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"Establishment of correlation between N fractions with soil properties in Soils of Tuljapur tahsil of Osmanabad District"

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Abstract: *The present investigation was carried out to study establishment of correlation between N fractions with soil properties in soils of Tuljapur tahsil of Osmanabad district. For this purpose 180 representative soil samples were collected from 30 villages of Tuljapur tahsil. The collected soil samples were grouped into three orders viz. Vertisols, Inceptisols and Entisols. Out of the total surveyed soil samples, 34 per cent samples were grouped under Vertisols while, 47 per cent and 19 per cent samples were grouped under Inceptisols and Entisols, respectively and orderwise anaysis was carried out. In chemical analysis, the soils under study area were alkaline in reaction, safe in limit of electrical conductivity and moderately calcareous to calcareous in nature. The organic carbon content in soils was found low to medium. The soils were found to be low in all the fractions of N viz. total N, available N, total hydrolysable N, amino acid N, acid insoluble N, ammonical N and nitrate N. The pH and $CaCO_3$ showed negative and significantly correlated with all the fractions of nitrogen in Inceptisols and Entisols. Whereas, organic carbon showed positive and significant correlation with different fractions of nitrogen in all soil orders. However, electrical conductivity showed negative and significant correlation with all the fractions of N except total N in Vertisols and EC did not showed any relation with N fractions in Inceptisols and Entisols under study.*

Keywords: *correlation, N fractions, soil properties, Vertisols, Inceptisols and Entisols.*

INTRODUCTION

Osmanabad district is located between 18^0 28' to 19^0 28' North altitude and 76^0 25' to 77^0 25' East latitude. The geographical area of the district is 7512.40 sq. km. Osmanabad district is the South western part of Marathwada region of Maharashtra state with annual rainfall 769 mm. Maximum and minimum temperature of this district is 43.3^0C and 11.9^0C, respectively. The elevation is 725-750 m from mean sea level and which comes under Central Maharashtra Plateau Agro-climatic Zone and Semi- arid region. Osmanabad district comprises 8 tahsils, out of these Tuljapur tahsil is considered for the study. The chemical characteristics like, pH, EC, organic carbon and calcium carbonate are important as these affect on availability of nutrients in soil and thereby on crop growth and production. The soil must supply the nutrients that are essential for plant growth and necessary component of human and animal food for sustainable agriculture. The total nitrogen in soil generally varies from 0.02 to 0.44 percent and its percent of clayey soil of Maharashtra is 0.045. The total nitrogen content of the soil depends on several factors like soil type, texture, soil pH, soil Eh, climate, topography, vegetation, and fertilizer management. Nitrogen in soil exists in two major forms i.e. organic and inorganic nitrogen. 98 percent total nitrogen is present in the organic form and only about 2 percent in inorganic form. The inorganic form is liable to be lost through different types of losses like run off, ammonia volatization, leaching, denitrification and fixation by clay minerals. The organic form of nitrogen, mainly the hydrolysable form is slowly mineralized and is transformed to minerals nitrogen through ammonization, ammonificatin and nitrification processes and made available to crops.Nitrogen is necessary for life however, it is ironic that more than 99 percent of the N exists as N_2 in the atmosphere and is not available to > 99 per cent of living organisms. Nitrogen is the most important mineral nutrient for crop production and its adequate supply in the soil in different forms, which roots can take up is essential for high yields. Until recent times, specialized abilities of certain types of microbes living

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in the soil and lightning strikes are the only ways to convert N_2 molecules to reactive N forms (the process is called fixation) which made their way from the environment into living organisms. Plants turn this fixed N into organic nitrogen – the form combined with carbon (C) in a wide variety of molecules essential both to plants and animals that will eat them. The N cycle gets completed through the process of denitrification, in which organisms use reactive forms of N such as nitrate as their energy source and return N_2 molecules to the atmosphere (Singh and Singh, 2009). Organic N forms can be fractionated into amino acid, amino sugars, hydrolysable NH_4-N, unidentified and non hydrolysable-N. Out of these, amino acid and amino sugars are of microbial origin and influenced by changes in microbial activity. Trees may differentially influence organic fractions of N in soil and also losses from applied urea. Crops are reported to display preference for specific N fraction to meet their N requirement *e.g.* pearl millet for amino acid and hydrolysable NH_4, while rice and wheat for amino acid and amino sugars. Therefore, it is hypothesized that in desirable agroforestry systems companion tree species shall enrich N fraction preferred by companion crops, and reduce delay period of nitrification. (Burman *et al.,* 2002)

The present study is undertaken on "Establishment of correlation between N fractions with soil properties in Soils of Tuljapur tahsil of Osmanabad District" with following objective: To establish correlation between N fractions with soil properties

MATERIALS AND METHODS

Geography and climate of Osmanabad district, Soils of Osmanabad district, Selection of site or location, Collection of soil samples, Preparation of soil samples

Chemical properties of soil

Soil pH, EC, Organic carbon, Calcium carbonate

Nitrogen fractions in soils

Available nitrogen, Total nitrogen, Total hydrolysable nitrogen, Amino acid nitrogen, Acid insoluble nitrogen, Ammonical nitrogen, Nitrate nitrogen

Statistical analysis

Materials: Geography and climate of Osmanabad district

Osmanabad district is located between 18^0 28' to19^0 28' North altitude and 76^0 25' to 77^0 25' East latitude. The geographical area of the district is 7512.40 sq. km. Osmanabad district is the South western part of Marathwada region of Maharashtra state. Annual rainfall is 769 mm. Maximum and minimum temperature of this district is 43.3^0C and 11.9^0C, respectively. The elevation is 725-750 m from mean sea level and which comes under Central Maharashtra Plateau Agro-climatic Zone and Semi- arid Region.

Soils of Osmanabad district

Soils of Osmanabad district mostly belongs to order Vertisols, Inceptisols and Entisols. The soils were varied in colour due to presence of different types of minerals like plagioclase, augite, calcite, dolomite, magnetite *etc*. The soils in the area vary widely in both texture and depth. The soils of the area are rough and rocky largely consisting of basalt. Thin deposits of fertile black soil are found in the northern part and in the South at the western region. Most of the land of the district is full of rock and thin layers of soil except Kumbhari, Kilaj, Masala, Hangarga and Kathi where the land consists of rich fertile black cotton soil.

Selection of site or location

Tuljapur tahsil consist of 109 villages, out of these 30 villages were selected for this study. The villages were selected randomly in such way that it should cover whole area of the tahsil. The selected villages from Tuljapur tahsil of Osmanabad district were Kakramba, Khandala, Wadgaodev, Kilaj, Horti, Jalkot, Hangarga, Sindhagao, Lohgao, Sindhafal, Masala, Kati, Jalkotwadi, Wadgao, Suratgao, Pinpala, Devkurali, Dhotri, Eatkal, Nilegao, Gujnur, Khumbhari, Nanduri, Vasantvadi, Chivari, Andur Tirthbuduruk, Aapsinga, Kamtha, Mardi for collection of soil samples.

Collection of soil samples

In order to study the fertility status of soils from Tuljapur tahsil of Osmanabad district, six soil samples were collected from each village. One hundred and eighty representative surface (0-20 cm) soil samples were collected. The soils were grouped into different orders according to USDA classification.

Preparation of soil samples

Soil samples collected from different villages of Tuljapur tahsil were brought to the laboratory, thoroughly mixed, air dried in shade, ground with wooden mortar and pestle and passed through 2 mm sieve. The sieved soil samples were stored in cloth bags/polythene bags with proper labeling for subsequent analysis. All the precautions outlined by

Jackson (1973) were scrupulously followed in order to avoid contamination.

Methodology: The standard methods were followed for determination of physico- chemical properties and forms of N in soils which are given below.

Soil pH: It was determined in soil: water suspension (1:2.5) using glass electrode pH meter (Jackson, 1973).

Electrical conductivity: It was estimated from supernant solution of soil water suspension (1:2.5) by using conductivity bridge (Jackson, 1973).

Organic carbon: Modified method of Walkley and Black (1934) was used for determination of organic carbon.

Calcium carbonate: Free calcium carbonate was determined with rapid titration method as outlined by Piper (1966).

Nitrogen fractions

Available nitrogen: It was analysed by alkaline potassium permagnate method as suggested by Subbiah and Asija (1956).

Total nitrogen: Total nitrogen from soil samples was estimated by micro kjeldhal method as described by Page *et al.* (1989).

Total hydrolysable nitrogen: It was estimated by steam distillation method as suggested by Bremner (1965).

Amino acid nitrogen: It was estimated by steam distillation method as described by Bremner (1965).

Acid insoluble nitrogen: It was analysed by steam distillation method as described by Bremner (1965).

Ammonical nitrogen: It was evaluated by steam distillation method as suggested by Bremner (1965).

Nitrate nitrogen: It was evaluated by steam distillation method as suggested by Bremner (1965).

RESULTS AND DISCUSSION

In order to determine the nitrogen fractions of the soils from Tuljapur tahsil of Osmanabad district, one hundred and eighty representative surface soil samples were collected from different villages.

The collected soil samples were grouped into three orders. 34 per cent soil samples were grouped under the order Vertisol while, 47 per cent and 19 per cent soil samples were grouped under the order Inceptisol and Entisol, respectively.

Soil samples from Tuljapur tahsil of Osmanabad district were analyzed for its chemical properties and nitrogen fractions. The correlation between chemical properties and different fractions of nitrogen in soil were also worked out. The results obtained after analysis are presented and discussed under following head.

Chemical properties in soils of Tuljapur tahsil

Out of 180 soil samples, 62 samples were grouped under Vertisols, while, 84 and 34 soil samples were placed in Inceptisols and Entisols, respectively. The data on chemical properties of soils from Tuljapur tahsil are presented orderwise categorization of soils (Table 1).

Vertisols: out of 62 soil samples of Vertisols, 5 samples (8 %) were normal and 57 samples (92 %) were alkaline in pH.

All samples (100%) in Vertisols showed normal range hence these soils were safe for crops. Out of 62 samples, 20 samples (32%) were low, 28 samples (45%) were medium and 14 samples (23%) were high in organic carbon. $CaCO_3$ content in the soils ranged from 5.0 to 81.0 g kg^{-1} with an average 48.7 g kg^{-1}. Out of 62 samples, 27 samples (45%) were non-calcareous and 35 samples (55%) were calcareous in nature.

Inceptisols: The soil pH varied from 7.0 to 8.9 with an average value of 8.2. It is revealed from the data 10 per cent soils were found neutral in reaction and 90 per cent soils were alkaline in reaction. Data revealed that all the soil samples from inceptisols were safe in EC. Out of 84 samples from Inceptisols, 27 samples were (32%) low, 33 samples (39%) were medium and 24 samples (29%) were high in organic carbon content. Out of 84 soil samples, 31 samples were (37%) non calcareous in nature, 27 samples (32%) were calcareous and remaining 26 samples (31%) were highly calcareous.

Entisols

These soils were varied in pH from 6.1 to 8.9 with a mean value of 8.0. Out of 34 soil samples, 5 samples (15%) were neutral and 29 samples (85%) were alkaline in reaction. All the soil samples in Entisols order were safe, as far EC categorization. Most of soils in Entisols were low to medium in organic carbon content. Out of 34 soil samples, 23 samples (68%) were non- calcareous and remaining 11 samples were (32%) calcareous in nature. Thus, the majority soil samples in Entisols showed non-calcareous in nature.

The data revealed that 92, 90 and 85 per cent soil samples in Vertisols, Inseptisols and Entisols, respectively were alkaline in reaction. These values of pH indicated that most of the soils under study were alkaline in reaction. The alkaline reaction of soil is probably due to the presence of sufficient free lime content and basaltic alluvium parent material rich in

alluminosilicates and alkaline earth from which these are derived. Similar findings were also reported by Mali and Raut (2001) that most of the soils of Latur district were alkaline in nature under Vertisols, Inceptisols and Entisols. With regards to soil EC, 100 per cent soil samples showed safe EC for growing crops. The values of EC obtained in the investigation were found within desirable range as proposed by Richard and Cambell (1948). When EC exceeds 4 dSm^{-1}, the present salts become harmful to the crop growth. However, EC values below 1.0 dSm^{-1} was considered as normal. Normal range of EC of soil of Chakur and Shirur- anantpal tahsil were ranged from 0.13 to 0.79 and 0.12 to 0.75 dSm^{-1}, respectively reported by Jagtap (2007).

It was observed that in Vertisol 32, 45 and 23 per cent soil samples were low, medium and high in organic carbon content, respecrively while, in case of Inceptisols 32, 39 and 29 per cent soil samples were low, medium and high respectively. With regards to Entisol 44, 29 and 27 soil samples were low, mdium and high in organic carbon content, respectively. From the values of organic carbon, it was clearly depicted that the majority of soil samples were low to medium in range. The agro climate and agro ecological unit is very important from standpoint of soil fertility and plant growth. The content of organic carbon in soils depends on the range of precipitation within experimental area, considerable variation in precipitation is observed. The differences in the level of organic carbon in these soils are largely attributed to the pattern of rainfall in the area. In addition, hot and dry climate is directly related with the temperature variation in the region/ecological unit. Organic carbon is also attributed to the variation in decomposition rate. Similar results are also reported by Malewar *et al.* (2004).

Majority soils from Vertisols and Inceptisols were calcareous in nature and contribute 56 and 37 per cent while, 68 per cent soils from Entisols were non calcareous. Relative more accumulation of $CaCO_3$ in Vertisols and associated black soils may be partly associated with their recent origin with rich in alkali earth and partly due to calcification process prevalent in this region (Joshi, 2000). Dhage *et al*. (2000) reported that the $CaCO_3$ content in Shevgaon tahsil (A.nagar district) was ranged from 11.4 to 161.3 g kg^{-1}. Similar range of $CaCO_3$ (13.0 to 156 g kg^{-1}) was recorded in swell- shrink soils of Vidarbha region (Padole and Mahajan, 2003). Similarly, Waghmare *et al.* (2007) reported that the $CaCO_3$ content in Ausa tahsil of Latur district was ranged from 8.80 to 125 g kg^{-1}.

Status of nitrogen fractions in soils of Tuljapur tahsil

The data on total N, available N, total hydrolysable N, amino acid N, acid insoluble N, ammonical N and nitrate N are presented under Vertisols, Inceptisols and Entisols, respectively.

It is seen from the data (Table 2) total N content in Vertisols varied widely from 0.039 to 0.100 per cent with a mean value of 0.069 per cent. In Inceptisols, total N content ranged from 0.025 to 0.089 per cent with an average of 0.058 per cent. However, the total N content in Entisols varied from 0.021 to 0.081 with a mean value of 0.059. Relatively higher total nitrogen content in Vertisols is due to high clay content and lower values of total nitrogen in Inceptisols and Entisols may be associated with different parent material and it's rate of disintegration (Sharma and Mishra 1988) similar results also reported by Kumar *et al.*, (1995) that the total N contents in the soils varied from 0.07 to 0.11 and 0.06 to 0.15 per cent in the surface and subsurface soils, respectively.

From the results, it was observed that the available nitrogen content ranged from 106.60 to 404.50 kg ha^{-1} with an average of 189.01 kg ha^{-1} in Vertisols. In Inceptisols, available N varied from 90.90 to 373.20 kg ha^{-1} with a mean value 192.11 kg ha^{-1}. However, the available N content in Entisols varied from 100.40 to 276.00 kg ha^{-1} with an average value 184.57 kg ha^{-1}. The lower content of available nitrogen in this area was associated with hot and dry climate. Low content of organic matter and low total nitrogen reserve and in term C: N ratio of immobilized forms of nitrogen was reported by Malewar (1995). Similar results also reported by Waghmare and Takankhar (2007) that in soil of Ausa and Nilanga Tahsil of Latur district available N content ranged from 102.2 to 385.7 kg ha^{-1} and 100.3 to 366.9 kg ha^{-1}, respectively.

The mean values for total hydrolysable, amino acid, acid insoluble, ammonical and nitrate nitrogen in all the surface soil samples of Vertisols were recorded 531.18, 244.61, 167.65, 25.16 and 10.48 mg kg^{-1}, respectively. In Inceptisols, the mean values of total hydrolysable, amino acid, acid insoluble, ammonical and nitrate nitrogen recorded were 441.56, 203.09, 141.64, 20.87 and 8.69 mg kg^{-1}, respectively. However, in Entisols the mean values for total hydrolysable, amino acid, acid insoluble, ammonical and nitrate nitrogen recorded were 454.10, 207.57, 140.48, 21.28 and 8.86 mg kg^{-1}. Vertisols showed higher mean values for total hydrolysable, amino acid, acid insoluble, ammonical and nitrate nitrogen as compared to Inceptisols and Entisols which is

Table 1
Order wise categorization of soils from Tuljapur tahsil on the basis of chemical properties

Parameter		*Soil orders*								
		Vertisols			*Inceptisols*			*Entisols*		
pH		*Acidic (< 6.5)*	*Neutral (6.5-7.5)*	*Alkaline (> 7.5)*	*Acidic (< 6.5)*	*Neutral (6.5-7.5)*	*Alkaline (> 7.5)*	*Acidic (< 6.5)*	*Neutral (6.5-7.5)*	*Alkaline (> 7.5)*
	%	0	8	92	0	10	90	0	15	85
	No. Samples	0	5	57	0	8	76	0	5	29
EC(dSm^{-1})		Safe (< 0.8)	M.safe (0.8-2.5)	Unsafe (>2.5)	Safe (< 0.8)	M.safe (0.8-2.5)	Unsafe (>2.5)	Safe (< 0.8)	M.safe (0.8-2.5)	Unsafe (>2.5)
	%	100	0	0	100	0	0	100	0	0
	No.Samples	62	0	0	84	0	0	34	0	0
Organic carbon ($g\ kg^{-1}$)		Low (< 5)	Medium (5- 10)	High (> 10)	Low (< 5)	Medium (5- 10)	High (> 10)	Low (< 5)	Medium (5- 10)	High (> 10)
	%	32	45	23	32	39	29	44	29	27
	No. Samples	20	28	14	27	33	24	15	10	9
$CaCO_3$ ($g\ kg^{-1}$)		N.ca (<50)	Ca. (50-100)	H.ca (>100)	N.ca (<50)	Ca. (50-100)	H.ca (>100)	N.ca (<50)	Ca. (50-100)	H.ca (>100)
	%	45	55	0	37	32	31	68	32	0
	No. Samples	27	35	0	31	27	26	23	11	0

N.ca- Non calcareous, Ca. - Calcareous, H.ca-Highly calcareous, M.safe- Marginal safe

Table 2
Range and average value of nitrogen fractions in soil

Soil order	*Total N(%)*	*Available N(kg ha^{-1})*	*Total hydrolysable N (mg kg^{-1})*	*Amino acid N (mg kg^{-1})*	*Acid insoluble N (mg kg^{-1})*	*Ammonical N (mg kg^{-1})*	*Nitrate N (mgkg^{1})*
Vertisols	0.039-0.100 (0.069)	106.60-404.50 (189.01)	292.00-750.00 (531.18)	136.50-350.00 (244.61)	90.00-250.00 (167.65)	14.04-36.00 (25.16)	5.85- 15.00 (10.48)
Inceptisols	0.025-0.089 (0.058)	90.90-373.20 (192.11)	190.00-672.00 (441.56)	87.50-311.50 (203.09)	60.00-228.50 (141.640	9.00-32.04 (20.87)	3.75-13.35 (8.69)
Entisols	0.021- 0.081 (0.059)	100.40-276.00 (184.57)	157.50-633.36 (454.10)	73.50-284.20 (207.57)	52.50-199.50 (140.48)	7.56-29.16 (21.28)	3.15- 12.15 (8.86)

Table 3
Correlation between chemical properties and nitrogen fractions in Vertisols

chemical properties	*Total N*	*Available N*	*Total Hydrolysable N*	*Amino Acid N*	*Acid insoluble N*	*Ammonical N*	*Nitrate N*
pH	-0.643**	-0.792**	-0.724**	-0.728**	-0.582**	-0.727**	-0.650**
EC	-0.220	-0.266*	-0.285*	-0.297*	-0.308*	-0.297*	-0.320*
O.C	0.309*	0.821**	0.699**	0.714**	0.607**	0.713**	0.641**
$CaCO_3$	-0.356**	-0.668**	-0.601**	-0.654**	-0.492**	-0.653**	-0.497**

* Significant at 5% level: - 0.230
** Significant at 1% level: - 0.325

Table 4
Correlation between chemical properties and nitrogen fractions in Inceptisols

chemical properties	*Total N*	*Available N*	*Total Hydrolysable N*	*Amino Acid N*	*Acid insoluble N*	*Ammonical N*	*Nitrate N*
pH	-0.712**	-0.828**	-0.712**	-0.444**	-0.577**	-0.688**	-0.704**
EC	-0.014	-0.059	-0.078	-0.094	0.033	-0..092	0.031
O.C	0.668**	0.762**	0.666**	0.345**	0.631**	0.664**	0.666**
$CaCO_3$	-0.582**	-0.669**	-0.621**	-0.183	-0.696**	-0.646**	-0.560**

* Significant at 5% level: - 0.212
** Significant at 1% level: - 0.283

partly attributed to higher content of total nitrogen in these soils as compared to other soil groups. Further, higher values of various fractions of nitrogen in Vertisols and Inceptisols may be associated with finer texture of soil and high organic carbon content. These findings are in accordance with the results of Singh and Singh (2007) and Soniya *et al*. (2011).

Correlation coefficient between chemical properties and nitrogen fractions in soils of Tuljapur tahsil

Correlation studies were carried out so as to understand the dependency of total, available and other fractions of nitrogen in relation to soil properties. The results obtained on soil properties and nitrogen fractions were subjected to the simple correlation. The results of simple correlation coefficients of nitrogen fractions with chemical properties are presented in Vertisols, Inceptisols and Entisols.

Vertisols

The data on correlation coefficient between chemical properties and different fractions of nitrogen in Vertisols are presented in Table 3. From the results it was indicated that total nitrogen was significantly affected by pH, organic carbon and $CaCO_3$ content but it could not established any relationship with electrical conductivity. pH and $CaCO_3$ showed negative but significant relationship with total nitrogen content which is evident by 'r' value -0.643** and -0.356**, respectively. Further, it was indicated that organic carbon was positively and significantly correlated with total nitrogen which is expressed by'r' value 0.309*.

pH, EC and $CaCO_3$ showed negatively significant relationship with available nitrogen whereas, organic carbon was associated positively and significantly relationship with available nitrogen which was evident by 'r' values for pH (-0.792**), EC (-0.266*), $CaCO_3$ (-0.668**) and organic carbon (0.821**).

The remaining fractions of nitrogen also found to be influenced by soil properties. pH, EC, and $CaCO_3$ content were negatively but significantly correlated with total hydrolysable N (-0.724**, -0.285* and -0.601**), amino acid N (-0.728**, -0.297* and -0.654**), acid insoluble N (-0.582**, -0.308* and -0.492**), ammonical N (-0.582**, -0.297* and -0.653**) and nitrate N (-0.650**, -0.320* and -0.497**). However, organic carbon content showed significantly positive correlation with total hydrolysable N (0.699**), amino acid N (0.714**), acid insoluble N (0.607**), ammonical N (0.713**) and nitrate N (0.641**).

Inceptisols

The data on correlation coefficient between chemical properties and nitrogen fractions in Inceptisols is presented in Table 4.

In Inceptisols, pH and $CaCO_3$ content showed significantly negative correlation with total nitrogen which is evident by 'r' values of -0.712** and -0.582, respectively. Further, it was noticed that organic carbon was showed positively significant correlation with total N which is indicated by 'r' value 0.668**. Electrical conductivity in Inceptisols did not showed any correlation with total nitrogen.

pH and $CaCO_3$ were established negative relationship with available nitrogen content whereas, organic carbon was established positive and significant correlation with available nitrogen which was evident by 'r' values for pH (-0.828**), $CaCO_3$ (-0.669**) and organic carbon (0.762**). However, electrical conductivity could not established any relation with available nitrogen.

The remaining fractions of nitrogen also found to be influenced by soil properties. pH and $CaCO_3$ content were negatively but significantly correlated with total hydrolysable N (-0.712** and -0.621**), acid insoluble N (-0.577** and -0.696**), ammonical N (-0.688** and -0.646**) and nitrate N (-0.704** and -0.560**) except amino acid N which did not reach to the level of significance with $CaCO_3$ but negatively significant with pH (-0.444**). Electrical conductivity did not reach to level of significance with all the fractions of nitrogen. However, organic carbon showed significantly positive correlation with total hydrolysable N (0.666**), amino acid N (0.345**), acid insoluble N (0.631**), ammonical N (0.664**) and nitrate N (0.666**).

Entisols

The data regarding correlation coefficient between chemical properties and nitrogen fractions in Entisols are presented in Table 5.

In Entisols, the data indicated that all nitrogen fractions were significantly influenced by pH, organic carbon and $CaCO_3$ but in case of EC, nitrogen fractions did not reach to the significance level except nitrate nitrogen.

Soil pH and $CaCO_3$ were showed negative but significant relationship with total N (-0.752** and -0.835**), available N (-0.666** and -0.424*), total hydrolysable N (-0.663** and -0.695**), amino acid N (-0.595** and -0.649**), acid insoluble N (-0.609** and -0.758**), ammonical N (-0.650** and -0.772**) and nitrate N (-0.753** and -0.942). Electrical conductivity

Table 5
Correlation between chemical properties and nitrogen fractions in Entisols

Chemical properties	*Total N*	*Available N*	*Total Hydrolysable N*	*Amino Acid N*	*Acid insoluble N*	*Ammonical N*	*Nitrate N*
pH	-0.752**	-0.666**	-0.663**	-0.595**	-0.609**	-0.650**	-0.753**
EC	-0.103	-0.118	-0.114	-0.050	-0.100	0.028	-0.244**
O.C	0.734**	0.565**	0.590**	0.518**	0.573**	0.610**	0.815**
$CaCO_3$	-0.835**	-0.424*	-0.695**	-0.649**	-0.758**	-0.772**	-0.942**

* Significant at 5% level: - 0.349
** Significant at 1% level: - 0.449

established negatively significant correlation with nitrate nitrogen (r = -0.244**) only. However, organic carbon was showed positively significant correlation with total N (0.734**), available N (0.565**), total hydrolysable N (0.590**), amino acid N (0.518**), acid insoluble N (0.573**), ammonical N (0.610**) and nitrate N (0.815**).

In general, the negative relationships between almost all the forms of N pH and $CaCO_3$ content observed that total N decreased with increasing depth in all the profiles, which could be mainly due to decrease in organic carbon in lower layers. Organic N almost followed the trend of total N and decreased with depth in all the profiles. There was no consistent trend in the distribution of NH_4-N with depth. These observations corroborate the findings of Singh *et al.* (1992) who studied the distribution and status of different forms of N in soils of Haryana. Similar findings were also reported by Kaistha *et al.* (1990) from different agroclimatic zones of Himachal Pradesh. Available N was negatively correlated with pH. This might be due to increased rate of denitrification at lower pH values. (Meena *et al.*, 2006)

The organic carbon was positively and significantly correlated with all the forms of N. These results are in accordance in the soils of Mizoram. Such interrelations were also reported by Reza *et al.* (2012) in the soils of Assam.

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