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Nutrient Uptake in Rice Crop as Influenced by Vermicompost and Nitrogen Application

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ABSTRACT

Vermicompost scheduling on nutrient uptake at different growth stages of rice crop were assessed at two field experiments conducted during 2011-12 and 2012-13 in the Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. Different levels of vermicompost along with nitrogen (N) were included in the study. Initially higher nutrient availability in soil in these treatments responded well to plant growth and plant nutrient contents and a significant variation in dry matter accumulation and plant nutrient contents was noticed. Since dry matter yield and nutrient content were maximum/significantly higher in these treatments therefore significantly higher nutrient uptake is obvious. Application of sub optimal level of inorganic N also reflected its impact on dry matter production, plant nutrient content and there by recorded lower quantities of plant nutrient uptake by recorded lower quantities. The nutrients uptake in plant samples at different growth stages differed significantly with the application of Vermicompost and NPK. Plant nutrient uptake was declined with the advancement in crop growth. Plant nutrient uptake was higher in T_2 (100% NPK) at different growth stages of rice during both the years while minimum was found in control. Plant iron, zinc, copper and manganese uptake at different growth stages differ significantly with the application of different treatments. The maximum plant uptake of these micronutrients during entire growth period was found with the application of 100% NPK and it was followed by T_3 where Two ton vermicompost was applied as basal.

Introduction

Since soils have become starved for primary, secondary and micronutrients for decade. Deficiency of secondary and micro plant nutrients is mainly attributed to almost neglect of organic manures by farmers. 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. Long term experiments have indicated that continuous and intensive use of chemical fertilizers have resulted in numerous problems like micronutrients deficiencies, nutrient imbalances in soil and plant system, pest infestation, environmental degradation, deterioration of soil health stagnation of crop yields.Use of both organic and inorganic fertilizers to increase crop production is called integrated nutrient management. Rai *et al.*, 2011 also reported that he effect of phosphate and sulphur were found effective in increasing the availability of P at higher doses and the amount of P was found greater in the surface soil in comparison to sub-soil. INM system refers to a balanced use of chemical fertilizer in combination with organic sources. These organic sources may be organic manures, green manure, rural wastes, crop residues, biofertilizers and vermicompost. Country wide different organic sources of plant nutrients had been evaluated as a possible component of INM and among these vermicompost is most important.

Vermicompost had slight edge over most commonly used organic source farm yard manure by virtue of its higher nutrient content and easily decomposability owing to slightly lower C: N ratio. Conversion of natural ecosystems into agricultural lands for intensive cultivation severely depletes SOC pools (Kumar *et al.*, 2013). The positive effect of vermicompost application on crop growth, yield and soil properties is well documented and established. Rao *et al.,* (2000), Zahid (2001) had reported better growth of chickpea, tomato and rice with the application of vermicompost. Kumar *et al.*, 2017 and Kumar *et al.*, 2017 have also been reported significant use of vermicompost along with nitrogen in rice crop. 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. Reduction in soil pH was also observed with the addition of vermicompost which is obvious due to production of various organic acids on the decomposition of vermicompost (Duhan and Singh, 2002) and (Rai *et al.*, 2012) which helps in nutrient availability especially micronutrient in soil. Robinson *et al.*, (1992) reported that the nutrients present in vermicompost are readily available which signifies the effect of vermicompost in soil. There is no doubt about the role of organic sources on the crop productivity and soil sustainability but the question is timing of its application. Most of the organic sources are applied in soil well before sowing or as basal so that it may stabilize its C: N ratio to an ideal value. In the present study an attempt was made to study the effect of timing of vermicompost application in integrated mode onNutrient uptake in rice crop at different growth stages as influenced by vermicompost and nitrogen application.

Materials and Methods

Two field experiments were conducted during 2011-12 and 2012-13 in the CRC of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) which is located at latitude of 29^0 40′ north and longitude of 77^0 42′ east. The experimental soil was sandy loam in texture having, low organic carbon, available nitrogen and medium in phosphorus and potassium. To study the effect of vermicompost scheduling on plant nutrient uptake at different growth stages of rice crop consisting ten treatments including; T_1-Control (without NPK) in rice, T_2-100% RDF to rice, T_3-75% N,100% P and K + Vermicompost @ 2 ton ha^{-1}as basal to rice, T_4-75% N, 100% P and K +Vermicompost @ 2 ton ha^{-1} at tillering stage to rice, T_5-75% N, 100% P and K + Vermicompost @ 2 ton ha^{-1} at panicle initiation, T_6-75% N, 100% P and K + Vermicompost @ 2 ton ha^{-1} at flowering stage to rice, T_7-50% N, 100% P and K + Vermicompost @ 4 ton ha^{-1} as basal to rice, T_8-50% N, 100% P and K + Vermicompost @ 4 ton ha^{-1} at tillering stage to rice, T_9-50% N, 100% P and K + Vermicompost @ 4 ton ha^{-1} at panicle initiation to rice and T_{10}-50% N, 100% P and K + Vermicompost @ 4 ton ha^{-1} at flowering stage to rice. Recommended dose of fertilizers (NPK) for rice crop was 120, 60 and 60 kg ha^{-1}, respectively. The pH was determined in (1:2) soil water suspension (Jackson, 1973), The soluble salts in soils were measured with a conductivity meter, the electrical conductivity was expressed as deci Siemens per meter (dSm-1), organic carbon was estimated by modified Walkley and Black (1934) method as described by Jackson (1967), available nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1956), 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 (Hanway and Heidal, 1952), available zinc, iron, manganese and copper in soil were extracted by DTPA extractant (Lindsay and Norvell, 1978). 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.

Results and Discussion

Nitrogen uptake (kg ha^{-1}) by rice at different stages

The N uptake by rice at maximum tillering in the treatment having100% NPK application was significant higher than the other treatments during both the years (Table 1). Nitrogen uptake by rice did not differ significantly among the treatments having 75% N, 100% PK application although slightly higher value was recorded for the treatment with basal application of vermicompost during both the years. N uptake by rice increased with the advancement in crop growth. At panicle initiation N uptake by rice varied from 15.85 to 48.79 and 12.98 to 46.85 Kg ha^{-1} during 2011 and 2012 respectively. At flowering stage plant N uptake varied from 30.34 to 81.45 and 26.55 to 87.81 Kg ha^{-1} during 2011 and 2012 respectively. Maximum and significantly higher N uptake than the remaining treatments was found with the application of 100% NPK during both the years. The N uptake by rice grain varied from 30.55 to 50.29 and 23.40 to 58.85 Kg ha^{-1} during 2011 and 2012 respectively. Nitrogen uptake by rice grain did not differ significantly with the timing of vermicompost application during both the years.

Nitrogen uptake by rice straw varied from 8.14 to 28.20 and 11.99 to 30.61 Kg ha^{-1} during 2011 and 2012 respectively. The maximum N uptake by rice straw statistically at par to T_3 and significantly higher than the remaining treatments was found with the application 100% NPK (T_2). Application of vermicompost with 75%N, 100% PK at flowering stage resulted in significantly lower N uptake than the treatment where vermicompost was applied as basal which was statistically at par to $T_4$and T_5 during both the years.

Phosphorus uptake (kg ha^{-1}) by rice at different growth stages

The uptake of phosphorus increased with the advancement in crop growth and maximum uptake at every growth stage was recorded with the application of 100% NPK (Table 2). Phosphorus uptake by rice plant remained unaffected due application of vermicompost as basal during both the years. Phosphorus uptake by rice plant at panicle initiation stage varied from 4.00 to 15.42 and 4.72 to 16.55 Kg ha^{-1} during 2011 and 2012 respectively. Phosphorus uptake did not differ significantly among the treatments consisting application of 75%N, 100%PK. Similarly P uptake did not varied significantly among the treatments consisting application of 50%N, 100%PK during 2012 but T_9 and T_{10} were found significantly inferior to T_7 in respect of P uptake during 2011. The phosphorus uptake by rice plant at flowering stage varied from 4.95 to 16.84 and 5.31 to 19.11 Kg ha^{-1} during 2011 and 2012 respectively.

Phosphorus uptake by rice in T_3 was found significantly higher than the treatments consisting application of 75% N, 100% PK with or without vermicompost during both the years. Basal application of vermicompost was found significantly better than the application of vermicompost at other stages during both the years. The Phosphorus uptake by rice grain varied from 3.88 to 11.94 and 2.74 to 13.07 Kg ha^{-1} during 2011 and 2012 respectively. Maximum and significantly higher P uptake by rice grain than the other treatments with exception of T_3 was recorded with the application of 100% NPK during both the years. Significantly lower P uptake than the T_3 was recorded in case of T_6 during both the years where vermicompost was applied at flowering stage. Similar trend was also recorded in case of the treatments consisting 50% N 100% PK.

Phosphorus uptake by rice straw varied from 1.96 to 10.66 and 2.30 to 12.46 Kg ha^{-1} during 2011 and 2012 respectively. The uptake of phosphorus by rice straw with the application of 100% NPK was found significantly higher than the remaining treatments during both the years. During 2011 only T_3 was significantly better than T_6 in respect of straw P uptake while all the remaining treatments consisting application of 75%N, 100% PK were found significantly better than T_6 during 2012.

Potassium uptake (kg ha^{-1}) by rice at different growth stages

Potassium uptake by rice plant at panicle initiation stage varied from 12.43 to 41.85 and 12.94 to 42.49 Kg ha^{-1} during 2011 and 2012 respectively (Table 3). Maximum and significantly higher K uptake than the remaining treatments was noted in T_2 during both the years. Uptake of K by rice plant did not differ significantly due to basal application of vermicompost over 75%N, 100% PK during 2011but a significant effect was noticed during 2012 and T_3 was found significantly better than T_5 and T_6. The potassium uptake by rice plant at flowering stage varied from 29.29 to 66.76 and 28.89 to 67.94 Kg ha^{-1} during 2011 and 2012, respectively. A significant effect of vermicompost application over 75% N, 100% PK was noticed during both the years and potassium uptake by rice plant was significantly higher in T_3 where vermicompost was applied as basal than the treatments where either vermicompost was applied at panicle initiation or still to be applied at flowering. Such effect was not noticed in case of 50 % NPK.

Table.1 Effect of different treatments on nitrogen uptake (Kg ha^{-1}) in rice at different growth stages

Treatments	Max. Tillering		Panicle Initiation		Flowering		At harvest			
							Grain		Straw	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	8.34	7.32	15.85	12.98	30.34	26.55	30.55	23.40	8.14	11.99
T_2	19.22	18.65	48.79	46.85	81.45	87.81	50.29	58.85	28.20	30.61
T_3	15.53	13.39	37.69	37.14	67.80	75.40	46.73	53.52	25.78	27.46
T_4	15.11	12.51	36.07	33.44	63.46	62.09	43.19	49.03	23.97	25.35
T_5	13.84	11.47	34.11	30.09	58.18	56.50	42.22	48.36	22.06	24.61
T_6	13.88	11.26	30.60	30.83	57.53	52.02	42.99	41.44	20.74	23.12
T_7	11.80	10.05	32.72	26.47	56.23	53.51	44.67	45.42	20.28	21.57
T_8	10.62	8.68	29.30	24.66	54.53	50.84	41.10	41.70	16.90	19.71
T_9	10.42	8.39	23.92	22.37	54.06	48.79	44.43	40.60	15.49	18.39
T_{10}	9.90	7.93	23.37	21.36	51.83	45.72	39.26	36.88	17.37	19.91
SE(m)	0.80	1.15	1.92	2.65	3.38	2.91	3.24	2.97	1.18	1.26
CD at 5%	2.40	3.44	5.76	7.92	10.10	8.70	9.69	8.88	3.53	3.78

Table.2 Effect of different treatments on phosphorus uptake (Kg ha^{-1}) in rice at different growth stages

Treatments	Max. Tillering		Panicle Initiation		Flowering		At harvest			
							Grain		Straw	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	2.52	2.26	4.00	4.72	4.95	5.31	3.88	2.74	1.96	2.30
T_2	6.12	6.26	15.42	16.55	16.84	19.11	11.94	13.07	10.66	12.46
T_3	4.03	3.70	9.53	10.81	14.19	16.79	10.69	11.89	6.19	8.81
T_4	3.63	3.30	8.95	8.97	12.26	14.44	9.30	10.67	5.48	9.86
T_5	3.43	2.90	8.97	8.93	11.80	12.96	9.95	11.18	5.87	8.51
T_6	3.32	2.96	8.59	8.73	11.23	11.18	8.72	8.39	4.94	6.25
T_7	3.38	2.82	8.10	7.52	11.16	11.39	8.92	9.42	5.44	6.68
T_8	3.10	2.47	7.91	7.66	8.80	9.07	8.50	8.37	4.70	6.41
T_9	2.78	2.28	6.52	7.13	8.09	8.62	7.10	7.31	5.32	5.55
T_{10}	2.79	2.39	6.30	6.88	7.22	7.45	5.64	6.22	4.47	4.76
SE(m)	0.23	0.27	0.50	0.65	0.57	0.82	0.66	0.51	0.35	0.49
CD at 5%	0.69	0.82	1.50	1.95	1.71	2.45	1.96	1.54	1.06	1.47

Table.3 Effect of different treatments on potassium uptake (Kg ha^{-1}) in rice at different growth stages

Treatments	Max. Tillering		Panicle Initiation		Flowering		At harvest			
							Grain		Straw	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	8.19	6.68	12.43	12.94	29.29	28.89	3.94	5.33	36.15	40.76
T_2	18.30	17.58	41.85	42.49	66.76	67.94	16.19	21.16	77.30	80.38
T_3	13.86	12.50	31.59	32.31	59.60	62.05	14.02	18.45	73.26	75.71
T_4	13.19	11.00	29.59	29.60	53.30	54.41	12.41	16.59	67.08	71.33
T_5	12.39	10.39	27.96	26.89	46.25	47.86	11.34	15.36	64.12	68.53
T_6	12.20	10.31	27.42	26.98	45.87	46.13	10.20	13.28	62.86	68.07
T_7	10.97	8.87	24.71	23.28	41.95	42.80	8.68	12.39	60.83	67.58
T_8	10.10	7.63	24.31	22.15	40.01	40.50	7.81	11.01	57.24	61.49
T_9	9.45	7.50	20.26	20.85	38.44	39.49	7.09	10.48	52.66	58.09
T_{10}	9.10	7.51	19.64	20.04	37.39	36.86	6.25	9.34	52.20	56.26
SE(m)	0.58	0.76	1.478	1.44	3.52	1.72	0.70	0.91	2.67	2.79
CD at 5%	1.73	2.27	4.425	4.30	10.54	5.16	2.10	2.70	7.99	8.36

Table.4 Effect of different treatments on iron (Fe) uptake (g ha^{-1}) in rice at different growth stages

Treat-ments	Max. Tillering		Panicle Initiation		Flowering		At harvest			
							Grain		Straw	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	177.87	144.33	294.20	299.52	507.79	523.45	116.34	118.21	526.73	581.40
T_2	309.49	302.68	686.78	708.63	953.32	1005.68	222.30	271.95	975.54	993.64
T_3	259.32	225.59	542.35	579.57	856.42	905.08	208.23	250.09	915.82	934.72
T_4	253.00	213.49	530.31	538.10	766.01	798.63	194.01	232.32	879.21	882.78
T_5	237.37	199.49	512.77	499.29	704.34	723.12	180.46	220.22	845.44	870.45
T_6	240.87	202.02	507.66	511.38	713.15	736.53	176.29	202.64	852.79	887.13
T_7	220.05	180.97	467.42	442.13	671.65	708.46	166.85	214.30	837.01	891.97
T_8	210.29	161.36	477.70	435.11	649.32	682.24	160.75	191.88	784.38	830.68
T_9	197.44	158.88	402.75	415.30	628.36	671.59	150.86	187.20	734.00	781.02
T_{10}	192.68	160.76	401.07	406.33	621.65	638.85	143.06	175.32	738.11	772.83
SE(m)	10.08	14.82	29.51	27.07	35.93	36.71	10.58	15.76	34.06	55.94
CD at 5%	30.19	44.38	88.34	81.06	107.58	109.93	31.67	48.18	101.99	167.49

Table.5 Effect of different treatments on zinc (Zn) uptake (g ha^{-1}) in rice at different growth stages

Treat-ments	Max. Tillering		Panicle Initiation		Flowering		At harvest			
							Grain		Straw	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	22.49	20.20	38.21	43.56	71.93	79.51	46.70	45.91	36.73	43.18
T_2	56.67	56.84	116.17	131.88	201.31	214.59	120.36	144.55	131.55	147.40
T_3	45.06	40.82	85.92	102.13	161.88	185.08	109.37	130.61	117.37	130.59
T_4	42.44	38.04	79.57	90.21	138.95	155.62	101.44	119.79	106.49	118.25
T_5	40.20	34.63	75.46	81.13	120.27	136.15	91.86	110.14	96.32	111.61
T_6	33.54	34.78	72.64	80.96	114.43	131.04	86.87	93.56	84.53	103.34
T_7	37.37	30.27	64.14	70.21	105.31	116.77	80.03	92.06	76.34	96.06
T_8	31.69	25.45	62.93	66.18	103.17	112.87	76.13	80.40	66.83	80.26
T_9	26.79	24.35	54.81	64.14	92.22	105.63	65.56	73.68	60.17	69.85
T_{10}	28.73	24.64	54.52	62.70	90.60	99.39	62.67	69.33	59.48	67.19
SE(m)	1.81	3.32	4.35	4.45	6.47	10.34	7.38	7.81	6.69	9.57
CD at 5%	5.41	9.95	13.02	13.34	19.37	29.00	22.09	23.39	20.03	28.65

Table.6 Effect of different treatments on copper (Cu) uptake (g ha^{-1}) in rice at different growth stages

Treatments	Max. Tillering		Panicle Initiation		Flowering		At harvest			
							Grain		Straw	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	12.06	12.96	16.30	21.54	26.81	31.81	22.37	38.72	8.93	6.84
T_2	35.87	37.37	66.68	83.25	91.94	117.59	71.05	103.99	59.70	47.27
T_3	29.04	27.31	48.40	67.50	73.17	97.20	57.65	82.07	48.11	39.23
T_4	26.66	25.36	45.25	60.26	52.47	76.09	47.05	77.29	44.12	32.99
T_5	23.25	22.52	40.67	50.27	49.28	65.63	41.98	71.44	37.81	27.62
T_6	22.88	21.99	38.73	49.69	43.75	61.92	40.92	70.69	29.67	24.61
T_7	19.53	19.22	32.10	38.69	36.88	55.79	36.53	67.07	25.15	21.82
T_8	17.46	16.04	30.74	34.22	33.21	51.59	35.22	61.49	20.97	18.06
T_9	14.89	14.99	23.79	30.92	28.98	45.64	30.19	56.11	17.10	13.84
T_{10}	14.44	14.82	22.72	29.44	26.04	42.29	28.73	54.84	15.74	11.72
SE(m)	1.12	2.10	2.34	3.62	7.60	6.08	1.85	6.51	2.77	2.47
CD at 5%	3.36	6.28	7.01	10.83	22.77	18.20	5.53	19.49	8.28	7.38

Table.7 Effect of different treatments on manganese (Mn) uptake (g ha^{-1}) in rice at different growth stages

Treatments	Max. Tillering		Panicle Initiation		Flowering		At harvest			
							Grain		Straw	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	104.02	85.57	161.19	164.39	266.28	291.21	69.09	66.51	324.09	346.95
T_2	183.05	180.64	398.43	427.77	580.77	620.88	181.09	201.71	634.65	648.49
T_3	151.52	133.63	311.29	345.20	502.25	545.38	157.34	176.69	581.58	597.38
T_4	145.86	125.51	301.32	312.94	428.09	460.06	139.52	154.09	548.02	558.69
T_5	134.47	116.23	289.73	289.56	386.86	414.58	128.93	141.09	522.23	548.09
T_6	134.31	118.17	286.54	292.77	385.34	413.13	119.80	123.04	515.64	546.74
T_7	122.47	105.28	260.61	254.31	353.94	393.47	108.98	118.35	502.83	541.11
T_8	116.62	93.01	263.32	249.19	346.90	379.29	105.52	111.01	475.16	505.60
T_9	109.67	91.89	220.57	235.94	327.07	373.38	92.72	107.40	437.16	471.57
T_{10}	106.99	92.95	218.54	231.83	325.69	355.73	88.62	101.50	440.01	464.74
SE(m)	5.45	7.28	17.20	22.66	24.23	21.48	9.89	9.36	20.02	25.57
CD at 5%	16.31	21.79	51.51	67.86	10.75	64.31	28.61	28.03	59.94	76.55

The Potassium uptake by grain varied from significantly 3.94 to 16.19 and 5.33 to 21.16 Kg ha^{-1} during 2011 and 2012 respectively. The uptake of Potassium by rice grain with the application of 100% NPK application was statistically at par to the uptake recorded in T_3 and significantly higher than the remaining treatments during both the years.

Uptake of Potassium declined significantly with the application of vermicompost at flowering stage than the application at transplanting or maximum tillering stages during both the years.

Maximum K uptake in straw varied from 36.15 to 77.30 and 40.76 to 80.38 Kg ha^{-1} during 2011 and 2012 respectively. The uptake of K by rice straw with the application of 100% NPK was statistically at par to T_3 and significantly higher than the rest of the treatments during both the years. Uptake of potassium by rice straw was significantly higher with the early application of vermicompost (T_3 and T_7) than delayed application (T_6 and T_{10}).

Iron uptake (g ha^{-1}) by rice at different growth stages

At maximum tillering stage and Panicle initiation the uptake of iron (Fe) in plant having 100% NPK application was found significantly higher than rest of the treatments during both the years (Table 4). While at flowering T_3 was found at par with T_2. At maximum tillering and panicle initiation stage iron uptake did not differ significantly due to application of vermicompost. At flowering stage significantly higher iron uptake was found with the earlier application of vermicompost than delayed. T_3 and T_4 were found significantly better than the rest of the treatments of 75% N 100% PK during both the years. The Iron (Fe) uptake (g ha^{-1}) by rice grain varied from 116.34 to 222.30 and 118.21 to 271.95 g ha^{-1} during 2011 and 2012 respectively. Uptake of iron by rice grain did not varied significantly due to application timings of vermicompost although higher value was recorded with early application. Maximum Iron (Fe) uptake (g ha^{-1}) by rice straw varied from 526.73 to 975.54 and

581.40 to 993.64 g ha^{-1} during 2011 and 2012 respectively. Uptake of iron by rice straw with the application of 100% NPK was significantly higher than the most of the treatments during 2011, but during 2012 only three treatments T_1, T_9 and T_{10} differ significantly from T_2.

Zinc uptake (gha^{-1}) by rice at different growth stages

At maximum tillering and panicle initiation stage the uptake of zinc in case of T_2 was significantly higher than the remaining treatments during both the years however at flowering T_3 was found statistically at par to T_2 during 2012 (Table 5).

The application effect of vermicompost on uptake of zinc at maximum tillering and panicle initiation was not clear. Zn uptake by rice plant at flowering stage varied from 71.93 to 201.31 and 79.51 to 214.59 gha^{-1} during 2011 and 2012 respectively. Significantly higher zinc uptake at flowering was recorded due to basal application of vermicompost along 75% N, 100% PK than the remaining treatments consisting application of 75% N, 100% PK and vermicompost.

With the exception of T_6, rest of the treatments consisting application of vermicompost and 75% N, 100% PK were found statistically at par in respect of Zn uptake by rice grain. With delayed application of vermicompost, Zn uptake by rice grain declined.

Maximum zinc uptake by rice straw statistically similar to T_3 and significantly higher than the remaining was found with the application of 100% NPK during both the years. Minimum zinc uptake by rice straw significantly lower than the most of the treatments during both the years was found in case of T_1 (Control).

Copper uptake (g ha^{-1}) by rice plant at different stages

With exception of flowering stage during 2011, the uptake of copper with the application of 100% NPK was significantly higher than the remaining treatments at all the growth stages during both the years (Table 6). Copper uptake in T_2 was found statistically at par to T_3 at flowering stage of 2011. No clear cut effect of vermicompost application on copper uptake at maximum tillering was noticed. At panicle initiation stage copper uptake varied from 16.30 to 66.68 and 21.54 to 83.25 g ha^{-1} during 2011 and 2012 respectively. Basal application of vermicompost along with 75% N, 100% PK resulted in significantly higher Cu uptake than the treatments where no vermicompost was applied. The uptake of copper (g ha^{-1}) by rice plant at flowering stage varied from 26.81 to 91.94 and 31.81 to 117.59 g ha^{-1} during 2011 and 2012 respectively. The uptake copper (Cu) by rice plant having 100% NPK application (T_2) was found statistically similar toT_3 and significantly higher than the rest of the treatments during 2011 but such effect was not noticed during 2012 and T_2 differ significantly from T_3. The effect of vermicompost application along with 75% N, 100% PK on the uptake of copper (g ha^{-1}) at this stage was found significant only with basal application of vermicompost during both the years and it was significantly higher than T_5. The copper uptake (g ha^{-1}) by rice grain varied from 22.37 to 71.05 and 38.72 to 103.99 g ha^{-1} during 2011 and 2012 respectively. The timing effect of vermicompost application was inconsistent while during 2011, most of the treatments consisting vermicompost application with 75% N, 100% PK differ significantly but such effect was not noticed during 2012. The uptake of copper by rice straw varied from 8.93 to 59.70 and 6.84 to 47.27g ha^{-1} during 2011 and 2012 respectively. Basal application of vermicompost along with 75%N, 100%PK resulted in significantly higher copper uptake than the treatments where vermicompost was applied at panicle initiation or flowering stage but with 50% N, 100% PK the application effect of vermicompost was not found.

Manganese uptake (g ha^{-1}) by rice plant at different stages

At maximum tillering stage, Panicle initiation and flowering stages the uptake of Mn with T_2 was significantly higher than the remaining treatments but uptake of Mn by rice grain and straw in T_3 was found statistically similar to T_2 during both the years (Table 7). At maximum tillering stage uptake of Mn did not differ significantly due to basal application of vermicompost during both the years. At panicle initiation stage manganese uptake (g ha^{-1}) by rice plant varied from 161.19 to 398.43 and 164.39 to 427.77 g ha^{-1} during 2011 and 2012 respectively. No effect of vermicompost application on Mn uptake was found during both the years. The manganese (Mn) uptake (g ha^{-1}) in plant at flowering stage varied from 266.28 to 580.77 and 291.21 to 620.88 g ha^{-1} during 2011 and 2012 respectively. A significant effect of vermicompost application with 75% N, 100% PK on Mn uptake was found while in case 50% N, 100% PK no celerity was seen. The manganese uptake (g ha^{-1}) in grain varied from 69.09 to 181.09 and 66.51 to 201.71 g ha^{-1} during 2011 and 2012 respectively. The uptake of Mn by rice grain was significantly higher with the basal application of vermicompost during 2012, along with 75% N, 100% PK than T_5 and T_6 during both the years. The uptake of Mn by rice grain did not differ significantly due application of vermicompost along with 50% N, 100% PK. Uptake of manganese (g ha^{-1}) by rice straw varied from 324.09 to 634.65 and 346.95 to 648.49 g ha^{-1} during 2011 and 2012 respectively. Maximum uptake statistically at par to T_3 and significantly higher than the remaining treatments both the years was found in T_2. The uptake of Manganese did not differ significantly due to timing of vermicompost application although slightly higher values were recorded with early application.

Effect on nutrients uptake by rice at different stages

Comparatively higher uptake was also recorded with the early than delayed application of vermicompost. Initially higher nutrient availability in soil in these treatments responded well to plant growth and plant nutrient contents and a significant variation in dry matter accumulation and plant nutrient contents was noticed. Uptake is the product of dry matter yield and nutrient content. Since dry matter yield and nutrient content were maximum/significantly higher in these treatments therefore significantly higher nutrient uptake is obvious. In absence of fertilizer application the dry matter yield and nutrient content of plant sample was lower/significantly lower therefore significantly less nutrient uptake than the rest in control treatment is well expected. Application of sub optimal level of inorganic N also reflected its impact on dry matter production, plant nutrient content and there by recorded lower quantities of plant nutrient uptake by recorded lower quantities. The similar result was observed by Manna *et al.*, 2001, Vyas *et al.*, 2001, Sharma *et al.*, 2013, Singh *et al.*, 2017 and Tamuly *et al.*, 2014.

Duhan and Singh (2002) also reported that uptake of nutrients increased significantly with increasing N levels. Moreover, application of N along with GM (green manuring) showed additive effect on these parameters. Under all GM treatments, the uptake was always higher with 120 kg N ha^{-1} than with the lower levels of N. The highest uptake of all micronutrients was obtained where 120 kg N ha^{-1} was applied under GM. Jat and Ahlawat, (2006) observed that the N and P uptake in chickpea-maize cropping system as influenced by the application of vermicompost, indicated that vermicompost application at 3t/ha significantly increased N and P uptake by the cropping system in both the seasons over the control. Linda *et al.*, (2010) found that raising mineral nitrogen fertilizer level from 25 to 50, 75 and 100 kg N/fed resulted in significant increases in NPK uptake of grain and straw. The wheat grain and straw NPK contents were significantly increased by application of compost and humic acid treatments. Vanilarasu and Balakrishnamurthy (2014) observed that application of organic manure and amendments increases uptake of leaf nutrient contents like nitrogen, phosphorous and potassium of banana.

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