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Effect of Vermicompost Application on Nitrogen Transformation in Soil

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Authors' contributions

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

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ABSTRACT

Aim: To know the effect of vermicompost application on nitrogen transformation in soil.
Study Design: Completely Randomized Design (CRD).
Place of Study: Experimental site of Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour.
Methodology: The present study includes two pot experiments i.e., with and without the effect of root rhizosphere of cauliflower have been conducted. The different of nitrogen were analysed from both the experiments by using standard methods.
Results: Available nitrogen content increased slowly and reached to peak at 40th day and 50th day that may be due to the addition of organic substrate through vermicompost which leads to the maximum activity of microbes. Ammonium N content changes in soil are quite similar to the available nitrogen in a greenhouse study. But in incubation study changes is differ. Nitrate nitrogen content changes quite dissimilar to the ammonium content. Nitrate content increased slowly and reached to a maximum at the 40th day after addition of vermicompost in both experiments. N content in cauliflower whole plant significantly and positively correlated (r = 0.88**) to soil available nitrogen content.
Conclusion: From the presented study, it may be inferred that ten days prior application of vermicompost can provide maximum support of nitrogen to the plant which can maximize nitrogen use efficiency for crop production.

Keywords: Vermicompost; nitrogen transformation; cauliflower.

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1. INTRODUCTION

Chemical fertilizer increases crop yield and productivity but continuous use of chemical fertilizers without using organic matter can cause deterioration in soil properties and reduce the productivity of the soil. In fact, there has been an observed decline in rice yield and this can be attributed to the declining soil nitrogen supplying capacity [1] and changing soil organic matter quality [2]. Nutrient recycling through vermicomposting is now a day being considered as the concept of integrated nutrient management. The initial effect of organic fertilizer is not immediately evident as with inorganic fertilizer but the long-term effect of its use may be more advantageous at the end, as far as soil fertility, sustainability and productivity are concerned.

Vermicomposting is considered as a viable and environmentally sound method of waste management that hastens the decomposition of the organic waste under controlled conditions, thereby reducing its volume and other environmental problem. The treatment by vermicomposting leads to the development of microbial populations, which cause numerous physicochemical changes within the mixture. It involves a highly complex biological process, involving many species of earthworm, bacteria, fungi and actinomycetes etc. which converts a low-value material into a higher value product. A wide range of bio-wastes can be composted including materials generated by agriculture, food processing, wood processing, sewage treatment, industrial and municipal waste. Finished compost contain small amounts of the primary nutrients (N, P, K) and secondary nutrients (Ca, Mg, S), it also provides vital micronutrients such as iron, manganese, copper and zinc which are essential to plant health in minute quantities and which are often missing from synthetic fertilizers and are overlooked by the farmer. The use of vermicompost as fertilizer is one of the correct destinations, because it allows nutrient cycling within the production unit, making the soil system sustainable by changing the physical, chemical and biological properties. The fertilizer potential of vermicompost is often attributed to its different concentrations and amounts of nutrients, especially nitrogen. Nitrogen plays the most important role in the agricultural production and as it is a constituent of protein, it increases the food value. Nitrogen transformation during composting are largely related to the microbial activity. Plant growth is often improved when plants are nourished with both NO_3^- and NH_4^+ compared to either NO_3^- or NH_4^+ alone. There is increasing evidence that mixtures of these two forms are beneficial for some crops like corn, sorghum, soybean, wheat and barley [3] and also it was reported that it improve plant growth may be due to changes in the physicochemical properties of soils, overall increases in microbial activity or to the effects of plant growth regulators produced by the micro-organisms [4]. Available N includes NH_4^+, NO_3^- and NO_2^- forms. Since, NO_2^- is highly unstable in soil; it is either immediately oxidized to NO_3^- form or reduced to NH_4^+ form. The dynamics of these two forms are influenced by the aeration status of the soil. The NO_3^- accumulated in the soil is either taken up by the crop or leaches down to the lower soil horizon as it is readily soluble in water.

There are huge sources of organic biomass like banana pseudo-stem, maize plant, sugarcane bagasse, water hyacinth and many other organic wastes which are locally available in Bihar and that can be converted into vermicompost. But information are scarce on nitrogen dynamics in soil under vermicompost application. Such information are needed for developing proper guidelines or strategies for effective utilization of vermicompost for better crop production. Hence, this study was aimed to investigate the effects of vermicompost application on nitrogen transformation in soil with and without plant root rhizosphere to compare.

2. MATERIALS AND METHODS

A greenhouse experiment was conducted at Bihar Agricultural University, Sabour to understand the effect of vermicompost application on nitrogen transformation in the soil for 90 days period during 2016. For this, two pot experiments have been taken with and without the effect of root rhizosphere (i.e., greenhouse; 18 pots with cauliflower crop and incubation study; 18 pots without any plant. Treatments were T1 = control, T2 = chemical fertilizer (N:P:K :: 80:40:40), T3 = 2250 mg vermicompost kg^{-1} soil, T4 = 4500 mg vermicompost kg^{-1} soil, T5 = 9000 mg vermicompost kg^{-1} soil, T6 = 18000 mg vermicompost kg^{-1} soil. Vermicompost was prepared by water hyacinth mixing with cow dung (10:1) using *Eisenia foetida* and cauliflower crop was taken for greenhouse study in pots. The bulk surface soil (0-15 cm) was collected from the research farm of BAU, Sabour and five (5) kg of processed soil taken in each pot and mixed thoroughly with different treatments. Physicochemical properties of used vermicompost and soil are present in the table:

Physicochemical properties	Vermicompost	Soil
pH (1:2.5)	6.81	7.94
EC (dSm^{-1})	2.00	0.20
OC (%)	23.10	0.67
Min. N ($mg\ kg^{-1}$)	443.40	98.28
NH_4^+ N ($mg\ kg^{-1}$)	219.30	18.16
NO_3^- N ($mg\ kg^{-1}$)	157.60	7.60
Av. P ($mg\ kg^{-1}$)	52.30	11.42
Av. K ($mg\ kg^{-1}$)	1882.33	97.20
Dehydrogenase activity (μg TPF h^{-1} g^{-1} dry soil)	87.55	19.79

The experimental design was completely randomised with three replications. Immediately after application of treatments, pots were kept in the greenhouse at a controlled condition throughout experiment maintaining moisture level near 75% of Field capacity, allowed one day to equilibrate the whole mass in the pot and then the first sample was drawn. Further sampling was done at 10 days. Collected sample was stored in a clean polythene bag into a refrigerator for chemical analysis like mineralizable N, ammonical nitrogen, nitrate nitrogen and organic carbon. Mineralizable nitrogen was estimated by alkaline permanganate oxidation method as described by [5]. Exchangeable NH_4^+ and NO_3^- nitrogen present in soil and vermicompost were determined by the method of [6] as described by [7]. Organic carbon was determined by wet digestion method of [8] as described in [9].

3. RESULTS AND DISCUSSION

Under greenhouse experiment mineralisable nitrogen release maximum at 10th day and thereafter decreased slowly up to 90th day in all the treatment pots but release at 10th day and 20th were statistically at par in almost all the treatments. Vermicompost applied pots released available nitrogen up to a long time with a higher rate than control and chemical fertiliser applied pot (Table 1). Maximum release was obtained in T6 (168.16 mg kg^{-1}) which was 49.38% over control followed by T5 (157.48 mg kg^{-1}), T4 (151.95 mg kg^{-1}), T2 (137.40 mg kg^{-1}), T3 (127.48 mg kg^{-1}) and T1 (112.57 mg kg^{-1}). Available N content in 10th day and 20th day were not significantly different and significantly decreased during later stages in almost all the treatments, which indicated that maximum mineralization took place during the 10th day and 20th day due to the presence of cauliflower root rhizosphere. Its content increased at the end of the experiment with the increasing level of vermicompost but it was more pronounced in higher doses of vermicompost which was higher than the initial contents (0 days) that were quite different from control (T1) and chemical fertiliser treatment (T2).

While under incubation experiment the available nitrogen content transformation in soil applied with vermicompost of various levels is changes differently (Table 2). Treatment T2 i.e. chemical fertilizer applied pot showed maximum (161.82 mg kg^{-1}) at 20th day followed by control (113.56 mg kg^{-1}) at the 30th day and vermicompost applied pots at 40th day (T3 – 141.74 mg kg^{-1} & T4 – 147.52 mg kg^{-1}) and at 50th day (T5 – 168.51 mg kg^{-1} & T6 - 180.75 mg kg^{-1}). Available nitrogen content increased slowly in vermicompost applied pot and reached to peak at 40th day and 50th day that may be due to the addition of organic substrate through vermicompost which leads to the maximum activity of rapid multiplication of the microbial population. Thereafter, its content decreased that may be due to a shortage of organic substrate that leads to the immobilisation of mineralised nitrogen that as a result of survival of the microbial population. The minimum content of available nitrogen was found at 60th day in T3 (108.18 mg kg^{-1}) & T4 (95.23 mg kg^{-1}) and at 70th day in T5 (91.57 mg kg^{-1}) & T6 (88.14 mg kg^{-1}) treatment that may be due to maximum immobilisation by the maximum microbial population and minimum food substrate. Its content further increased up to 90th day which may be ascribed by the death of microbes subsequently release of nitrogen.

Transformation of ammonical nitrogen under greenhouse study changes in the soil are quite similar to the available nitrogen (Table 3). Its content increased to the maximum within 10th days and thereafter decreased gradually and found minimum at the 90th day in all the treatments that might be due to the uptake of NH_4^+ ion by the cauliflower and nitrification of NH_4^+ to NO_3^- ion. With the increasing levels of vermicompost, NH_4^+ content increased over a long period upto 90th day. Maximum increased was obtained in T6 over maximum increased in control by 132.55% followed T5 (127.57%), T4 (112.19 %), T3 (87.24%) among the vermicompost treated pots.

Table 1. Available nitrogen content (mg kg^{-1}) in soil under the effect of root rhizosphere at important physiological growth stages of cauliflower

Treatments	Days of soil sampling						
	0	**10th**	**20th**	**40th**	**60th**	**90th**	**Mean**
T1 (Control)	98.29	112.57	111.72	102.56	101.06	93.29	**103.25**
T2 (N:P:K::80:40:40)	130.65	137.40 (22.05)*	136.76	130.13	128.09	103.21	**127.71**
T3 (2250 mg VC kg^{-1} soil)	111.68	127.48 (13.24)	121.30	118.65	116.57	111.58	**117.88**
T4 (4500 mg VC kg^{-1} soil)	113.95	151.95 (34.98)	141.23	135.96	131.98	117.68	**132.12**
T5 (9000 mg VC kg^{-1} soil)	115.22	157.48 (39.89)	149.67	145.43	140.82	125.03	**138.94**
T6 (18000 mg VC kg^{-1} soil)	117.93	168.16 (49.38)	164.66	161.41	151.54	133.91	**149.60**
Mean	**114.62**	**142.51**	**137.56**	**132.36**	**128.34**	**114.12**	
CV (%)	10.73						
	Treatment (T)		**Days after application (D)**			**T x D**	
CD (0.05)	9.14		9.14			NS	

**Value in the parenthesis indicates % increase (maximum) over control (maximum); VC = Vermicompost*

Table 2. Ammonical nitrogen content (mg kg^{-1}) in soil under the effect of root rhizosphere at important physiological growth stages of cauliflower

Treatments	Days of soil sampling						
	0	**10th**	**20th**	**40th**	**60th**	**90th**	**Mean**
T1 (Control)	33.67	37.79	30.96	25.47	20.05	19.33	**27.88**
T2 (N:P:K::80:40:40)	60.09	83.11 (119.92)*	62.43	58.23	50.34	43.38	**59.60**
T3 (2250 mg VC kg^{-1} soil)	38.24	70.76 (87.24)	58.05	50.62	45.31	43.63	**51.10**
T4 (4500 mg VC kg^{-1} soil)	40.30	80.19 (112.19)	65.02	59.40	56.77	51.27	**58.82**
T5 (9000 mg VC kg^{-1} soil)	41.88	86.00 (127.57)	66.93	60.79	58.35	56.65	**61.77**
T6 (18000 mg VC kg^{-1} soil)	42.53	87.88 (132.54)	73.95	63.83	62.26	60.56	**65.17**
Mean	**42.79**	**74.29**	**59.56**	**53.06**	**48.85**	**45.80**	
CV (%)	13.50						
	Treatment (T)		**Days after application (D)**			**T x D**	
CD (0.05)	4.85		4.85			11.88	

**Value in the parenthesis indicates % increase (maximum) over control (maximum); VC = Vermicompost*

Table 3. Nitrate nitrogen content (mg kg^{-1}) in soil under the effect of root rhizosphere at important physiological growth stages of cauliflower

Treatments	Days of soil sampling						
	0	**10th**	**20th**	**40th**	**60th**	**90th**	**Mean**
T1 (Control)	13.46	30.09	35.71	32.56	28.72	26.34	**27.81**
T2 (N:P:K::80:40:40)	18.07	42.75	60.12 (68.35)*	59.58	54.31	46.41	**46.87**
T3 (2250 mg VC kg^{-1} soil)	17.16	44.28	51.02	52.36 (46.62)	50.24	45.88	**43.49**
T4 (4500 mg VC kg^{-1} soil)	17.50	45.24	53.71	56.83 (59.14)	51.75	50.21	**45.87**
T5 (9000 mg VC kg^{-1} soil)	17.78	49.31	55.91	58.23 (63.06)	55.34	53.45	**48.34**
T6 (18000 mg VC kg^{-1} soil)	18.57	55.95	58.00	60.12 (68.35)	58.56	56.58	**51.30**
Mean	**17.09**	**44.60**	**52.41**	**53.28**	**49.82**	**46.48**	
CV (%)	19.16						
	Treatment (T)		**Days after application (D)**		**T x D**		
CD (0.05)	5.60		5.60		NS		

**Value in the parenthesis indicates % increase (maximum) over control (maximum); VC = Vermicompost*

Table 4. Organic carbon (%) in soil under the effect of root rhizosphere at important physiological growth stages of cauliflower

Treatments	Days of soil sampling						
	0	**10th**	**20th**	**40th**	**60th**	**90th**	**Mean**
T1 (Control)	0.54	0.54	0.55	0.54	0.54	0.54	**0.54**
T2 (N:P:K::80:40:40)	0.55	0.53	0.54	0.54	0.54	0.54	**0.54**
T3 (2250 mg VC kg^{-1} soil)	0.55	0.56	0.57 (3.63)*	0.56	0.56	0.56	**0.56**
T4 (4500 mg VC kg^{-1} soil)	0.56	0.58 (5.45)	0.58 (5.45)	0.58 (5.45)	0.57	0.58	**0.58**
T5 (9000 mg VC kg^{-1} soil)	0.58	0.59	0.60 (9.09)	0.59	0.59	0.59	**0.59**
T6 (18000 mg VC kg^{-1} soil)	0.60	0.62 (12.72)	0.61	0.62 (12.72)	0.61	0.62 (12.72)	**0.62**
Mean	**0.57**	**0.57**	**0.58**	**0.57**	**0.57**	**0.57**	
CV (%)	2.22						
	Treatment (T)		**Days after application (D)**		**T x D**		
CD (0.05)	0.01		NS		NS		

**Value in the parenthesis indicates % increase (maximum) over control (maximum); VC = Vermicompost*

Table 5. Available nitrogen content (mg kg^{-1}) changes in soil under laboratory incubation study

Treatments	Days of soil sampling										
	0	**10th**	**20th**	**30th**	**40th**	**50th**	**60th**	**70th**	**80th**	**90th**	**Mean**
T1 (Control)	98.65	105.40	110.00	113.56	109.38	103.81	92.74	96.83	101.12	90.03	**102.15**
T2 (N:P:K::80:40:40)	129.36	147.80	161.82(42.49)*	144.45	138.04	108.79	109.21	109.17	113.68	112.05	**127.44**
T3 (2250 mg VC kg^{-1} soil)	110.79	120.09	130.11	138.45	141.74(24.81)	129.91	108.18	110.90	113.59	118.15	**122.19**
T4 (4500 mg VC kg^{-1} soil)	113.94	128.39	135.89	141.57	147.52(29.90)	126.93	95.23	107.19	117.81	129.95	**124.44**
T5 (9000 mg VC kg^{-1} soil)	115.18	138.20	142.12	145.53	151.02	168.51(48.38)	135.58	91.57	116.93	132.75	**133.74**
T6 (18000 mg VC kg^{-1} soil)	117.68	146.85	152.02	160.87	166.51	180.75(59.16)	138.36	88.14	122.52	140.84	**141.45**
Mean	**114.27**	**131.12**	**138.66**	**140.74**	**142.37**	**136.45**	**113.22**	**100.63**	**114.28**	**120.63**	
CV (%)	8.16										
	Treatment (T)		**Days after application (D)**			**T x D**					
CD (0.05)	6.46		8.34			20.42					

Value in the parenthesis indicates % increase (maximum) over control (maximum); VC = Vermicompost

Table 6. Ammonical nitrogen content (mg kg^{-1}) in soil under laboratory incubation study

	Days of soil sampling										
Treatments	**0**	**10th**	**20th**	**30th**	**40th**	**50th**	**60th**	**70th**	**80th**	**90th**	**Mean**
T1 (Control)	27.92	33.05	35.52	36.54	29.35	25.58	24.25	27.29	28.55	28.60	**29.67**
T2 (N:P:K::80:40:40)	46.34	64.83	71.77 (96.41)*	56.63	52.21	37.27	46.46	48.49	48.23	49.58	**52.18**
T3 (2250 mg VC kg^{-1} soil)	31.33	67.50	69.45	66.20	69.83 (91.10)	52.52	40.40	45.49	49.64	52.60	**54.50**
T4 (4500 mg VC kg^{-1} soil)	34.54	68.56	71.61	70.33	72.45 (98.27)	54.57	41.52	38.24	51.74	54.61	**55.82**
T5 (9000 mg VC kg^{-1} soil)	35.51	70.17	76.26	76.17	77.66 (112.53)	59.33	49.32	42.68	53.76	57.60	**59.85**
T6 (18000 mg VC kg^{-1} soil)	37.45	72.21	78.70	79.56	81.43 (122.85)	64.51	47.16	42.29	57.28	65.74	**62.63**
Mean	**35.51**	**62.72**	**67.22**	**64.24**	**63.82**	**48.96**	**41.52**	**40.75**	**48.20**	**51.46**	
CV (%)	11.41										
	Treatment (T)		**Days after application (D)**			**T x D**					
CD (0.05)	3.79		4.89			11.97					

Value in the parenthesis indicates % increase (maximum) over control (maximum); VC = Vermicompost

Table 7. Nitrate nitrogen content (mg kg^{-1}) in soil under laboratory incubation study

	Days of soil sampling										
Treatments	**0**	**10th**	**20th**	**30th**	**40th**	**50th**	**60th**	**70th**	**80th**	**90th**	**Mean**
T1 (Control)	19.13	28.59	30.82	29.40	30.74	30.57	25.83	25.58	27.81	26.12	**27.46**
T2 (N:P:K::80:40:40)	30.34	49.95	51.32	59.33(92.50)*	57.76	45.59	45.97	44.66	46.47	46.72	**47.81**
T3 (2250 mg VC kg^{-1} soil)	24.66	40.29	45.60	43.45	50.24	53.25	55.41(79.78)	50.36	47.34	47.14	**45.77**
T4 (4500 mg VC kg^{-1} soil)	22.77	41.26	45.54	42.88	53.80(74.56)	52.77	43.18	45.45	46.21	47.22	**44.11**
T5 (9000 mg VC kg^{-1} soil)	23.48	45.67	47.62	46.73	51.77	64.77(110.15)	52.47	50.63	50.46	55.62	**48.92**
T6 (18000 mg VC kg^{-1} soil)	24.80	49.48	53.69	55.31	54.43	61.74(100.32)	55.21	52.64	54.21	56.65	**51.82**
Mean	**24.20**	**42.54**	**45.76**	**46.18**	**49.79**	**51.45**	**46.35**	**44.89**	**45.42**	**46.58**	
CV (%)	12.63										
	Treatment (T)		**Days after application (D)**			**T x D**					
CD (0.05)	3.54		4.57			NS					

Value in the parenthesis indicates % increase (maximum) over control (maximum); VC = Vermicompost

Table 8. Organic carbon (%) in soil under laboratory incubation study

Treatments	Days of soil sampling										
	0	**10th**	**20th**	**30th**	**40th**	**50th**	**60th**	**70th**	**80th**	**90th**	**Mean**
T1 (Control)	0.54	0.54	0.55	0.54	0.53	0.53	0.54	0.54	0.55	0.54	**0.54**
T2 (N:P:K::80:40:40)	0.54	0.53	0.54	0.54	0.53	0.54	0.54	0.54	0.55	0.54	**0.54**
T3 (2250 mg VC kg^{-1} soil)	0.55	0.56 (1.81)*	0.55	0.55	0.56	0.55	0.55	0.55	0.56	0.56	**0.56**
T4 (4500 mg VC kg^{-1} soil)	0.55	0.58 (5.45)	0.57	0.57	0.58	0.57	0.57	0.56	0.57	0.58	**0.57**
T5 (9000 mg VC kg^{-1} soil)	0.56	0.59	0.59 (7.27)	0.58	0.58	0.59	0.59	0.59	0.59	0.59	**0.58**
T6 (18000 mg VC kg^{-1} soil)	0.60	0.61	0.61 (10.9)	0.60	0.61	0.60	0.60	0.60	0.60	0.61	**0.61**
Mean	**0.56**	**0.57**	**0.57**	**0.56**	**0.57**	**0.57**	**0.57**	**0.56**	**0.57**	**0.57**	
CV (%)		2.16									
	Treatment(T)		**Days after application (D)**			**T x D**					
CD (0.05)	0.01		NS			NS					

Value in the parenthesis indicates % increase (maximum) over control (maximum); VC = Vermicompost

While in case of incubation experiment the changes in NH_4^+ content in soil (Table 4) is entirely different from greenhouse study. In control pot (T1) and chemical fertilizer pot (T2) showed maximum NH_4^+ content in 30th day (36.54 mg kg^{-1}) and 20th day (71.77 mg kg^{-1}), respectively whereas all the vermicompost applied pots resulted in maximum NH_4^+ at 40th days but rate of increase was maximum at 10th day in all the treatment pots that may be described by the maximum rate of ammonification by the rapidly growing microbial population within 10 days. Sudden significantly decreased its content found in subsequent later stage i.e. at 50th day and became minimum at 70th day followed by its increasing value during later stages at a slower rate. It may be described by the rapid rate of nitrification as well as immobilization of ammonium ion between the 40th day and 50th day resulted in a sudden decrease of ammonium content at the 50th day and rate of immobilisation became maximum at 70th day resulted in minimum content of ammonium ion. Eckhardt et al. [10] reported that the higher contents of available N-NH_4^+, especially in the cattle manure treatment were observed during the first 28 days of incubation. During the period between 28 and 112 days, a reduction in the contents of N-NH_4^+ in the soil was observed, accompanied by the increase in contents of N-$NO3^-$, because of the ammoniac N oxidation from the nitrifying bacterial wastes (nitrification).

In greenhouse experiment, the nitrate nitrogen content change showed a different trend that of ammonical nitrogen. Nitrate content (Table 5) increased slowly and reached to a maximum at 20th days in control (T1) (35.71 mg kg^{-1}) and chemical fertiliser (T2) (60.12 mg kg^{-1}) pots whereas in vermicompost treated pots at 40th day. Addition of vermicompost increase ammonification rapidly that resulted in maximum ammonium production in the 10th day followed by gradual increasing nitrification of ammonium ions and formation of nitrate in soil and reached its content maximum at the 40th day. This nitrification process continued up to 90th day at a better rate and produced nitrate as well as maintained a good level over the experimental period that reflected on statistically non-significant decrease in the content of nitrate in the later stages although cauliflower gained full nutrition (nitrate nitrogen) from vermicompost treated pots that were unlike to T1 (35.71 mg kg^{-1}) and T2 (60.12 mg kg^{-1}).

While in incubation experiment the nitrate nitrogen (Table 6) content changes in soil changes differently. A pot where no treatment was applied i.e. control (T1) nitrification starts immediately and nitrate content reached maximum value to subsequent stages which were non-significantly increase or decrease up to 90 days study. Nitrate content in chemical fertilizer treated pot increased gradually and reached maximum at 30th day and 50th day which were statistically at par followed by sudden decreased at 50th day and maintained a same level in the subsequent stages that may be described by subsequent mineralisation – immobilisation of nitrogen occurred in soil by the soil microbes as there were no other nitrate consumers. Vermicompost treated pot showed a gradual increase in nitrate content that might be the result of slow nitrification and reached maximum value at 50th day followed by a sudden decrease in the subsequent days and maintained a similar level that was opposite to ammonium content changing trends. The long time required for reaching to a maximum content of nitrate in the vermicompost treated pots that may be due to start of ammonification followed by slow nitrification of produced NH_4^+ in the soil in absence of any living plant root.

In greenhouse experiment, the organic carbon (Table 7) content in control and inorganic fertiliser applied pots were the same over the experiment period. With the increasing level of vermicompost organic carbon content increased significantly but with the progressing of the experiment organic carbon content was not significantly increased. Highest quantity of organic C found in T6 (0.60 %) at 0 day of study. Its content increased with the progressing of the experiment to 0.62% which was 12.72% increased over control. Romaniuk et al. [11] also reported similar results with the application of 10 t ha^{-1} and 20 t ha^{-1} vermicompost in the soil.

The organic carbon content (Table 8) change in soil over the incubation study was quite similar to greenhouse pot experiment. Here, the highest quantity of organic carbon found in T6 (0.60 %) at 0 days of study but it increased with progressing of the experiment to 0.61% which was 10.9% increase over control with is little less than greenhouse pot experiment that may be due to lack of root rhizosphere effect on microbial activity in soil.

3.1 Plant Response under Greenhouse Pot Experiment

The nitrogen content in cauliflower whole plant after 90 days of growth varied from 3.12 to 3.61% overall the treatments. Its content increases with increasing level of vermicompost but chemical fertiliser pot resulted in much fewer contents (3.17%). T3 treatment also showed very less content (3.13%) which is statistically at par with control (T1). This result indicates that 2250 mg vermicompost per kg soil i.e. 5 t/ha vermicompost (T3) only was not sufficient to organically cauliflower cultivation. Nehra and Grewal [12] also reported that the highest uptake of nutrients was observed with the highest dose of vermicompost application. Nitrogen content in plant and mean average N content in the soil after 90 days of growth of cauliflower were positively and significantly correlated (r = 0.88**). Average available N content in soil leads to the nutrition of cauliflower plant over 90 days of an experiment which reflected on N % in the plant. N content in curd and dry matter weight showed similar types of results that of nitrogen content in the whole plant. Nitrogen content in curd varied from 5.08 to 5.29% and dry matter weight of cauliflower whole plant varied from 44.79 to 54.94 g over all the treatments.

3.2 The Total Nitrogen Content in the Soil

Total nitrogen content remained at par over 90 days of an experiment for both sets of sub-experiments. The initial total nitrogen content in soil was in 0.073% (control). Addition of chemical fertilizer treatment and different levels of vermicompost, no significant increase in its content was found or no significant decrease of total nitrogen content was found after harvest of cauliflower at 90^{th} day.

4. CONCLUSION

The nitrogen release pattern is quite different in the soil in absence of living plant root. Plant root rhizosphere hastens nitrogen availability at a faster rate that is very much important to the researchers and farmers' to fit vermicompost to the crop cultivation system. Ten (10) days prior application of vermicompost can provide maximum support of nitrogen to the plant which can maximise nitrogen use efficiency for crop production as well as economise the farmers' expenditure. In spite of basal application, vermicompost as top dressing can be fitted in crop cultivation system according to the choice of nitrogen application time.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Cassman KG, Dobermann A, Sta PC, Cruz, Gines GC, et al. Soils organic matter and in the indigenous nitrogen supply of intensive irrigated rice systems in the tropics. Plant & Soil. 1996;182:267-278.
2. Olk DC, Cassman KG, Randall EW, Kinchesh O, Sanger LJ, Anderson JM. Changes in chemical properties of soil organic matter with intensified rice cropping in tropical lowland soils. European Journal of Soil Science. 1996;47:293-303.
3. Tisdale SL, Nelson WL, Beaton JD, Havlin JL. Soil fertility and fertilizers, 5th Edn. PHI Private Ltd., New Delhi; 1995.
4. Norman Q. Arancon, Paola A. Galvis, Clive A. Edwards. Suppression of insect pest populations and damage to plants by vermicomposts. Bioresource Technology. 2005;96:1137–1142.
5. Subbiah BV, Asija GL. A rapid procedure for determination of available nitrogen in soils. Current Science. 1956;25: 259-260.
6. Kenny DR, Bremner JM. Chemical index of soil nitrogen availability. Nature, London. 1962;211:892-893.
7. Page AL, Miller RH, Keeney DR. (eds). Methods of soil analysis: Part 2, Chemical and Microbiological Properties. Agronomy Series No 9, American Society of Agronomy, Madison, WI; 1982.
8. Walkley A, Black IA. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 1934;37:29-37.
9. Black CA. Methods of Soil Analysis, Parts 1 & 2, American Society of Agronomy, Publisher, Madicen, Wisconsin, USA. 1965;1-1378.
10. Eckhardt DP, Redin M, Jacques RJS, Lorensini F, Leandro dos Santos M, Weiler DA, Antoniolli ZI. Mineralization and efficiency index of nitrogen in cattle manure fertilizers on the soil. Ciência Rural, Santa Maria. 2016;46(3):472-477.

11. Romaniuk R, Giuffré L, Romero R. A soil quality index to evaluate the vermicompost amendments effects on soil properites. Journal of Environmental Protection. 2011;2:502-510.
12. Nehra AS, Grewal KS. Influence on integrated use of organic manures and inorganic fertilizers on soil fertilizer and yield of wheat. Proceedings of International Conference on Nature Farming and Ecological Balance, Hisar, 7 - 10 March. 2001;155.