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Nitrogen losses through leachate and its distribution

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Abstract : *A column experiment was conducted to elucidate information on the nitrogen losses with clay loam and sandy clay loam soil collected from the farm of UPASI, Coonoor and UPASI, Valparai respectively with 5 levels of nitrogen viz., 0, 250, 375, 500 and 625 kg ha^{-1} and two different rainfall intensities viz., i_1 = 40 mm hr^{-1}(medium rainfall intensity) and i_2 = 60 mm hr^{-1} (high rainfall intensity). The losses of nitrogen fractions through leachate were analyzed for a month period. The results indicated that the nitrogen application increased the concentration of NH_4-N and NO_3-N in the leachate collected under both the soils. The NH_4-N concentration was high in the leachate collected under sandy clay loam soil (33.99 mg l^{-1}) whereas NO_3-N concentration was high in the leachate collected under clay loam soil (17.75 mg l^{-1}). Between the rainfall intensities, the NO_3-N concentration was high in the leachate collected from clay loam soil under medium rainfall intensity and the reverse trend was observed under sandy clay loam soil. The distribution of NH_4-N and NO_3-N was higher in the clay loam soil than sandy clay loam soil. The NH_4-N content increased with increase in the depth of soil column under both the soil. The NO_3-N distribution followed the similar trend under sandy clay loam soil. But in the clay loam soil, the highest NO_3-N content was detected at 14-21 cm depth under medium rainfall intensity.*

Key words : *Clay loam, Sandy clay loam, Nitrogen loss, Leachate, Distribution.*

Introduction

Success of food grain production and increase in the yield of plantation crops in developing countries hinge on the expansion of fertilizer use. Conventional tea plantations make heavy use of chemical fertilizers and pesticides. Among the chemical fertilizers, nitrogen fertilizer plays an important role in a crop such as tea where the stimulation of vegetative growth is the ultimate aim of the planter. However, the nitrogen use efficiency is low (13-42 %) due to losses through volatilization, denitrification through biological and chemical mechanisms, leaching and runoff losses due to rain (Ranganathan, 1969). The leaching loss may be in the form of NH_4-N and NO_3-N depending upon the transformation reactions that are taking place in the soil. Hence there is an imperative need to understand the nitrogen losses and its impact on environment. Column experiment was conducted to study the nitrogen losses through leachate under different nitrogen levels and rainfall intensities.

Materials and Methods

The soils used for the present experiment were collected from United Planters Association of Southern India (UPASI), Coonoor (Attavalli series) and UPASI, Valparai (Attavalli series) to study the nitrogen losses through leachate with 5 levels of nitrogen at 0, 250, 375, 500 and 625 kg ha^{-1} and two levels of simulated rainfall intensity at 254 and 382 cc hr^{-1}. These soils are classified under Typic Dystropepts. The basic characteristics of the soils used in the study are given in Table 1.

Calculation of intensity of water

Cylinder area	=	πr^2
r	=	4.5 cm
Area	=	63.585 cm^2
Intensity	=	4 cm hr^{-1}
Total volume of water	=	63.585 x 4 = 254 cc hr^{-1}

Details of the experiment : A cylindrical column of 40 cm height and 9.0 cm diameter was constructed with PVC pipes. Bulk density of each soil was estimated and the quantity of soil required to create the *in situ* bulk density in each 15 cm height of PVC pipe was also determined. The bottom 0-15 cm was filled with 22.5-45 cm depth soil and the next 15-30 cm was filled with 0-22.5 cm depth soil to obtain required bulk density value as in field condition. In total, 2.1 kg of Coonoor soil or 2.2 kg of Valparai soil was taken in each column to obtain required bulk density. The bottom of each column was sealed with a netlon and supported by wire gauge and the column was mounted on a wooden stand. Provisions were made to collect leachate from each column.

Soil in each column was saturated with water. Next day, different levels of nitrogen in the form of urea (0, 0.159, 0.238, 0.318 and 0.397 g N per column, calculated

Table – 1 : Properties of the experimental soil.

	Particulars	Coonoor soil		Valparai soil	
		0-22.5 cm	22.5-45 cm	0-22.5 cm	22.5-45 cm
1.	Physical Properties				
	a. Particle size distribution (g kg^{-1})				
	Clay	398	362	300	290
	Silt	160	260	200	230
	Fine sand	220	169	165	208
	Coarse sand	209	191	327	270
	Texture	cl	cl	Scl	scl
	b. Bulk density (Mg m^{-3})	1.08	1.11	1.25	1.18
	c. Particle density (Mg m^{-3})	2.5	2.22	2.28	2.22
	d. Pore space (%)	56.6	51.4	45.1	47.1
	e. Pore space volume (ml)	10.0	9.5	7.21	8.0
	f. Field capacity (%)	22.4	22.0	20.0	14.4
	g. Wilting point (%)	19.0	17.0	17.0	13.0
II.	Physico-chemical properties				
	a. Soil reaction	4.75	4.85	4.41	4.01
	b. Electrical conductivity (dSm^{-1})	0.51	0.16	0.31	0.05
	c. Cation exchange capacity [cmol(p^{+}) kg^{-1}]	12.5	11.27	7.55	5.59
III.	Chemical properties				
	a. Organic carbon (g kg^{-1})	30.8	25.9	24.13	13.37
	b. Total nitrogen (g kg^{-1})	3.20	2.10	2.10	1.08
	c. KMno$_4$ -N (mg kg^{-1})	316.0	176.0	192.1	130.3
	d. Ammoniacal nitrogen (mg kg^{-1})	56.0	28.0	28.0	14.0
	e. Nitrate nitrogen (mg kg^{-1})	42.0	14.0	28.0	14.0
	f. Ammonium fixing capacity(Cmol kg^{-1})	2.5	2.0	2.0	2.0

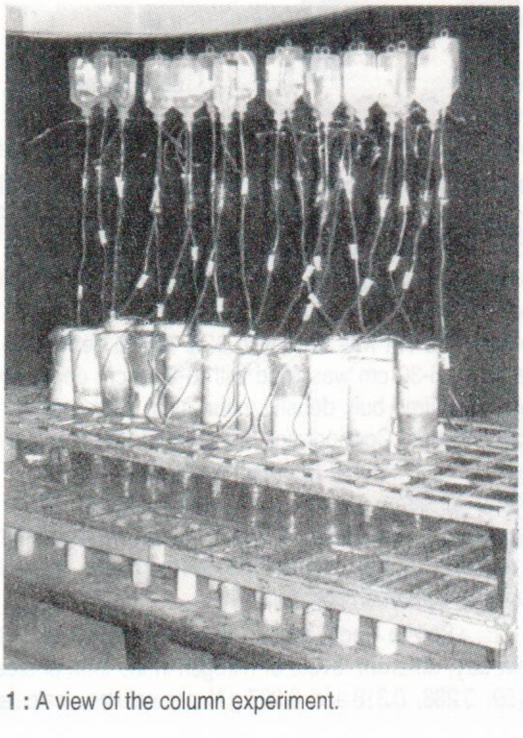

Fig. 1 : A view of the column experiment.

based on the weight of the surface 7.5 cm layer of soil equivalent to 0, 250, 375, 500 and 625 kg N ha^{-1}) were applied. Potassium was added at the ratio of 4:3 (N:K) in all the treatments. Simulated water was added in each column by means of 500 ml capacity graduated bottle with an adapter to regulate the flow with its tube connection to maintain the uniform flow velocity of water. The view of column experiment is shown in Fig. 1.

The simulated rainfall was scheduled on first day and then it was given once in three days for the period of one month. The leachate collected at each phase of the simulated rainfall (10 times) and the soil samples drawn at different depths from each column at the end of the experiment were analyzed for various nitrogen fractions. Analytical methods adopted for water and soil samples are given in Table 2. Treatments were replicated twice and the results were analyzed statistically by FCRD method (Gomez and Gomez, 1984).

Results and Discussion

NH_4-N concentration of leachate : Between the two forms of leaching losses of nitrogen studied, a higher proportion of NH_4-N loss was observed compared to that

Table – 2 : Details of analytical methods employed in the soil and water analysis.

	Determination	Methodology	References
	Soil analysis		
A.	Physical properties		
	1. Particle size analysis	International pipette method	Piper (1966)
	2. Bulk density, Particle density & Pore space	Keen - Raczkowski brass cup method	Piper (1966)
	3. Moisture retention at 1/3 bar and 15 bar pressure	Pressure plate apparatus method	Richards (1965)
B	Physico-chemical properties		
	1. Soil reaction	pH meter with glass electrode (1:2.5 soil : water suspension)	Jackson (1973)
	2. Electrical conductivity	'Elico' conductivity bridge (1:2.5 soil : water suspension)	Jackson (1973)
	3. Cation exchange capacity	Neutral normal ammonium acetate method	Schollenberger and Dreibelbis (1930)
C.	Chemical properties		
	1. Organic carbon	Chromic acid wet digestion method	Walkley and Black (1934)
	2. Total nitrogen	Macrokjeldahl method	Piper (1966)
	3. Urea nitrogen	Colorimetric method	Douglas and Bremner (1970)
	4.Ammoniacal and nitrate nitrogen	Steam distillation method	Bremner and Keeney (1966)
	5. Ammonium fixing capacity	Steam distillation method	Silva and Bremner (1966)
	6. $KMnO_4$ -N	Alkaline permanganate method	Subbiah and Asija (1956)
	Water analysis		
	1. Ammoniacal and nitrate nitrogen	Steam distillation method	Bremner and Keeney (1966)

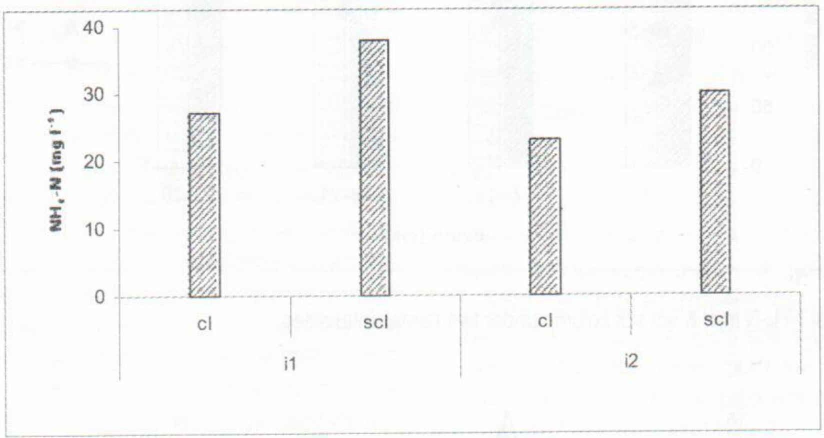

Fig. 2 : NH_4-N concentration of leachate collected from different soils and rainfall Intensities.

of NO_3-N. It is possible that the NH_4^+ was displaced from the soil colloidal complex by Fe^{++} and Mn^{++} (Singh and Singh, 1988).

The concentration of NH_4-N in the leachate collected under sandy clay loam soil was 26.1 per cent higher than clay loam soil (Fig. 2). It might be attributed to the retention of NH_4-N due to fixation in clay lattices of clay loam soil. The NH_4 fixing capacity in clay loam soil was 20 per cent higher than sandy clay loam soil. It further confirms the observation. This result is in accordance with the findings of Ray *et al.* (1957).

Generally, leaching loss of nutrients in soil was directly proportional to the amount of water moving through the profile (Owens, 1960). It might be the reason to increase the NH_4-N concentration at medium rainfall intensity (Fig. 2). Another reason might be the dilution effect that reduced the NH_4-N concentration under high rainfall intensity. The NH_4-N concentration attained peak in different days after fertilizer application based on the urea hydrolysis, priming effect and nitrification rate.

NH_4-N distribution in soil column : The distribution of NH_4-N in the soil column after leachate study showed that in both the soils, the NH_4-N content was higher than NO_3-N. It could be due to the presence of large amount of NH_4 ions remaining in the soil colloids in exchangeable form on the colloidal particles than in soil solution. Nitrate ions, on the other hand, mostly remain in the soil solution, though some of these might be bound to the positive sites of the soil colloids (Panda and Chamuah, 2002). Application of nitrogen altered the quantity of NH_4-N significantly and the maximum NH_4-N was observed at 625 kg N ha^{-1} treated soil and this increase over control was 87.8 per cent in clay loam soil and 120.5 per cent in sandy clay loam soil.

The data on NH_4-N further indicated that its accumulation in clay loam soil was 38 per cent higher than sandy clay loam soil (Fig. 3). This is due to higher adsorption capacity and clay content of clay loam soil than sandy clay loam.

The content of NH_4-N at the surface was low and it increased with increase in depth. The distribution of NH_4-N varied from 10.3 to 33.5 per cent over that of surface in clay loam soil, whereas in sandy clay loam soil it varied from 40.4 to 80.0 per cent (Fig. 3). The variation might be due to variation in the texture of soil and the movement of water (Burns, 1974). According to Obcema *et al.* (1984), the downward movement of NH_4-N was more when compared to both upward and lateral movements. Between the rainfall intensities NH_4-N content distributed at different depths was higher under

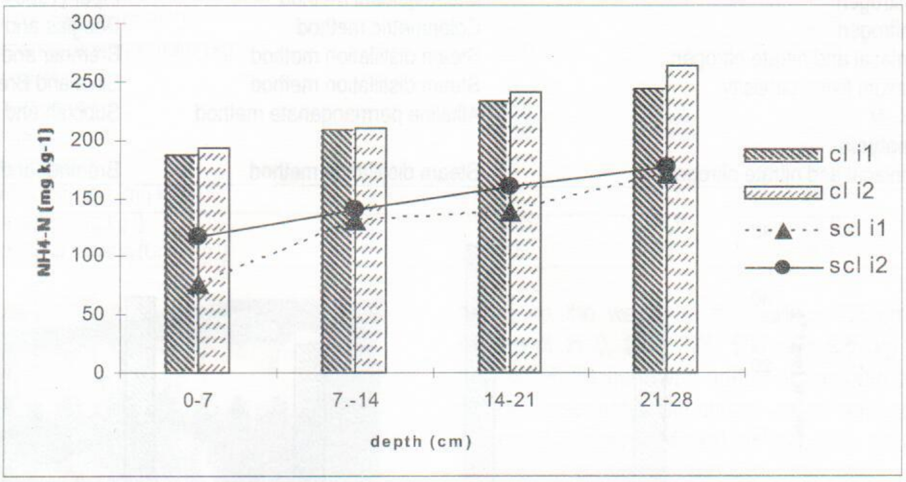

Fig. 3 : Distribution of NH_4-N in cl & scl soil column under two rainfall intensities.

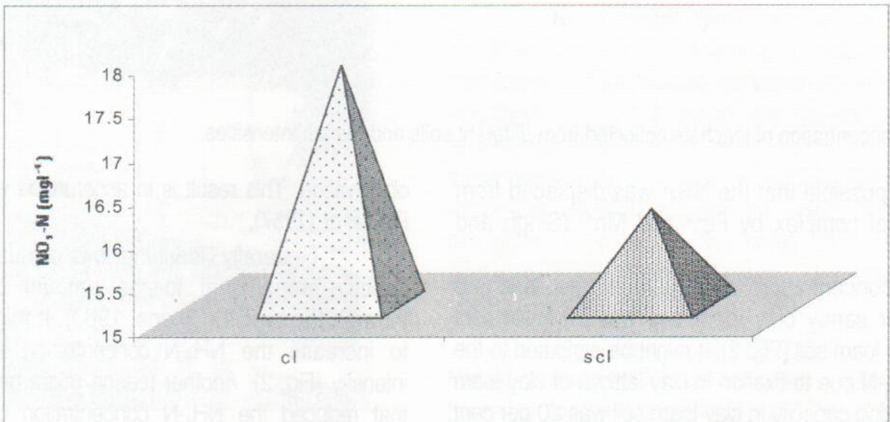

Fig. 4 : NO_3-N concentration of leachate under different soils.

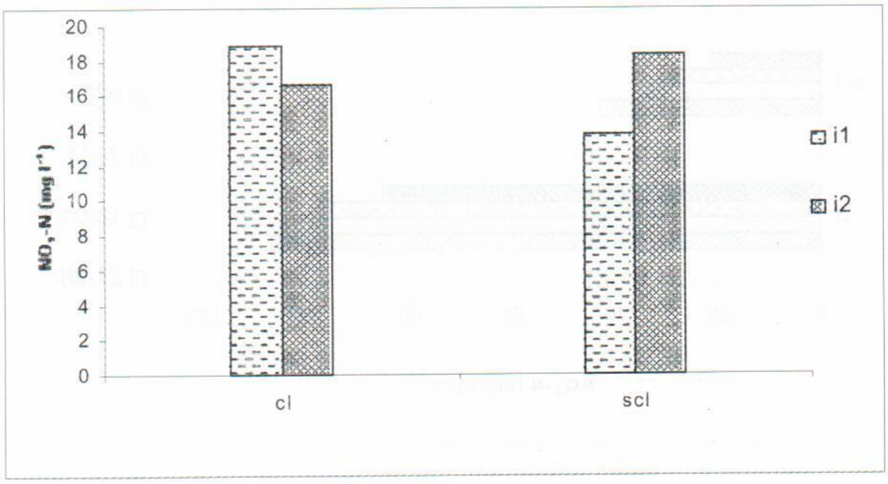

Fig. 5 : NO3-N concentration of leachate collected from different soils and rainfall Intensities.

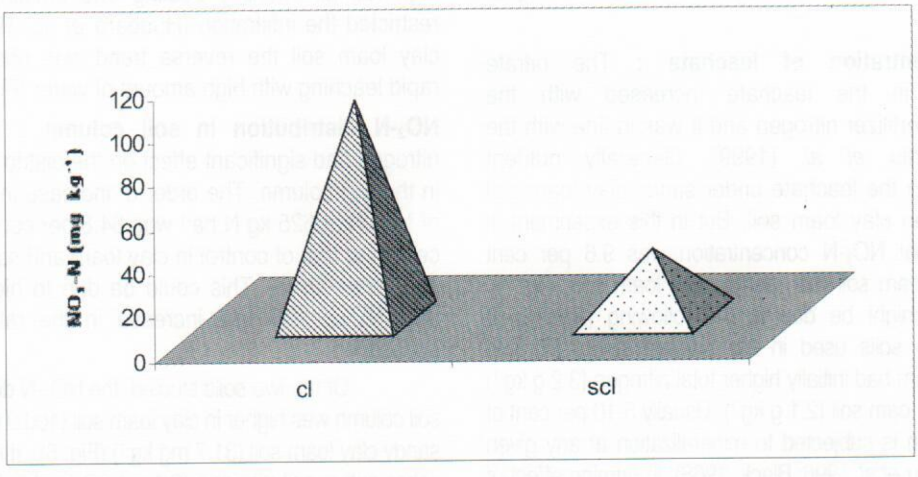

Fig. 6 : NO3-N content under different soil column.

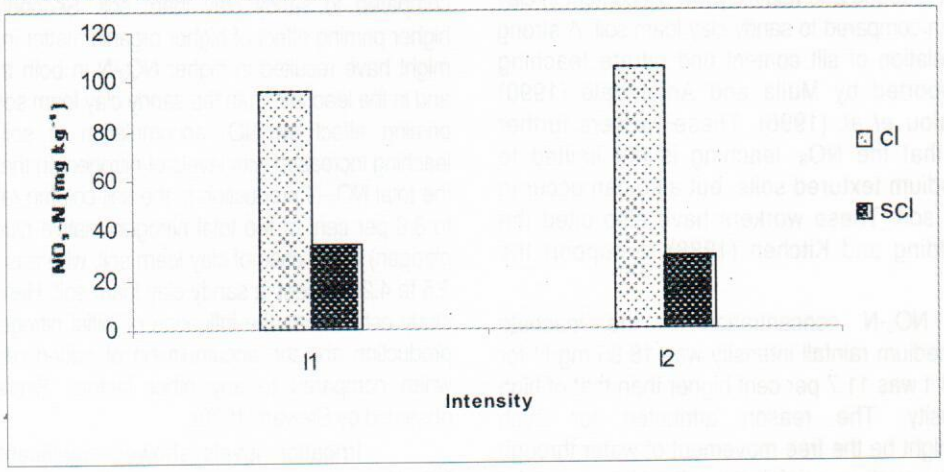

Fig. 7 : NO3-N content under different rainfall intensities and soil column.

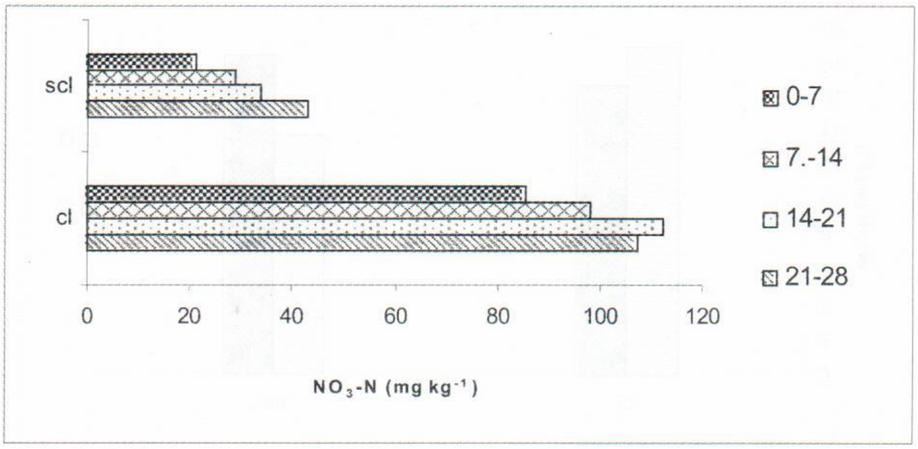

Fig. 8 : Distribution of NO_3-N under different soil column depth.

high rainfall intensity. It might be due to higher mineralization.

NO_3-N concentration of leachate : The nitrate concentration in the leachate increased with the application of fertilizer nitrogen and it was in line with the results of Unlu *et al.* (1999). Generally nutrient concentration in the leachate under sandy clay loam soil was higher than clay loam soil. But in this experiment, it was noticed that NO_3-N concentration was 9.6 per cent higher in clay loam soil than sandy clay loam soil (Fig. 4). This variation might be due to the following reasons: i) among the two soils used in the present study, the fine textured clay loam had initially higher total nitrogen (3.2 g kg^{-1}) than sandy clay loam soil (2.1 g kg^{-1}). Usually 5-10 per cent of the total nitrogen is subjected to mineralization at any given time (Kessavalou *et al.* 1996; Black, 1968); ii) priming effect of added fertilizer nitrogen and relatively low silt content in clay loam soil when compared to sandy clay loam soil. A strong negative correlation of silt content and nitrate leaching has been reported by Mulla and Annandale (1990) and Kessavalou *et al.* (1996). These workers further pointed out that the NO_3^- leaching is not limited to coarse to medium textured soils, but also can occur in fine textured soil. These workers have also cited the work of Spalding and Kitchen (1988) to support the above views.

The NO_3-N concentration in the leachate collected at medium rainfall intensity was 18.85 mg l^{-1} for clay loam and it was 11.7 per cent higher than that of high rainfall intensity. The reason attributed for such observation might be the free movement of water through soil slab under medium rainfall intensity whereas under high rainfall intensity sealing and crusting might have restricted the infiltration (Hubbard *et al.,* 1989). In sandy clay loam soil the reverse trend was observed due to rapid leaching with high amount of water (Fig. 5).

NO_3-N distribution in soil column : The levels of nitrogen had significant effect on the distribution of NO_3-N in the soil column. The order of increase in concentration of NO_3-N at 625 kg N ha^{-1} was 64.8 per cent and 93.9 per cent over that of control in clay loam and sandy clay loam soil, respectively. This could be due to higher substrate (NH_4-N) content with increase in the rate of nitrogen application.

Of the two soils studied, the NO_3-N distribution in the soil column was higher in clay loam soil (100.9 mg kg^{-1}) than in sandy clay loam soil (31.7 mg kg^{-1}) (Fig. 6). It might be due to richer native soil nitrogen (3.1 g kg^{-1}) in clay loam soil when compared to sandy clay loam soil. Secondly, a relatively higher priming effect of higher organic matter in clay loam soil might have resulted in higher NO_3-N in both the soil column and in the leachate than the sandy clay loam soil. This trend of priming effect on NO_3 accumulation in soil column and leaching increased with levels of nitrogen. In the present study the total NO_3-N production in the soil column ranged from 5.6 to 8.6 per cent of the total nitrogen (native nitrogen + added nitrogen) in the case of clay loam soil, whereas it ranged from 2.5 to 4.2 per cent in sandy clay loam soil. Hence the present study estabilishes the influence of initial nitrogen on the NO_3 production and the accumulation of added nitrogen fertilizer when compared to any other factors. Similar result was observed by Stewart (1970).

Irrigation levels showed significant variation in NO_3-N content. In sandy clay loam soil, the highest content was recorded in the soil column under medium intensity of rainfall and it decreased with increase in irrigation (Fig. 7). This might be due to rapid leaching of NO_3-N with high amount of water with the passage of time. However such trend was not reflected in clay loam soil (Fig. 7). It might be due to the sealing and crusting effect that restricted the infiltration under high rainfall intensity (Hubbard *et al.*, 1989) which might have resulted in less depletion of NO_3-N in clay loam soil under high rainfall intensity.

The accumulation of NO_3-N gradually increased with the depth. The distribution varied from 14.86 per cent to 31.6 per cent over that of surface in different depths under clay loam soil. In sandy clay loam soil, it varied from 35.4 to 101.8 per cent. The bottom layers of the soil column contained 25.6 to 101.8 per cent while the surface layers contained only 14.86 to 35.4 per cent indicating the downward movement of NO_3-N due to leaching from the surface.

In sandy clay loam soil, the highest NO_3-N content (42.86 mg kg^{-1}) was measured at 21-28 cm depth after one month period, whereas in clay loam soil, the highest value was detected at 14-21 cm depth (112.5 mg kg^{-1}) (Fig. 8). The NO_3-N leaching potential in a soil system depends primarily on soil texture, amount and frequency of precipitation / irrigation and dynamics of nitrogen transformation. Similar findings were reported by Smith and Cassel (1991), Rousselle (1913) and Day (1956).

The reason for the highest NO_3-N at 14-21 cm depth under medium rainfall intensity in clay loam soil might be due to the insufficiency of added water for translocation of various forms of soil nitrogen through leaching and hence there was relatively low depletion rate. The data obtained from this investigation with respect to this parameter is in accordance with the results of Chaudhary and Bhatnagar (1978) and Hunter *et al.* (1982). Another reason could be that the ions passing through larger (macro) pores will reach a greater depth than those travelling through smaller pores at the same time (Kolenbrander, 1970).

According to Day (1956) the NO_3-N movement is not due to complete displacement of the soil solution by leaching, but the gradual dilution out of the top soil, which is referred to as hydrodynamic dispersion. The distribution factor (K) is a measure for the vertical dispersion of soluble substances in the soil profile. It is closely related with air content in the soil at pF 2.0 (Kolenbrander, 1970).

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