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Residual Effect of Applied Vermicompost and NPK to Rice on Growth and Yield of Succeeding Wheat and Chemical Properties of Soil

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A B S T R A C T

Two consecutive field experiments after rice crop were conducted during 2011-12 and 2012-13 in the Crop Research Centre, of Sardar Vallabhbhai Patel University of Agriculture and Technology, Uttar Pradesh. Ten different treatments were implied to evaluate the residual effect of vermicompost and applied inorganic fertilizers on wheat crop. Significantly taller plants than T_2 during both the years were measured in those treatments where 4 ton vermicompost was applied in rice. Spike length and test weight of wheat remained unaffected due to residual effect while the number of grains per spike was significantly affected. Grain yield varied from 20.00 to 48.70 and 21.30 to 49.50 q ha^{-1} during 2011-12 and 2012-13, respectively while straw yield 36.35 to 71.24 and 39.53 to 73.04 q ha^{-1} during 2011-12 and 2012-13, The maximum grain yield 48.70 and 49.50 q ha^{-1} during 2011-12 and 2012-13, respectively and straw yield 71.24 and 73.04 q ha^{-1} was recorded in T_{10} where along with 50% N, 100% P and K 4 ton vermicompost was applied in rice at flowering and 100% NPK to wheat. Residual effect of 4 ton vermicompost application on available soil K was significant. Organic carbon (%), pH and electrical conductivity (dSm^{-1}) were not significant.

Introduction

From the time of independence in 1947 until 1965, agricultural production in India was unable to meet the country's needs. Severe droughts in the mid-1960s threatened famine which was averted only by substantial shipments of food grains from the United States. The green revolution i.e. introduction of the new high yielding varieties of wheat, rice and maize was the technological response to a worldwide food storage which became threatening in the period after World War II. The green revolution transformed farming practice in many regions of the tropics and sub tropics where the principal food crops were rice, wheat and maize. The average wheat productivity of India is 2.83 t ha^{-1}. No doubt increased production of rice and wheat filled self-sufficiency in food grain production, however, indiscriminate use of inorganic fertilizers and plant protection chemicals for maximizing crop yield has resulted in the deterioration of the physical, chemical and biological properties of rice–wheat growing soils. There is a growing concern about the sustainability of the rice-wheat cropping system as the growth rate of rice and wheat yields are either stagnant or have declined. Therefore despite the early benefits, it became apparent that there are many negative impacts from the green revolution such as reduced natural fertility of soil, salinization of the agricultural soil, decline in soil organic matter, and poor soil physical condition particularly in rice-wheat system.

To sustain or increase the productivity of rice-wheat system, it is important that soil status must be perfect the level of organic matter in soil should be enough and overall the soil must be without any constraints. Some of the secretions of worms and associated microbes act as growth promoter along with other nutrients. It has attracted the attention not only of scientists but also of farmers worldwide. Since it is a natural organic product which is eco-friendly, it does not leave any adverse effects either in the soil or in the environment. The C/N ratio of vermicompost is much lower (16:1) than that of FYM (30:1). The effect of earthworms on plant growth may be due to several reasons apart from the presence of macro and micronutrients in their secretions and vermicast in considerable quantities. Certain metabolites produced by earthworms may also be responsible to stimulate the plant growth. Vermicompost also helps in preventing plant diseases (Rao, 2000). The mucus associated with the cast being hygroscopic absorbs water and improve water holding capacity. A positive effect of vermicompost application on yield attributes and yield of various crops had been reported by Vasanthi and Kumar Swamy (2000), Ranwa and Singh (1999), Das *et al.*, (2002) and Singh *et al.*, (2005). Dussere (1992) reported that vermicompost helps to improve and protect fertility of top soil and also helps to boost up productivity by 40% with 20 to 60% lower inputs, It also enhance the quality of end products and thereby creating significant impact on flexibility in marketing as well as increases the storage time. Vermicompost contain 30 to 50 percent substance which help in the stimulation of plant growth, particularly that of roots. Robinson *et al.*, (1992) reported that the nutrients present in vermicompost are readily available. In the present study an attempt was made to study the effect of timing of vermicompost application in integrated mode on main crop rice and its residual effect on succeeding wheat crop.

Materials and Methods

Two field experiments were conducted at the Crop Research Centre (CRC), Chirodi of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) located at latitude of 29^0 40′ north and longitude of 77^0 42′ east and at an altitude of 237 meter above mean sea level (MSL). The area receives on an average 862 mm of rains annually of which 90% is confined to rainy season.

A composite soil sample was collected from a depth of 0-15cm of the experimental site. The experimental soil was sandy loam in texture (Sand, 63.2%, Silt 18.5 % and Clay 18.3 %), alkaline in pH (8.04), having low organic carbon (0.43%), available nitrogen (155.5 kg/ha) medium in phosphorus (13.8 kg/ha) and potassium (141.5 kg/ha). To study the residual effect of vermicompost on growth performance of wheat crop and chemical properties of soil ten treatments were implied in randomized block design with three replication in rice-wheat system during 2011-12 and 2012-13. Treatment details included, T_1 - Control without NPK in rice and wheat, T_2 -100% RDF to rice and wheat, T_3 -75% N,100% P&K + Vermicompost @ 2 t ha^{-1} as basal to rice followed by 100% RDF to wheat,

T_4 -75% N, 100% P&K + Vermicompost @ 2 ton ha^{-1} at tillering stage to rice followed by 100% RDF to wheat, T_5 -75% N, 100% P&K + Vermicompost @ 2 ton ha^{-1} at panicle initiation followed by 100% RDF to wheat, T_6 -75% N, 100% P&K + Vermicompost @ 2 ton ha^{-1} at flowering stage to rice followed by 100% RDF to wheat, T_7 -50% N,100% P&K + Vermicompost @ 4 ton ha^{-1} as basal to rice followed by 100% RDF to wheat, T_8- 50% N,100% P&K + Vermicompost @ 4 ton ha^{-1} at tillering stage to rice followed by 100% RDF to wheat, T_9-50% N,100% P&K + Vermicompost @ 4 ton ha^{-1} at panicle initiation to rice followed by 100% RDF to wheat and T_{10} -50% N,100% P&K + Vermicompost @ 4 ton ha^{-1} at flowering stage to rice followed by 100% RDF to rice. RDF for rice 120, 60, 60 N P and K kg ha^{-1} and for wheat 150, 75, 60 kg ha^{-1} for both the years.

Observations recorded during crop growth and after harvest

Growth observations viz. number of tillers per meter length from the randomly selected row at harvesting, plant height was measured with the help of meter scale from the base of plant to the tip of the tallest leaf up to emergence of spike and thereafter up to the tip of panicle/ spike average shoot height was computed and expressed in cm. at harvest, Length of five panicles or spikes were measured, Number of grains obtained from the five panicles or spikes were counted and expressed as mean number of grains per panicle or spike, 1000 grains were counted and weighed for test weight which was expressed in gram, the weight of grains of wheat harvested from the net plot area was recorded in kg and finally expressed in q ha^{-1}.

The straw yield was computed on difference basis. Grain yield was subtracted from the biological yield of net plot and expressed as kg ha^{-1} and finally expressed in q ha^{-1}.

Chemical analysis

The soil samples were collected after harvesting of the wheat and processed with standard procedure. The pH was determined in soil water suspension (1:2) was determined with the help of glass electrode on a pH meter (Jackson, 1967). The soluble salts (dSm^{-1}) in soils were measured with a conductivity meter, also known as “salt bridge”. Organic carbon was estimated by wet digestion method as described by Jackson (1967). Available N was determined by alkaline permanganate method. The determination of available phosphorus was done by Olsen’s method (Olsen *et al.,* 1954). Available potassium was determined by using neutral ammonium acetate as an extractant and potassium concentration was read by using flame photometer in the filtered extract. The raw data collected for all parameters at different crop stages during the course of investigation was compiled and subjected to statistical analysis using the analysis of variance technique (Gomez and Gomez, 1984). The critical difference (at 5 % level of probability) was computed for comparing treatment mean in cases where effect came out to be significant by F- test.

Results and Discussion

Tillers/m row length and plant height (cm)

With exception of T_1, the tillers/meter row length remained unaffected due to residual effect of preceding rice crop treatments, although comparatively more number of tillers than T_2 were counted in those treatments where 4 ton vermicompost was applied to rice (Table 1). Significantly lower number of tillers/meter row length than the remaining treatments were counted in T_1. Significantly taller plants than T_2 during both the years were measured in those treatments where 4 ton vermicompost was applied in rice at various growth stages. Delayed application of 4 ton vermicompost to rice also resulted in significantly taller plant than the treatments where early application of 2 ton vermicompost was made. The number of tillers/m row length of wheat at harvest did not differ significantly due to residual effect of applied vermicompost. Although number of tillers/m row length in the treatments consisting application of 4 ton vermicompost to rice were comparatively higher than T_2 (100% NPK) but difference could not reach to the level of significance.

Spike length (cm), number of grains per spike and test weight (g) of wheat

Spike length (cm) remained unaffected due to residual effect and ranged from 7.20 to 10.80 and 7.90 to 11.30 cm during 2011-12 and 2012-13, respectively (Table 2). The maximum spike length 10.80 and 11.30 during 2011-12 and 2012-13, respectively, was recorded in T_{10} where along with 50% N, 100% P and K, 4 ton vermicompost was applied in rice at flowering stage and 100% NPK to wheat.

The number of grains per spike varied from 25.30 to 55.90 and 26.40 to 56.00 during 2011-12 and 2012-13, respectively (Table 2). The maximum grains per spike than the other treatments 55.90 and 56.00 during 2011-12 and 2012-13 were recorded in T_{10} where along with 50 % N, 100% P and K, 4 ton vermicompost was applied in rice at flowering and 100% NPK to wheat. Only T_1 was found significantly inferior to rest of the treatments in respect of number of grains per spike while remaining treatments were statistically at par.

It is clear from the table 2 that the test weight remained unaffected due to residual effect during both the years. The test weight (g) varied from 36.48 to 39.18 and 36.74 to 39.51g during 2011-12 and 2012-13, respectively. The maximum test weight during both the years was found in T_{10}. Delayed application of 4 ton vermicompost in rice resulted in slightly higher test weight than the T_2. Delayed application of 4 ton vermicompost to rice crop resulted in comparatively higher yield attributing characters. In case of number of grains per spike only T_1 was found significantly inferior than the rest of the treatments. Higher number of grains was found with delayed application of vermicompost to rice. This variation may be due to comparatively better physical environment that affects nutrient transformation and absorption from the soil and thereby responds to vegetative as well as reproductive phase of plants.

Grain yield (q ha^{-1}), Straw yield (q ha^{-1}) and Biomass yield

Grain yield varied from 20.00 to 48.70 and 21.30 to 49.50 q ha^{-1} during 2011-12 and 2012-13, respectively (Table 3). The maximum grain yield 48.70 and 49.50 q ha^{-1} during 2011-12 and 2012-13, respectively, was recorded in T_{10} where along with 50% N, 100% P and K, 4 ton vermicompost was applied in rice at flowering and 100% NPK to wheat. Significant residual effect of 4 ton vermicompost application to rice at different growth stages on grain yield of wheat was found.

The straw yield varied from 36.35 to 71.24 and 39.53 to 73.04 q ha^{-1} during 2011-12 and 2012-13, respectively (Table 3). The maximum straw yield 71.24 and 73.04 q ha^{-1} during 2011-12 and 2012-13, was recorded in T_{10} where along with 50% N 100% P and K 4 ton vermicompost was applied in rice crop at flowering and 100% NPK to wheat. Residual effect of 4 ton vermicompost application to rice on straw yield of wheat was significant during both the years but no residual effect was obtained with the application of 2 ton vermicompost. T_{10} was found significantly better than T_2 and all the treatments consisting application of 2 ton vermicompost to rice. Biomass yield of wheat varied from 56.35 to 119.94 and 60.83 to 122.54 q ha^{-1} during 2011-12 and 2012-13, respectively (Table 3). A significant residual effect of 4 ton vermicompost application to rice on biomass yield of wheat was observed but such effect was not noticed clearly in case of 2 ton vermicompost application.

Table.1 Residual effect of preceding rice crop treatments on plant height (cm) and number of tillers m^{-1} row length of wheat crop at harvest

Treatments	Plant height (cm)		No. of tillers/ m row length	
	2011-12	2012-13	2011-12	2012-13
T_1	64.5	66.1	58.6	61.8
T_2	74.4	76.6	85.8	86.3
T_3	75.3	77.3	84.3	85.2
T_4	76.8	78.2	86.4	86.7
T_5	77.2	79.4	87.6	87.9
T_6	78.6	81.7	88.5	87.6
T_7	81.7	84.2	96.3	97.3
T_8	83.3	86.1	94.1	94.5
T_9	85.9	87.7	95.9	94.7
T_{10}	87.1	88.9	97.3	95.2
SE(m)	2.20	2.79	2.72	2.57
CD at 5%	6.58	8.36	8.13	7.69

Table.2 Residual effect of preceding rice crop treatments on yield attributing characters of wheat crop

Treatments	Length of spike(cm)		No. of grains $spike^{-1}$		Test wt. (g)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
T_1	7.2	7.9	25.3	26.4	36.48	36.74
T_2	8.0	8.5	54.1	44.3	37.19	37.38
T_3	8.2	8.7	54.3	54.5	37.45	37.62
T_4	8.3	8.6	54.4	54.6	37.48	37.57
T_5	8.5	9.2	54.2	54.4	37.40	37.52
T_6	8.7	9.4	54.5	54.8	37.49	37.56
T_7	9.5	10.3	55.6	55.7	38.37	38.54
T_8	9.6	10.2	55.7	55.8	38.56	38.73
T_9	9.3	10.6	55.8	55.9	38.42	38.95
T_{10}	10.8	11.3	55.9	56.0	39.18	39.51
SE(m)	2.18	2.10	2.00	1.86	2.05	1.79
CD at 5%	N.S.	N.S.	5.99	5.56	N.S.	N.S.

Table.3 Residual effect of preceding rice crop treatments on grain, straw and biological yield (q ha^{-1}) of wheat

Treatments	Grain Yield (q ha^{-1})		Straw Yield (q ha^{-1})		Biological Yield (q ha^{-1})	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
T_1	20.0	21.3	36.35	39.53	56.35	60.83
T_2	35.0	37.8	50.16	53.37	85.16	91.17
T_3	37.0	39.2	51.79	54.29	88.79	93.49
T_4	38.3	40.4	53.86	55.82	92.16	96.22
T_5	40.0	43.1	56.52	58.09	96.52	101.19
T_6	41.3	44.6	57.43	59.64	98.73	104.24
T_7	43.0	45.8	61.48	63.75	104.48	109.55
T_8	44.3	46.3	63.22	67.12	107.52	113.42
T_9	45.3	47.1	63.47	62.81	108.77	109.91
T_{10}	48.7	49.5	71.24	73.04	119.94	122.54
SE(m)	1.97	1.25	3.36	3.54	3.25	3.48
CD at 5%	5.90	5.22	10.07	10.61	9.72	10.41

Table.4 Residual effect of preceding rice crop treatments on available nitrogen (Kg ha^{-1}) in soil at different growth stages of wheat

Treatments	Tillering Stage		Jointing Stage		Heading Stage		Harvest	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
T_1	195.42	176.18	170.63	165.65	164.74	157.58	151.28	147.93
T_2	209.14	210.32	203.79	204.82	193.49	194.69	203.75	199.35
T_3	215.94	210.97	208.35	207.38	204.54	202.83	203.84	204.57
T_4	216.48	213.45	212.44	210.62	209.24	206.42	205.48	208.74
T_5	216.78	216.29	214.44	213.46	211.57	210.35	208.78	209.56
T_6	218.65	219.36	218.56	216.27	214.84	213.47	209.68	211.24
T_7	226.54	221.23	219.64	217.39	215.88	214.37	211.56	214.76
T_8	226.36	222.74	225.93	223.75	219.45	219.57	215.72	215.73
T_9	229.27	223.87	227.72	224.39	223.35	220.83	219.33	219.46
T_{10}	231.85	227.45	229.58	226.53	226.24	222.78	221.93	223.56
SE(m)	2.36	2.58	2.011	2.59	2.30	2.57	2.30	2.47
CD at 5%	7.06	7.71	6.02	7.76	6.89	7.71	6.90	7.41

Table.5 Residual effect of preceding rice crop treatments on available phosphorus (Kg ha^{-1}) in soil at different growth stages of wheat

Treatments	Tillering Stage		Jointing Stage		Heading Stage		Harvest	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
T_1	12.43	14.74	12.20	13.58	10.73	12.85	10.25	11.29
T_2	13.40	15.47	12.67	13.62	12.30	12.94	11.95	11.75
T_3	14.78	16.67	13.37	13.84	12.14	12.97	11.65	11.88
T_4	14.53	16.44	14.31	14.28	13.68	13.04	12.46	12.34
T_5	16.56	16.37	14.49	14.84	14.07	14.44	13.43	12.73
T_6	17.44	17.27	13.54	14.57	13.67	13.11	12.32	11.83
T_7	14.38	16.25	13.17	13.55	12.71	13.24	11.76	11.64
T_8	14.68	15.84	12.38	13.39	12.57	13.19	11.24	11.15
T_9	16.34	16.85	13.67	13.87	12.88	13.31	11.85	11.68
T_{10}	16.33	16.83	13.39	13.65	12.75	13.29	11.98	11.79
SE(m)	2.18	2.11	2.10	1.97	1.94	2.09	2.13	1.98
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table.6 Residual effect of preceding rice crop treatments on available potassium (Kg ha^{-1}) in soil at different growth stages of wheat

Treatments	Tillering Stage		Jointing Stage		Heading Stage		Harvest	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
T_1	211.56	192.78	198.76	173.53	196.25	168.93	184.75	162.39
T_2	230.28	233.73	228.10	232.75	225.38	229.46	224.84	224.64
T_3	234.44	236.48	231.95	234.33	227.14	228.79	224.25	223.43
T_4	235.76	249.93	232.85	243.22	228.27	233.83	225.43	227.85
T_5	244.47	251.57	238.84	248.33	234.57	247.54	232.32	243.76
T_6	245.50	251.83	239.65	247.74	235.39	244.55	233.85	240.26
T_7	245.65	259.16	239.73	257.87	235.34	254.94	235.73	247.83
T_8	245.72	261.26	239.83	259.57	236.42	256.32	233.79	250.85
T_9	246.06	263.57	241.57	251.35	238.24	259.55	235.33	252.47
T_{10}	247.08	264.04	244.60	262.83	241.86	260.77	239.14	254.35
SE(m)	2.31	2.55	2.34	2.24	2.01	2.42	2.55	2.32
CD at 5%	6.92	7.64	7.02	6.70	6.02	7.25	7.63	6.96

Table.7 Residual effect of preceding rice crop treatments on organic carbon (%) of soil in different growth stages of wheat crop 2011-12 to 2012-13

Treatments	Tillering Stage		Jointing Stage		Heading Stage		Harvest	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
T_1	0.388	0.382	0.385	0.377	0.383	0.373	0.378	0.369
T_2	0.459	0.463	0.456	0.458	0.454	0.456	0.452	0.454
T_3	0.468	0.475	0.465	0.473	0.463	0.469	0.460	0.464
T_4	0.462	0.475	0.460	0.473	0.458	0.471	0.456	0.469
T_5	0.471	0.478	0.469	0.476	0.466	0.474	0.464	0.472
T_6	0.468	0.474	0.465	0.469	0.463	0.467	0.460	0.465
T_7	0.465	0.460	0.463	0.458	0.460	0.456	0.459	0.454
T_8	0.457	0.459	0.456	0.464	0.453	0.463	0.452	0.460
T_9	0.469	0.463	0.465	0.461	0.463	0.460	0.461	0.458
T_{10}	0.478	0.483	0.476	0.481	0.474	0.478	0.472	0.476
SE(m)	0.024	0.026	0.025	0.025	0.026	0.024	0.026	0.027
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table.8 Residual effect of preceding rice crop treatments on pH of soil at different growth stages of Wheat 2011-12 to 2012-13

Treatments	Tillering Stage		Jointing Stage		Heading Stage		Harvest	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
T_1	8.15	8.09	8.03	7.97	7.91	7.85	7.79	7.73
T_2	7.19	7.88	7.75	7.72	7.59	7.56	7.43	7.40
T_3	7.82	8.04	7.68	7.97	7.54	7.93	7.40	7.87
T_4	7.79	8.02	7.66	7.95	7.53	7.76	7.40	7.66
T_5	7.74	7.97	7.61	7.54	7.48	7.41	7.35	7.28
T_6	7.75	7.69	7.62	7.56	7.49	7.43	7.36	7.30
T_7	7.69	7.72	7.64	7.62	7.58	7.48	7.52	7.34
T_8	7.66	7.98	7.61	7.91	7.55	7.87	7.50	7.82
T_9	7.65	7.96	7.60	7.88	7.53	7.83	7.49	7.77
T_{10}	7.68	7.67	7.63	7.59	7.57	7.46	7.53	7.36
SE(m)	0.55	0.51	0.23	0.18	0.24	0.16	0.26	0.19
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table.9 Residual effect of preceding rice crop treatments on EC (dSm^{-1}) of soil at different growth stages of wheat 2011-12 to 2012-13

Treatments	Tillering Stage		Jointing Stage		Heading Stage		Harvest	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
T_1	0.28	0.25	0.28	0.25	0.24	0.23	0.31	0.29
T_2	0.22	0.22	0.24	0.21	0.22	0.20	0.25	0.24
T_3	0.21	0.23	0.22	0.20	0.23	0.20	0.23	0.25
T_4	0.23	0.22	0.25	0.23	0.21	0.19	0.26	0.24
T_5	0.21	0.24	0.21	0.22	0.21	0.21	0.25	0.26
T_6	0.23	0.22	0.24	0.23	0.22	0.20	0.24	0.25
T_7	0.24	0.23	0.25	0.24	0.24	0.22	0.25	0.27
T_8	0.26	0.25	0.24	0.24	0.22	0.23	0.28	0.26
T_9	0.26	0.24	0.26	0.25	0.22	0.24	0.29	0.25
T_{10}	0.25	0.23	0.24	0.24	0.23	0.22	0.27	0.24
SE(m)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD at 5%	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04

Maximum biomass production than the other treatments was found in case of T_{10} during both the years. Treatments consisting application of 4 ton vermicompost during preceding rice crop did not differ significantly in respect of biomass production.

All the treatments consisting 4 ton vermicompost to rice and 100% NPK to wheat produced significantly higher grain and straw yield of wheat than T_2 where 100% NPK was applied to rice as well as wheat.

This significant variation in crop yield may be supposed due to improved physical environment of soil due to residual effect of vermicompost that had resulted in better plant growth and yield attributing characters with residual effect nutrients availability were also higher (Aruna and Shaik, 2005). Application of farmyard manure at 10 tons ha^{-1} contributes 30 – 60 kg N ha^{-1} in rice besides leaving a significant residual effect on succeeding crop (Sharma, 1995). Bhandari *et al.*, (1992) also reported the residual effect of organic sources applied to rice on succeeding wheat. Significant residual effect on wheat crop was also reported by Rajput and Warsi (1992).

N, P, and K availability

At tillering stage available soil N (kg ha^{-1}) varied from 195.42 to 231.85 and 176.18 to 227.45 during 2011-12 and 2012-13, respectively (Table 4). In most cases the residual effect of vermicompost application to rice on available soil N at this stage of wheat was significant during both the years. Availability of N in T_2 was found significantly lower than the treatments where vermicompost was applied during Kharif season. Available soil N at jointing stage declined from the value recorded at tillering during both the years. Available N in soil at this stage varied from 170.63 to 229.58 and 165.65 to 226.53 kg ha^{-1} during 2011-12 and 2012-13, respectively. Most of the Treatments having vermicompost application during rice season exhibited their significant residual effect over T_2 in respect of available soil N during both the years. Availability of soil N was slightly higher with the delayed application of vermicompost to rice. The available N in soil at heading stage varied from 164.74 to 226.24 and 157.58 to 222.78 kg ha^{-1} during 2011-12 and 2012-13, respectively. All the treatments consisting application of vermicompost during rice crop exhibited a significant effect over T_2. Delayed application of either 2 or 4 ton vermicompost in rice season showed slightly higher N availability. At harvesting available N in soil differ significantly under different treatments and varied from 151.28 to 221.93 and 147.93 to 223.56 kg ha^{-1} during 2011-12 and 2012-13 respectively.

At tillering stage available P in soil varied from 12.43 to 17.44 and 14.74 to 17.27 kg ha^{-1} during 2011-12 and 2012-13 respectively (Table 5). Minimum available P in soil was found in the control plot (T_1), while maximum available P in the plot fertilized with 75% N, 100% P and K + vermicompost @ 2 ton ha^{-1} at flowering stage of rice and 100 % NPK to wheat (T_6) during both the years. At jointing stage available P in soil decline from the previous content in all the treatments and ranged from 12.20 to 14.49 and 13.58 to 14.84 kg ha^{-1} during 2011-12 and 2012-13 respectively. Minimum availability was found in T_1 while maximum in T_5. The available P in soil at heading stage further decreased in all the treatments and varied from 10.73 to 14.07 and 12.85 to 14.44 kg ha^{-1} during 2011-12 and 2012-13, respectively. At harvest P in soil varied from 10.25 to 13.43 and 11.29 to 12.73 kg ha^{-1} during 2011-12 and 2012-13, respectively.

Soil available K at jointing stage declined from the value recorded at tillering during both the years under different treatments. Available K in soil at this stage varied from 198.76 to 244.60 and 173.53 to 262.83 (kg ha^{-1}) during 2011-12 and 2012-13, respectively (Table 6). The available K in soil at heading stage varied from 196.245 to 241.863 and 168.93 to 260.77 kg ha^{-1} during 2011-12 and 2012-13 respectively. At harvesting available soil K varied from 184.75 to 239.14 and 162.39 to 254.35 kg ha^{-1} during 2011-12 and 2012-13, respectively. Maximum available K at this stage was found in T_{10} during both the years. At harvest it was also noticed that availability of potassium was significantly lower with the basal application of vermicompost than at flowering stage in previous rice crop. Minimum and significantly lower available soil K than the rest of the treatments during both the years was found in T_1 control.

In comparison to T_2 of N and K in soil at different growth stages was significantly higher in the treatments where vermicompost was applied. Since the added organic sources did not mineralized completely within the season of application, some portion is left undecomposed or un-mineralized this portion benefit the succeeding crop through the supplementation of plant nutrients and improvement in soil physical environment (Santhi *et al.*, 1999 and Kamla Kanwar, 2002). Substantial improvement in soil fertility due to residual effect was also reported by Aruna and Shaik, 2005. Residual effect of different treatments applied to soyabean on succeeding wheat was also reported by Kundu *et al.*, 2006. Phosphorous availability did not differ significantly due to residual effect although a significant difference was expected.

Organic carbon (%), pH and Electrical Conductivity (dSm^{-1})

At tillering stage the organic carbon percent varied from 0.388 to 0.478 and 0.382 to 0.483 during 2011-12 and 2012-13, respectively (Table 7). The highest organic carbon percent 0.478 and 0.483 percent were recorded in T_{10} during 2011-12 and 2012-13, respectively, where along with 50% N, 100% P and K, 4 ton vermicompost was applied at flowering stage of preceding rice crop. Further with the advancement in crop growth percent organic carbon declined in all the treatments during both the years. At jointing, heading and harvest percent organic carbon varied from 0.385 to 0.476, 0.383 to 0.474 and 0.378 to 0.472, respectively during 2011-12 while 0.377 to 0.481, 0.373 to 0.478 and 0.369 to 0.476, respectively during 2012-13.

At tillering stage the soil pH varied from 7.19 to 8.15 and 7.67 to 8.09 during 2011-12 and 2012-13, respectively (Table 8). The maximum pH 8.15 and 8.09 during 2011-12 and 2012-13, respectively, was recorded in T_1 where no fertilizer was applied. The minimum soil pH 7.65 and 7.67 during 2011-12 and 2012-13, respectively was found with the delayed application of 4 ton vermicompost to rice crop. Soil pH further declined with the advancement in crop growth. In all the cases lower soil pH was recorded in the treatments receiving vermicompost application during the rice crop cultivation.

At tillering stage electrical conductivity (dSm^{-1}) of soil varied from 0.21 to 0.28 and 0.22 to 0.25 dSm^{-1} during 2011-2012 and 2012-2013, respectively (Table 9). The highest electrical conductivity at this stage was found in T_1 during both the years. Electrical conductivity of soil at jointing stage varied from 0.21 to 0.28 and 0.20 to 0.25 (dSm^{-1}) during 2012 and 2013, respectively. At this stage maximum electrical conductivity of soil 0.28 and 0.25(dSm^{-1}) during 2011-12 and 2012-13 respectively, was also found in T_1. Electrical conductivity ranged from 0.21 to 0.24 and 0.23 to 0.31 dSm^{-1} at heading stage and wheat harvest, respectively, during 2011-12 while 0.19 to 0.23 and 0.24 to 0.29 dSm^{-1} respectively during 2012-13. Although slightly higher values were recorded with the application of higher dose of vermicompost but a particular trend of treatments effect at different growth stages was not observed.

Residual effect of applied vermicompost to rice on organic carbon content of soil during the growth of wheat was non-significant. Similarly the residual effect on soil pH was also non-significant. Soil pH and organic carbon percent in soil declined with the advancement of wheat crop growth. With the decomposition of organic matter different organic acids are produced which are supposed to reduce the soil pH (Rajput and Warsi, 1992). Electrical conductivity was higher due to residual effect. It may be explained due to release of different minerals by the organic matter decomposition that will enrich the salt concentration of soil solution.

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