

Original Research Article

STATUS OF NITROGEN POOLS UNDER IMPORTANT CROPPING SYSTEMS IN INCEPTISOLS AND VERTISOLS OF NORTHERN TELANGANA, INDIA

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. CS₁ has maintained higher amount of available nitrogen content (237 kg ha⁻¹) followed by CS₂ (219 kg ha⁻¹) > CS₄ (189 kg ha⁻¹) > CS₃ (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, NO₃-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 CS₁ > CS₄ > CS₂ > CS₃ with the values 53.13, 48.26, 44.49 and 41.49 %. On the other hand, percent contribution of NO₃ -N towards available N followed different order as CS₄ (40.08%) > CS₃ (37.42%) > CS₂ (32.44%) > CS₁ (20.92%).

Keywords: Vertisols, nitrogen fertilizers, human health, disease-resistant cultivars

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 (Huber and Thompson, 2007). 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 (Stevenson, 1982). 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 (Clark, 1982). To increase crop yields, growers worldwide apply over 80 million metric tons of nitrogen fertilizers per year (Epstein and Bloom, 2005). 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 (Galloway and Cowling, 2002; Galloway *et al.*, 2002). Ridley and Hedlin (1980) 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.* (2003) 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 NH₃ by plant canopy has been reported (Fageria *et al.*, 2005). Furthermore, in intensive cropping systems, where no-tillage system is adopted, depletion or loss of organic matter has been reported (Johnson *et al.*, 2006), 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 (Fageria *et al.*, 2003). In developing countries, intensive agricultural production systems have increased the use of N fertilizer in efforts to produce and sustain high crop yields (Fageria *et al.*, 2003). 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% (Newbould, 1989; Collins *et al.*, 2007), and N recovery efficiency for cereal production (rice, wheat, sorghum, millet, barley, maize, oat, and rye) is approximately 33% (Raun and Johnson, 1999). 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

MATERIAL AND METHODS

soil samples were collected from four cropping systems in Inceptisol and Vertisol at three depths. Sampling sites detailed description are given below.

Table 1 Soil samples 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°32'32'' 78°59'07''	Ramadugu 18°39'27' , 78°59'07' ,	Chennur 18° 88'37'' 79° 79'52''	Nennal 19° 06'75'' 79° 58'76''	Morthad 18° 86'53'' 78° 43'61''
Rice-Maize	Gagadhara, 18°36'30'' 07°90'20''	Gangadhar 18° 36'07'' 07° 90'15''	Gutrajpally 18° 84'51'' 78° 98'48''	Chennur 18° 88'44'' 79° 79'53'' ''	Nennal 19° 07'36'' 79° 58'77'' ''
Trmeric-Sesame	Gangadhara 18°36'07'' 07°90'15''	Ramadugu 18° 50'47'' 07° 85'83''	Ramadugu 18° 50'48'' '' 07° 85'82''	Chennur 18° 88'14'' 79° 30'53''	Nennal 19° 08'36'' 79° 59'58''
Cotton Fallow	Polasa 18° 84'44'' 78° 95'44''	Padkal 18° 69'75'' 78° 27'55''	Jakranpally 18° 71'55'' 78° 26'54''	Kota armur 18° 79'31'' 78° 32'66''	Morthad 18° 81'86'' 78° 41'07''
Vertisol					
Rice-Rice	Ragatlapalle 18° 22'38'' 78° 41'11''	Gullapet 18° 86'14'' 78° 95'86''	Mohanrao pet 18° 81'30'' 78° 76'46''	Anantharam 18° 85'34'' 78° 97'63''	Chennur 18° 73'11'' 79° 80'51''
Rice-Maize	Upparmalyal 18° 32'38'' 07° 85'90''	Anatharam 18° 85'35'' 78° 97'73''	Thakalapally 18° 85'41'' 78° 97'30''	Thakalapally 18° 85'43'' 78° 97'36''	Chennur 18° 88'41'' 79° 77'53''
Trmeric-Sesame	Ragatlapalle 18° 22'34'' 07° 84'10''	Chennur 18° 73'38'' 79° 80'40''	Manchirya l 18° 95'20'' 79° 45'36''	Chennur 18° 73'32'' 79° 80'36''	Kalamadugu 19° 08'62'' 78° 95'22''
Cotton-Fallow	Palem 18° 87'05'' 78° 44'21''	Palem, 18° 87'10'' 78°	Velpur 18° 87'56'' 78° 44'13	Thakallapally 18° 85'28''	Thakallapally 18° 85'28''

		44°20''	''	78° 97'68''	78° 97'77''
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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 H₂SO₄ following the method as proposed by Subbiah and Asija (1956).

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)

3.4.13 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 NO₃-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)

3.4.14 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 H₂SO₄ 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 H₂SO₄ until bluish green colour turns pink, the used up H₂SO₄ gives the titer value for calculating total nitrogen content in soil (Page et al., 1982).

RESULTS AND DISCUSSION

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.

4. 3. 1. Available-Nitrogen:

It is observed that all the soils comes 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 (Yang *et al.*, 2019) 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, CS₁ has maintained higher amount of available Nitrogen content (237 kg ha⁻¹) followed by CS₂ (219 kg ha⁻¹) > CS₄ (189 kg ha⁻¹) > CS₃ (184 kg ha⁻¹) at surface soil (0-15 cm). The same trend was observed in the sub surface soils also. CS₁ and CS₂ 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 (Whitting and Chanton, 2001). Anaerobic conditions were pronounced in CS₁ and CS₂ 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 (Krishna, 2016, Majumder, 2016) might helped CS₁ and CS₂ 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.

4. 3. 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 three 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 (Ghatol and Malwar, 1978). Similar results were also reported by Das *et al.* (2006) and Tabassum *et al.* (2010). 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. CS₁ has maintained significantly higher amount of TN (1493 kg ha⁻¹) followed by CS₂ (1344 kg ha⁻¹) > CS₄ (1253 kg ha⁻¹) > CS₃ (1177 kg ha⁻¹) at surface soil (0-15 cm). The same trend was observed in the sub surface soils also. CS₁ 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 (Whitting and Chanton, 2001). Anaerobic conditions were pronounced in CS₁ and CS₂ 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 (Krishna, 2016, Majumder, 2016) might helped CS₁ and CS₂ 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 NH₄-N adsorption and desorption in the dominant type of clay i.e. montmorillonite type (Nieder *et al.*, 2010), mineralization (Villasenor *et al.*, 2015) and nitrification rates, which in turn is mediated by soil biomass (Jensen *et al.*, 2000; Sainz *et al.*, 2004 and Sahrawat, 2006) as well as the degree of K saturation in the intermediate layers of clay minerals (Nieder *et al.*, 2010) may be the reason for higher ammonical nitrogen under vertisols. Lower NH₄-N under inceptisols was also reported by Dhamak *et al.*, 2014. Such lower values may be due to lower clay content associated partly with different parent material and its rate of disintegration (Ghatol and Malewar, 1978), besides lower amount of total N (Dhamak *et al.*, 2014).

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, $\text{NO}_3\text{-N}$ contributed 32.52 percent towards available N in inceptisols, whereas the share was 30.33 percent under vertisols. With depth, an abrupt decline of $\text{NO}_3\text{-N}$ 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 possess more bases and primary minerals provide more favorable environment for diazotroph communities (Stone *et al.*, 2015 and Pajares *et al.*, 2016), hence recorded higher $\text{NO}_3\text{-N}$.

Cropping system also has significantly influenced both ammoniacal nitrogen and nitrate nitrogen content of soils. CS_1 has recorded significantly higher amount of ammoniacal 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 ammoniacal 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 $\text{NH}_4\text{-N}$ 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 $\text{NO}_3\text{-N}$ content. An abrupt decline was observed with depth in all the cropping systems. $\text{NO}_3\text{-N}$ content of soil in cropping system followed an order of $\text{CS}_2 > \text{CS}_4 > \text{CS}_3 > \text{CS}_1$. However, the percent contribution of $\text{NO}_3\text{-N}$ towards available N followed different order as CS_4 (40.08%) > CS_3 (37.42%) > CS_2 (32.44%) > CS_1 (20.92%).

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

Soil order	Available N (Kg ha ⁻¹)			Ammonical N (Kg ha ⁻¹)			Nitrate N (Kg ha ⁻¹)			Total N (Kg ha ⁻¹)		
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
S₁	196	121	69	87.1	54.3	34.9	63.2	37.6	23.6	1195	1034	909
S₂	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												
CS₁	237	175	100	131.7	92.6	50.9	56.7	34.6	19.0	1493	1487	1225
CS₂	219	172	84	96.4	67.1	42.4	82.4	49.4	26.0	1344	1227	922
CS₃	184	101	71	71.6	43.4	30.2	63.7	40.7	26.6	1177	1056	799
CS₄	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												
S₁CS₁	227	159	91	118.8	84.2	49.5	51.8	31.6	20.2	1279	1275	1078
S₁CS₂	208	152	76	85.5	54.4	39.4	74.9	43.9	27.1	1225	1017	863
S₁CS₃	173	86	66	69.1	39.2	28.1	58.3	38.0	27.5	1067	896	788
S₁CS₄	176	86	45	75.1	39.2	22.4	67.7	36.9	19.8	1207	991	908
S₂CS₁	247	192	108	144.7	101.1	52.2	61.6	37.7	17.9	1706	1739	1371
S₂CS₂	231	192	93	107.3	79.8	45.4	90.0	55.0	24.9	1463	1437	982
S₂CS₃	195	117	75	74.0	47.6	32.3	69.0	43.3	25.6	1287	1216	811
S₂CS₄	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

S₁- Inceptisols, S₂- Vertisols, CS₁- Rice-Rice, CS₂- Rice-Maize, CS₃- Cotton –Fallow, CS₄- Turmeric-Sesame, SE m: Standard error of mean, CD: Critical difference, CV: Critical Variance.

Results revealed that, CS₁ has recorded significantly higher NH₄-N and lower NO₃-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 (Agehara and Warncke, 2005). In oxidized conditions thermodynamically stable form of N was nitrate ions, while under reduced or moderately oxidized conditions, ammonium ions will dominate (Husson, 2013). Soils under CS₁ 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 CS₁ NH₄-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 (Sooksa-nguan *et al.*, 2009). The higher concentration of NH₄ -N in CS₁ may be due to reduced nitrification induced by lack of oxygen in soils because of continuous flooding during the crop growing season and reduced root growth resulted in lower nitrifying bacterial activity.

Higher NO₃-N was observed in the treatment CS₂, 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 CS₂ 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 NO₃-N. Similar results were also supported by Prasad *et al.* (1986) Santhy *et al.* (1998) and Jain *et al.* (2003).

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

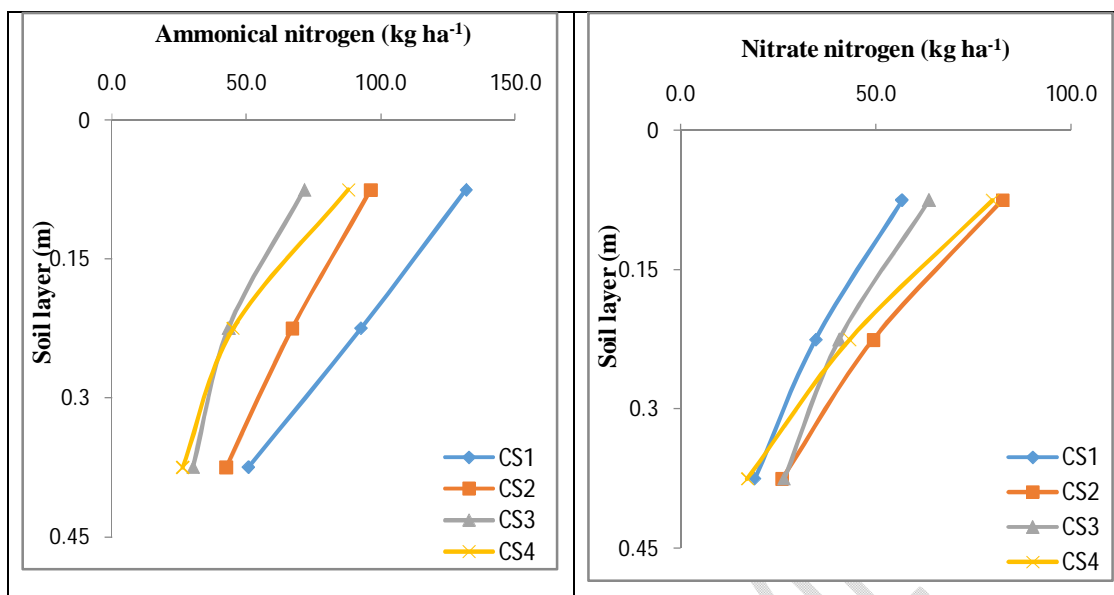


Fig. 1 Distribution of ammonical and nitrate nitrogen under different cropping systems along the depths.

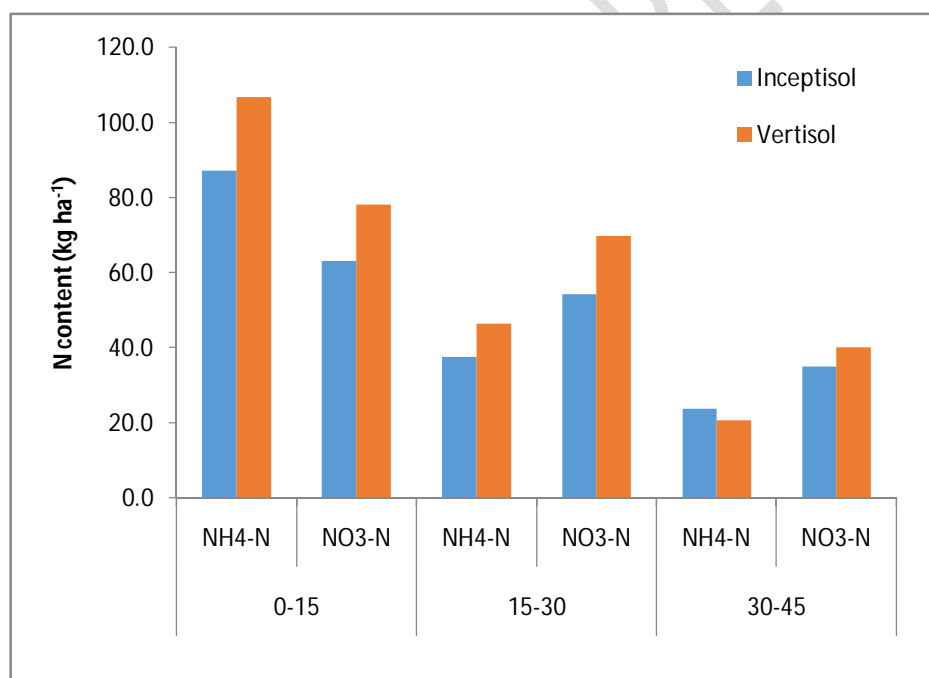


Fig. 2. Depth wise allocation of ammonical and nitrate nitrogen content under inceptisols and Vertisols.

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, CS₁ has maintained higher amount of available nitrogen content (237 kg ha⁻¹) followed by CS₂ (219 kg ha⁻¹) > CS₄ (189 kg ha⁻¹) > CS₃ (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, NO₃-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 CS₁ (53.13%) > CS₄ (48.26%) > CS₂ (44.49%) > CS₃ (41.49%). However, the percent contribution of NO₃ -N towards available N followed different order as CS₄ (40.08%) > CS₃ (37.42%) > CS₂ (32.44%) > CS₁ (20.92%).

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