and marine systems and as trace gases important in tropospheric and stratospheric chemistry and global climate. Prilled urea is a fast releasing nitrogen fertilizer which causes considerable loss as ammonia volatilization, immobilization, denitrification and surface run off etc. Use of neem

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oil in various form such as neem oil cake, neem oil and other neem product have been found useful in reducing the release of N from urea and increase its use efficiency (Reddy and Prasad, 1975). On the other hand, use of slow releasing nitrogenous fertilizer such as, urea super granule (USG) and neem coated urea have potential to reduce the losses as well as to increases N use efficiency in crops.

Water has unique properties which promote a wide variety of physical, chemical and biological processes. However, the great challenge for the coming decades will be the task of increasing food production with less water, particularly in countries with limited water and land resources as well as inefficient usage of water. An important problem, deserving more attention, is nitrate movement and the loss of nitrate from a soil profile due to leaching. Thus nitrogen fertilizers must remain in the root zone to be taken up by the plants for extends period. Maize, one of the major cereal crop grown in India, ranks third position among cereal crops after wheat and rice. The present investigation was, therefore, undertaken to observe the performance of different slow or controlled released nitrogen fertilizers with varying irrigation depth on maize crop.

MATERIALS AND METHODS

Texture of the bulk surface soil (0-30 cm depth) soil under investigation is loamy sand, very deep belongs to the soil order Inceptisols (*Typic Ustochrept*) under middle Gujarat conditions. The study was carried out in high-density PVC column having 15 cm internal diameter. The total length of column was 100 cm consisting of 15 cm long separable 6 segments (cylinders). These segments were connected to each other by means of adhesive plastic cello tape (Mitsubhishi Make) and at the top of the column, seperate 10.0 cm long section was joined for water application. The columns were sealed at the lower end with an appropriate size of plastic cap, having a few holes for drainage and then columns were placed on plastic container (also acted as stand). The soil was air-dried and ground to pass through 2 mm sieve and was analyzed for physico-chemical properties using standard procedures. Then, the uniform bulk of the soil was stored in polyethylene bags, and later used for filling of soil columns. The treatments comprised each of three levels of nitrogen carriers (prilled urea, urea super granule (USG) and neem coated urea (NCU)) and irrigation regimes (8.0, 6.0 and 4.0 cm depth) as well as two growth periods (40 and 80 days after sowing) in soil column (Table 3). Before packing the soil, the bottom of each column was covered with filter paper (Whatman No.1). Loose (no compaction) soil was filled in columns in such a way to attain field bulk density i.e. after land preparation on the basis of mass and volume, around 1.42 ± 0.01 g/cm^3. In this manner, the columns were packed to a height of 100 cm with total weight of 25 kg soil. Before the sowing of the seeds, mixing of fertilizers in upper segment in columns, single seed of maize (cultivar HQPM 1) was sown in the center of the soil column at the depth of 2-3 cm. The columns were irrigated near to ½ pore volume for distribution of nitrogen throughout the column. The subsequent irrigations were given in each column as per treatments at 15 days intervals, according to different depth of irrigation water were calculated (Table 2). As per treatments the amount of nitrogen through different carriers (Urea, Urea super granule and Neem coated urea) @ half of 150 kg/ha (2.72 g) was mixed in upper 5 cm layers in each column. A common dose of P_2O_5 @ 50 kg/ha through Single Super Phosphate (Table 1). The remaining half dose of nitrogenous fertilizers was applied at 15 days after sowing in the set of both growth stages. After the harvest of crop from each column, the plant and soil samples were collected carefully with separation of each segments of whole soil column. Then, collected soil and plant samples were transferred for further processes likewise cleaning of soil samples, filled in polythene bags and bags were tagged with the treatments information, and also after the cutting of plant samples from each column, it was tagged as per treatment details and stored. The processed soil samples were analyzed for important soil properties. The depthwise distribution of ammonical and nitrate contents in soil samples were estimated by Modified Kjeldahl's method and Phenoldisulphonic acid yellow colour method (spectrophotometric), respectively (Jackson,1973). The statistical analysis of the various parameters studied in the investigation was carried out by using standard statistical methods described by Cochran and Cox (1967).

RESULTS AND DISCUSSION

Effect of nitrogen carriers

Among nitrogen carriers, incorporation of USG significantly increased ammonical nitrogen as compared to NCU and urea in each segment of column. Application of NCU also recorded significantly higher ammonical nitrogen as compared to urea throughout the column. Numerically the highest NH_4^+-N (51.9 ppm) was noticed under USG in surface soil sample (Table 4). The ammonical nitrogen due to different nitrogen carries was progressively decreased with increase in depth of soil. The USG and NCU slowly released and transformed ammonium nitrogen. Cho (1971) reported that concentration of NH_4^+-N decreased almost linearly with increasing depth. The decrease in NH_4^+-N content at subsequently lower depths might be due to low rate of hydrolysis (Singh and Singh, 1999). The depth wise distribution of nitrate nitrogen was increased with increased in depth of soil column. Numerically the highest (13.9 ppm) nitrate N was recorded due to application of USG at 85-100 cm depth of soil in column (Table 5). It remained significantly higher in each segment of column under use of USG and/ or NCU compared to urea. It might be due to slowly released nitrate N from USG and slow transformation from NCU due to its inhibitory effect on transforming bacteria resulting in high nitrate content compared to prilled urea. Nitrate nitrogen not adsorbed on soil colloid surface and moved to deeper depth. The NO_3^--N in deep soil layers was greater in fertilized than unfertilized plots was noted by Getmanets and Avramenko (1976).

Table 1. Quantity of nitrogen and Phosphorus carriers applied per column as per treatments

Carriers	Application rate (kg/ha)	Applied quantity of carriers (g/column)
Urea	150	5.45
Urea super granule	150	5.45
Neem coated urea	150	5.45
Single super phosphate	50	5.24

Table 2. Amount of water applied for different depths of irrigation

Depth of irrigation (cm)	Quantity of water per column (ml)
8.0	1413
6.0	1060
4.0	707

Table 3. Treatment details

Treatment combinations	Treatment details
T_1 ($N_1I_1D_1$)	Urea + 8.0 cm + 40 DAS
T_2 ($N_1I_1D_2$)	Urea + 8.0 cm + 80 DAS
T_3 ($N_1I_2D_1$)	Urea + 6.0 cm + 40 DAS
T_4 ($N_1I_2D_2$)	Urea + 6.0 cm + 80 DAS
T_5 ($N_1I_3D_1$)	Urea + 4.0 cm + 40 DAS
T_6 ($N_1I_3D_2$)	Urea + 4.0 cm + 80 DAS
T_7 ($N_2I_1D_1$)	USG + 8.0 cm + 40 DAS
T_8 ($N_2I_1D_2$)	USG + 8.0 cm + 80 DAS
T_9 ($N_2I_2D_1$)	USG + 6.0 cm + 40 DAS
T_{10} ($N_2I_2D_2$)	USG + 6.0 cm + 80 DAS
T_{11} ($N_2I_3D_1$)	USG + 4.0 cm + 40 DAS
T_{12} ($N_2I_3D_2$)	USG + 4.0 cm + 80 DAS
T_{13} ($N_3I_1D_1$)	NCU + 8.0 cm + 40 DAS
T_{14} ($N_3I_1D_2$)	NCU + 8.0 cm + 80 DAS
T_{15} ($N_3I_2D_1$)	NCU + 6.0 cm + 40 DAS
T_{16} ($N_3I_2D_2$)	NCU + 6.0 cm + 80 DAS
T_{17} ($N_3I_3D_1$)	NCU + 4.0 cm + 40 DAS
T_{18} ($N_3I_3D_2$)	NCU + 4.0 cm + 80 DAS

Effect of irrigation regimes

The data pertaining to depth wise distribution of ammonical nitrogen as affected by irrigation regimes (Table 4) revealed that amount of ammonical nitrogen in each segment progressively decreased with decrease in amount of water applied. In each segment of soil column, application of 8.0 cm depth of water regime was significantly superior to that of 6.0 and 4.0 cm depth of water regimes with respect to ammonical nitrogen. Similarly, application of 6.0 cm depth of water regime was also significantly better than that of 4.0 cm with respect to ammonical nitrogen content in each segment of soil column. The maximum (59.8 ppm) ammonical N was registered under 8.0 cm depth of irrigation water in surface soil sample. Ammonium was fixed on soil particles restrict the leaching losses with irrigation flux. The decreased in NH_4^+-N with increase in soil depth was also reported by Agrawal and Kumar (1978). The reduction in available nitrogen under restricted irrigation was noticed by Reddy and Dakshinamurti (1976). Nitrate-N in each segment of column was increased with decreased in water amount (Table 5). The maximum (14.0 ppm) nitrate N was registered with the application of 4.0 cm depth of irrigation water at 85-100 cm depth of soil in column. The nitrate-N followed the trend of 4.0 > 6.0 > 8.0 cm depth of irrigation. It also increased with increase in soil depth. The nitrate nitrogen has also prone to less adhesion on colloidal surface due to negative charge. The increased in downward movement of nitrate with increase in amount of water applied was also reported by Tahir and Mian (1971).

Effect of growth periods

The ammonical nitrogen throughout the column was significantly decreased when determined during early growth stage (40 DAS) as compared to that of later growth period of 80 DAS (Table 4). The decreasing trend in the amount of ammonical nitrogen with the advancement of crop growth period might be due increased utilization by plants and microbes (Saha *et al.*, 1982). The released of nitrate nitrogen in different segments of the column was significantly increased with increase in growth period i.e. it was significantly lower when determined during early growth stage (40 DAS) as compared to that of later growth period of 80 DAS (Table 5). The ammonium and nitrate nitrogen throughout the column was significantly higher when analyzed during advanced growth stage (80 DAS) as compared to that of early growth period of 40 DAS**.**

Table 4. Ammonical nitrogen content (depth wise) in soil as influenced by different treatments

Treatment	Ammonical N (ppm) Soil Depth (cm)					
	0-20	20-35	35-50	50-65	65-80	80-100
Nitrogen Carrier (N)						
N_1 (Urea)	41.0	38.1	35.6	33.7	32.0	29.3
N_2 (USG)	51.9	50.0	47.7	45.1	43.0	41.0
N_3 (NCU)	50.7	47.6	44.9	42.5	40.7	38.8
S. Em. ±	0.23	0.18	0.19	0.16	0.21	0.20
CD (P=0.05)	0.68	0.54	0.55	0.46	0.62	0.60
Irrigation regime (I)						
I_1 (8.0 cm)	59.8	56.2	53.0	50.6	48.1	45.1
I_2 (6.0 cm)	45.6	42.9	40.1	37.7	36.1	34.1
I_3 (4.0 cm)	38.2	36.7	35.1	32.9	31.5	29.9
S. Em. ±	0.23	0.18	0.19	0.16	0.21	0.20
CD (P=0.05)	0.68	0.54	0.55	0.46	0.62	0.60
Growth duration (D)						
D_1 (40 DAS)	35.1	32.3	29.9	28.0	26.3	24.2
D_2 (80 DAS)	60.6	58.2	55.5	55.8	50.8	48.5
S. Em. ±	0.19	0.15	0.15	0.13	0.17	0.16
CD (P=0.05)	0.56	0.44	0.45	0.38	0.51	0.49
Interaction						
N x I	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
N x D	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
I x D	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
N x I x D	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
C.V. %	1.66	1.38	1.50	1.33	1.87	1.91

Effect of interaction

At a given source of nitrogen fertilizer, the ammonical nitrogen content increased with decrease in amount of water applied at both the growth stages. Significantly the highest (76.7 ppm) ammonical nitrogen was registered when neem

Table 5. Nitrate nitrogen content (depth wise) in soil as influenced by different treatments

Treatment	Ammonical N (ppm) Soil Depth (cm)					
	0-20	20-35	35-50	50-65	65-80	80-100
Nitrogen Carrier (N)						
N_1 (Urea)	7.7	8.1	8.5	9.1	9.1	9.1
N_2 (USG)	9.5	10.6	12.1	12.5	12.7	13.9
N_3 (NCU)	9.2	10.1	10.9	11.8	12.0	11.5
S. Em. ±	0.05	0.01	0.03	0.02	0.03	0.02
CD (P=0.05)	0.1	0.03	0.09	0.06	0.09	0.05
Irrigation regime (I)						
I_1 (8.0 cm)	7.8	8.2	9.2	9.7	9.8	9.8
I_2 (6.0 cm)	8.9	9.6	10.4	10.8	10.7	10.7
I_3 (4.0 cm)	9.8	10.9	11.9	12.9	13.4	14.0
S. Em. ±	0.05	0.01	0.03	0.02	0.03	0.02
CD (P=0.05)	0.1	0.03	0.09	0.06	0.09	0.05
Growth duration (D)						
D_1 (40 DAS)	7.0	8.2	9.4	10.0	10.1	10.3
D_2 (80 DAS)	10.6	11.0	11.6	12.3	12.5	12.7
S. Em. ±	0.04	0.01	0.02	0.02	0.03	0.01
CD (P=0.05)	0.1	0.03	0.07	0.05	0.08	0.04
Interaction						
N x I	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
N x D	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
I x D	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
N x I x D	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
C.V. %	1.94	0.41	0.99	0.58	0.97	0.51

Table 6. Interaction effect of nitrogen carriers, irrigation regimes and growth duration on ammonical nitrogen content in soil (depth wise)

Depth(cm)		Ammonical N (ppm)											
		N_1			N_2			N_3			S. Em.	CD	C.V.
		I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3	±	(P=0.05)	%
0-20	D_1	30.7	28.3	22.7	58.1	33.1	28.3	57.7	31.7	25.6	0.561	1.67	1.66
	D_2	61.2	55.6	47.7	74.6	63.6	53.6	76.6	61.2	51.2			
20-35	D_1	26.6	24.7	21.6	54.7	31.3	26.7	53.2	28.4	23.6	1.313	1.31	1.38
	D_2	57.7	52.3	45.7	72.7	61.9	52.6	72.4	58.6	49.7			
35-50	D_1	22.6	22.1	20.7	52.6	28.4	24.7	50.1	26.3	22.0	0.453	1.35	1.50
	D_2	54.7	49.7	43.7	69.7	59.6	51.2	68.1	54.8	48.4			
50-65	D_1	21.9	20.5	18.2	50.2	25.6	22.7	47.7	23.9	21.6	0.380	1.13	1.33
	D_2	52.6	47.6	41.6	66.2	58.3	47.4	65.2	50.7	46.0			
65-80	D_1	19.7	19.0	17.6	48.3	23.0	21.3	46.0	22.2	19.6	0.510	1.52	1.87
	D_2	48.5	46.6	40.5	63.1	56.6	45.5	62.6	49.3	44.3			
80-100	D_1	16.6	17.2	15.9	44.6	20.8	20.0	43.6	20.7	18.7	0.491	1.46	1.91
	D_2	44.4	43.6	38.2	61.7	54.7	44.3	59.7	47.7	42.3			

coated urea was used in combination with 8.0 cm depth of irrigation water was applied up to second growth period (N_3 x I_3 x D_2) lower as compared to that of 6.0 cm depth of irrigation water (Table 6). Beri *et al.* (1978) reported that most of the urea leached down with wetting front in initially dry soil. A part of the nitrogen remained close to the surface was hydrolyzed urea (NH_4^+-N). Significantly the highest (19.2 ppm) nitrate-N was registered when USG was used in combination with 4.0 cm depth of irrigation during advanced growth period (N_2 x I_3 x D_2) at 80-100 cm depth in soil column (Table 7). Similarly Singh and Yadav (1991) reported that NH_4^+-N did not move to lower layers in early stage of crop growth, but latter some NH_4^+-N moved to 15-30 cm layer and NO_3^--N leached to lower layers as irrigation rate increased (5 cm to 7.5 cm).

CONCLUSION

Thus from the results, it is quite evident to conclude that use of either slow released nitrogenous fertilizer like urea super granule or nitrification inhibitor materials like neem coated urea enhanced the biological yield and nutrients uptake by maize. They also provide sustained supply of nitrate nitrogen during crop growth period. Transport of nitrate nitrogen in lower depths of soil can be reduced by limited use of irrigation water.

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