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Residual Effect of Different Sources of Nutrients on Available NPK in Soil after Harvest of Maize in Rice Fallow Maize Cropping System

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Authors' contributions

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

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ABSTRACT

A field experiment was conducted for two consecutive years (2011-2012 and 2012-2013) on fine texture soils of Agricultural college farm, Bapatla. The experiment was laid out in a randomized block design in *kharif* season with four treatments. The treatments consisted of M_1 (RDF (Recommended dose of fertilizers) - Control), M_2 (10t FYM (Farm Yard Manure) ha^{-1} + RDF), M_3 (1.5t vermicompost ha^{-1} + RDF), M_4 (Green manuring + RDF). During the immediate *rabi,* the experiment was laid out in a split-plot design without disturbing the soil for succeeding maize with the four treatments given to *kharif* rice as main plot treatments and each of these divided into five sub-plots to receive five levels of fertilizer NPK application *viz.*, N_1 - 75% NPK, N_2 - 100% NPK, N_3 - 125% NPK, N_4 - 150% NPK and N_5 - 175% NPK for succeeding maize.

Data collected on available NPK after harvest of maize crop were significantly increased with the application of 100% NPK in combination with FYM @10t ha^{-1} to preceding rice crop, irrespective of the NPK levels applied to succeeding maize crop. However, it was on par with that of green manuring together with 100% NPK during both the years of the study.

Keywords: FYM; green manuring; vermicompost; available NPK.

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1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops of the world, occupying third rank in production after wheat and rice (Bharath et al. 2017). In India, after rice and wheat, maize ranks third in terms of area sown and production. Maize has wide distribution and is uses as food, feed and fodder. It is an exhaustive crop and requires very high doses of nitrogen and other nutrients. Ensuring balanced quantity of nutrients in a given soil for the plant growth is a major challenge as yield potentials vary among soils. For maintaining sustained crop production, balanced manuring is essential. Wide use of short statured high yielding varieties and hybrids is common in maize. The organic sources can improve the nutrient use efficiency of added chemical fertilizers by reducing nutrient losses and enhancing nutrient availability to plant. Integration and incorporation of organic manure (FYM/urban compost) in the agricultural systems helps to improve soil structure, microbial activity and moisture conservation and which helps to stabilize the production and productivity of the crops [1].

The changes of soil N pools after green manure incorporation involve transformations between soil N fractions, such as microbial biomass N, dissolved organic N, and mineral N. The positive effect of green manure incorporation on succeeding crop growth is proposed to relate to the stimulated microbial processes. Along with nitrate and ammonium, dissolved organic N is another soluble N source for microbes or plant uptake (Kielland, 1994). These three components are recognized as active fractions in soil N cycling and closely associated with plant N uptake (Stark, 2007).

2. MATERIALS AND METHODS

Experiment was conducted in the field number 49A and 49B of the Agricultural College Farm, Bapatla, during the years 2011-12 and 2012-13, respectively. Prior to preparatory cultivation of the experimental site, soil samples from 0 to 15 cm depth were collected at random and a composite soil sample during both the years was analyzed for different physico-chemical properties. The results of the soil analytical data indicated that the experimental soil is clay and sandy clay during first and second year, respectively in texture, slightly alkaline in reaction, low in organic carbon (0.52 and 0.50% during first and second year, respectively) and available nitrogen (175.6 and 159.8 kg ha^{-1} during first and second year, respectively), and high in available phosphorus (95.3 and 93.9 kg P_2O_5 ha^{-1} during first and second year, respectively) and potassium (960.0 and 925.6 kg K_2O ha^{-1} during first and second year, respectively). The experiment consisted of four main treatments *viz.*, M_1 (RDF - Control), M_2 (10t FYM ha^{-1} + RDF), M_3 (1.5t vermicompost ha^{-1} + RDF), M_4 (Green manuring + RDF) and replicated five times in randomized block design.

The recommended fertilizer dose was applied as 160:40:40 kg N, P_2O_5 and K_2O ha^{-1}. During the immediate *rabi,* the experiment was laid out in a split-plot design without disturbing the soil for succeeding maize with the four treatments given to *kharif* rice as main plot treatments and each of these divided into five sub-plots to receive five levels of fertilizer NPK application *viz.*, N_1 - 75%NPK, N_2 - 100% NPK (200 kg N, 60 kg P_2O_5 and 50 kg K_2O), N_3 - 125% NPK, N_4 - 150% NPK and N_5 - 175% NPK for succeeding maize. The experiment on rice - maize sequence as detailed above was repeated on a separate site but in the same block during *kharif* 2012 and *rabi* 2013, respectively. Popular cultivars of rice and maize, BPT – 5204 and 30 V 92, respectively, were used for the study.

FYM and vermicompost were added 7 days before transplanting of rice on dry weight basis. Dhaincha crop was raised with the seed rate of 60kg ha^{-1} in individual plots and it was incorporated 7 days before transplanting of rice as green manure at flowering stage. Nitrogen was applied in the form of DAP and remaining N was applied in the form of urea, in three equal splits, first split at 10 DAS, second split at knee high stage and third split at tasseling stage. Half dose of K and full dose of P was applied, in the form of MoP and DAP respectively, at 10 days after sowing. Remaining half dose of K was applied at tasseling stage. All fertilizers were applied in pocketing method as per the treatments.

Plot wise surface (0-15) soil sample were collected immediately after harvest of rice. The soil samples were air dried in shade, ground and screened through 2mm sieve and used for laboratory analysis. Soil reaction (pH) was measured by using glass electrode pH meter in 1:2.5 ratio of soil water suspension [2], Conductivity is measured with supernant liquid of 1:2.5 soil water suspensions by using electrical conductivity meter [2]. Available nitrogen was estimated by alkaline permanganate method by using macro Kjeldahl distillation unit [3]. Available

Table 1. Nutrient content in organics applied

Organics	2011-12				2012-13			
	%C	%N	% P_2O_5	% K_2O	%C	%N	% P_2O_5	% K_2O
FYM	26.60	0.71	0.25	0.54	26.00	0.65	0.20	0.74
Vermi compost	12.54	1.80	0.81	0.72	13.00	1.80	0.79	0.81
Dhaincha	36.50	3.40	0.41	2.07	40.00	3.30	0.40	2.67

phosphorus was extracted with Olsen's reagent [4] and estimated using spectrophotometer as described by Watanabe and Olsen [5]. Available potassium was extracted with neutral normal ammonium acetate and estimated with the help of flame photometer [2]. The data was statistically analyzed using the method of analysis of variance technique for split plot design for *rabi* data [6] and means were tested for significance. The treatment differences were tested by F-test [6].

3. RESULTS AND DISCUSSION

3.1 Available N

The data on post-harvest status of available N in soil is presented in the Table 2. The variation observed in the status of available N after the completion of rice-maize sequence was consistent during both the years of the study.

Irrespective of rate of NPK level applied to maize in the sequence, the status of available N after harvest of maize was significantly higher following organics application together with 100% NPK than that of inorganic alone added to preceding rice crop during second year of the study. But during first year of the study application of FYM @ 10t ha^{-1} along with 100% NPK to preceding rice crop (M_2) had shown significant increase over 100% NPK alone applied to preceding rice crop (M_1) and remaining organic treatments (M_3 and M_4) were on par with M_1. All the organics applied to preceding rice were on par with each other during both the years of study. Dinesh and Dubey [7] reported that mineralization of net nitrogen was significantly higher in soil amended with organic matter as compared to unamended soil. Similar results with the application of vermicompost were also reported by Nehra et al. [8].

Irrespective of nutrient management followed to preceding rice, the status of available N in soil after harvest of succeeding maize significantly increased with increasing level of NPK from 75 to 150% to succeeding maize during first year of the study. This might be attributed to the fact that with higher fertilizer dose, higher amount of fertilizer N could be converted into available form by the biochemical reaction of fertilizer N with soil organic matter [9].

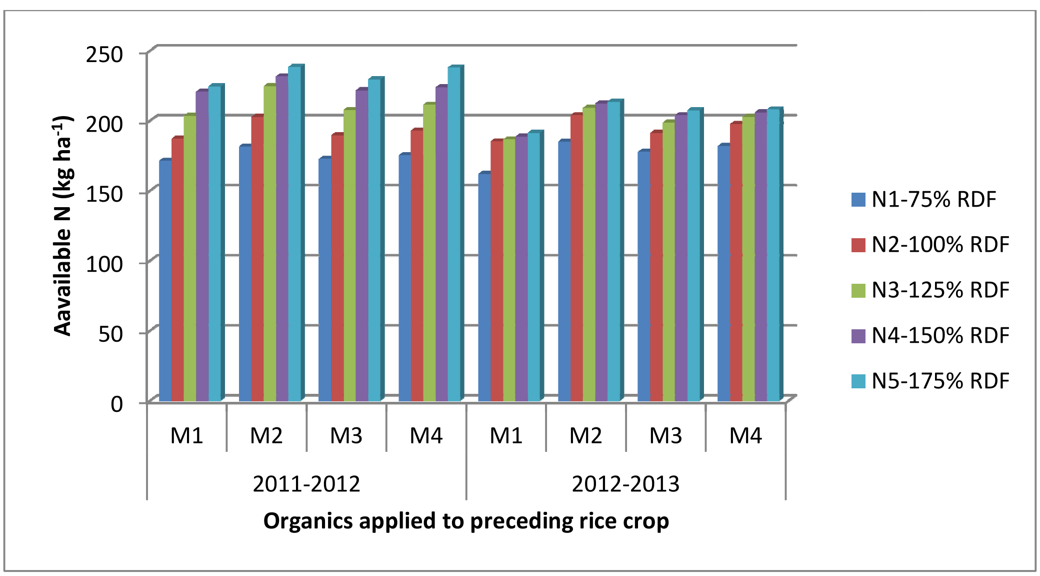

Fig. 1. Influence of manures applied to preceding rice crop and NPK levels on available N (kg ha^{-1}) in soil after harvest of maize

Table 2. Influence of organics applied to preceding rice crop and NPK levels on available N (kg ha^{-1}) in soil after harvest of maize

NPK levels	2011-2012				Mean	2012-2013				Mean
	Organics applied to preceding rice crop					Organics applied to preceding rice crop				
	M1	M2	M3	M4		M1	M2	M3	M4	
N1-75% RDF	171.33	181.52	172.61	175.23	175.17	162.03	185.02	177.71	181.89	176.66
N2-100% RDF	187.14	202.73	189.44	192.87	193.05	185.23	203.84	191.30	197.57	194.48
N3-125% RDF	203.42	224.61	207.54	211.34	211.73	186.49	209.07	198.61	202.79	199.24
N4-150% RDF	220.72	231.55	221.61	223.70	224.40	188.47	212.20	203.84	205.93	202.61
N5-175% RDF	224.43	238.31	229.32	237.88	232.49	191.30	213.56	207.29	208.02	205.04
Mean	201.41	215.74	204.11	208.20	207.36	182.70	204.74	195.75	199.24	195.61

	SEm ±	CD (p=0.05)	CV (%)	SEm ±	CD (p=0.05)	CV (%)
M	3.721	12.88	6.9	3.985	13.79	7.9
N	3.325	9.58	5.5	2.949	8.49	5.2
M x N Interaction						
N at same M	6.650	19.16		5.897	16.99	
M at same or diff. N level	7.016	14.56		6.611	13.82	

M_1- RDF (Control), M_2- FYM 10t ha^{-1} + RDF, M_3 - Vermicompost 1.5t ha^{-1} + RDF, M_4- Green manuring + RDF
M - Organics applied to preceding rice crop;
N - Nutrient levels applied to maize crop

Table 3. Influence of organics applied to preceding rice crop and NPK levels on available P_2O_5 (kg ha^{-1}) in soil after harvest of maize

NPK levels	2011-2012				Mean	2012-2013				Mean
	Organics applied to preceding rice crop					Organics applied to preceding rice crop				
	M1	M2	M3	M4		M1	M2	M3	M4	
N1-75% RDF	55.77	64.40	60.23	60.50	60.23	56.61	61.62	60.09	60.23	59.63
N2-100% RDF	60.64	70.10	65.09	66.48	65.58	58.42	66.07	63.70	64.26	63.11
N3-125% RDF	67.15	75.53	71.21	71.63	71.38	64.40	70.38	68.43	70.24	68.36
N4-150% RDF	71.63	82.90	74.69	75.53	76.19	67.46	71.77	69.27	68.57	69.27
N5-175% RDF	72.19	84.57	76.36	77.19	77.58	68.01	73.72	70.80	70.24	70.69
Mean	65.48	75.50	69.52	70.27	70.19	62.98	68.71	66.46	66.71	66.21

	SEm ±	CD (p=0.05)	CV (%)	SEm ±	CD (p=0.05)	CV (%)
M	0.912	3.16	5.0	0.883	3.06	5.2
N	1.338	3.85	6.6	1.017	2.93	5.3
M x N Interaction						
N at same M	2.676	7.71		2.035	5.86	
M at same or diff. N level	2.561	5.24		2.023	4.16	

M_1- RDF (Control), M_2- FYM 10t ha^{-1} + RDF, M_3 - Vermicompost 1.5t ha^{-1} + RDF, M_4- Green manuring + RDF
M - Organics applied to preceding rice crop
N - Nutrient levels applied to maize crop

Table 4. Influence of organics applied to preceding rice crop and NPK levels on available K_2O (kg ha^{-1}) in soil after harvest of maize

NPK levels	2011-2012				Mean	2012-2013				Mean
	Organics applied to preceding rice crop					Organics applied to preceding rice crop				
	M1	**M2**	**M3**	**M4**		**M1**	**M2**	**M3**	**M4**	
N1-75% RDF	581.00	635.47	590.08	626.39	608.23	573.55	624.96	607.60	604.93	602.76
N2-100% RDF	608.23	674.72	653.62	689.72	656.57	612.27	651.00	616.28	635.64	628.80
N3-125% RDF	632.54	686.07	671.87	692.87	670.84	632.30	703.08	685.72	677.04	674.54
N4-150% RDF	634.42	695.29	675.73	693.67	674.78	642.32	729.12	691.73	685.72	687.22
N5-175% RDF	634.68	702.13	681.00	694.07	677.97	677.04	746.48	702.41	711.76	709.42
Mean	618.17	678.74	654.46	679.34	657.68	627.50	690.93	660.75	663.02	660.55

	SEm ±	**CD (p=0.05)**	**CV (%)**	**SEm ±**	**CD (p=0.05)**	**CV (%)**
M	12.725	44.04	7.5	9.253	32.02	5.4
N	10.438	30.07	5.5	11.057	31.85	5.8
M x N Interaction						
N at same M	20.877	60.14		22.114	63.70	
M at same or diff. N level	22.597	47.04		21.837	44.86	

M_1- RDF (Control), M_2- FYM 10t ha^{-1} + RDF, M_3 - Vermicompost 1.5t ha^{-1} + RDF, M_4- Green manuring + RDF
M - Organics applied to preceding rice crop
N - Nutrient levels applied to maize crop

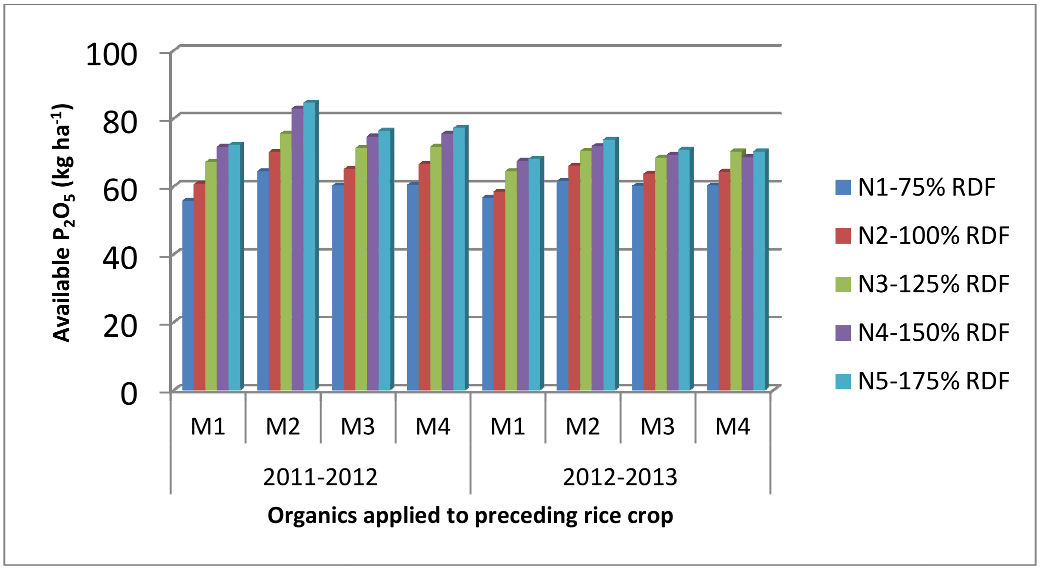

Fig. 2. Influence of manures applied to preceding rice crop and NPK levels on available P_2O_5 (kg ha^{-1}) in soil after harvest of maize

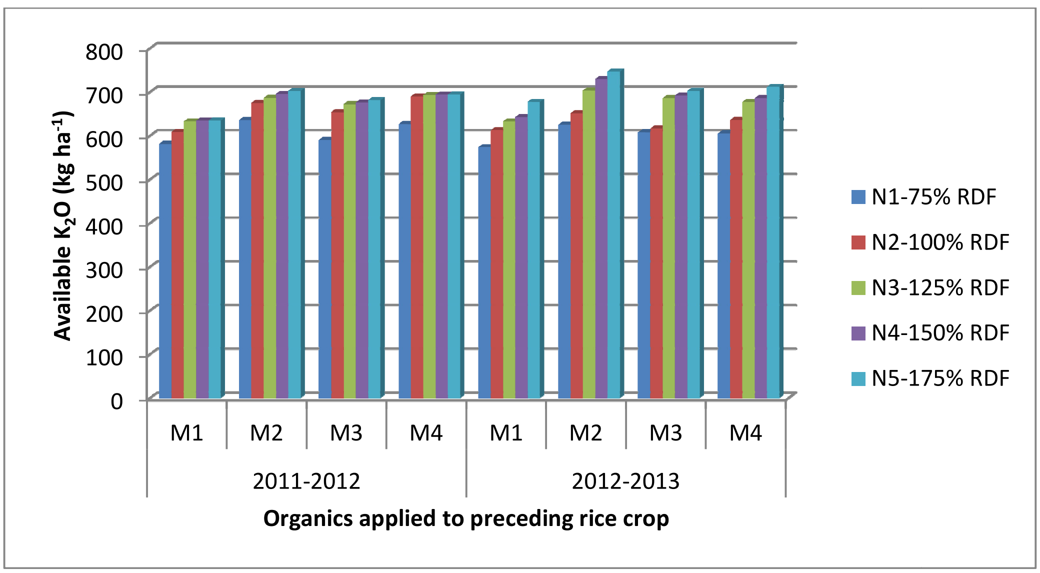

Fig. 3. Influence of manures applied to preceding rice crop and NPK levels on available K_2O (kg ha^{-1}) in soil after harvest of maize

The mean highest available N was recorded in the treatment M_2 with 215.74 and 204.74kg ha^{-1} followed by M_4 with 208.20 and 199.24 kg ha^{-1} during first and second year of the study. Role of FYM, vermicompost and green manuring in releasing N and improving N availability in soil was reported by Singh et al. [10] and Govindan and Thirumurigan [11]. Dudhat et al. [12] also reported that application of FYM alone or in combination with chemical fertilizer significantly increased the residual status of available N in soil. The interaction effect was found statistically significant. The highest available N was recorded in the treatment M_2N_5 with 238.31 and 213.56 kg ha^{-1} in 2012 and 2013, respectively. When manure was applied to the soil, it had a longer lasting effect as indicated by the positive response of the cowpea to previous season applied FYM [13].

3.2 Available P_2O_5

The variation observed in the status of available P_2O_5 (Table 3) after the completion of rice-maize sequence was dependent on the fertilizer management to both crops during both the years of the study.

Irrespective of rate of NPK level applied to maize in the sequence, the status of available P_2O_5 after harvest of maize was significantly higher in the treatment following organic application together with 100% NPK than that of inorganic alone given to preceding rice crop during both the years of study. All these organic treatments were on par except M_3 during first year of the study wherein it was significantly inferior to M_2. Singh et al. [14] reported buildup of available P in the soil with combination of *Sesbania aculeate* and BGA applied to preceding rice over control. Ayoola and Makinde [15] suggested that decomposed cow dung fortified with N can be applied @ 2.5t ha^{-1} as it increased soil P content by 1%. Meelu and Morris [16] revealed that application of 12t FYM ha^{-1} to rice in rice-wheat cropping system resulted in a saving of 20kg P_2O_5 in succeeding wheat crop. Dudhat et al. [12] reported that the application of FYM alone or in combination with chemical fertilizer significantly increased the residual status of available P in soil.

Irrespective of nutrient management provided to preceding rice, the status of available P in soil after harvest of succeeding maize significantly increased with increasing level of NPK from 75 to 150% to succeeding maize in 2012 whereas, it was increased up to 125% NPK in 2013. These results were in line with Huang et al. [17] who concluded that soil P was sufficiently increased by promoting N fertilizer levels. Though, available P_2O_5 increased due to application of 175% NPK but not significant over 150% NPK level, irrespective of nutrient management provided to preceding rice. The mean highest available P_2O_5 was recorded in the treatment M_2 with 75.5 and 68.71 kg ha^{-1} followed by M_4 with 70.27 and 66.71 kg ha^{-1} during first and second year of the study. FYM application significantly increased the available P content of soil as also observed by Maskina et al. [18].

The interaction effect was found statistically significant. The highest available N was recorded in the treatment M_2N_5 with 84.57 and 73.72kg ha^{-1} P_2O_5 followed by M_2N_4 with 82.90 and 71.77kg ha^{-1} in 2012 and 2013, respectively. During decomposition of organic manures various organic acids would be produced which solubilized phosphatase and other phosphate bearing minerals and thereby lowered the phosphate fixation and increased its availability [19]. Manna et al. [20] reported that available P content increased due to addition of FYM over control. Mahala et al. [21] also noticed the positive residual significant effect of FYM on succeeding mustard crop in terms of the available P in soil.

3.3 Available K_2O

The data on post-harvest status of available K_2O in soil are presented in the table 4. Irrespective of rate of NPK level applied to maize in the sequence, the status of available K_2O after harvest of maize was significantly higher following organic application together with 100% NPK than that of inorganic alone given to preceding rice crop during both the years of study except M_3 (vermicompost @ 1.5t ha^{-1} in combination with 100% NPK), which was on par with inorganic alone (M_1) provided to preceding rice crop during second year of study. All these organic treatments were on par with each other during both the years of study. The buildup of soil available K_2O due to green manure or FYM application was due to addition of K through the solubilizing action of certain organic acids produced during FYM decomposition and greater capacity of organic colloids to hold K in the available form Vidyavathi et al. [19].

The residual effect of 100kg K_2O ha^{-1} or 50t FYM ha^{-1} applied to potato was important for the succeeding crops of maize, greengram and jute in different rotations [22]. As earlier reported by Maskina et al. [18], application of FYM significantly increased the available K content of the soil. Ayoola and Makinde [15] suggested that decomposed cow dung fortified with N can be applied @ 2.5t ha^{-1} as it increased soil K content by 62%. Meelu and Morris [16] revealed that application of 12t FYM ha^{-1} to rice in rice-wheat cropping system resulted in a saving of 30kg K_2O ha^{-1} in succeeding wheat crop.

Irrespective of nutrient management followed to preceding rice, the status of available K in soil after harvest of succeeding maize increased with increasing level of NPK from 75 to 175% to succeeding maize during both the years of study. Large depletion of non-exchangeable K fraction from the soil might have occurred due to continuous cropping, as also reported earlier by Meelu et al. [23]. The synergistic relation of N with PK helped in increasing the nutrient content in soil irrespective of nutrient management practice [19].

The mean highest available K was recorded in the treatment M_4 with 679.34 kg ha^{-1} K_2O followed by M_2 with 678.74 kg ha^{-1} K_2O during first year of the study. During second year of the study it was recorded in the treatment M_2 with 690.93 kg ha^{-1} K_2O followed by M_4 with 663.02 kg ha^{-1} K_2O. The interaction effect was found statistically significant. The highest available K_2O was recorded in the treatment M_2N_5 with 702.13 and 746.48 kg ha^{-1} K_2O followed by M_2N_4 with 695.29 and 729.12 kg ha^{-1} in 2012 and 2013, respectively.

There was heavy mining of K from soil and replenishment through fertilizer and organic manure being not enough to satisfy the harvested K because of contribution of non-exchangeable K pool towards K content under rice-maize cropping, it had become difficult to maintain even initial K status despite K application at recommended rates. Potassium balance in soil was positive (20.7 kg K ha^{-1}) with 80 kg K_2O ha^{-1} application [24].

4. CONCLUSION

Residual fertility status of soil in terms of available nutrients (N, P, K) after harvest of rice crop was relatively higher in the treatments those received organics along with 100% NPK imposed than that of 100% NPK alone (Anexure I). Residual fertility status in terms of available nutrients (N, P and K) after harvest of each cropping sequence was higher by following organics along with 100% NPK imposed to preceding rice crop than that of 100% NPK alone. The fertility status was increased with the increasing level of NPK from 75% to 175%, irrespective of the nutrients imposed to preceding rice crop. Application of organics in combination with 100% NPK (160:40:40 kg of $N:P_2O_5:K_2O$) to preceding rice crop and application of 125% NPK (250:75:60 kg of $N:P_2O_5:K_2O$) to maize is recommendable nutrient management for rice fallow maize cropping system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Annexure I

Effect of organics on available nutrient status of soil (kg ha^{-1}) after harvest of rice

Treatment	2011-2012			2012-13		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
RDF (Control)	183.14	81.87	794.35	179.38	86.22	793.95
FYM 10t ha^{-1} + RDF	213.88	98.51	891.63	201.33	99.53	879.22
Vermicompost 1.5t ha^{-1} + RDF	199.39	96.27	843.71	198.20	93.11	845.71
Green manuring + RDF	211.99	97.57	876.39	199.45	99.51	869.99
Initial	175.60	95.33	960.00	159.80	93.93	925.60
SEm ±	5.24	3.42	19.32	5.207	2.673	16.350
CD (P: 0.05)	16.14	10.53	53.59	16.04	8.23	45.36
CV (%)	5.80	8.17	5.07	5.98	6.32	4.32

Peer-review history:
The peer review history for this paper can be accessed here:
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