Vol. 49, No. 3, pp 208-216, 2021
Indian Journal of Soil Conservation

Nitrogen distribution in soil under urea ammonium nitrate (UAN) and urea application in drip fertigated cabbage (*Brassica oleraceae* var. *capitata*)

Madhavananda Gundappagol[1,*], Manoj Khanna[1], Man Singh[1], Susama Sudhishri[1], Jitendra Rajput[2] and Dimple[3,*]

[1]Water Technology Center, ICAR-Indian Agricultural Research Institute (IARI), New Delhi; [2]Division of Agricultural Engineering, ICAR-IARI, New Delhi; [3]Department of Soil and Water Engineering, CTAE, MPUAT, Udaipur.

*Corresponding author:
E-mail: madhavanand30@gmail.com (Madhavananda Gundappagol);dimpibachchan20@gmail.com (Dimple)

ARTICLE INFO

DOI : 10.59797/ijsc.v49.i3.190

Article history:
Received : May, 2021
Revised : December, 2021
Accepted : December, 2021

Key words:
Cabbage
Fertigation
Nitrate
Nitrogen distribution
Urea
Urea ammonium nitrate

ABSTRACT

Nitrogen (N) is essential for plants. It involves in a number of important functions, including growth, leaf area development, and crop production. Optimum availability of nitrogen to the plants is vital to achieve higher production. Liquid fertilizer urea ammonium nitrate (UAN) is advantageous to Urea because it contains all three N forms *viz.,* NO_3^- (nitrate), NH_4^+ (ammonium), and Urea (amide). In this context, present study was taken to understand nitrogen (N) distribution in the soil under varying levels of UAN and Urea fertilizers in drip fertigated cabbage crop. Treatments included four different doses (0 kg N ha^{-1}, 40 kg N ha^{-1}, 80 kg N ha^{-1}, and 120 kg N ha^{-1}) with three split applications at 15 days intervals after transplanting under three replications. Results revealed that mineral N content decreased with increase in depth at emitter and 22.5 cm away from the emitter. The horizontal distribution also decreased with increase in distance from the emitter but vertical distribution at 45 cm from the emitter, the N concentration increases with increase in depth. The availability of the mineral nitrogen in UAN applied plots found to be significantly higher than the urea applied plots that resulted in higher uptake and higher yield under UAN applied plots. Results also showed that the nitrogen fertilizer can be saved up to 30-35% using UAN over urea as nitrogen fertilizer source. The findings of present investigation would be helpful in applying optimum nitrogen fertilizer dosage at the right place to achieve higher nitrogen efficiency in cabbage crop.

1. INTRODUCTION

Crop production process is often limited by water and nutrient availability to the crop. They are the two key factors in the agricultural production system. Drip irrigation with fertigation provides an effective and cost-efficient way to supply water and nutrients to crops (Hanson *et al.,* 2006). However, less than optimum management of drip irrigation with fertigation system resulting in excess water and nutrient use, thereby diminishing expected yield benefits and contributing to ground water pollution.

Application of fertilizer when mixed with drip irrigation system is called as drip fertigation. This method reduces operational costs and provides an opportunity to split the application of fertilizer doses, suiting to the nutritional requirement of the crops. India occupies second place in terms of cultivated area and production of cabbage crop which mostly grown in Uttar Pradesh and Odisha. Cabbage is very responsive to nitrogen fertilization. Cabbage is both drip irrigated and surface irrigated crop. The application of solid / dry fertilizer through manual broadcasting has been predominant practice to apply nutrients to crops in India and fertigation with urea is also in use. It has often been spread on places far away from the crop and insolubility of dry / solid nitrogenous fertilizers in fertigation resulting to reduction in nutrient use efficiency, non-uniform distribution of fertilizers, non-uniform crop growth, stimulating weed growth, wastage of fertilizer and negative environmental impacts. In semi-arid environments, a significant part of the applied nitrogen fertilizer is leached by deep percolation (Playan and Faci, 1997). The best fertilizer management options are based on small and frequent nitrogen applications through improved fertilizer application technique and different fertilizers *e.g.,* liquid fertilizers like urea ammonium nitrate (UAN). UAN is available at 28%, 30% and 32% of nitrogen content with 100% solubility.

Nitrogen uptake by the aboveground biomass of plants is a very important item of information. Fertilizer N can cause high nitrate accumulation in plants, especially in most leafy vegetables (Chen *et al.,* 2004). Solutions of UAN are widely used as a source of N for plant nutrition. Which is advantageous than urea because it contains all three N forms *viz.,* NO_3^- (nitrate), NH_4^+ (ammonium), and urea (amide). The NO_3^- portion (25% of the total N) is immediately available for plant uptake. The NH_4^+ fraction (25% of the total N) can also be assimilated directly by most plants, but is rapidly oxidized by soil bacteria to form NO_3^-. The remaining urea portion (50% of the total N) is hydrolyzed by soil enzymes to form Nh_4, which is subsequently transformed to NO_3^- in most soil conditions. But Urea contains amide form of nitrogen which is not immediately available to plants and problem of volatile losses. And liquid UAN also have the potential to increase the crop yield, Nitrogen use efficiency and improve system uniformity because of least clogging in UAN based fertigation system. There are several factors which regulates the crop production including fertilizer application, irrigation techniques, and growing environment conditions, etc. (Erley *et al.,* 2009; Tiwari *et al.,* 2003; Everaarts and De Moel, 1998). Optimum application of nitrogen in cabbage ensures better production (Ma *et al.,* 2015). However, over or under application deteriorates crop yield in many crops and soil quality (Min *et al.,* 2012; Shi *et al.,* 2008; Shen *et al.,* 2010). Nitrogen (N) application is essential for better production of vegetables crops and to ensure better yields and excellent quality (Zhang *et al.,* 2015; Tilman *et al.,* 2002). Nitrogen application upholds the overall growth, yield and quality of radish (Khatri *et al.,* 2019).

Drip fertigation with UAN allows fertilizer to be applied in smaller amounts than dry fertilizer application throughout the growing season when the plant needs nutrients. Drip fertigation with liquid fertilizer like UAN could provide advantages over fertigation with urea and traditional method of field spreading or broadcasting or soil injection techniques (Rajan *et al.,* 2014). Selecting optimal nitrogen application rate, nitrogen source, method and time of application are prime requisites for its efficient management. The present study carried out with focus on understanding tempo-spatial dynamics of nitrogen in soil under drip fertigated cabbage crop to develop management strategies to for better utilization of the nitrogen.

2. MATERIALS AND METHODS

Experimental Site

The research experiment was carried out at the field of Water Technology Centre, Indian Agricultural Research Institute (IARI). IARI is situated in West Delhi between the latitudes of 23°38'22"N and 33°39'05"N and longitudes of 77°9'45"E and 77°10'24"E at an average elevation of 228.61 in above the mean sea level. The IARI covers the total land size of about 500 ha. The research fields, which form a fundamental part of the IARI campus, cover an area of about 340 ha, of which about 300 ha is irrigated by an interlinked chain of tube-wells and water storage tanks, while the left over is used for dry land farming research experiments.

Climatic Conditions

Climate of Delhi is semi-arid, subtropical with hot dry summer and cool winter and it comes in the Agro-eco-region - IV. The mean annual temperature is 25.5°C. May and June are the hottest months with 30 years normal maximum temperature of 39°C and which varies from 43.9°C to 45.0°C. The period from December to February is the winter season. The mean temperature of 14°C in the month of January is considered to be coldest. However, the minimum temperature dips below 1°C. 75% of the rainfall is received during monsoon season (June to September) from the mean annual rainfall of 710 mm. Some winter showers are also received during December March. Through western disturbances some Frost also occurs occasionally during month of December-January. The average RH in different months varies from 34.1% to 97.9% and mean daily evaporation ranged between 3 mm day^{-1} to 9 mm day^{-1}. Average wind speed varies from 0.45 m s^{-1} to 3.96 m s^{-1}.

Soils

Soils of IARI represent the Yamuna basis with a distinctive alluvium profile. The entire farm is covered under several soil series. The soil type ranges from sandy loam to clay loam. The texture up to depth of about 150 cm appears almost homogeneous. As per USDA textural classification, major portion of the area belongs to sandy loam class. There are only minor pockets representing clay, sandy clay and sandy clay loam texture classes. Porosity is about 40% and soil belongs to good class as far as its permeability is concerned.

Initial soil samples were collected before planting from different depths and available Nitrogen (N), Phosphorus (P) and Potassium (K) were determined by using standard laboratory methods. The available N was estimated by alkaline $KMnO_4$ method (Subbiah and Asija, 1956) and available P content in soil was estimated by Olsen's method (Olsen, 1954). Whereas, available K was determined using neutral normal ammonium acetate extraction method and flame photometry as described (Jackson, 2015) and expressed in kg ha^{-1}. A balance sheet of N, P and K used of the crop was prepared by comparing the net change in nutrient status of soil after harvest of the crop. Available N, P and K in different depths are presented in Table 1. Fig.1 shows the average values of selected weather parameters at ICAR-IARI, Pusa, experimental farm.

Treatment Details

The recommended dose of fertilizers (RDF) were 120 kg ha^{-1} of N, 60 kg ha^{-1} of P, and 40 kg ha^{-1} of K. Application

Table: 1
Available N, P and K before planting

Depth (cm)	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})
0-15	102.46	23.68	162.75
15-30	96.32	16.02	102.09
30-45	89.80	12.14	88.38
45-60	83.60	10.10	81.40

of single super phosphate (SSP) and muriate of potash (MoP) (P&K) as basal dose as per RDF.

UAN application treatments

T1 0 kg of N ha^{-1} (0% of RDF)
T2 40 kg of N ha^{-1} (33% of RDF)
T3 80 kg of N ha^{-1} (66% of RDF)
T4 120 kg of N ha^{-1} (100% of RDF)
T5 0 kg of N ha^{-1} (0% of RDF)
T6 40 kg of N ha^{-1} (33% of RDF)
T7 80 kg of N ha^{-1} (66% of RDF)
T8 120 kg of N ha^{-1} (100% of RDF)

Experimental Layout

Experiment was conducted with golden acre variety of cabbage in the year 2016-17. Cabbage was transplanted on October 31st and November 1st. Plant to plant and row to row spacing were 45 cm and 45 cm, respectively. The field size was 1500 sq m and plots size was 9 m × 4 m. The experiment was planned with eight treatments and three replications. Fertigation schedule for the experiment is displayed in Table 2. The treatments considered in the study are given below:

Replication 1		Replication 2		Replication 3	
T2 4 m	T6 9 m	T7	T3	T4	T5
T4	T7	T5	T1	T1	T8
T3	T5	T8	T4	T3	T7
T1	T8	T6	T3	T2	T6
UAN	UREA				

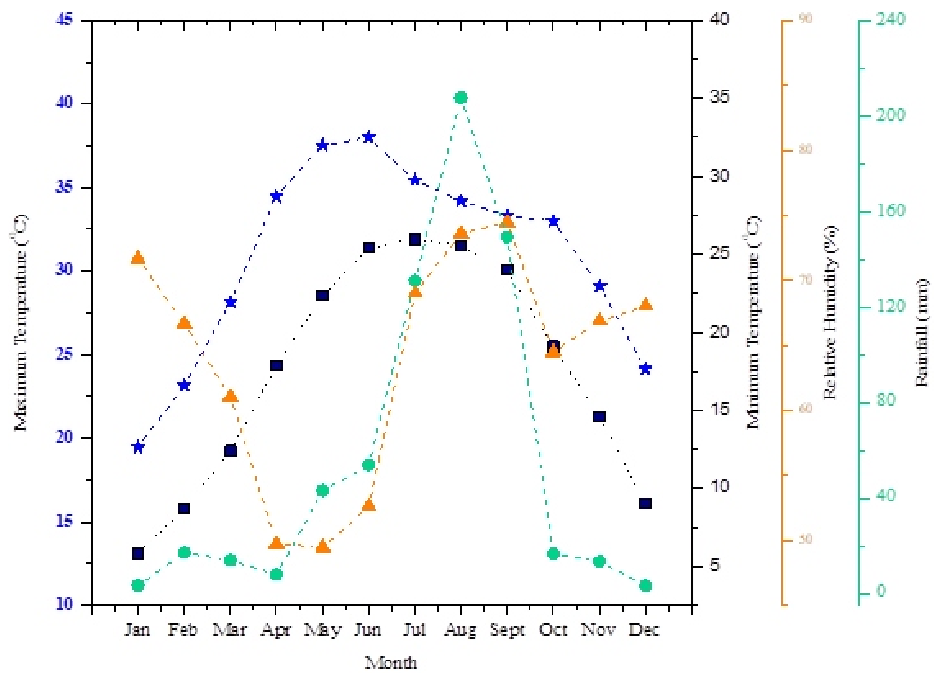

Fig. 1. Average values of selected climatic parameters during year 2007-2016

Table: 2
Fertigation schedule for the field experiment

Fertigation (F)	Fertigate date	UAN application (kg ha^{-1})			UREA application (kg ha^{-1})		
		40	80	120	40	80	120
I	17/11/2016	47.7	95.33	142.7	29	58	87
II	1/12/2016	47.7	95.33	142.7	29	58	87
III	15/12/2016	47.7	95.33	142.7	29	58	87

Fertigation Schedule

Treatment wise requirement of N fertilizers were estimated as per the plot size. The fertilizer was applied in 3 equal split doses with 15 days interval between each fertigation (1) Vegetative stage *i.e.* 15 DAT, (2) at Head initiation *i.e.* 30 DAT and (3) at Head enlargement *i.e.* 45 DAT.

Soil Sampling

Soil samples were collected one day before and after each fertigation (vertical sampling) from different depths [15 cm (I), 30 cm (II), and 45 cm (III)] and (horizontal sampling) at different distances from emitter [near the emitter (I), 22.5 cm from the dripper (II) and, 45 cm from the dripper (III)] using tube auger as per the sampling schedule to determine the amount of mineral Nitrogen in the various layers of soil and their distribution. Vertical and horizontal soil sampling shown in Fig. 2.

Laboratory Estimations

Analysis of mineral N

Ammonium N (NH_4-N) and Nitrate N (NO_3-N) were estimated. Soil (10 g) was extracted with 50 mL of 2 M KCl solution. The content was steam distilled with MgO and Devarda's alloy (50% Cu, 45% Al, 5% Zn) using a Kjeldhal distillation unit (Gerhardt Vepodest 30). The liberated NH_4 and NO_3-N were absorbed in 20 mL of 2% boric acid containing mixed indicator. The distillation was continued until 100 mL of distillate was collected within a time of 7 min than titrated with 0.01 N H_2SO_4. And calculated Mineral N in different depths after and before each fertigation.

Nitrogen balance

Nitrogen balance shows the difference between the total quantity of nitrogen found in the soil after fertigation and the quantity of nitrogen into the soil before the fertigation. The surplus nitrogen may remain in the soil, leach into groundwater and volatilize into the air. Thus, nitrogen balance is an indicator of the nitrogen loss from the soil. It also helps to compare the nitrogen variation pattern in different source of fertilizer application. The analysis of nitrogen balance would indicate nitrogen utilization pattern under UAN application and Urea application.

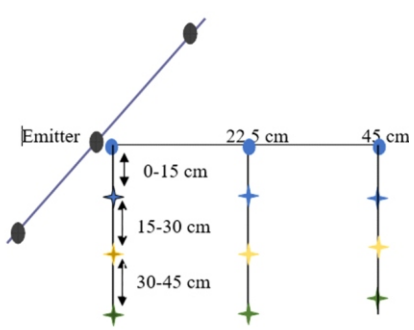

Fig. 2. Vertical and horizontal soil sampling

3. RESULTS AND DISCUSSIONS

Nitrogen Distribution in Soil Profile Under Drip Fertigation with UAN and Urea Application in Cabbage

Cabbage is shallow rooted vegetable crop. Its effective root zone depth is 25-35 cm. Effective root zone depth is the depth from which the roots of an average full-grown plant are capable of reducing soil moisture and nutrition to the level that it should be replaced by fertigation. In other words, it is the soil depth from which various crops extract most of water and nutrition needed (Reddy and Reddi, 2002).

The recommended dose of nitrogen for cabbage crop is 120 kg N ha^{-1}. This requirement of nitrogen was provided through UAN and urea which contains 28 and 46% nitrogen, respectively. It was applied to each plot in three split doses with drip fertigation. Authors García-Navarro *et al.,* 2000 study revealed that short fertilizer applications toward the beginning or end should be avoided to achieve high fertilizer distribution uniformity.

Most of the nutrients that plant uptake are not directly extracted from soil by crops. Plants extract nutrients which are dissolved in the water. Mineral N such in ammonium and nitrate forms are mainly present in soil solution. Such nutrient ions are absorbed by the roots alongwith soil water. The nutrient uptake through this mechanism is directly related to the amount of water used by the plants (transpiration) (Haynes and Swift, 1987). It is important that sufficient amount of mineral N (nitrate and ammonium) is available in the root zone in order to be absorbed and thus utilized properly by the crop. Soil samples were collected spatially and temporarily during the crop growing season before and after fertigation. The mineral nitrogen (ammonium and nitrate form of N) available in soil could be determined using the Kjeldhal apparatus by standard laboratory method. This section contains the comparison of mineral N in soil profile under UAN and Urea application treatments in different doses. This would help us to understand the extent of leaching losses and volatilization losses under two nitrogen sources and the amount of nitrogen available in the root zone. The results as per the fertigation schedule are presented and discussed below.

Nitrogen Distribution 24 hrs Before I Fertigation

Fig. 3 represents the average mineral nitrogen concen-

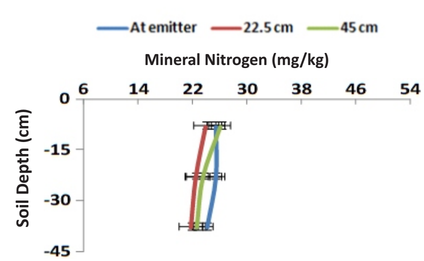

Fig. 3. Average mineral N distribution 24 hrs before I fertigation

trations observed in nine different soil depths at various soil sampling points throughout the field 24 hrs before first fertigation (15 DAT). Which also indicate initial N content in the soil. The figure indicates that the mineral nitrogen concentration was ranged between 21.9 to 26.2 mg kg^{-1} in different soil depths. It was also observed that concentration decreases with the increase in soil depth. The maximum mineral nitrogen was observed in upper two layers (0-15 and 15-30 cm) in all the three locations *i.e.* at emitter, 22.5 cm and 45 cm from the emitter.

Nitrogen Distribution 24 hrs After First Fertigation

Fig. 4 presents mineral nitrogen distribution in root zone after the first fertigation in both UAN and urea applied treatments. The figure indicates that, the highest nitrogen was found in all treatments at the location near emitter (T_2 - 31.1 mg kg^{-1}, T_3 - 36.05 mg kg^{-1}, T_4 - 43 mg kg^{-1}, T_6 - 28.3 mg kg^{-1}, T_7 - 33.2 mg kg^{-1}, T_8 - 37.5 mg kg^{-1}. Nitrogen was largely stored in the upper layers at the emitter *i.e.* mineral nitrogen concentration decreases with increase in depth at the emitter and 22.5 cm from the emitter. But there was very little availability of the mineral nitrogen at the soil surface (0-15 cm) at the distance of 45 cm from the emitter; It ranged between 21.2-26 mg kg^{-1} in all the treatments.

The spacing between two drip lateral lines was 90 cm *i.e.* assuming that each emitter would cover 45 cm horizontally for water and nutrient. However, it was observed that water and nitrogen were not available at 45 cm from the emitter at the soil surface. It could be due to soil type at experimental field. Main reason for reduced availability of N is due to less mobile nature of ammonium (Shen *et al.,* 2010).

The availability of mineral nitrogen at the 22.5 cm from the emitter was also observed as 31.3-38.2 mg kg^{-1}. This was because of nitrate accumulation at the boundary of the wetted volume (Li *et al.,* 2004). Therefore, the mineral N concentration was also observed higher at the 22.5 cm from the emitter. These results suggested that one drip line covering two crop rows are sufficient for water and nutrient distribution and availability to crop.

The figures also showed that higher mineral N availability (20-25%) in the UAN applied treatments as compared to the urea applied treatments. This could be due to composition of UAN which contains nitrogen in all the three forms *viz.,* nitrate-25%, ammonium-25%, and 50% in amide form. Cabbage absorbs nitrogen in the form of nitrate which was immediately available from the UAN fertilizer application to the crop after fertigation at emitter (T_2 - 31.1 mg kg^{-1}, T_3 - 36.05 mg kg^{-1}, T_4 - 43 mg kg^{-1}. However, as urea contains nitrogen in amide form and cabbage crop absorbs nitrogen only in nitrate form which lead to delayed nutrient availability to the crop. The availability of nutrient in urea applied plots required more time to convert nitrogen in to ammonium and nitrate form by the process of hydrolysis. Therefore, the mineral N in the urea applied treatments were less as compared to UAN applied treatments (T_6 - 28.3 mg kg^{-1}, T_7 - 33.2 mg kg^{-1}, T_8 - 37.5 mg kg^{-1}.

Nitrogen Distribution 24 hrs Before II Fertigation

Fig. 5 shows the available mineral N concentration in different depths in soil profile 24 hrs before II fertigation in both the UAN and Urea applied treatments. The figure indicates that, the observed mineral N content in the 0 kg applied treatments was reduced (16.96-17.67 mg kg^{-1}) as compared to concentration after first fertigation (21.3-26.7 mg kg^{-1}). In all UAN and urea applied treatments, the mineral N content at emitter and 22.5 cm from the emitter reduced at 0-15 cm, increased in 15-30 cm and again decreased in 30-45 cm (T_4 at emitter, 0 -15 cm - 33.9 mg kg^{-1}, 15-30 cm - 38.9 mg kg^{-1}, 30-45 cm - 31.1 mg kg^{-1}. This could be due to higher interval between two fertigation events (15 days) as compared to irrigation interval (7 days). An irrigation

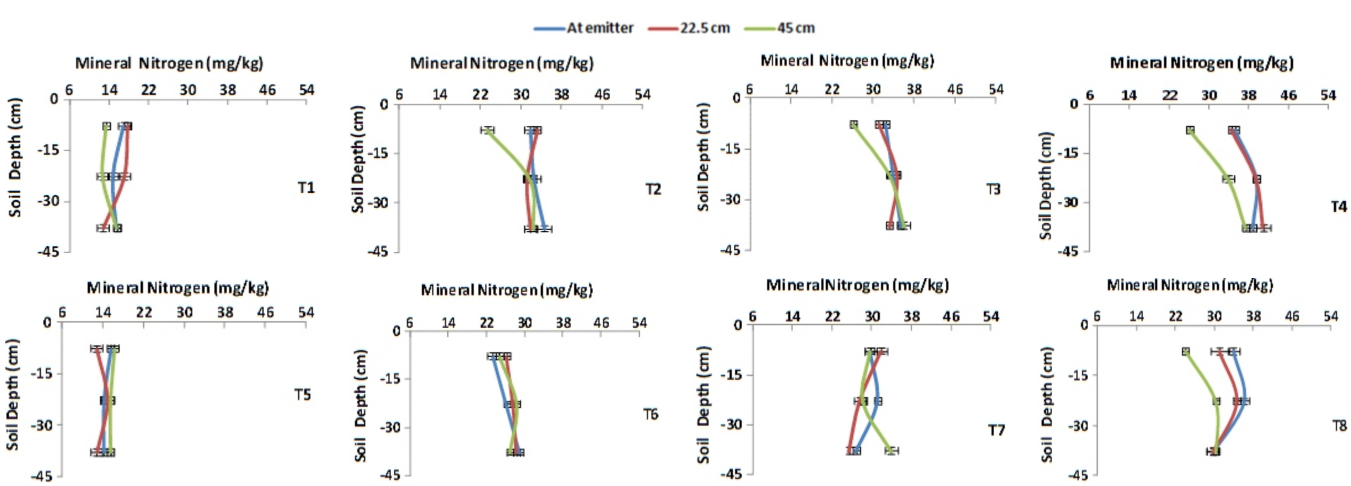

Fig. 4. Nitrogen distribution 24 hrs after first fertigation (T1 to T4 – UAN treatments and T5 to T8 – Urea treatments)

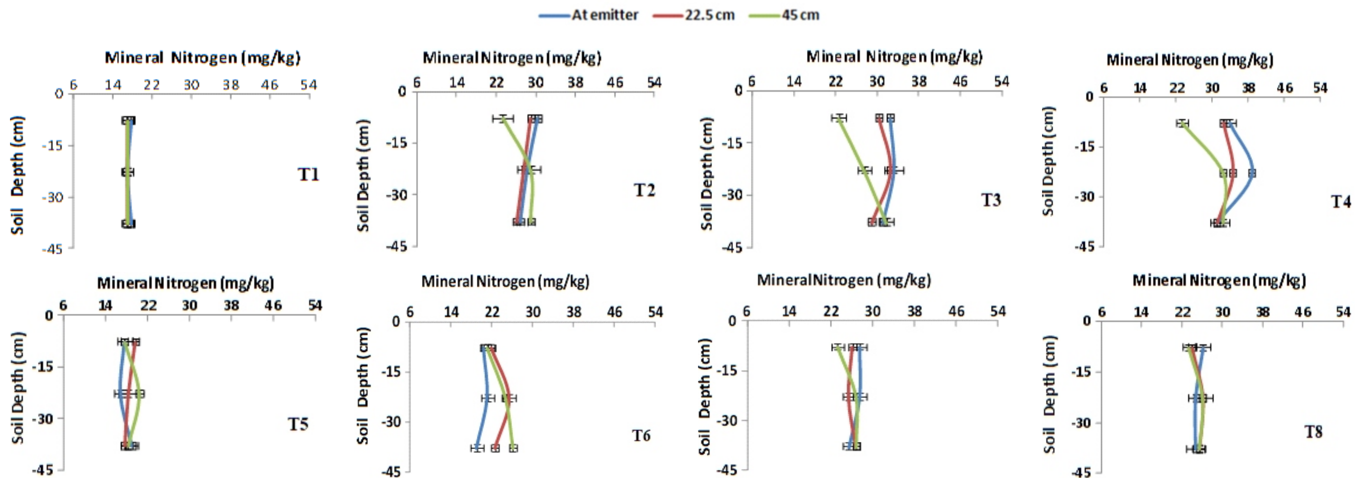

Fig. 5. Nitrogen distribution 24 hrs before II fertigation

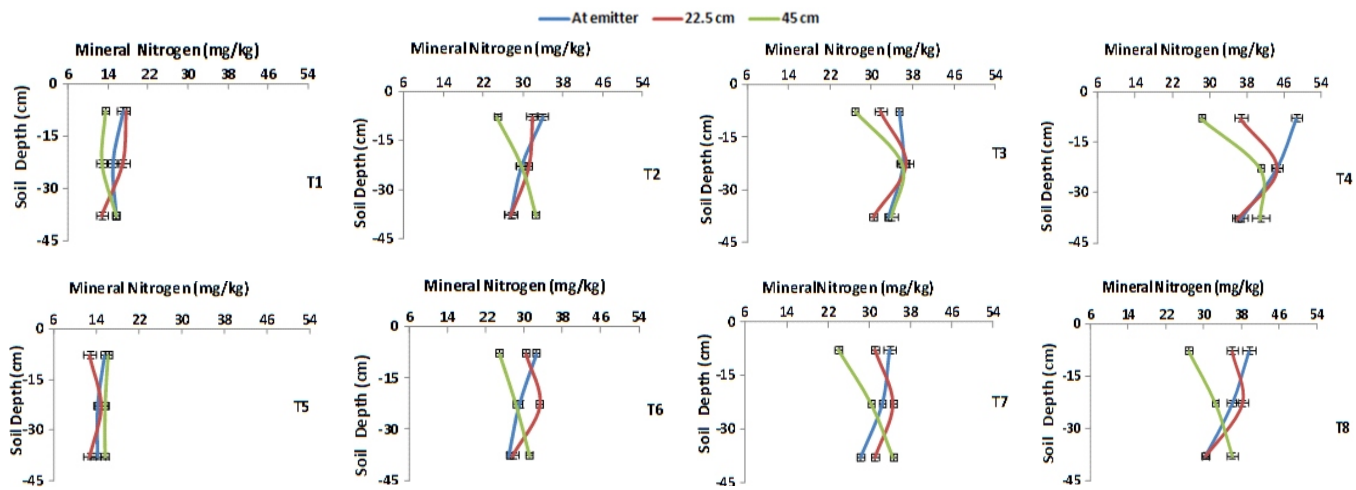

Fig. 6. Nitrogen distribution 24 hrs after III fertigation

event between the two-fertigation lead to the movement of N content from upper layer to the deeper layers and leaching from the deeper layers. It was observed that, there was not much reduction in mineral N content from after first fertigation to before II fertigation in UAN applied treatments (T_4 at emitter, 0-15 cm - 43.3-38.9 mg kg^{-1}) as compared to the N concentration in Urea applied treatments from after I fertigation to before II fertigation (38.6-26.2 mg kg^{-1}). The difference between after first fertigation and before II fertigation in UAN applied treatments was observed as 4.2 mg kg^{-1} but in Urea applied treatment it was 12.4 mg kg^{-1} which could be due to composition of UAN. Nitrate was available immediately after the fertigation and ammonium was converted before the II fertigation. Therefore, nitrate was available throughout the growing period of the crop. But it was observed in the urea applied treatments due to different composition of urea.

The same trend continued in nitrogen distribution 24 hrs before III fertigation. However, the difference in Urea applied treatments was reduced to 36.4-33.9 mg kg^{-1}. It was because amide form from urea applied in the first fertigation was converted into ammonium and nitrate at the third fertigation. At the end of the crop season, it would no longer beneficial to the crop uptake. But in UAN applied treatments the same difference continued and found to be beneficial for the crop.

Nitrogen Distribution 24 hrs After III Fertigation

Fig. 6 depicts the nitrogen distribution 24 hrs after III fertigation and compares the mineral nitrogen concentration among different doses of both UAN and urea applied treatments. The figure showed trend of nitrogen concentration depth wise was same as I and II fertigation but mineral N content increased in both the nitrogen sources. Higher increase was found in urea applied treatments than UAN treatments of previous fertigation because hydrolysis of II fertigation. But availability of mineral N in UAN applied treatments was more than urea treatments throughout crop period.

Nitrogen Distribution Two Days Before Harvesting

Fig. 7 shows the nitrogen concentration in soil profile in different depths in both the nitrogen source fertilizers in different treatments. At end of the harvest of the crop mineral N concentration at 0 kg N treatments was ranged between 7.1-9.6 mg kg^{-1}. In UAN applied treatments, it ranged between 20.3-29.6 mg kg^{-1} and in urea applied treatments it was observed between 19.7-28.7 mg kg^{-1}. It was expected that there will be maximum nitrogen concentration in both UAN and urea applied treatments at time of harvest of the crop, however, it was observed that there was drastic reduction in the mineral N content in both treatments. This could be due to rainfall (64 mm) in the month of January (II fortnight) leading to leaching of the nitrogen from the soil profile.

Comparison of Mineral Nitrogen in Soil Under UAN and Urea

It has been observed that the mineral nitrogen availability was higher under UAN nitrogen source compared to Urea as nitrogen source at various soil depths (vertical distribution) and at distance from the emitter (horizontal distribution) as displayed in the Table 3. The negative values as displayed in the Table 3 showed that nitrogen availability was more under urea than UAN.

4. CONCLUSIONS

The study recorded the effect of nitrogen source at different nitrogen levels on distribution of nitrogen in the soil. These samples were analyzed for mineral N concentration in the laboratory. The nitrogen distribution trend in the soil profile showed the mineral N content decreases with increase in depth at emitter and 22.5 cm from the emitter. The horizontal distribution also decreased with increase in distance from the emitter but vertical distribution at 45 cm from the emitter the N concentration increased with increase in depth. Nitrogen distribution in both UAN and urea applied

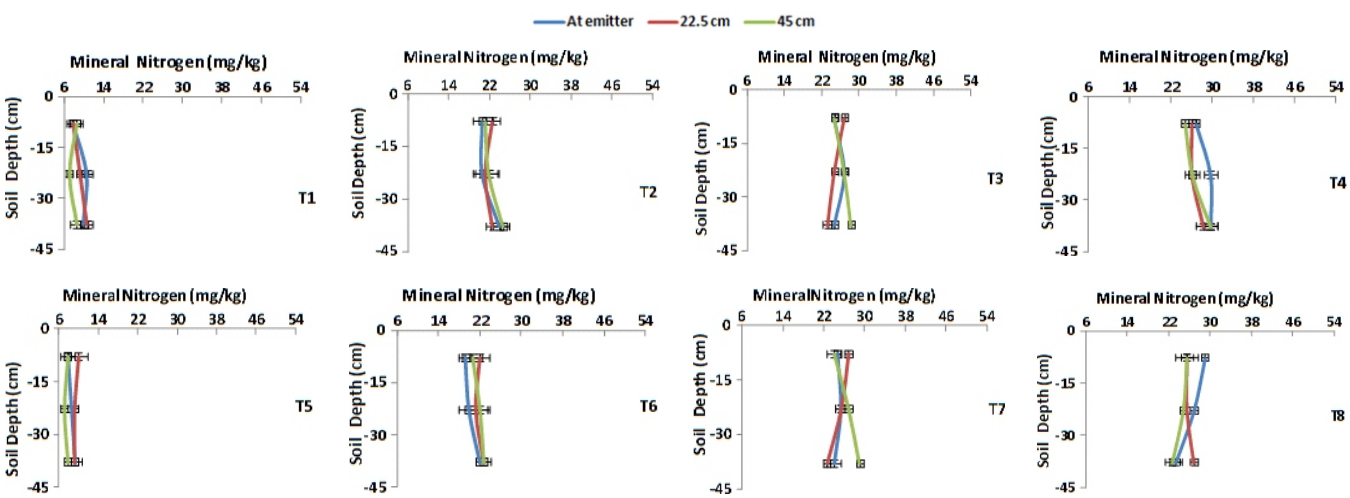

Fig. 7. Nitrogen distribution two days before harvesting

Table: 3
Mineral nitrogen availability in UAN compared to Urea at different soil depths and distance from emitters under different application levels

Distance from emitter (cm)	At emitter			22.5 cm			45 cm		
Soil depth (cm)	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
Mineral nitrogen availability under UAN over Urea under 40 kg ha^{-1} application									
Nitrogen availability under UAN over Urea fertilizer (%) — 24 hrs after first fertigation	4.75	5.11	3.00	2.39	-4.43	15.13	3.30	11.08	10.26
24 hrs before second fertigation	48.29	33.29	40.70	32.27	8.33	15.61	10.00	17.14	10.82
24 hrs after second fertigation	11.89	7.69	14.73	16.25	14.63	21.17	9.68	7.89	9.53
24 hrs before third fertigation	36.35	24.36	19.53	27.04	12.80	12.52	-5.70	12.52	21.07
24 hrs after third fertigation	4.34	2.45	2.64	4.64	-6.38	0.00	0.00	5.02	4.57
48 hours before harvesting	7.39	3.59	9.68	3.24	0.00	0.00	3.46	0.00	-62.51

Table: 3
Continued...

Distance from emitter (cm)		At emitter			22.5 cm			45 cm	
Soil depth (cm)	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
Mineral nitrogen availability under UAN over Urea under 80 kg ha^{-1} application									
Nitrogen availability under UAN over Urea fertilizer (%)				24 hrs after first fertigation					
	8.52	-2.11	10.54	-2.18	-10.22	-10.26	0.00	-6.66	-4.16
				24 hrs before second fertigation					
	17.95	20.49	22.20	16.25	27.78	7.89	-3.04	2.64	18.43
				24 hrs after second fertigation					
	2.02	0.00	15.79	11.61	32.51	14.27	0.00	12.52	13.04
				24 hrs before third fertigation					
	9.53	14.28	13.63	15.79	8.90	20.49	2.75	11.89	27.52
				24 hrs after third fertigation					
	4.16	10.85	17.51	2.28	6.12	-2.25	11.78	18.59	-2.05
				48 hours before harvesting					
	0.00	5.54	2.95	0.00	-2.79	3.14	2.95	0.00	-2.45
Mineral nitrogen availability under UAN over Urea under 120 kg ha^{-1} application									
Nitrogen availability under UAN over Urea fertilizer (%)				24 hrs after first fertigation					
	15.11	4.02	9.53	6.25	-7.41	10.01	19.99	2.30	-7.98
				24 hrs before second fertigation					
	64.89	48.59	31.45	50.02	35.14	22.20	9.09	18.93	27.78
				24 hrs after second fertigation					
	21.14	6.00	19.53	19.99	29.80	25.01	5.91	4.34	6.25
				24 hrs before third fertigation					
	4.16	9.79	30.95	11.38	14.26	38.09	8.82	11.61	23.22
				24 hrs after third fertigation					
	23.22	23.52	20.92	1.97	16.66	18.59	5.25	26.08	13.73
				48 hours before harvesting					
	-7.32	10.54	27.26	2.75	2.75	5.25	-2.79	5.70	31.26

plots were similar in terms of distribution pattern. *i.e.* movement of nitrogen with water. The availability of the mineral nitrogen in UAN applied plots found to be significantly higher than the urea applied plots. It may be concluded that using UAN as fertilizer source can reduce 30-35% nitrogen requirement by replacing urea as fertilizer source. Selection of optimal fertilizer dosage and fertilizer sources can help in increasing the nitrogen availability in the soil.

Conflict of Interest: The authors declare that they have no conflict of interest.

REFERENCES

Hanson, B.R., Hutmacher, R.B. and May, D.M. 2006. Drip irrigation of tomato and cotton under shallow saline groundwater conditions. *Irrig. Drain. Syst.,* 20: 155-175, doi.org/10.1007/s10795-005-9000-9.

Playan, E. and Faci, J.M. 1997. Border fertigation: field experiments and a simple model. *Irrig. Sci.,* 17: 163-171.

Chen, B.M., Wang, Z.H., Li, S.X., Wang, G.X., Song, H.X. and Wang, X.N. 2004. Effects of nitrate supply on plant growth, nitrate accumulation, metabolic nitrate concentration and nitrate reductase activity in three leafy vegetables, *Plant Sci.,* 167: 635-643.

Erley, G.S.A., Dewi, E.R., Nikus, O. and Horst, W.J. 2009. Genotypic differences in nitrogen efficiency of white cabbage (*Brassica oleracea* L.). *Plant Soil,* 328, 313-325.

Tiwari, K.N., Singh, A. and Mal, P.K. 2003. Effect of drip irrigation on yield of cabbage (*Brassica oleracea* L. *var. capitata*) under mulch and non-mulch conditions. *Agric. Water Manag.,* 58: 19-28.

Everaarts, A.P. and De Moel, C.P. 1998. The effect of nitrogen and the method of application on yield and quality of white cabbage. *Eur. J. Agron.,* 9: 203-211.

Ma, B.L., Biswas, D.K., Herath, A.W., Whalen, J.K., Ruan, S.Q., Caldwell, C., Earl, H., Vanasse, A., Scott, P. and Smith, D.L. 2015. Growth, yield, and yield components of canola as affected by nitrogen, sulfur, and boron application. *J. Plant Nutr. Soil Sci.,* 178: 658-670.

Min, J., Zhang, H.L. and Shi, W.M. 2012. Optimizing nitrogen input to reduce nitrate leaching loss in greenhouse vegetable production. *Agric. Water Manag.,* 111: 53-59.

Shi, W.M., Yao, J. and Yan, F. 2008. Vegetable cultivation under greenhouse conditions leads to rapid accumulation of nutrients, acidification and salinity of soils and groundwater contamination in south-eastern China. *Nutr. Cycl. Agroecosyst.,* 83: 73-84.

Shen, W.S., Lin, X.G., Shi, W.M., Min, J., Gao, N., Zhang, H.Y., Yin, R. and He, X.H. 2010. Higher rates of nitrogen fertilization decrease soil enzyme activities, microbial functional diversity and nitrification capacity in a Chinese polytunnel greenhouse vegetable land. *Plant Soil,* 337: 137-150.

Zhang, X., Davidson, E.A., Mauzerall, D.L., Searchinger, T.D., Dumas, P. and Shen, Y. 2015. Managing nitrogen for sustainable development. *Nature,* 528: 51-59.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S. 2002. Agricultural sustainability and intensive production practices. *Nature,* 418: 671-677.

Khatri, K.B., Ojha, R.B., Pande, K.R. and Khanal, B.R. 2019. The effects of different sources of organic manures in growth and yield of radish (*Raphanus sativus* L.). *Int. J. Appl. Sci. Biotech.*, 7(1): 39-42.

Rajan, K., Haris, A.A. and Prasad, L.K. 2014. Efficacy of conventional, solid soluble and liquid fertilizers applied through drip-fertigation on tomato. *Indian J. Horti.,* 71(2): 217-221.

Subbiah, B.V. and Asija, G.L. 1956. A rapid method for the estimation of nitrogen in soils. *Curr. Sci.*, 26: 259-260.

Olsen, S.R. 1954. *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. United States Department of Agriculture; Washington.

Jackson, M.L. 2005. Soil chemical analysis: advanced course. UW-Madison Libraries Parallel Press.

Reddy, T.Y. and Reddi, G.H.S. 2002. Mineral nutrition, manures and fertilizers. *Principles of Agronomy,* 1st edition. Kalyani Publishers, New Delhi, pp 183-193.

García-Navarro, P., Playan, E. and Zapata, N. 2000. Solute transport modeling in overland flow applied to fertigation. *J. Irrig. Drain. Eng.*, 126(1): 33-40.

Haynes, R.J. and Swift, R.S. 1987. Effect of trickle fertigation with three forms of nitrogen on soil pH, levels of extractable nutrients below the emitter and plant growth. *Plant Soil*, 102(2): 211-221.

Li, J., Zhang, J. and Rao, M. 2004. Wetting patterns and nitrogen distributions as affected by fertigation strategies from a surface point source. *Agric. Water Manage.*, 67(2): 89-104.