SPATIAL AND TEMPORAL DISTRIBUTION OF NITROGEN IN MAIZE UNDER DRIP FERTIGATION

ABSTRACT

Field experiment was conducted during *kharif* 2018, *rabi* 2018-19 and *kharif* 2019 at Dr. NTR College of Agricultural Engineering, Bapatla, Andhra Pradesh to study the spatial and temporal distribution of nitrogen in maize. The experiment was laid out in split plot design consisting of three irrigation levels 0.6, 0.8 and 1.0 ETc and four nitrogen levels consisting of fertigation levels 80%, 100%, 120% RDN on sandy clay loam soil. There were significant variation due to irrigation and fertility levels at all the stages of crop growth. Generally, the availability of nitrogen increased when irrigation as well as fertilizer level increased up to maturity stage. The maximum available nitrogen was in the depth of 0- 30 cm range and then decreased vertically.

Key words: Nutrient distribution, Drip fertigation, Maize crop

1. INTRODUCTION

Fertigation is particularly important for irrigated agriculture in sandy soils where large quantities of fertilizers should be applied to meet crop requirements and to prevent loss by leaching. It has been proved as one of the superior method for applying water and nutrients through the drip irrigation system.

Nitrogen applied to soil undergoes number of transformations like hydrolysis, mineralization, ammonia volatization, nitrification and denitrification. The process of nitrification converts the NH_4-N to NO_3-N (nitrate nitrogen), which is highly vulnerable to leaching along with the soil water. The leached NO_3-N is generally not available to plant and contaminates the ground water storage. When there is a high drainage condition in the soil profile leaching of nitrate occurs and accumulated with NO_3-N (Di and Cameron, 2002). Careful use of water and nitrogen can lessen the total of NO_3-N leaching below the root zone of crop (Drost and Koening, 2001). It is not possible to completely eradicate leaching losses while obtaining optimum crop water productivity, but uniform water and nutrient application can reduce the leaching losses to a lowest.

Optimization of fertigation parameters based on lowering nitrate leaching in one incident is not sufficient, and proper application of fertigation in the crop period should be considered at the same time. Ideal application of nutrients in the root zone of crop ensures their optimum utilization, higher crop yield and subsidiary nutrients losses. Therefore, optimization of fertigation has dominant role in implementation of micro-irrigation systems to acquire better quality and quantity of agricultural production without degradation of soil and groundwater.

Thus to understand the movement of nutrient with water in drip irrigation, it is essential to study the distribution of water and nitrogen in the different soil layers. Hence, the present study has been planned at Dr NTR College of Agricultural Engineering, Bapatla to study the nutrient dynamics in order to increase irrigation water and fertilizer use efficiency to avoid pollution of ground water in maize crop. Maize (*Zea mays*) well known as Queen of cereals, also called corn belongs to Graminae family. It is the principal one of the cereal crops of the world. Maize is an extensive staple food in many regions of the world and it is recycled in food processing, feed industry and in various other industrial applications.

2. MATERIALS AND METHODS

2.1 STUDY AREA

The field experiment was conducted during *kharif* 2018, *rabi* 2018-19 and *kharif* 2019 under maize crop at the field irrigation laboratory, Department of Soil and Water Engineering, Dr. N. T. R. College of Agricultural Engineering, Bapatla, Guntur district of Andhra Pradesh State, India. “Geographically the experimental site is located at latitude of 16^0 N and longitude of 88^0 E with an altitude of 6 m above mean sea level” .[21]

2.2 PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL

Soil samples were collected at every 15 cm layers from land surface till the soil depth of 90 cm using soil augur to characterize the soil. The collected soil samples were analysed in laboratory for determining the physical and chemical properties (Table 1 and 2).

Table 1. Physical properties of the experimental soil [21]

Soil depth from surface (cm)	Mineral content (% mass)			Textural class	Hydraulic conductivity (cm/h)	Bulk density (g/cm^3)	Field capacity (% vol)	Permanent wilting point (% vol)
	Clay	Silt	Sand					
0-15	35	10	55	Sandy clay loam	0.94	1.37	21.48	6.73
15-30	35	10	55	Sandy clay loam	0.50	1.57	27.17	9.12
30-45	30	10	60	Sandy clay	0.46	1.53	28.24	10.56
45-60	35	5	60	Sandy clay loam	0.96	1.63	27.69	10.92
60-75	35	5	60	Sandy clay loam	0.96	1.63	27.73	11.61
75-90	30	5	65	Sandy clay loam	0.95	1.67	26.62	10.75

Table 2. Chemical properties of the experimental soil[21]

Soil depth from surface (cm)	pH	EC (ds m^{-1})	Organic carbon (%)	Available		
				N(kg ha^{-1})	P(kg ha^{-1})	K(kg ha^{-1})
0-15	5.62	0.10	0.27	141.12	28.21	141.12
15-30	6.86	0.16	0.12	147.39	34.88	87.36
30-45	7.05	0.20	0.10	119.16	21.03	87.36
45-60	5.34	0.11	0.09	56.44	13.33	53.76
60-75	5.14	0.05	0.075	40.76	12.82	53.76
75-90	5.42	0.03	0.06	25.08	11.28	47.07

2.3 DESIGN AND INSTALLATION OF FERTIGATION SYSTEM

A drip irrigation system was designed for the experiment under DEKALB DKC 8161 variety of hybrid maize crop. The lateral lines were spaced at 1.2 m interval. Inline drip emitters with 2.0 lph rated discharge were placed on the lateral line at a spacing of 30 cm. Each plot has three laterals with a net plot size of 8.0 m × 3.6 m (28.8 m^2). A total of 36 plots were designed for the entire field area of 1350 m^2 (54 × 25 m). A control valve was provided to each plot to regulate the operation of irrigation and fertigation. The installation of surface drip irrigation system in the experimental field was shown in Plate.1.

Plate 1. Experimental details

Field experiment was conducted with DEKALB DKC 8161 variety of hybrid maize under drip irrigation in split plot design consisting of three irrigation levels as main treatment and four fertigation levels as sub treatments with three replications during *kharif* 2018 and *rabi* 2018-19 at the Field irrigation lab, Dr. NTR College of Agricultural Engineering, Bapatla. Maize seed was sown in a paired row system as plant to plant and row to row spacings were 20 cm and 40 cm, respectively [(80 cm + 40 cm) × 20 cm] (Fig.1).

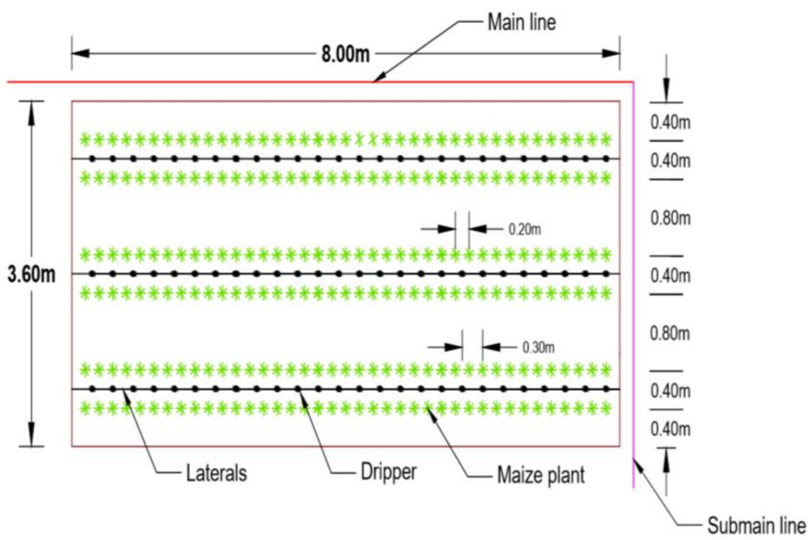

Fig. 1 Layout of each plot in the experiment

The treatments in the experiment are as follows:

Main plots: Irrigation levels (I)

I = 0.6, 0.8 and 1.0 of the crop evapotranspiration as I1, I2 and I3

Sub plots: Fertigation levels (N)

N_1= Drip fertigation with 80% of recommended dose of nitrogen (CF)

N_2= Drip fertigation with 100% of recommended dose of nitrogen (CF)

N_3= Drip fertigation with 120% of recommended dose of nitrogen (CF)

N_4= No drip fertigation (manual application) with 100% of recommended dose of nitrogen (CF)

(CF= Conventional Fertilizers)

2.4 MANURING AND FERTILIZER APPLICATION

Farm yard manure (FYM) was applied to the field at the rate of 24.7 t ha^{-1} in the final ploughing operation. The fertilizers used in the experiment were urea, single super phosphate and muriate of potash. Therecommended dose of fertilizers for *Kharif* is 180:60:50 Kg ha^{-1} NPK and 200:80:80 Kg ha^{-1} NPK for *rabi*(VyavasayaPanchangam, ANGRAU, 2018). Treatment wise requirement of N, P and K were estimated. P was applied as basal application manually and the 50% of K was applied in basal at the time of sowing and remaining 50% of K was applied at flowering stage manually. To optimize the fertigation scheduling, the estimated quantity of N for treatments was applied through venturi under drip fertigation at every 10 days interval. Standard cultural practices were adopted during both the crop-growing seasons. The fertigation schedule for maize crop grown seasons during *kharif* and *rabi* are shown in Table 3 and 4. The details of fertigation date and quantity of nitrogen in each fertigation for three seasons are given in Table 5.

Table 3Fertigation schedule for Kharif season

Crop stages (Days after sowing, DAS)	Nitrogen quantity (%)	80%RDN (144kg N.ha^{-1})	100%RDN (180kg N.ha^{-1})	120%RDN (216kg N.ha^{-1})
Vegetative stage (6-30 DAS)	25	36	45	54
Reproductive stage (31-60 DAS)	50	72	90	108
Maturity stage (61-75 DAS)	25	36	45	54
Total	**100**	**144kg N.ha^{-1}**	**180kg N.ha^{-1})**	**216kg N.ha^{-1})**

Table 4 Fertigation schedule for Rabi season

Crop stages (DAS)	Nitrogen quantity (%)	80%RDN (160kg N.ha^{-1})	100%RDN (200kg N.ha^{-1})	120%RDN (240kg N.ha^{-1})
Vegetative stage (6-30 DAS)	25	40	50	60
Reproductive stage (31-60 DAS)	50	80	100	120
Maturity stage (61-75 DAS)	25	40	50	60
Total	**100**	**160kg N.ha^{-1}**	**200kg N.ha^{-1}**	**240kg N.ha^{-1}**

Crop stage	**Fertigation date and quantity of urea in each treatment (g)**					
	Kharif 2018			**Rabi 2018-19**		
	Date of fertigation	**Treatment**	**Quantity of Urea**	**Date of fertigation**	**Treatment**	**Quantity of Urea**
Vegetative stage (6-30 DAS)	29.07.2018	N1	1050	30.11.2018	N1	1120
		N2	1320		N2	1400
		N3	1590		N3	1680
		N4	1320		N4	1400

	08.08.2018	N1	1050	10.12.2018	N1	1120
		N2	1320		N2	1400
		N3	1590		N3	1680
		N4	1320		N4	1400
Reproductive stage (31-60 DAS)	18.08.2018	N1	1410	20.12.2018	N1	1500
		N2	1770		N2	1870
		N3	2120		N3	2250
		N4	1770		N4	1870
	28.08.2018	N1	1410	29.12.2018	N1	1500
		N2	1770		N2	1870
		N3	2120		N3	2250
		N4	1770		N4	1870
	07.09.2018	N1	1410	09.01.2019	N1	1500
		N2	1770		N2	1870
		N3	2120		N3	2250
		N4	1770		N4	1870
Maturity stage (61-75 DAS)	17.09.2018	N1	1050	19.01.2019	N1	1120
		N2	1320		N2	1400
		N3	1590		N3	1680
		N4	1320		N4	1400
	27.09.2018	N1	1050	29.01.2019	N1	1120
		N2	1320		N2	1400
		N3	1590		N3	1680
		N4	1320		N4	1400

Table 5 Fertilizer application schedule during crop seasons

2.5 DETERMINATION OF AVAILABLE NITROGEN IN SOIL

Available nitrogen in a soil represents that fraction of the total N which is usable by the plants. The inorganic N in soil is predominantly in NH_4^- and NO_3^- forms. To determine the available nitrogen, soil samples were collected at 0, 15, 30, 45 cm distance from emitter across the lateral in the depths of 0-15, 15-30, 30-45, 40-60 cm interval using soil augur at crop initial stage, development stage, maturity stage and post harvest to determine the soil nitrogen (N) content for their spatial distribution in different soil layers. Kjeldahl method was used to analyse the soil samples for estimating the nitrate and ammonium concentration in different soil layers. Distillation and titration are the two primarily processes involved in determining the ammonium and nitrate form of nitrogen. Steam distillation of extracted samples derived from well stirred 2M KCI solution was carried out with MgO to determine ammonium concentration in the soil. To obtain the nitrate form of nitrogen, steam distillation of same sample was again done with Devarda's alloy. During each case, gas liberated through steam distillation was collected in H_3BO_3 indicator solution. Titration was carried out with standard 0.02 N H_2SO_4 solutions to obtain ammonium nitrogen and nitrate nitrogen concentration.

3. RESULTS AND DISCUSSION

3.1 Spatial and temporal distribution of nitrogen and nitrogen uptake during crop growing periods

3.1.1 AVAILABLE NITROGEN DURING *KHARIF* 2018

During *kharif* 2018 (Fig.2,3,4 and 5) the more availability of nitrogen (144.4, 197.6, 197.6 and 116.6 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm at emitter in the treatment I_1N_1. In 15 cm from emitter the highest availability of nitrogen was observed as 150.5 kg ha^{-1} at 15-30 cm depth in vegetative stage and the higher availability of nitrogen (200.7, 207.0 and 119.2 kg ha^{-1}) was observed at a depth of 0-15 cm for reproductive stage, maturity stage and post harvest respectively. In treatment $I_1N_2$the higher availability of nitrogen (150.5, 200.7, 241.5 and 119.2 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at emitter in a depth of 15-30 cm. In 15 cm from emitter the highest availability of nitrogen was observed as 147.4 kg ha^{-1} at 15-30 cm and 30-45 cm depth in vegetative stage and the higher availability of nitrogen (216.4, 247.7 and 159.9 kg ha^{-1}) was observed at a depth of 0-15 cm for reproductive stage, maturity stage and post harvest respectively. In treatment $I_1N_3$the higher availability of nitrogen (156.8, 207.0, 238.3 and 128.6 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm at emitter. In 15 cm from emitter the highest availability of nitrogen was observed as 169.3, 210.1 and 150.5 kg ha^{-1} at 15 cm depth in vegetative stage, reproductive stage, and post harvest. In case of maturity stage, the higher availability of nitrogen 235.2 kg ha^{-1} was observed at a depth of 15-30 cm. In case of I_1N_4 the higher availability of nitrogen (166.2, 191.3, 222.7 and 119.2 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm at emitter. In 15 cm from emitter the highest availability of nitrogen (172.5, 203.8, 225.8 and 141.1 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 0-15 cm.

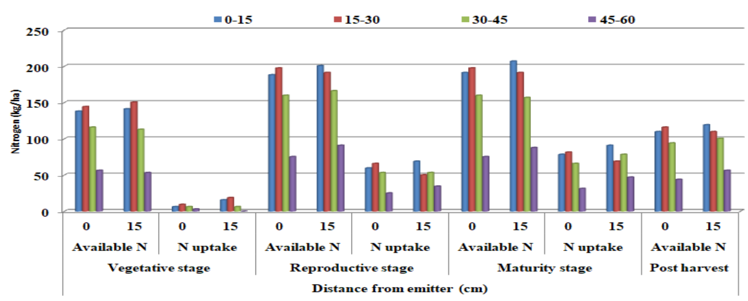

Fig. 2 Available N and N uptake in soil at different depths for I_1N_1 during *kharif*2018

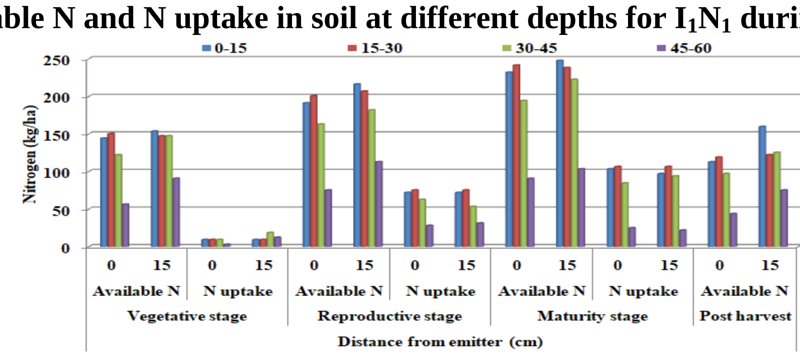

Fig. 3 Available N and N uptake in soil at different depths for I_1N_2 during *kharif* 2018

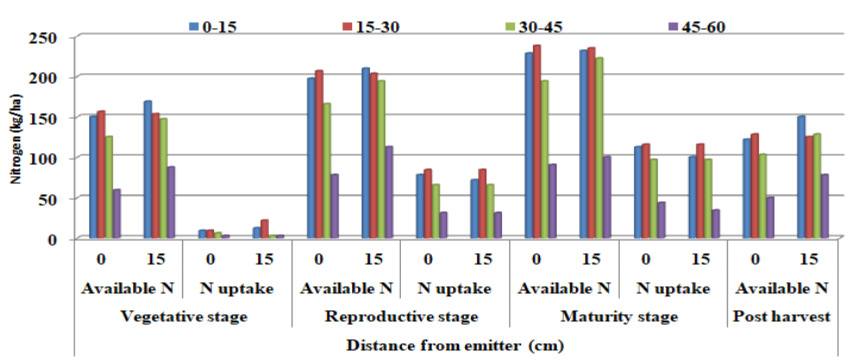

Fig. 4 Available N and N uptake in soil at different depths for I_1N_3 during *kharif* 2018

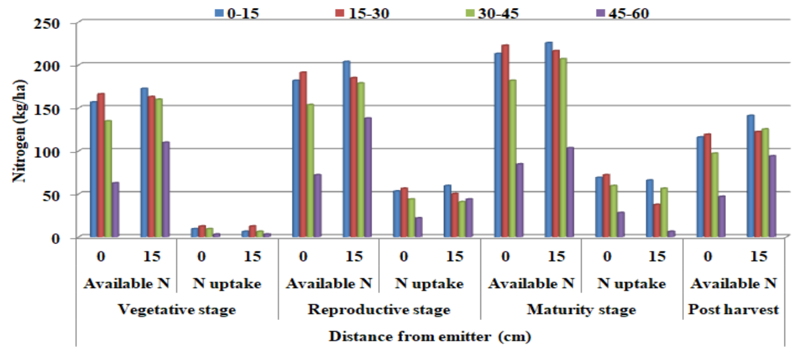

Fig. 5 Available N and N uptake in soil at different depths for I_1N_4 during *kharif* 2018

For I_2 treatments (Fig.6,7,8 and 9) the higher availability of nitrogen (150.5, 207.0, 247.7 and 125.4 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm at emitter in the treatment I_2N_1. In 15 cm from emitter, the highest availability of nitrogen (163.1, 216.4, 247.7 and 144.3 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 0-15 cm. In treatment $I_2N_2$the higher availability of nitrogen (159.9, 216.4, 254.0 and 125.4 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm at emitter in the treatment. In 15 cm from emitter the highest availability of nitrogen (172.5, 225.8, 257.2 and 141.1 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 0-15 cm. In case of 30 cm from emitter at vegetative stage the same amount of available nitrogen was found between the depth 0-30 cm (134.8 kg ha^{-1}) and at 15-30 cm depth the higer available nitrogen was found in reproductive and maturity stage. At post harvest it was higher in top 15 cm depth (103.5 kg ha^{-1}). In treatment I_2N_3, the higher availability of nitrogen was found in 15-30 cm depth at emitter (169.3, 216.4, 257.2 and 125.4 kg ha^{-1}) and 30 cm from emitter (144.3, 191.3, 232.1 and 100.4 kg ha^{-1}). In 15 cm from emitter, it was higher at 0-15 cm depth (178.8, 228.9, 263.4 and 138 kg ha^{-1}). In case of I_2N_4 the higher availability of nitrogen (172.5, 197.6, 235.2 and 213.2 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm at emitter. In 15 cm from emitter, the highest availability of nitrogen (185.0, 207.0 and 241.5 kg ha^{-1} at vegetative stage, reproductive stage and maturity stage) was observed at a depth of 0-15 cm. At post harvest, it was higher at 15-30 cm depth (207 kg ha^{-1}).

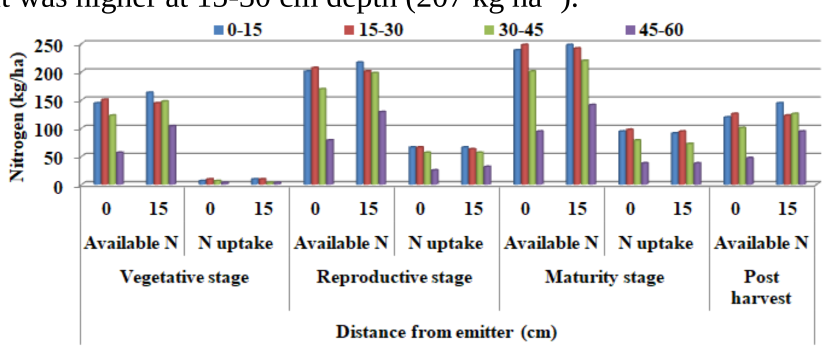

Fig. 6 Available N and N uptake in soil at different depths for I_2N_1 during *kharif* 2018

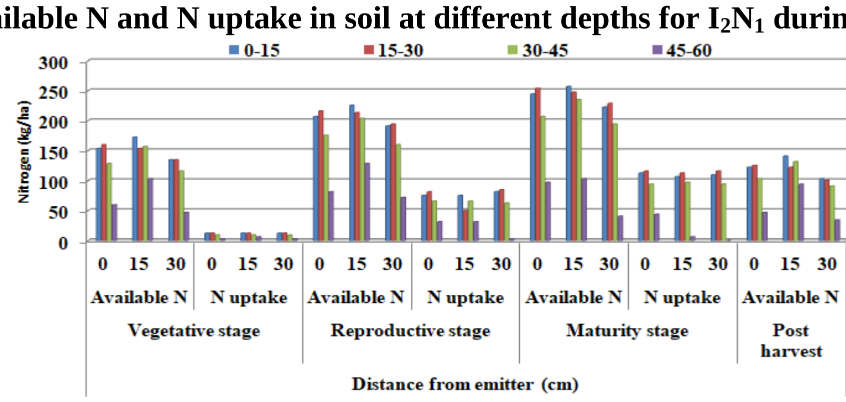

Fig. 7 Available N and N uptake in soil at different depths for I_2N_2 during *kharif* 2018

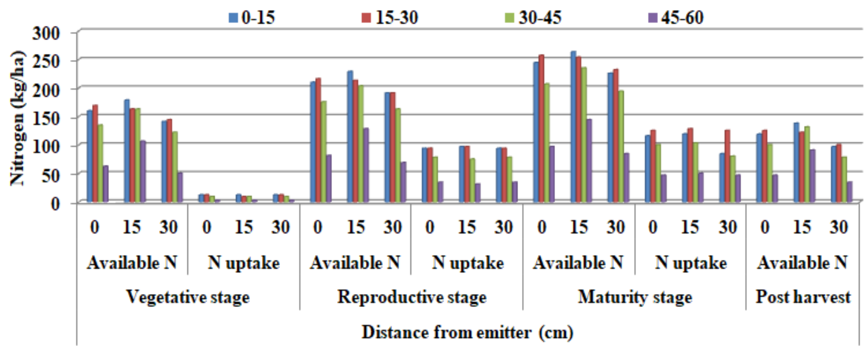

Fig. 8 **Available N and N uptake in soil at different depths for I_2N_3 during *kharif* 2018**

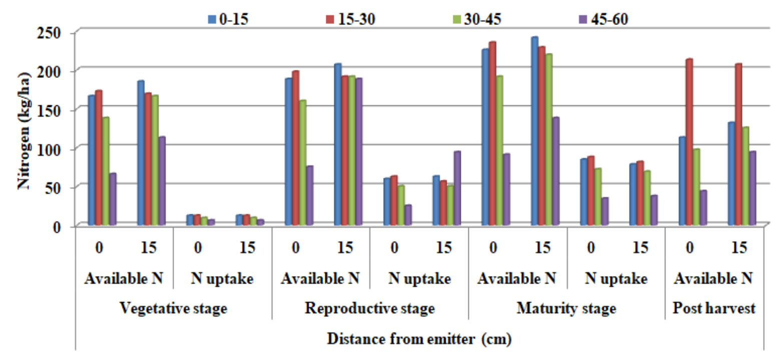

Fig. 9 **Available N and N uptake in soil at different depths for I_2N_4 during *kharif* 2018**

For I_3 treatments (Fig.10,11,12 and 13) the higher availability of nitrogen (153.7, 213.2, 241.5 and 128.6 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm at emitter in the treatment I_3N_1. In 15 cm from emitter the highest availability of nitrogen (166.2, 222.7, 250.9 and 141.1 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 0-15 cm. In treatment I_3N_2, the higher availability of nitrogen (163.1, 222.7, 250.9 and 128.6 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm at emitter. In 15 cm from emitter, the highest availability of nitrogen (175.6, 232.1, 257.2 and 141.1 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 0-15 cm. In case of 30 cm from emitter at vegetative stage, the same amount of available nitrogen was found between the depth 0-30 cm at vegetative stage (138.8.0 kg ha^{-1}) and post harvest (103.5 kg ha^{-1}). At reproductive stage, maturity stage it was higher at 15-30 cm depth (197.6 and 225.8 kg ha^{-1}). In case of 45 cm from emitter, the higher availability of nitrogen (134.8, 194.4, 222.7 and 100.4 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm.

In treatment $I_3N_3$the higher availability of nitrogen (175.6, 222.7, 247.7 and 125.4 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm at emitter. In 15 cm from emitter, the highest availability of nitrogen (232.1, 257.2 and 141.1 kg ha^{-1} at reproductive stage, maturity stage and post harvest) was observed at a depth of 0-15 cm. At vegetative stage, it was higher (200.7 kg ha^{-1}) in 30-45 cm depth. In case of 30 cm from emitter, the higher availability of nitrogen (150.5, 197.6 and 222.7 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage) was observed at a depth of 15-30 cm. At post harvest, it was higher (103.5 kg ha^{-1}) in 0-15 cm depth. In case of 45 cm from emitter, the higher availability of nitrogen (147.4, 194.4, 219.5 and 97.2 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm. The higher availability of nitrogen (175.6, 200.7, 222.7 and 119.2 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 15-30 cm at emitter in the treatment I_3N_4. In 15 cm from emitter, the highest availability of nitrogen (188.2, 210.1, 235.2 and 134.8 kg ha^{-1} at vegetative stage, reproductive stage, maturity stage and post harvest) was observed at a depth of 0-15 cm.

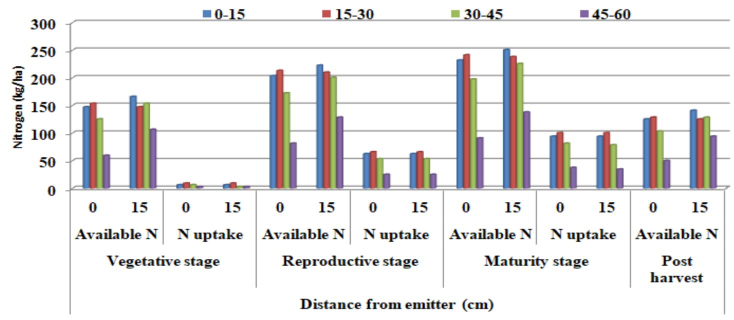

Fig. 10 Available N and N uptake in soil at different depths for I_3N_1 during *kharif* 2018

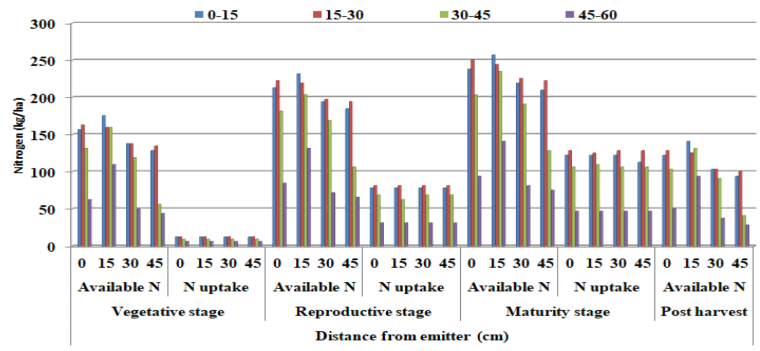

Fig. 11 Available N and N uptake in soil at different depths for I_3N_2 during *kharif* 2018

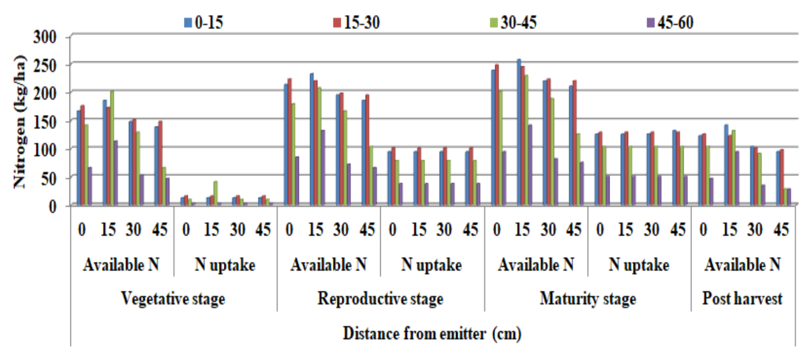

Fig. 12 Available N and N uptake in soil at different depths for I_3N_3 during *kharif* 2018

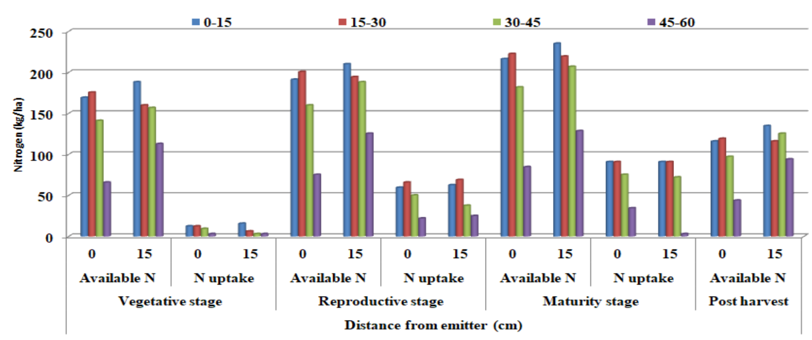

Fig. 13 Available N and N uptake in soil at different depths for I_3N_4 during *kharif* 2018

3.1.2 NITROGEN UPTAKE DURING *KHARIF* 2018

Total available nitrogen in the soil included ammonical nitrogen (NH_4 - N) and nitrate nitrogen ($N0_3$ – N). The nitrogen uptake from soil at four soil layers (0-15, 15-30, 30-45 and 45-60 cm) for vegetative stage, reproductive stage and maturity stage were estimated using the procedure described in Materials and Methods. The results showed a significant variation due to irrigation and fertility levels at all the stages of crop growth. Generally the nitrogen uptake was found to be increased when irrigation as well as fertilizer level increased up to maturity stage.

During *kharif* 2018 (Fig.2, 3, 4 and 5), the higher uptake of nitrogen (9.4, 65.9 and 81.5 kg ha^{-1} at vegetative stage, reproductive stage and maturity stage) was observed at a depth of 15-30 cm at emitter in the treatment I_1N_1. In 15 cm from emitter, the highest nitrogen uptake was observed as 18.8 kg ha^{-1} at 15-30 cm depth in vegetative stage and the higher nitrogen uptake (69.0 and 90.9 kg ha^{-1}) was observed at a depth of 0-15 cm for reproductive stage and maturity stage respectively. In treatment $I_1N_2$the higher nitrogen uptake (9.4 kg ha^{-1}) was observed at emitter in a depth of 0-45 cm in vegetative stage and higher nitrogen uptake (75.3 and 106.6 kg ha^{-1}) was observed at a depth of 15-30 cm in reproductive stage and maturity stage. In 15 cm from emitter, the highest nitrogen uptake was observed as 18.8 kg ha^{-1} at 30-45 cm depth in vegetative stage and the higher nitrogen uptake (75.3 and 106.6 kg ha^{-1}) was observed at a depth of 15-30 cm for reproductive stage and maturity stage respectively. In treatment I_1N_3,the higher nitrogen uptake (9.4, 84.7 and 116.0 kg ha^{-1} at vegetative stage, reproductive stage and maturity stage) was observed at a depth of 15-30 cm at emitter. In 15 cm from emitter, the highest nitrogen uptake was observed as 22.0, 84.7 and 116.0 kg ha^{-1} at 15-30 cm depth in vegetative stage, reproductive stage and maturity stage. In case of I_1N_4 the higher nitrogen uptake (12.5, 56.4 and 72.1 kg ha^{-1} at vegetative stage, reproductive stage and maturity stage) was observed at a depth of 15-30 cm at emitter. In 15 cm from emitter, the highest nitrogen uptake of 12.5 kg ha^{-1} at vegetative stage at a depth of 15-30 cm and 59.6 and 65.9 kg ha^{-1} of nitrogen uptake in reproductive stage and maturity stage was observed at a depth of 0-15 cm.

For I_2 treatments (Fig.6,7,8 and 9) the higher nitrogen uptake (6.4, 65.9 and 97.2 kg ha^{-1} at vegetative stage, reproductive stage and maturity stage) was observed at a depth of 15-30 cm at emitter in the treatment I_2N_1. In 15 cm from emitter, the highest nitrogen uptake of 9.4 kg ha^{-1} was observed at a depth of 0-30 cm in vegetative stage and 65.9 kg ha^{-1} was observed at a depth of 0-15 cm in reproductive stage and at maturity stage 64.1 kg ha^{-1} was observed at a depth of 15-30 cm. In treatment I_2N_2,the higher nitrogen uptake (12.5, 81.5 and 116.0 kg ha^{-1} at vegetative stage, reproductive stage and maturity stage) was observed at a depth of 15-30 cm at emitter in the treatment. In 15 cm from emitter, the highest nitrogen uptake of 12.5 kg ha^{-1} at vegetative stage was observed at a depth of 0-30 cm and 75.3 kg ha^{-1} at reproductive stage was observed at a depth of 0-15 cm and 112.9 kg ha^{-1} at maturity stage was observed at a depth of 0-15 cm. In case of 30 cm from emitter, the highest value (12.5, 84.7 and 116 kg ha^{-1} at vegetative stage, reproductive stage, and maturity stage) was observed at a depth of 15-30 cm. In treatment I_2N_3, the higher nitrogen uptake was found in 0-30 cm depth at emitter (12.5 and 94.1 kg ha^{-1}) in vegetative stage and reproductive stage. In maturity stage, the higher nitrogen uptake (125.4 kg ha^{-1}) was in 15-30 cm depth. At 15 cm from emitter, the highest nitrogen uptake of 12.5 kg ha^{-1} in 0-15 cm, 97.2 kg ha^{-1} in 0-30 cm and 128.6 kg ha^{-1} in 15-30 cm was observed at vegetative stage, reproductive stage, and maturity stage respectively. At 30 cm from emitter, the highest nitrogen uptake of 12.5 kg ha^{-1} in 0-30 cm, 94.1 kg ha^{-1} in 0-30 cm and 125.4 kg ha^{-1} in 15-30 cm was observed at vegetative stage, reproductive stage, and maturity stage respectively. In treatment I_2N_4,the higher nitrogen uptake of 12.5 kg ha^{-1} in 0-30 cm, 94.1 kg ha^{-1} in 0-30 cm and 62.7 and 87.8 kg ha^{-1} in 15-30 cm in vegetative stage, reproductive stage, and maturity stage at emitter was observed. At 15 cm from emitter, the highest nitrogen uptake of 12.5 kg ha^{-1} in 0-30 cm, 62.7 kg ha^{-1} in 0-15 cm and 81.5 kg ha^{-1} in 15-30 cm in vegetative stage, reproductive stage, and maturity stage was observed.

In I_3 treatment (Fig.10,11,12 and 13) the higher nitrogen uptake (9.4, 65.9 and 100.4 kg ha^{-1} at vegetative stage, reproductive stage and maturity stage) was observed at a depth of 15-30 cm at emitter in the treatment I_3N_1. In 15 cm from emitter, the highest nitrogen uptake (9.4, 65.9 and 100.4 kg ha^{-1} at vegetative stage, reproductive stage, and maturity stage) was observed at a depth of 15-30 cm. In treatment I_3N_2,the higher nitrogen uptake (12.5, 81.5 and 128.6 kg ha^{-1} at vegetative stage, reproductive stage, and maturity stage) was observed at a depth of 15-30 cm at emitter. In 15 cm from emitter, the highest nitrogen uptake (12.5, 81.5 and 125.4 kg ha^{-1} at vegetative stage, reproductive stage, and maturity stage) was observed at a depth of 15-30 cm.

In case of 30 cm and 45 cm from emitter, the highest nitrogen uptake (12.5, 81.5 and 128.6 kg ha^{-1} at vegetative stage, reproductive stage, and maturity stage) was observed at a depth of 15-30 cm. In treatment I_3N_3,the higher nitrogen uptake (15.7, 100.4 and 128.6 kg ha^{-1}) was observed at a depth of 15-30 cm at emitter, 15 cm from emitter, 30 cm from emitter and 45 cm from emitter for vegetative stage, reproductive stage, and maturity stage respectively. In the treatment I_3N_4 at emitter 12.5 kg ha^{-1} in 0-30 cm depth and 65.9 kg ha^{-11} in 15-30 cm depth and 90.9 kg ha^{-1} in 0-30 cm depth was observed for vegetative stage, reproductive stage, and maturity stage respectively. At 15 cm from emitter 12.7 kg ha^{-1} in 0-15 cm depth and 69 kg ha^{-1} in 15-30 cm depth and 90.9 kg ha^{-1} in 0-30 cm depth was observed for vegetative stage, reproductive stage, and maturity stage respectively.

3.1.3 AVAILABLE NITROGEN AND NITROGEN UPTAKE DURING *RABI* 2018-19

During *rabi* 2018-19, the available nitrogen in all treatments at vegetative stage, reproductive stage, maturity stage and post harvest at all depths are shown in Fig. 14 - 25.

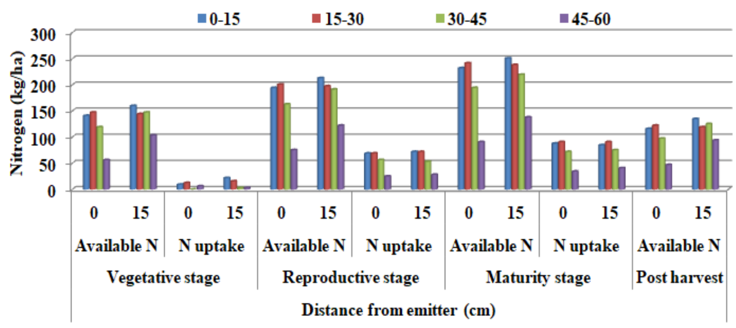

Fig. 14 Available N and N uptake in soil at different depths for I_1N_1 during *rabi* 2018-19

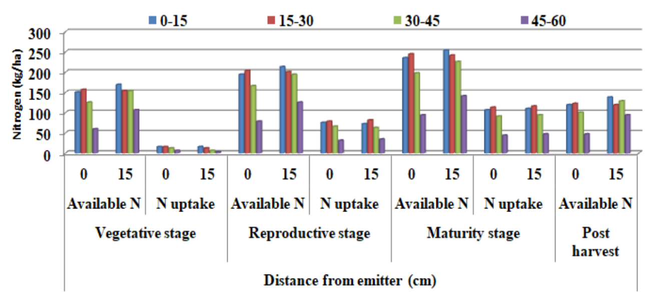

Fig. 15 Available N and N uptake in soil at different depths for I_1N_2 during *rabi* 2018-19

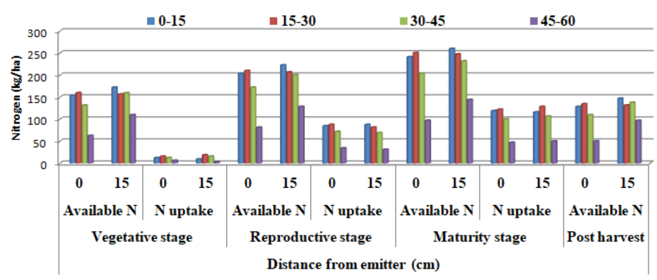

Fig. 16 Available N and N uptake in soil at different depths for I_1N_3 during *rabi* 2018-19

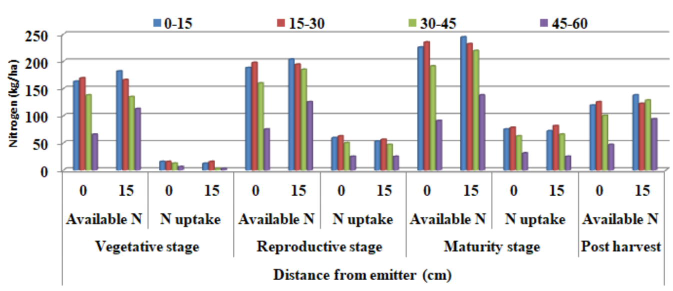

Fig. 17 Available N and N uptake in soil at different depths for I_1N_4 during *rabi* 2018-19

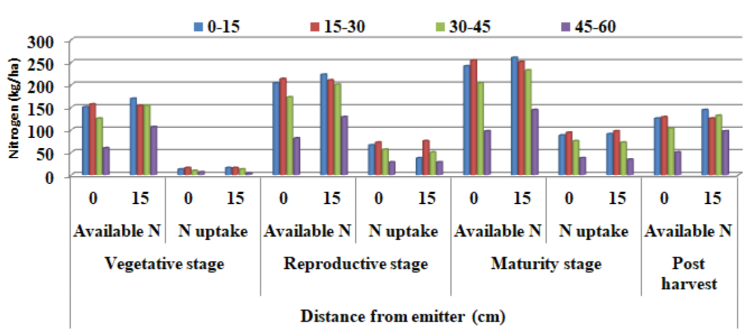

Fig. 18 Available N and N uptake in soil at different depths for I_2N_1 during *rabi* 2018-19

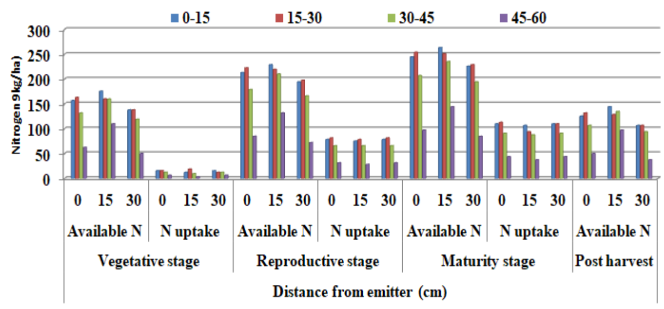

Fig. 19 Available N and N uptake in soil at different depths for I_2N_2 during *rabi* 2018-19

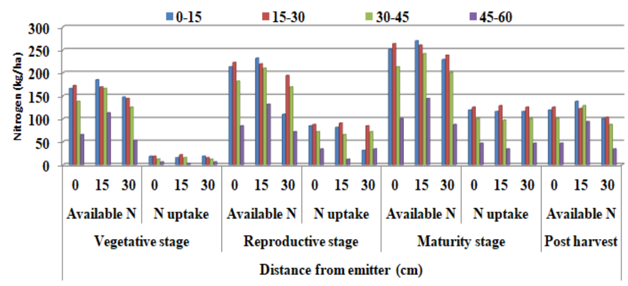

Fig. 20 Available N and N uptake in soil at different depths for I_2N_3 during *rabi* 2018-19

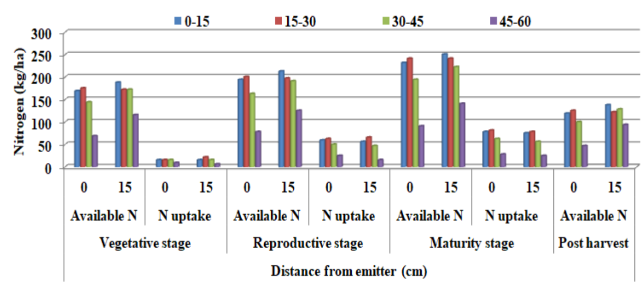

Fig. 21 Available N and N uptake in soil at different depths for I_2N_4 during *rabi*2018-19

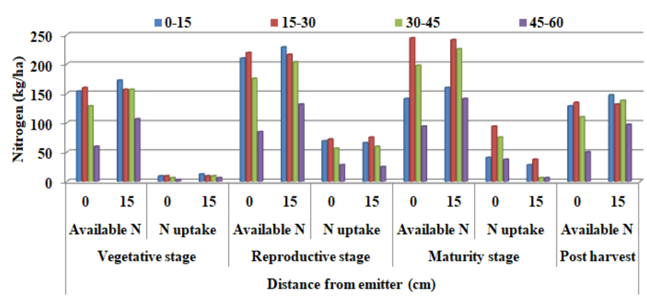

Fig. 22 Available N and N uptake in soil at different depths for I_3N_1 during *rabi* 2018-19

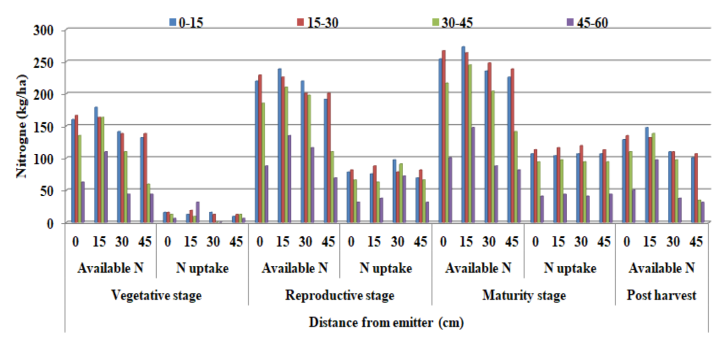

Fig. 23 Available N and N uptake in soil at different depths for I_3N_2 during rabi 2018-19

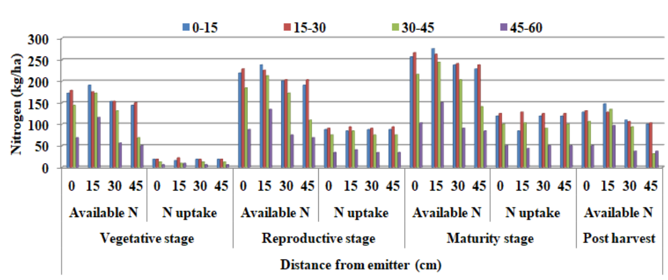

Fig. 24 Available N and N uptake in soil at different depths for I_3N_3 during *rabi* 2018-19

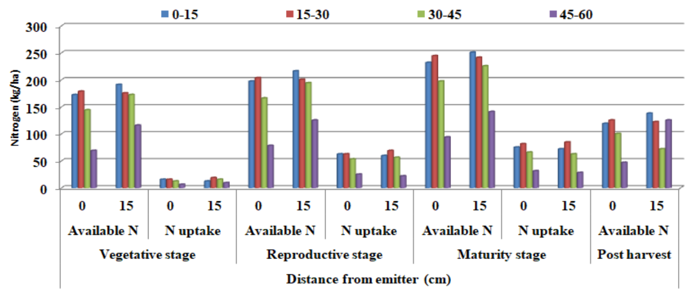

Fig. 25 Available N and N uptake in soil at different depths for I_3N_4 during *rabi* 2018-19

Locascio*et al*., (1989) reported that"nutrients applied in any irrigation must not be subject to excess irrigation either during that same irrigation or by subsequent irrigations since it leads to leaching off the nutrients. Due to improved growth characters, the plants tend to take more nutrients from the soil since it is available nearer to root zone at required level". This was in conformity with the findings of Black (1969), who reported"increased nutrient uptake under high frequency irrigation due to increased plant growth". Higher nutrient uptake of chilli under fertigation was also reported by Tumbare and Nikam (2004). Reducing the fertilizer dose resulted in lower availability of nutrients which might be the reason for lower uptake of nutrients by crops at lower dose of fertilizers (80 per cent).

Further, application of nutrients in more number of splits in drip fertigation resulted in minimum or no wastage of nutrients either through deep percolation or evaporation as reported by Kadam*et al*., (1995) and Rajput and Patel (2002) leading to higher uptake of nutrients. This enabled the crop to put forth better growth, yield attributes and reap bountiful yield.

The increment of N concentration in maize plants might be due to higher availability of the nutrients with the increasing fertigation levels that finally resulted in root growth and more physiological activities for nutrient absorbance. The availability of nutrients increased due to frequent application of nutrients in integration with better root activity. Further, loss of nutrients primarily as leaching was also minimized by using fertigation. These findings are in conformity with those reported by Sundar Raman *et al*. (2000), El-Yazied*et al*. (2007), Hassanein*et al*. (2007), Kumar *et al*. (2010), Richa (2013) and Padmaja*et al*. (2016)

4. CONCLUSION

There were significant variation due to irrigation and fertility levels at all the stages of crop growth. Generally, the availability of nitrogen was increased when irrigation as well as fertilizer level increased up to maturity stage. The maximum available nitrogen was in the depth of 0- 30 cm range and then decreased vertically.

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