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Status of Nitrogen Pools Under Important Cropping Systems in Inceptisols and Vertisols of Northern Telangana, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Vertisols have showed 11.58, 26.92 and 19.80 % higher amount of available nitrogen, 20.42, 36.65 and 16.72 % higher amount of total nitrogen in 0-15, 15-30 and 30-45 cm depths, respectively over inceptisols. CS_1 has maintained higher amount of available nitrogen content (237 kg ha^{-1}) followed by CS_2 (219 kg ha^{-1}) > CS_4 (189 kg ha^{-1}) > CS_3 (184 kg ha^{-1}) at surface soil (0-15 cm). In vertisols, ammonical nitrogen contributed 48.72 percent to available N, whereas in inceptisols it was 44.46%. Nitrate nitrogen content was recorded significantly higher under vertisols at 0-15 and 15-30 cm soil depths. At 30-45 cm depth inceptisols recorded significantly higher values. However, NO_3-N contributed 32.52 percent towards available N in inceptisols, whereas the share was 30.33 percent under vertisols. In the soil profile, percent contribution of ammonical nitrogen to available N followed as CS_1 > CS_4 > CS_2 > CS_3 with the values 53.13, 48.26, 44.49 and 41.49 %. On the other hand, percent contribution of NO_3 –N towards available N followed different order as CS_4 (40.08%) > CS_3 (37.42%) > CS_2 (32.44%) > CS_1 (20.92%).

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Keywords: Vertisols; inceptisols; cropping systems; ammonical-N; nitrate-N.

1. INTRODUCTION

Nitrogen (N) is assumed to be the most yield-limiting nutrient element for crop production throughout the globe and is applied in the largest quantity for most of the annual crops [1]. Sustainability of an agricultural production system that depends highly on the soil reserve to meet the N requirements cannot be effective for long in producing high yields of crops [2]. Except for legumes, which have the ability to fix their own N, N must be supplied externally to plants for growth. It is usually added as a fertilizer and is required for all types of soils [3]. To increase crop yields, growers worldwide apply over 80 million metric tons of nitrogen fertilizers per year [4]. Use of inorganic N fertilizers has had its most substantial beneficial effect on human health by increasing the yield of field crops and nutritional quality of foods needed to meet dietary requirements and food preferences for growing world populations [5,6]. Ridley and Hedlin [7] concluded that increased use of N fertilizer has had the most dramatic influence on increasing crop yields since the 1950s, in combination with disease-resistant cultivars to a lesser effect. Similarly, Camara et al. [8] reported that historically, few if any technologies have increased winter wheat yield in the United States more than N fertilization. The main reasons for N deficiency are high-quantity uptake by crop plants compared to other macronutrients (except K in some crops such as rice), also in grains or seeds, and its loss by leaching, denitrification, volatilization, soil erosion, and surface runoff. In addition, N is immobilized by soil microbes and undecomposed plant residues, which may cause temporary deficiency. Nitrogen loss in the form of NH_3 by plant canopy has been reported [9]. Furthermore, in intensive cropping systems, where no-tillage system is adopted, depletion or loss of organic matter has been reported [10], which may result in N deficiency in crop plants. Use of low rates for high-yielding modern crop cultivars, especially by farmers in developing countries, is another cause of N deficiency [11]. In developing countries, intensive agricultural production systems have increased the use of N fertilizer in efforts to produce and sustain high crop yields [11]. Consequently, N losses into the environment have also increased (Schmied et al. 2000). Even with the continuing research on N management, average worldwide N use efficiencies (NUE) are reported to be around 50% [12,13], and N recovery efficiency for cereal production (rice, wheat, sorghum, millet, barley, maize, oat, and rye) is approximately 33% [14]. Understanding the effect of cropping systems on the transformation of organic N into different forms is a prerequisite for managing N inputs in a given soil. The present study was undertaken to quantify changes in soil carbon and nitrogen fractions and microbial process of C&N transformation in soil and their interrelationships under continuous cropping systems with differential nutrient management practices.

2. MATERIALS AND METHODS

Soil samples were collected from four cropping systems in Inceptisol and Vertisol at three depths. Sampling sties detailed description are given in Table 1.

2.1 Available Nitrogen

Available nitrogen content of soil was determined by using hot alkaline potassium permanganate (0.32%) for oxidative hydrolysis of the soil organic matter and liberated ammonia was absorbed and condensed in boric acid and titrated against standard 0.02 N H_2SO_4 following the method as proposed by Subbiah and Asija [15].

2.2 Ammonical Nitrogen

Soil sample was extracted with 2 M KCL and filtered. Then the filtrate was steam distilled with 2.5% NaOH in the presence of 0.2 g MgO. The distillate was collected in 4% boric acid containing mixed indicator and was titrated with standard sulphuric acid (0.02 N) and expressed in mg kg^{-1} (Bremner, 1965).

2.3 Nitrate Nitrogen

Soil sample was extracted with 2 M KCL for an hour and filtered. Then the filtrate was steam distilled with 2.5% NaOH in the presence of 0.2 g Devarda’s alloy to obtain NO_3^-N. the distillate was collected in 4% boric acid containing mixed indicator and was titrated with standard sulphuric acid (0.02 N) and expressed in mg kg^{-1} (Bremner, 1965).

Table 1. Soil sampes collected from the following experimental sites with GPS locations

Inceptisol					
Cropping system	**Site-1**	**Site-2**	**Site-3**	**Site-4**	**Site-5**
Rice-Rice	Gangadahara 18^{o}32’32’’ 78^{o}59’07’’	Ramadugu 18^{o}39’27’’ 78^{o}59’07’’	Chennur 18^{o} 88’37’’ 79^{o} 79’52 ’’	Nennal 19^{o} 06’75’’ 79^{o} 58’76’’	Morthad 18^{o} 86’53’’ 78^{o} 43’61’’
Rice-Maize	Gagadhara, 18^{o}36’30’’ 07^{o}90’20’’	Gangadahar 18^{o} 36’07’’ 07^{o}90’15’’	Gutrajpally 18^{o} 84’51’’ 78^{o} 98’48’’	Chennur 18^{o} 88’44’’ 79^{o} 79’53 ’’	Nennal 19^{o} 07’36’’ 79^{o} 58’77 ’’
Trmeric-Sesame	Gangadhara 18^{o}36’07’’ 07^{o}90’15’’	Ramadugu 18^{o} 50’47’’ 07^{o} 85’83’’	Ramadugu 18^{o} 50’48 ’’ 07^{o} 85’82’’	Chennur 18^{o} 88’14’’ 79^{o} 30’53’’	Nennal 19^{o} 08’36’’ 79^{o} 59’58’’
Cotton Fallow	Polasa 18^{o} 84’44’’ 78^{o} 95’44’’	Padkal 18^{o} 69’75’’ 78^{o} 27’55’’	Jakranpally 18^{o} 71’55’’ 78^{o} 26’54’’	Kota armur 18^{o} 79’31’’ 78^{o} 32’66’’	Morthad 18^{o} 81’86’’ 78^{o} 41’07’’
Vertisol					
Rice-Rice	Ragatlapalle 18^{o} 22’38’’ 78^{o} 41’11’’	Gullapet 18^{o} 86’14’’ 78^{o} 95’86’’	Mohanraopet 18^{o} 81’30’’ 78^{o} 76’46’’	Anantharam 18^{o} 85’34’’ 78^{o} 97’63’’	Chennur 18^{o} 73’11’’ 79^{o} 80’51’’
Rice-Maize	Upparmalyal 18^{o} 32’38’’ 07^{o} 85’90’’	Anatharam 18^{o} 85’35’’ 78^{o} 97’73’’	Thakalapally 18^{o} 85’41’’ 78^{o} 97’30’’	Thakalapally 18^{o} 85’43’’ 78^{o} 97’36’’	Chennur 18^{o} 88’41’’ 79^{o} 77’53’’
Trmeric-Sesame	Ragatlapalle 18^{o} 22’34’’ 07^{o} 84’10’’	Chennur 18^{o} 73’38’’ 79^{o} 80’40’’	Manchiryal 18^{o} 95’20’’ 79^{o} 45’36’’	Chennur 18^{o} 73’32’’ 79^{o} 80’36’’	Kalamadugu 19^{o} 08’62’’ 78^{o} 95’22’’
Cotton-Fallow	Palem 18^{o} 87’05’’ 78^{o} 44’21’’	Palem, 18^{o} 87’10’’ 78^{o} 44’20’’	Velpur 18^{o} 87’56’’ 78^{o} 44’13 ’’	Thakallapally 18^{o} 85’28’’ 78^{o} 97’68’’	Thakallapally 18^{o} 85’28’’ 78^{o} 97’77’’

2.4 Total Nitrogen

Estimation of total nitrogen can be done by taking 2.0 g of soil in to 500 ml kjeldahl flask, the soil was swirled with 1g of salicylic acid and 20 ml of concentrated H_2SO_4 for 30 minutes at room temperature. Then added 5g of sodium thiosulphate and 20 g of digestion mixture, allowed the contents for digestion and run the distillation unit by 40% NaOH, the released ammonia trapped in to 4% boric acid mixed indicator solution and titrated against 0.01 N H_2SO_4 until bluish green colour turns pink, the used up H_2SO_4 gives the titer value for calculating total nitrogen content in soil (Page et al. 1982).

3. RESULTS AND DISCUSSION

3.1 Nitrogen and its Pools

Nitrogen is the most limiting nutrient in crop production in India and the form of nitrogen available in the rhizosphere is considerably influenced by the presence of oxygen in the root zone. The available nitrogen, ammonical and nitrate nitrogen concentration was significantly influenced by cropping systems under inceptisols and vertisols.

3.1.1 Available-nitrogen

It is observed that all the soilscomes under lower category of available nitrogen content, irrespective of soil depth it was ranging from 45 to 247 kg ha^{-1}. Both the soil orders and cropping systems had significantly influenced available N content in soil (Table 1).

Vertisols have showed 11.58, 26.92 and 19.80% higher amount of available nitrogen content in 0-15, 15-30 and 30-45 cm depths, respectively over inceptisols. Irrespective of soil order, found an abrupt decline along soil depth, with middle (15-30 cm) and lower (30-45 cm) layers contained only 32.56 and 18.13% of total profile (0-45 cm) available nitrogen content. Available nitrogen content in soil primarily depends on organic residuals entering the soil, decomposition of organic matter [16] and on soil properties. Surface soil receives large amount of organic residuals like root biomass and exudates as active root zone of most of the crops limits to

0-20 cm soil depth. With increase in depth, residue return decreases, hence lower layers of soil showed low available nitrogen.

In cropping systems, CS_1 has maintained higher amount of available Nitrogen content (237 kg ha^{-1}) followed by CS_2 (219 kg ha^{-1}) > CS_4 (189 kg ha^{-1}) > CS_3 (184 kg ha^{-1}) at surface soil (0-15 cm). The same trend was observed in the sub surface soils also. CS_1 and CS_2 have shown significantly higher available nitrogen content in all the three soil depths over other cropping systems. Generally, high moisture of soil for a longer period of time contributes in accumulation of soil organic matter as well as soil nitrogen owing to soil anaerobic environment [17]. Anaerobic conditions were pronounced in CS_1 and CS_2 due to submergence might enhance soil available nitrogen by decreasing decomposition rate of soil organic matter. Moreover, greater below ground crop biomass produced under paddy crop [18,19] might helped CS_1 and CS_2 cropping systems in storing large amount of available soil nitrogen.

Interaction effect of soil orders and cropping systems were found to be non significant to influence available N in soils.

3.1.2 Total nitrogen, nitrate-nitrogen and ammonical-nitrogen

The amount of total nitrogen in soils was significantly higher in vertisols than inceptisols in all the thee depths. Vertisols have shown 20.42, 36.65 and 16.72 % higher amount of TN in 0-15, 15-30 and 30-45 cm depths, respectively over inceptisols (Table 2). Relatively higher total nitrogen content in vertisol might be due to high clay content and lower values of TN in inceptisols may be associated with different parent material and its rate of disintegration [20]. Similar results were also reported by Das et al. [21] and Tabassum et al. [22]. Irrespective of soil order, found an abrupt decline in the amount of TN along soil depth, with middle (15-30 cm) and lower (30-45 cm) layers contained only 34.80 and 27.90% of total profile (0-45 cm).

Total Nitrogen (TN) content ranged from 799 to 1507 kg ha^{-1} under different cropping systems. CS_1 has maintained significantly higher amount of TN (1493 kg ha^{-1}) followed by CS_2 (1344 kg ha^{-1}) > CS_4 (1253 kg ha^{-1}) > CS_3 (1177 kg ha^{-1}) at surface soil (0-15 cm). The same trend was observed in the sub surface soils also. CS_1 have shown significantly higher TN in all the three soil depths over other cropping systems. Generally, high moisture of soil for a longer period of time contributes in accumulation of soil organic matter as well as soil nitrogen owing to soil anaerobic environment [17]. Anaerobic conditions were pronounced in CS_1 and CS_2 due to submergence might enhance soil available nitrogen by decreasing decomposition rate of soil organic matter. Moreover, greater below ground crop biomass produced under paddy crop [18,19] might helped CS_1 and CS_2 cropping systems in storing large amount of available soil nitrogen.

Interaction effect of soil orders and cropping systems were found to be non significant for total nitrogen in soils.

Soil types and cropping systems have significantly influenced the amount of ammonical and nitrate nitrogen content in soil. Ammonical nitrogen was recorded significantly higher under vertisols over inceptisols in all the three depths. With depth an abrupt decline in ammonical nitrogen content was observed. In vertisols, ammonical N contributed 48.72 percent to available N, whereas in inceptisols it was 44.46%. Amount of ammonia in soil primarily depends on mineralization rate and soil clay content. Dynamics of NH_4-N adsorption and desorption in the dominant type of clay i.e. montmorillonite type [23], mineralization [24] and nitrification rates, which in turn is mediated by soil biomass [25-27] as well as the degree of K saturation in the intermediate layers of clay minerals [23] may be the reason for higher ammonical nitrogen under vertisols. Lower NH_4-N under inceptisols was also reported by Dhamak et al. [28]. Such lower values may be due to lower clay content associated partly with different parent material and its rate of disintegration [20], besides lower amount of total N [28].

Nitrate nitrogen content was recorded significantly higher under vertisols with a value of 78.2 and 46.5 kg ha^{-1} at 0-15 and 15-30 cm soil depths, respectively (Fig. 1). At 30-45 cm depth inceptisols recorded significantly higher values (23.6 kg ha^{-1}) over vertisols (20.7 kg ha^{-1}). However, NO_3-N contributed 32.52 percent towards available N in inceptisols, whereas the share was 30.33 percent under vertisols. With depth, an abrupt decline of NO_3- N was observed in both the soil types. NO_3 content in soil depends on nitrification rate soil aeration, moisture and type of microbial communities. Vertisols posses more bases and primary minerals provide more favorable environment for diazotroph communities [29,30], hence recorded higher NO_3-N.

Cropping system also has significantly influenced both ammoniocal nitrogen and nitrate nitrogen content of soils. CS_1 has recorded significantly higher amount of ammonical nitrogen in all the three depths with values of 131.7, 92.6 and 50.9 kg ha^{-1} at 0-15, 15-30 and 30-45 cm depth, respectively as compared with other cropping systems.

Significantly lower values were recorded in CS_3 at 0-15 and 15-30 cm depths, which was on par with CS_4. At 30-45 cm depth CS_4 has shown significantly lower value, which was on par with CS_3. In the soil profile, percent contribution of ammonical nitrogen to available N followed as CS_1 (53.13%) > CS_4 (48.26%) > CS_2 (44.49%) > CS_3 (41.49%). In all the cropping systems NH_4 N values declined with depth.

Nitrate nitrogen values were recorded significantly higher under CS_2 with values of 82.4 and 49.4 at 0-15 and 15-30 cm depth, which was on par with CS_4 with values 79.8 and 43.3 kg ha^{-1} (Fig. 1). At 30-45 cm depth CS_3 has recorded higher values, on par with CS_2. In all the depths, CS_1 has recorded significantly lower NO_3- N content. An abrupt decline was observed with depth in all the cropping systems. NO_3-N content of soil in cropping system followed an order of CS_2 > CS_4 > CS_3 > CS_1. However, the percent contribution of NO_3 –N towards available N followed different order as CS_4 (40.08%) > CS_3 (37.42%) > CS_2 (32.44%) > CS_1 (20.92%).

Results revealed that, CS_1 has recorded significantly higher NH_4-N and lower NO_3-N, may be because of soil N and aeration interactions. Soil aeration was dependent on the soil moisture which affects the nitrogen release from organic and inorganic nitrogen sources [31]. In oxidized conditions thermodynamically stable form of N was nitrate ions, while under reduced or moderately oxidized conditions, ammonium ions will dominate [32]. Soils under CS_1 were under submergence for 8-9 months in a year which causes anaerobic conditions, enhances redox potential. Such high redox potential restricts the conversion of ammonical N to nitrate N, as a result under CS_1 NH_4-N contributed lion share towards available N. Balance between ammonical and nitrate forms of nitrogen in soils also depends on the quality and quantity of nitrification, (function of availability of oxygen and microbial activity) and applied nitrogen [33]. The higher concentration of NH_4 –N in CS_1 may be due to reduced nitrification induced by lack of oxygen in soils because of continuous flooding duringthe crop growing season and reduced root growth resulted in lower nitrifying bacterial activity.

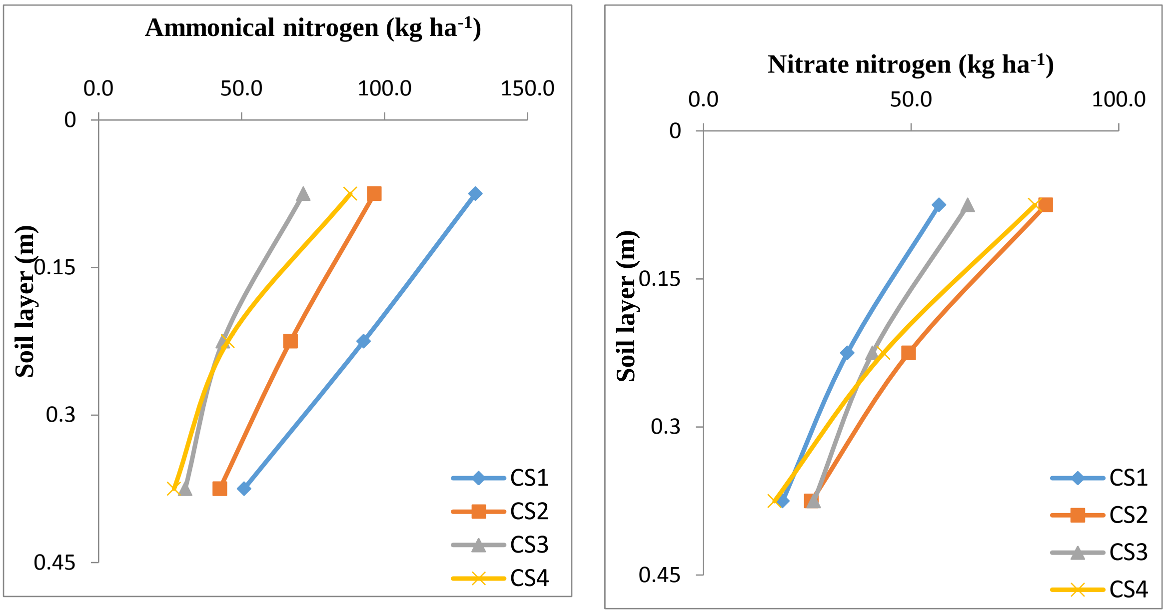

Fig. 1. Distribution of ammonical and nitrate nitrogen under different croppoing systems along the depths

Table 2. Influence of soil type and cropping systems on soil nitrogen fractions and total nitrogen content of soils (kg ha^{-1})

	Available N (Kg ha^{-1})			**Ammonical N (Kg ha^{-1})**			**Nitrate N (Kg ha^{-1})**			**Total N (Kg ha^{-1})**		
Soil order	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
S$_1$	196	121	69	87.1	54.3	34.9	63.2	37.6	23.6	1195	1034	909
S$_2$	219	153	83	106.7	69.9	40.0	78.2	46.5	20.7	1439	1413	1061
Sem	7.64	5.85	4.5	3.5	2.0	1.5	2.7	1.9	1.0	45.2	44.65	34.36
CD@5%	22.14	16.94	13.04	10.1	5.9	4.2	7.7	5.5	2.8	130.93	129.35	99.54
Cropping System												
CS$_1$	237	175	100	131.7	92.6	50.9	56.7	34.6	19.0	1493	1487	1225
CS$_2$	219	172	84	96.4	67.1	42.4	82.4	49.4	26.0	1344	1227	922
CS$_3$	184	101	71	71.6	43.4	30.2	63.7	40.7	26.6	1177	1056	799
CS$_4$	189	99	50	88.0	45.1	26.3	79.8	43.3	17.1	1253	1125	994
Sem	10.81	8.27	6.37	4.9	2.9	2.1	3.8	2.7	1.4	63.92	63.15	48.59
CD@5%	31.31	23.95	18.44	14.3	8.4	6.0	10.9	7.8	3.9	185.16	182.96	140.76
Interactions												
S$_1$CS$_1$	227	159	91	118.8	84.2	49.5	51.8	31.6	20.2	1279	1275	1078
S$_1$CS$_2$	208	152	76	85.5	54.4	39.4	74.9	43.9	27.1	1225	1017	863
S$_1$CS$_3$	173	86	66	69.1	39.2	28.1	58.3	38.0	27.5	1067	896	788
S$_1$CS$_4$	176	86	45	75.1	39.2	22.4	67.7	36.9	19.8	1207	991	908
S$_2$CS$_1$	247	192	108	144.7	101.1	52.2	61.6	37.7	17.9	1706	1739	1371
S$_2$CS$_2$	231	192	93	107.3	79.8	45.4	90.0	55.0	24.9	1463	1437	982
S$_2$CS$_3$	195	117	75	74.0	47.6	32.3	69.0	43.3	25.6	1287	1216	811
S$_2$CS$_4$	202	112	55	100.8	51.1	30.2	92.0	49.8	14.4	1299	1260	1079
Sem	15.29	11.69	9	7.0	4.1	2.9	5.3	3.8	1.9	90.39	89.3	68.72
CD@5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV	16.49	19.11	26.42	16.1	14.7	17.5	16.8	19.1	19.5	15.35	16.32	15.6

S_1- Inceptisols, S_2- Vertisols, CS_1- Rice-Rice, CS_2- Rice-Maize, CS_3- Cotton –Fallow, CS_4- Turmeric-Sesame, SE m: Standard error of mean, CD: Critical difference, CV: Critical Variance

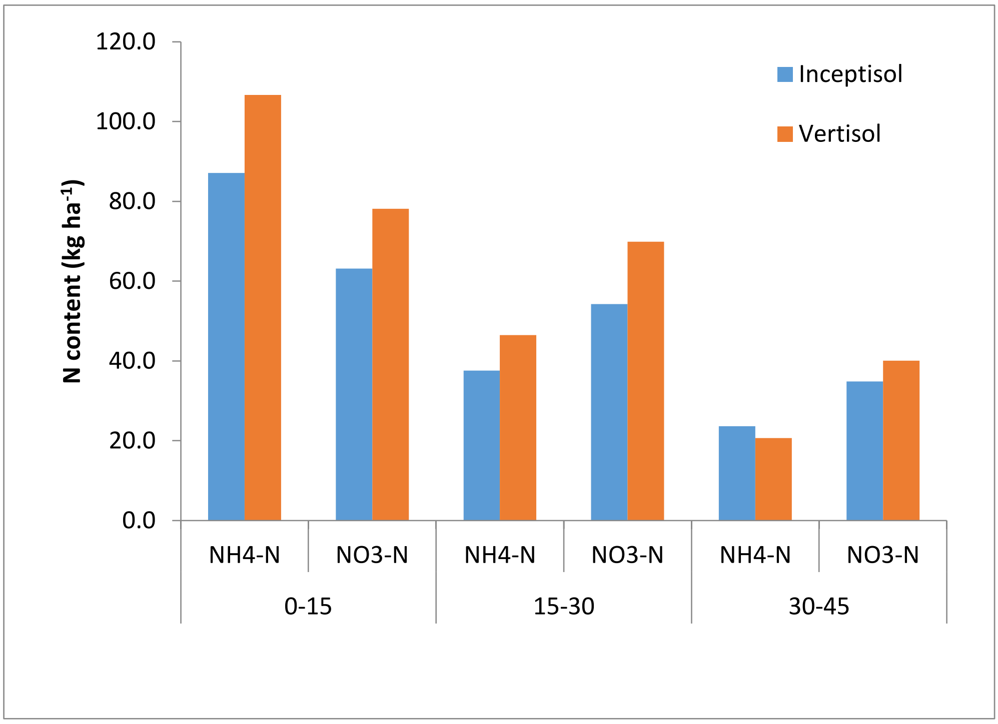

Fig. 2. Depth wise allocation of ammonical and nitrate nitrogen content under inceptisols and Vertisols

Higher NO_3-N was observed in the treatment CS_2, where huge amount of fertilizers were added to soil (for maize as it is an exhaustive crop) along with huge crop residue return to the soil (from rice crop residue). Under CS_2 cropping system alternate aerobic and anaerobic conditions prevails. These situation might have caused maximum nitrification which converts different forms of organic nitrogen and applied inorganic ammonical fertilizers to NO_3–N. Similar results were also supported by Prasad et al. [34] Santhy et al. (1998) and Jain et al. [35].

Interaction of soil orders and cropping systems were found to be non significant for total, ammonical and nitrate nitrogen of soils [36].

4. SUMMARY AND CONCLUSION

Vertisols have showed 11.58, 26.92 and 19.80% higher amount of available nitrogen content in 0-15, 15-30 and 30-45 cm depths, respectively over inceptisols. In cropping systems, CS_1 has maintained higher amount of available nitrogen content (237 kg ha^{-1}) followed by CS_2 (219 kg ha^{-1}) > CS_4 (189 kg ha^{-1}) > CS_3 (184 kg ha^{-1}) at surface soil (0-15 cm). The same trend was observed in the sub surface soils also. In vertisols, ammonical N contributed 48.72 percent to available N, whereas in inceptisols it was 44.46%. However, NO_3-N contributed 32.52 percent towards available N in inceptisols, whereas the share was 30.33 percent under vertisols. In the soil profile, percent contribution of ammonical nitrogen to available N followed as CS_1 (53.13%)> CS_4 (48.26%) > CS_2 (44.49%) > CS_3 (41.49%). However, the percent contribution of NO_3 –N towards available N followed different order as CS_4 (40.08%) > CS_3 (37.42%) > CS_2 (32.44%) > CS_1 (20.92%).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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