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Influence of Organic Nutrient Sources and Inorganic Fertility Levels on Nutrient Uptake of Aerobic Rice (*Oryza sativa* L.) during *Kharif* Season

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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 study was taken up to evaluate the influence of organic sources of nutrients and inorganic fertility levels in aerobic rice during *kharif* 2017 and *kharif* 2018 at Indian Institute of Rice Research, Rajendra Nagar, Hyderabad, Telangana. The experiment was laid out in split plot design with three replications. The treatment comprised of M_1: Neem leaf manure 6 t ha^{-1}; M_2: Vermicompost 2 t ha^{-1}; M_3: Goat manure 5 t ha^{-1}; M_4: Microbial consortia [seed treatment 4g kg^{-1} + soil application 4 kg ha^{-1}]. The sub-plot treatments comprised of S_1: Control; S_2: 50 % RDF; S_3: 75 % RDF; S_4: 100 % RDF [Recommended Dose of Fertilizer 120:60:40 kg ha^{-1}]. It was observed that, nutrient uptake by aerobic rice was significantly influenced with application of organic nutrient sources and inorganic nutrient levels. N, P and K uptakes by rice were higher with vermicompost @ 2 t ha^{-1} or goat manure @ 5 t ha^{-1} among organic sources and 100% RDF among nutrient levels. Vermicompost recorded significantly highest nitrogen (55.76, 71.7, 91.6 and 103.5 kg ha^{-1} respectively), phosphorus (9.04, 15.4, 18.0 and 20.5 kg ha^{-1}) and potassium (39.7, 60.0, 76.3, 107.1 kg ha^{-1}) uptake by rice crop at MT, PI, 50% FL and harvest and it was found at par with goat manure (*viz;* nitrogen : 50.79, 66.1, 85.6 and 97.7 kg ha^{-1} ; phosphorus : 8.33, 14.11, 16.4 and 19.2 kg ha^{-1} and potassium : 38.2, 59.5, 75.2 and 84.0 kg ha^{-1} at MT, PI, 50% FL and harvest) while the lowest nutrient uptake (*viz*; nitrogen: 37.86, 46.1, 60.9 and 77.3 kg ha^{-1}, phosphorus: 5.74, 8.59, 11.4 and 12.6 kg ha^{-1} and potassium: 25.8, 41.3, 48.6 and 71.5 kg ha^{-1}) was found with application neem leaf manure. Application of 100% RDF significantly increased N (63.58, 80.0, 99.1 and 123.1 kg ha^{-1}), P (9.90, 17.1, 19.9 and 24.3 kg ha^{-1}) and K (47.3, 70.8, 88.9 and 119.5 kg ha^{-1}) and the lowest N (26.37, 32.5, 45.6 and 47.0 kg ha^{-1}), P (4.11, 6.12, 7.7 & 7.8 kg ha^{-1}) and K (19.3, 28.3, 34.7 and 56.7 kg ha^{-1}) was recorded with control. Conjunctive use of 75% of RDF along with vermicompost (M_2S_3) or goat manure (M_3S_3) resulted in statistically on par nitrogen and phosphorus uptake with that of 100% RDF and the lowest nitrogen and phosphorus uptake were recorded with combination of either neem leaf manure or microbial consortia and no application of fertilizer (M_1S_1 and M_4S_1, respectively).

Keywords: Organic nutrient sources; fertility levels; aerobic rice and nutrient uptakes.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food crop of around half the world's population, cultivated over an area of 162.1 M ha globally with an annual production of 746.6 Mt and productivity of 4661 kg ha^{-1} (FAO, 2019-20). In Asia, the rice production is a key element for economic and social stability as more than two billion people depend on rice for their dietary requirements [1]. Among the four rice ecosystems, irrigated rice under lowland dominates in both area and production. In terms of global rice productivity, irrigated lowland rice comprises of 55 and 75% of area and production, respectively (Mahender et al., 2015). Tuong and Bouman [2] estimated that by 2025, 15-20 M ha of irrigated rice is estimated to suffer from some degree of water scarcity. Further, increasing scarcity due to increasing demand for water from various other sectors threatens the sustainability of irrigated rice production and calls for a major shift in rice cultivation system which not only improves the productivity but also provides economic security. Aerobic rice is an alternative and contingent rice production system where in rice crop is cultivated under non-puddled and non-saturated soil conditions. This concept is mainly targeted for irrigated lowlands, less water available areas and uplands [3] facilitating water saving and increasing water productivity by reducing its use during land preparation and limiting seepage, percolation and evaporation [4]. Aerobic rice also expedites less labour with their wider spread for a longer period than that in transplanted rice [5]. According to Chandrapala et al. [6], aerobic rice production system also provides an opportunity to resolve the edaphic conflicts between rice and non-rice crop and enhances the sustainability of rice-based cropping systems. Further, growing rice aerobically without puddling suggested to have positive implications on succeeding crops [7].

Rice shows excellent response to nitrogen application, but the recovery of applied nitrogen is quite low approximately 31-40% Sridhar *et al* [8]. The aerobic soil conditions, stimulating sequential nitrification and denitrification losses which could consequently lead to a greater loss of applied fertilizer and soil nitrogen compared with that under submergence conditions [9]. Furthermore, if an interaction exists between organic and inorganic nutrient management, then the integrated nutrient input will have to be practiced in aerobic soil condition for rice.

The low and unstable yields of aerobic rice were mainly due to water availability and nutrient stresses Sridhar *et al* [8]. Nutrients are delivered to roots primarily by mass flow and diffusion but the delivery rate decreases as the moisture content of the soil decreases. The lower soil moisture content in aerobic rice cultivation therefore reduces nutrients supply to the roots and resulted in the lower rate of plant uptake. Understanding of nutrient uptake and response to fertilization effects are also urgently required to establish optimized crop management technology. It is hypothesized that nitrogen management of rice are reasonably coordinated, the yield, quality, water use efficiency and nitrogen use efficiency of rice can be improved, and the sustainable development of agriculture can be promoted. However, the evidence is very scarce in this regard. Systematic field research on agro-techniques such as nutrient requirement for rice under aerobic conditions is however limited. In this context, the present study is undertaken to evaluate the response of aerobic rice to organic sources of nutrients and inorganic fertilizer levels during rainy season.

2. MATERIALS AND METHODS

Field experiments were conducted for two consecutive years *viz*. 2017 and 2018 during the *kharif (*summer*)* season at experimental farm of Indian Institute of rice research, Hyderabad, Telangana, India. The farm is geographically situated at an altitude of 542.7 m above mean sea level on 17°19” N latitude and 78°29” E longitudes. It comes under the Southern Telangana Agroclimatic Zone. The soil of the experimental field at the start of the experiment had Sandy clay loam texture, with a pH of 8.05, organic carbon (0.91%), available N (209 kg ha^{-1}), available P (26.3 kg ha^{-1}) and available K (382.2 kg ha^{-1}). The experiment was laid out in split-plot design with organic sources of nutrients as main plot and inorganic fertility levels as sub plot with three replications for two years. The treatment comprised of M_1: Neem leaf manure @ 6 t ha^{-1}; M_2: Vermicompost @ 2 t ha^{-1}; M_3: Goat manure @ 5 t ha^{-1}; M_4: Microbial consortia [seed treatment @ 4g kg^{-1} + soil application @4 kg ha^{-1}. The sub-plot treatments comprised of S_1: Control; S_2: 50 % RDF; S_3: 75 % RDF; S_4: 100 % RDF. Rice variety DRR Dhan-42 was used for sowing. The plot size for each treatment was 20 m^2 (3.7 m x 5.6 m). The land was prepared by ploughing once with mould board plough, followed by harrowing prior to establishment of the experiment. A seed rate of 25 kg ha^{-1} was used, seeds were treated with carbendazim 1 g kg^{-1} and the seed in the microbial consortia treatment were treated with microbial consortia @ 4 g kg^{-1} and dry seed was sown at an inter-row spacing of 20 cm and intra-row spacing of 10 cm. Total Nitrogen at 120 kg ha^{-1} fertilizer (Urea) was applied in three split doses, 50% at sowing, 25% at active tillering stage and 25% at panicle initiation stage. The P fertiliser (SSP) was applied entirely as a basal dose at 60 kg ha^{-1} and K fertiliser (muriate of potash) at 40 kg ha^{-1} was used as a source of potash fertiliser. Cultural practices such as weeding and irrigation were kept uniform for all the experimental treatments to avoid crop damage according to the locally adapted practices. Insects and diseases were controlled according to the locally adapted practices to avoid substantial yield loss. Five soil samples at 0 – 30 cm depth were collected initially at random in the experimental field before puddling and composite soil sample was obtained by quadrat method. Postharvest soil samples were drawn at 0 – 30 cm treatment wise and air dried under shade and passed through 2 mm sieve and used for NPK analysis. The plant samples collected for dry matter estimation at tillering, panicle initiation. flowering and at harvest from the respective treatments were oven dried and finely ground and used for chemical analysis to estimate NPK content in the straw at respective stages and grain at harvest. Nitrogen content of shoot and grain at harvest was estimated by Modified Micro Kjeldhal’s Method as outlined by Jackson [10] and expressed in percentage. Total phosphorus and potassium contents of whole plant at harvest were extracted by wet ashing method. The P content was estimated by Vanadomolybdate Yellow Colour Method [10] and K was determined by Photometeric Method [10]. The nitrogen, phosphorus and potassium uptake were estimated for each treatment separately using the following formulae:

$$\text{NPK uptake in grain (kg ha} - 1) = \frac{\text{N content (\%)} \times \text{grain yield (kg ha} - 1)}{100}$$

$$\text{NPK uptake in straw (kg ha} - 1) = \frac{\text{N content (\%)} \times \text{straw yield (kg ha} - 1)}{100}$$

At maturity, each plot was harvested manually excluding border plants. After harvest and threshing, the crop produce was sundried, cleaned, weighed and dried to 12 to 14 per cent moisture content in grain. Grain yield was expressed as kg ha^{-1} at 14% moisture and later at 0% moisture. Straw obtained from each net plot area after threshing was sun dried for four days and then weighed and expressed in kg ha^{-1} at 0% moisture content. Harvest index was calculated as the ratio of dry grain yield to total biomass at crop harvest. The data was subjected to analysis of variance to determine the influence of treatments [11]. Data was analysed using analysis of variance (ANOVA) to evaluate the differences among the treatments. Differences due to treatments were judged by least significant difference (LSD) at 5% probability level.

3. RESULTS AND DISCUSSION

3.1 Nitrogen Uptake by Aerobic Rice

The data on nitrogen uptake (kg ha^{-1}) by rice crop at different growth stages as influenced by various treatments and their interaction effect (Tables 1-4 & Fig.1 and 2). The results indicated that N uptake was significantly influenced by organic nutrient sources and inorganic nutrient levels during both the years of study. The nitrogen uptake was higher during 2018 as compared to 2017. Both vermicompost and goat manured treatments resulted in higher nitrogen uptake as compared to biofertilizer or neem leaf manured treatments during both the years of investigation. Of this pooled mean revealed that M_2 (vermicompost 2 t ha^{-1}) recorded significantly highest nitrogen uptake (55.76, 71.7, 91.6 and 103.5 kg ha^{-1} respectively) at MT, PI, 50% FL and harvest and it was found at par with M_3 treatment (goat manured 5 t ha^{-1}) (50.79, 66.1, 85.6 and 97.7 kg ha^{-1}), while the lowest nitrogen uptake (37.86, 46.1, 60.9 and 77.3 kg ha^{-1}) was found with application neem leaf manure 6 t ha^{-1}. According to pooled means of two years, nitrogen content of plant parts and total biomass production were higher under 100% RDF recorded the highest nitrogen uptake compared to 75% and 50% RDF. Application of 100% RDF (S_4) significantly increased N uptake during both the years (63.58, 80.0, 99.1 and 123.1 kg ha^{-1}), followed by 75% RDF (56.28, 69.3, 88.0 and 107.4 kg ha^{1}), 50% RDF (41.88, 23.5, 72.3 and 86.9 kg ha^{-1}) and the lowest N uptake was recorded with control (26.37, 32.5, 45.6 and 47.0 kg ha^{-1}). Interaction effect (Tables 2, 3 & 4 and Figs. 1 & 2) was significant during both the years. The treatment combination of M_2S_4 recorded the highest N uptake (91.4, 111.5 and 136 kg ha^{-1}, at PI, 50% FL & harvest respectively) was found on par with M_3S_4 [100% RDF + goat manure 5 t ha^{-1}] (88.1, 108.7 and 129.1 kg ha^{-1} respectively), M_2S_3 (86.6, 106.1 and 125.1 kg ha^{-1} respectively) and M_3S_3 (83.2, 106.3 and 119.4 kg ha^{-1} respectively) at PI, 50% FL and harvest. Nitrogen uptake was minimum with $M_1 S_1$ (27.6, 40.3 and 43.2 kg ha^{-1} respectively).

The amount of N removed from organically treated soils depends mainly on the extent of inorganic N made available from the soil organic pool [12]. A similar phenomenon might be the probable reason for higher N uptake from vermicompost and goat manure treated plots in the present investigation. Padmanabhan [13] and Chesti et al. [14]. Higher nitrogen uptake by rice at higher level of fertilizer application might be due to higher biomass production and accumulation of nitrogen in plant tissues at higher concentrations. Similar observations were made by Anil (2014), Padmaja (2013), Karthika [15] and Ajmal [16], who recorded the highest uptake of NPK at higher per cent recommended dose of N which was significantly superior to the immediate lower levels of fertilizer dose. Due to sustained availability of nitrogen from organic source for longer period during crop growth as synergistic use of organic and inorganic nutrient sources exhibits multiple effects and synchronizes nutrient release, promoted dry matter accumulation and translocation to the yield and thereby nitrogen uptake by crop and these findings are consistent with Devi et al. [17], Binoy and Sinha [18] and Dibakar Ghosh et al. [19].

3.2 Phosphorus Uptake

Perusal of the pooled mean data (Tables 5, 6, 7 and 8 & Figs. 3 & 4) revealed that significantly the highest phosphorus uptake by rice crop (9.04, 15.4, 18.0 and 20.5 kg ha^{-1}) was observed with M_2 treatment (vermicompost 2 t ha^{-1}) which was at par with M_3 (8.33, 14.11, 16.4 and 19.2 kg ha^{-1}) at MT, PI, 50% FL and harvest. The lowest mean phosphorus uptake (5.74, 8.59, 11.4 and 12.6 kg ha^{-1}) was noticed in M_1 treatment (neem leaf manure 6 t ha^{-1}) at MT, PI, 50% FL and harvest. Application of different levels of inorganic nutrients significantly influenced the P uptake indicating highest mean uptake by 100% RDF (9.90, 17.1, 19.9 and 24.3 kg ha^{-1}) at MT, PI, 50% FL and harvest as compared to 75%

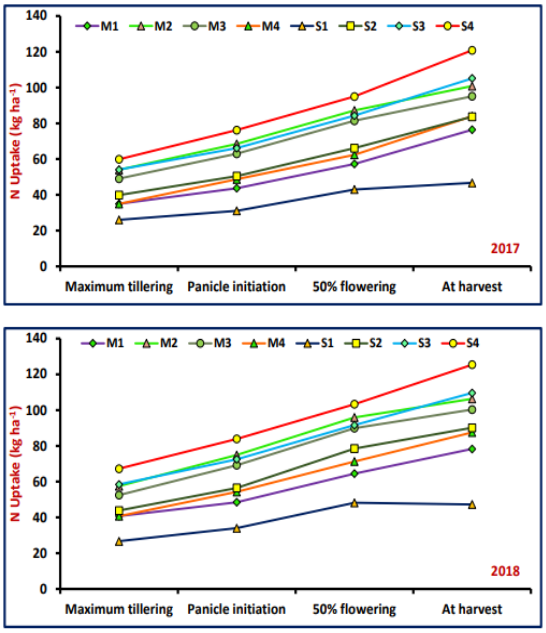

Fig. 1. Nitrogen uptake (kg ha^{-1}) of aerobic rice as influenced by organic nutrient sources and inorganic nutrient levels

Main treatments:	**Sub treatments:**
M_1- Neem leaf manure	**S_1- 0 % RDF**
M_2- Vermicompost	**S_2- 50 % RDF**
M_3-Goat Manure	**S_3- 75 % RDF**
	S_4- 100 % RDF

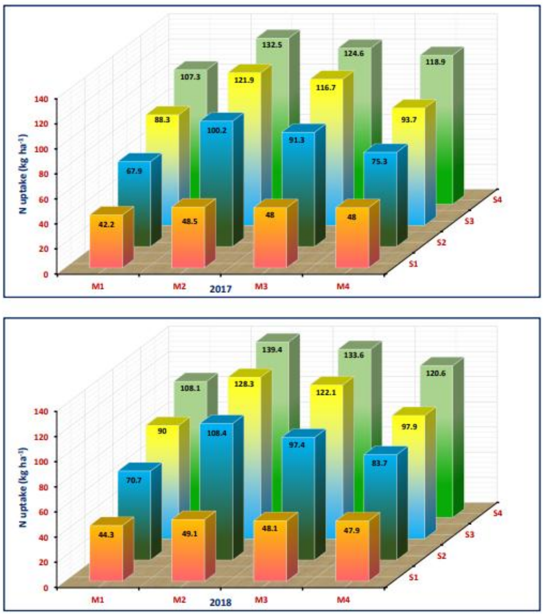

Fig. 2. Interaction effect of organic nutrient sources and inorganic nutrient levels on nitrogen uptake (kg ha^{-1}) of aerobic rice at harvest

Main treatments:	**Sub treatments:**
M_1- Neem leaf manure	**S_1- 0 % RDF**
M_2- Vermicompost	**S_2- 50 % RDF**
M_3-Goat Manure	**S_3- 75 % RDF**
	S_4- 100 % RDF

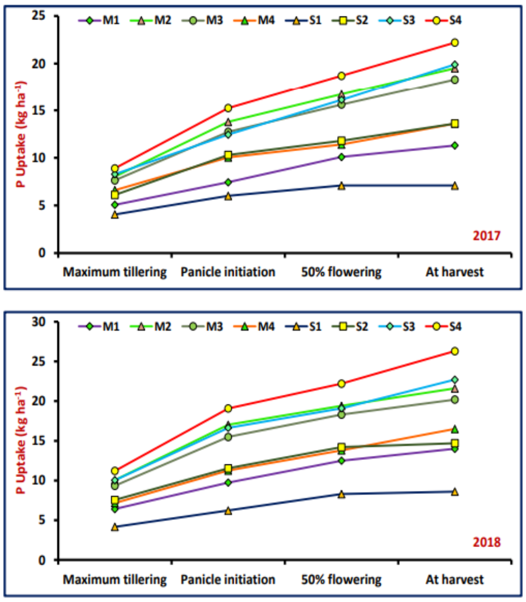

Fig. 3. Phosphorus uptake (kg ha^{-1}) of aerobic rice as influenced by organic nutrient sources and inorganic nutrient levels

Main treatments:	Sub treatments:
M_1- Neem leaf manure	S_1- 0 % RDF
M_2- Vermicompost	S_2- 50 % RDF
M_3-Goat Manure	S_3- 75 % RDF
	S_4- 100 % RDF

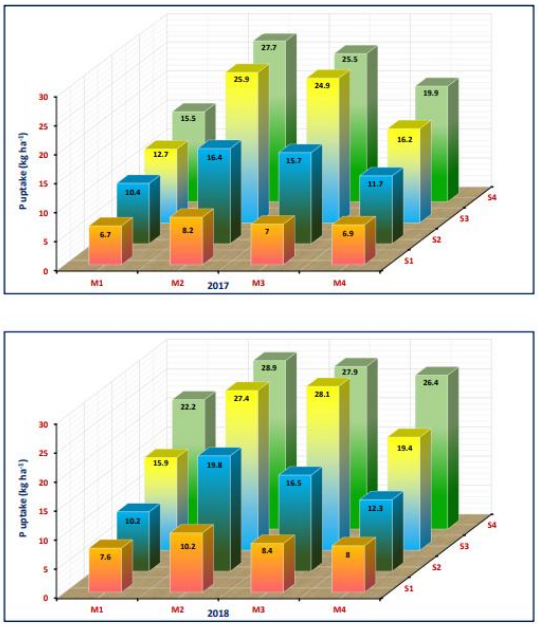

Fig. 4. Interaction of organic nutrient sources and inorganic nutrient levels on phosphorus uptake (kg ha^{-1}) of aerobic rice at harvest

Main treatments:	Sub treatments:
M_1- Neem leaf manure	S_1- 0 % RDF
M_2- Vermicompost	S_2- 50 % RDF
M_3-Goat Manure	S_3- 75 % RDF
	S_4- 100 % RDF

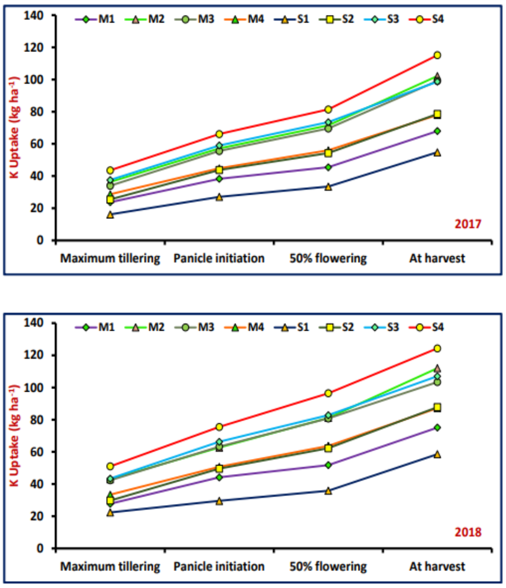

Fig. 5. Potassium uptake (kg ha^{-1}) of aerobic rice as influenced by organic nutrient sources and inorganic nutrient levels

Main treatments:	Sub treatments:
M_1- Neem leaf manure	S_1- 0 % RDF
M_2- Vermicompost	S_2- 50 % RDF
M_3-Goat Manure	S_3- 75 % RDF
	S_4- 100 % RDF

RDF (9.17, 14.5, 17.6 and 21.3 kg ha^{-1}) and 50% RDF (6.83, 10.92, 13.0 and 14.1 kg ha^{-1}) and lowest P uptake (4.11, 6.12, 7.7 & 7.8 kg ha^{-1}) was recorded with control. Interaction effect (Table 5 to 8 & Fig. 4) of organic nutrient sources and inorganic nutrient levels on P uptake was also found significant during both the years at PI, 50% FL & harvest. Two years of pooled mean suggested that nutrient application of 100% RDF + vermicompost 2 t ha^{-1} (M_2S_4) recorded the highest P uptake (20.57, 24.92 and 28.26 kg ha^{-1}) followed by combination of 100% RDF + goat manure 5 t ha^{-1} (20.21, 21.01 and 26.71 kg ha^{-1}) PI, 50% FL and harvest and lowest uptake were recorded with M_1S_1 (5.41, 7.70 & 7.13 kg ha^{-1}). Considerable increase in P uptake was attributed to higher grain and stover yields realized under organic manuring practices of vermicompost and goat manure as they supply the macro and micro nutrients and these manures were utilized as substrate by soil microbial population which in turn were involved in the process of mineralization. The combined effect of living ingredients and organic matter improved nutrient uptake, N, P use efficiencies, rice yield, and soil health [20] thus resulting in more availability of plant nutrients consequently more P uptake by the crop at harvest. The higher P uptake with higher levels of nutrition was due to development of extensive and more efficient root biomass with availability of more P for higher biomass production and higher concentration of nutrients in the plant. Abdullah [21] also reported that N and P uptake by rice crop increased due to increase in nutrients level from 0 to 100% RDF. The combined application of fertilizers and manures increased the phosphorus uptake of the plants, due to potential ability of organic manures in conversion of unavailable native and residual fertilizer P to more available chemical forms besides, increasing use efficiency of P applied to the current crop [22]. These results are in agreement with the findings of Devi et al. [17] and Kaur and Kumar [23].

3.3 Potassium Uptake

The data pertaining to two years mean suggested that potassium uptake by aerobic rice was influenced by organic nutrient sources and inorganic nutrient levels at different growth stages (Table 9 & Fig. 5), however their interaction was found to be non-significant. Significantly more potassium uptake by rice at different growth stages was recorded in M_2 treatment (39.7, 60.0, 76.3, 107.1 kg ha^{-1}) and was found at par with M_3 (38.2, 59.5, 75.2 and 84.0 kg ha^{-1}) followed by M_4 (31.0, 47.8, 59.9 and 82.6 kg ha^{-1}) and M_1 recorded lowest uptake (25.8, 41.3, 48.6 and 71.5 kg ha^{-1}) of potassium

Table 1. Nitrogen uptake (kg ha^{-1}) of aerobic rice at different growth stages as influenced by organic nutrient sources and inorganic nutrient levels

Treatment	Maximum tillering			Panicle initiation			50% flowering			At harvest		
	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean
Organic nutrient sources (M)												
M_1: Neem leaf manure 6 t ha^{-1}	34.96	40.76	37.86	43.7	48.5	46.1	57.3	64.5	60.9	76.4	78.3	77.3
M_2: Vermicompost 2 t ha^{-1}	54.01	57.51	55.76	68.5	74.9	71.7	87.2	95.9	91.6	100.8	106.3	103.5
M_3: Goat manure 5 t ha^{-1}	49.08	52.50	50.79	63.0	69.2	66.1	81.4	89.9	85.6	95.1	100.3	97.7
M_4: Microbial consortia 4g kg seed^{-1} & 4kg ha^{-1} soil application	34.96	40.76	37.86	48.7	54.3	51.5	62.4	71.3	66.9	84.0	87.5	85.7
SEm±	1.72	1.22	1.31	1.28	1.14	0.73	1.07	1.73	0.73	1.9	1.3	1.6
CD (*P=0.05*)	5.94	4.22	4.55	4.43	3.94	2.53	3.70	6.00	2.52	6.6	4.6	5.4
Inorganic nutrient levels (S)												
S_1: 0% RDF	26.06	26.69	26.37	31.1	34.0	32.5	43.0	48.2	45.6	46.7	47.3	47.0
S_2: 50%RDF	39.90	43.85	41.88	50.5	56.5	53.5	66.1	78.5	72.3	83.7	90.1	86.9
S_3: 75%RDF	54.11	58.45	56.28	66.1	72.5	69.3	84.3	91.6	88.0	105.1	109.6	107.4
S_4: 100%RDF	59.89	67.26	63.58	76.2	83.9	80.0	95.0	103.3	99.1	120.8	125.4	123.1
SEm±	1.62	2.02	1.63	1.35	1.48	1.24	1.46	1.71	1.33	1.9	2.0	1.8
CD (*P=0.05*)	4.74	5.90	4.76	3.94	4.31	3.61	4.27	4.99	3.88	5.5	5.7	5.2
Interaction												
MXS												
Sem±	3.25	4.04	3.26	2.70	2.95	2.47	2.92	3.42	2.66	3.80	3.94	3.58
CD (*P=0.05*)	NS	NS	NS	8.64	9.45	7.90	9.36	10.93	8.50	12.15	12.59	11.45
SXM												
Sem±	2.90	2.89	2.56	2.28	2.28	1.76	2.22	2.98	1.86	3.30	2.90	2.91
CD (*P=0.05*)	NS	NS	NS	7.29	7.31	5.63	7.10	9.54	5.94	10.57	9.28	9.31

Table 2. Interaction effect of organic nutrient sources and inorganic nutrient levels on nitrogen uptake (kg ha^{-1}) of aerobic rice at panicle initiation

Nutrient levels/	2017					2018					Pooled				
Nutrient sources	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	27.1	36.9	30.7	29.6	31.1	28.0	41.5	34.3	32.2	34.0	27.6	39.2	32.5	30.9	32.5
S_2	38.5	66.2	57.2	40.3	50.5	44.7	72.8	64.0	44.7	56.5	41.6	69.5	60.6	42.5	53.5
S_3	47.1	83.4	80.1	53.8	66.1	53.3	89.8	86.3	60.5	72.5	50.2	86.6	83.2	57.1	69.3
S_4	62.1	87.3	84.0	71.4	76.2	68.0	95.4	92.3	79.8	83.9	65.1	91.4	88.1	75.6	80.0
Mean	43.7	68.5	63.0	48.7		48.5	74.9	69.2	54.3		46.1	71.7	66.1	51.5	
Interaction	**M × S**		**S × M**			**M × S**		**S × M**			**M × S**		**S × M**		
SEm±	2.70		2.28			2.95		2.28			2.47		1.76		
CD (*P 0.05*)	8.64		7.29			9.45		7.31			7.90		5.63		

Table 3. Interaction effect of organic nutrient sources and inorganic nutrient levels on nitrogen uptake (kg ha^{-1}) of aerobic rice at flowering

Nutrient levels/	2017					2018					Pooled				
Nutrient sources	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	38.0	50.0	43.6	40.4	43.0	42.6	55.5	48.8	45.8	48.2	40.3	52.7	46.2	43.1	45.6
S_2	49.9	85.8	77.9	50.7	66.1	60.1	97.4	89.9	66.6	78.5	55.0	91.6	83.9	58.6	72.3
S_3	60.3	102.3	101.8	68.2	83.2	67.2	110.0	110.8	74.7	90.7	63.7	106.1	106.3	71.5	86.9
S_4	81.0	106.3	104.8	90.3	95.6	88.1	116.8	112.6	98.2	103.9	84.6	111.5	108.7	94.2	99.8
Mean	57.3	86.1	82.0	62.4		64.5	94.9	90.5	71.3		60.9	90.5	86.3	66.9	
Interaction	M × S		S × M			M × S		S × M			M × S		S × M		
SEm±	2.63		2.66			3.67		3.00			2.66		1.98		
CD (*P 0.05*)	8.42		8.52			11.73		9.60			8.51		6.34		

M_1: Neem leaf manure 6 t ha^{-1} M_2: Vermicompost 2t ha^{-1} M_3: Goat manure 5 t ha^{-1} M_4: Microbial consortia seed treatment 4g kg seed^{-1} & soil application 4 kg ha^{-1}
S_1: 0% RDF S_2: 50% RDF S_3: 75% RDF

Table 4. Interaction effect of organic nutrient sources and inorganic nutrient levels on nitrogen uptake (kg ha^{-1}) of aerobic rice at harvest

Nutrient levels/	2017					2018					Pooled				
Nutrient sources	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	42.2	48.5	48.0	48.0	46.7	44.3	49.1	48.1	47.9	47.3	43.2	48.8	48.1	47.9	47.0
S_2	67.9	100.2	91.3	75.3	83.7	70.7	108.4	97.4	83.7	90.1	69.3	104.3	94.3	79.5	86.9
S_3	88.3	121.9	116.7	93.7	105.1	90.0	128.3	122.1	97.9	109.6	89.2	125.1	119.4	95.8	107.4
S_4	107.3	132.5	124.6	118.9		108.1	139.4	133.6	120.6	125.4	107.7	136.0	129.1	119.8	123.1
Mean	66.3	100.7	94.4	76.4		78.3	106.3	100.3	87.5		77.3	103.5	97.7	85.7	
Interaction	**M × S**		**S × M**			**M × S**		**S × M**			**M × S**		**S × M**		
SEm±	3.80		3.30			3.94		2.90			3.58		2.91		
CD (*P 0.05*)	12.15		10.57			12.59		9.28			11.45		9.31		

M_1: Neem leaf manure 6 t ha^{-1} M_2: Vermicompost 2t ha^{-1} M_3: Goat manure 5 t ha^{-1} M_4: Microbial consortia seed treatment 4g kg seed^{-1} & soil application 4 kg ha^{-1}
S_1: 0% RDF S_2: 50% RDF S_3: 75% RDF S_4: 100% RDF

Table 5. Phosphorus uptake (kg ha^{-1}) of aerobic rice at different growth stages as influenced by organic nutrient sources and inorganic nutrient levels

Treatment	Maximum tillering			Panicle initiation			50% flowering			At harvest		
	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean
Organic nutrient sources (M)												
M_1: Neem leaf manure 6 t ha^{-1}	5.07	6.41	5.74	7.44	9.74	8.59	10.1	12.5	11.4	11.3	14.0	12.6
M_2: Vermicompost 2 t ha^{-1}	8.03	10.05	9.04	13.78	17.02	15.40	16.7	19.4	18.0	19.5	21.6	20.5
M_3: Goat manure 5 t ha^{-1}	7.64	9.34	8.33	12.73	15.49	14.11	15.6	18.3	16.4	18.3	20.2	19.2
M_4: Microbial consortia 4g kg seed^{-1} & 4kg ha^{-1} soil application	6.61	7.17	6.89	10.05	11.26	10.65	11.4	13.8	12.6	13.6	16.5	15.1
SEm±	0.30	0.22	0.30	0.34	0.37	0.24	0.45	0.40	0.52	0.49	0.66	0.57
CD (*P=0.05*)	1.03	0.75	1.03	1.18	1.30	0.85	1.57	1.37	1.78	1.71	2.28	1.97
Inorganic nutrient levels (S)												
S_1: 0% RDF	4.06	4.17	4.11	6.01	6.23	6.12	7.1	8.3	7.7	7.1	8.6	7.8
S_2: 50%RDF	6.11	7.55	6.83	10.31	11.54	10.92	11.8	14.2	13.0	13.6	14.7	14.1
S_3: 75%RDF	8.29	10.04	9.17	12.44	16.64	14.54	16.1	19.1	17.6	19.9	22.7	21.3
S_4: 100%RDF	8.90	11.21	9.90	15.23	19.08	17.15	18.7	22.2	19.9	22.2	26.3	24.3
SEm±	0.37	0.39	0.33	0.44	0.60	0.37	0.59	0.71	0.64	0.56	0.59	0.40
CD (*P=0.05*)	1.07	1.13	0.97	1.27	1.77	1.09	1.72	2.07	1.86	1.65	1.72	1.17
Interaction												
MXS												
Sem±	0.74	0.77	0.67	0.44	1.21	0.74	1.18	1.42	1.27	1.13	1.18	0.80
CD (*P=0.05*)	NS	NS	NS	1.27	3.87	2.38	3.77	4.55	4.08	3.61	3.8	2.6
SXM												
Sem±	0.58	0.54	0.55	0.68	0.87	0.55	0.91	1.00	1.00	0.92	1.08	0.85
CD (*P=0.05*)	NS	NS	NS	2.17	2.79	1.75	2.91	3.19	3.21	2.9	3.5	2.7

Table 6. Interaction of organic nutrient sources and inorganic nutrient levels on phosphorus uptake (kg ha^{-1}) of aerobic rice at panicle initiation

Nutrient levels/ Nutrient sources)	2017					2018					Pooled				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	5.04	7.27	6.63	5.10	6.01	5.77	7.79	5.65	5.71	6.23	5.41	7.53	6.14	5.41	6.12
S_2	7.38	13.24	11.58	9.04	10.31	8.66	14.59	13.00	9.90	11.54	8.02	13.92	12.29	9.5	10.92
S_3	8.10	15.4	14.27	12.07	12.44	10.60	21.75	21.34	12.89	16.64	9.33	18.57	17.80	12.5	14.54
S_4	9.3	19.2	18.45	13.97	15.23	13.92	23.94	21.96	16.52	19.08	11.60	21.57	20.21	15.2	17.15
Mean	7.4	13.8	12.73	10.05		9.74	17.02	15.49	11.26		8.59	15.40	14.11	10.7	
Interaction	M × S		S × M			M × S		S × M			M × S		S × M		
SEm±	0.44		0.68			1.21		0.87			0.74		0.55		
CD (*P 0.05*)	1.27		2.17			3.87		2.79			2.38		1.75		

Table 7. Interaction of organic nutrient sources and inorganic nutrient levels on phosphorus uptake (kg ha^{-1}) of aerobic rice at flowering

Nutrient levels/ Nutrient sources	2017					2018					Pooled				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	6.87	8.47	6.54	6.62	7.12	8.53	9.57	7.41	7.86	8.34	7.70	9.02	6.97	7.24	7.73
S_2	8.70	14.83	13.85	10.02	11.85	10.82	16.94	16.71	12.43	14.23	9.76	15.88	15.28	11.23	13.04
S_3	10.45	20.67	20.69	12.72	16.13	13.20	24.05	23.78	15.42	19.11	11.82	22.36	22.24	14.07	17.62
S_4	14.21	22.94	21.51	16.33	18.74	17.29	26.91	25.17	19.58	22.24	15.75	24.92	21.01	17.95	19.91
Mean	10.06	16.73	15.65	11.42		12.46	19.37	18.27	13.82		11.26	18.05	16.37	12.62	
Interaction	M × S		S × M			M × S		S × M			M × S		S × M		
SEm±	1.18		0.91			1.42		1.00			1.27		1.00		
CD (*P 0.05*)	3.77		2.91			4.55		3.19			4.08		3.21		

M_1: Neem leaf manure 6 t ha^{-1} M_2: Vermicompost 2t ha^{-1} M_3: Goat manure 5 t ha^{-1} M_4: Microbial consortia seed treatment 4g kg seed^{-1} & soil application 4 kg ha^{-1}

S_1: 0% RDF S_2: 50% RDF S_3: 75% RDF S_4: 100% RDF

Table 8. Interaction of organic nutrient sources and inorganic nutrient levels on phosphorus uptake (kg ha^{-1}) of aerobic rice at harvest

Nutrient levels/ Nutrient sources	2017					2018					Pooled				
	M$_1$	**M$_2$**	**M$_3$**	**M$_4$**	**Mean**	**M$_1$**	**M$_2$**	**M$_3$**	**M$_4$**	**Mean**	**M$_1$**	**M$_2$**	**M$_3$**	**M$_4$**	**Mean**
S$_1$	6.7	8.2	7.0	6.9	7.2	7.6	10.2	8.4	8.0	8.6	7.13	9.23	7.72	7.43	7.88
S$_2$	10.4	16.4	15.7	11.7	13.6	10.2	19.8	16.5	12.3	14.7	10.32	18.08	16.10	11.97	14.12
S$_3$	12.7	**25.9**	24.9	16.2	19.9	15.9	27.4	28.1	19.4	22.7	14.33	26.64	26.51	17.78	21.31
S$_4$	15.5	27.7	25.5	19.9	22.2	22.2	28.9	27.9	26.4	26.3	18.89	28.26	26.71	23.14	24.25
Mean	11.3	19.5	18.3	13.7		14.0	21.6	20.2	16.5		12.7	20.6	19.3	15.1	
Interaction	**M × S**		**S × M**			**M × S**		**S × M**			**M × S**		**S × M**		
SEm±	1.13		0.92			1.18		1.08			0.80		0.85		
CD (*P 0.05*)	3.61		2.94			3.78		3.47			2.55		2.72		

M$_1$: Neem leaf manure 6 t ha^{-1} M$_2$: Vermicompost 2t ha^{-1} M$_3$: Goat manure 5 t ha^{-1} M$_4$: Microbial consortia seed treatment 4g kg seed^{-1} & soil application 4 kg ha^{-1}
S$_1$: 0% RDF S$_2$: 50% RDF S$_3$: 75% RDF S$_4$: 100% RDF

Table 9. Potassium uptake (kg ha^{-1}) of aerobic rice at different growth stages as influenced by organic nutrient sources and inorganic nutrient levels

Treatment	Maximum tillering			Panicle initiation			50% flowering			At harvest		
	2017	**2018**	**Pooled Mean**	**2017**	**2018**	**Pooled Mean**	**2017**	**2018**	**Pooled Mean**	**2017**	**2018**	**Pooled Mean**
Organic nutrient sources (M)												
M$_1$: Neem leaf manure 6 t ha^{-1}	23.8	27.8	25.8	38.3	44.2	41.3	45.5	51.8	48.6	68.0	75.1	71.5
M$_2$: Vermicompost 2 t ha^{-1}	36.4	43.0	39.7	57.2	62.7	60.0	71.5	81.1	76.3	102.1	112.0	107.1
M$_3$: Goat manure 5 t ha^{-1}	34.0	42.4	38.2	55.6	63.3	59.5	69.6	80.8	75.2	99.1	103.4	84.0
M$_4$: Microbial consortia 4g kg seed^{-1} & 4kg ha^{-1} soil application	28.7	33.4	31.0	44.8	50.7	47.8	56.0	63.7	59.9	78.0	87.2	82.6
SEm±	1.23	1.33	1.09	1.76	1.36	1.52	2.17	1.93	1.39	2.35	2.35	3.79
CD (*P=0.05*)	4.25	4.60	3.77	6.08	4.71	5.25	7.50	5.63	4.06	8.14	8.13	13.12
Inorganic nutrient levels (S)												
S$_1$: 0% RDF	16.2	22.4	19.3	27.1	29.6	28.3	33.5	35.9	34.7	54.8	58.6	56.7
S$_2$: 50%RDF	25.5	29.8	27.7	43.8	49.6	46.7	54.3	62.3	58.3	78.6	87.8	83.2
S$_3$: 75%RDF	37.6	43.4	40.5	59.0	66.3	62.7	73.5	82.8	78.1	98.7	107.0	102.8
S$_4$: 100%RDF	43.6	51.0	47.3	66.1	75.5	70.8	81.4	96.4	88.9	115.1	124.3	119.5
SEm±	1.03	1.52	0.84	1.57	1.01	1.22	1.95	3.85	2.78	2.1	2.9	5.10
CD (*P=0.05*)	3.00	4.44	2.44	4.60	2.96	3.55	5.69	12.33	8.90	6.2	8.5	14.87
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

at all growth stages. Nutrient level of 100% RDF recorded significantly higher mean potassium uptake (47.3, 70.8, 88.9 and 119.5 kg ha^{-1}) than 75% RDF (40.5, 62.7, 78.1 and 102.8 kg ha^{-1}) and 50% RDF (27.7, 46.7, 58.3 and 83.2 kg ha^{-1}) and lowest K uptake was recorded with control (19.3, 28.3, 34.7 and 56.7 kg ha^{-1}). Similar observations were made by Mandal et al. [24] who recorded the highest uptake of NPK at 100 per cent recommended dose of NPK which was significantly superior to the immediate lower levels of fertilizer dose. The interaction effect between organic sources of nutrients and inorganic nutrient levels was found non-significant during both the years of study. The enhanced K uptake under organic manuring with vermicompost or goat manure treatments might be due to acceleration in the process of mineralization of fixed, native and applied potassium, resulting in more availability of K which caused more uptake by rice crop at harvest in both the years. Similarly, Kumar and Mathew [25] reported beneficial effect of vermicompost and recorded an increase in the nutrient uptake by rice. Potassium uptake by aerobic rice was significantly influenced by organic nutrient sources and inorganic nutrient levels.

4. CONCLUSIONS

Nutrient uptake by aerobic rice was significantly influenced with application of organic nutrient sources and inorganic nutrient levels. N, P and K uptakes by rice were higher with vermicompost @ 2 t ha^{-1} or goat manure @ 5 t ha^{-1} among organic sources and 100% RDF among nutrient levels. Conjunctive use of 75% of RDF along with vermicompost (M_2S_3) or goat manure (M_3S_3) resulted in statistically on par nitrogen and phosphorus uptake with that of 100% RDF and the lowest nitrogen and phosphorus uptake were recorded with combination of either neem leaf manure or microbial consortia and no application of fertilizer (M_1S_1 and M_4S_1, respectively.).

CONFERENCE DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kadiyala JW, Jones RS, Mylavarapu YC, Li MD, Reddy. Identifying irrigation and nitrogen best management practices for aerobic rice–maize cropping system for semi-arid tropics using CERES-rice and maize models”. Agricultural Water Management. 2012;149:23-32.
2. Tuong P, Bouman BAM, Martin Mortimer. More Rice, Less Water—Integrated Approaches for Increasing Water Productivity in Irrigated Rice-Based Systems in Asia, Plant Production Science. 2008;8(3):231-241.
3. Belder P, Bouman BAM, Speirtz JHJ, Peng S, Castaneda AR, Visperas RM. Crop performance, nitrogen and water use in flooded and aerobic rice. Plant Soil. 2005;273:167–182.
4. Peng S. Lixiao Nie, Xiang J Aerobic rice for water saving agriculture. A. review. Environmental Sciences. 2012;96:252–259.
5. Kumar VK, Ladha K. Chapter Six - Direct Seeding of Rice: Recent Developments and Future Research Needs. Advances in Agronomy. 2012;111:297-413.
6. Chandrapala AG, Yakadri M, Kumar M, Raj B. Productivity andeconomics of rice (*Oryza sativa*): Maize (*Zea mays*) as influenced by methods of crop establishment, Zn and S application in rice. Indian J. Agron. 2010;55:171–176.
7. Sreedevi B, Latha PC, Senguttuvelu P, Ram T, Viraktamath BC. Aerobic rice-An alternative cultivation method for water constrained rice environments. 2nd International Conference on Agricultural and Horticultural Sciences. 2014;2:4.
8. Sridhar K, Srinivas A, Avil Kumar K, Ram Prakash T, Raghuveer Rao P. Influence of alternate wetting and drying irrigation and nitrogen levels on grain quality, soil fertility, nutrient uptake in rice genotypes during rabi season. The Pharma Innovation Journal. 2022; 11(10):1959-1965.
9. Buresh RJ, Haefele SM. Changes in paddy soils under transition to water saving and diversified cropping systems. In: Paper to be presented at World Congress of Soil Science, Brisbane, Australia; 2010.

10. Jackson ML. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 1967;1-49.
11. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John Wiley & Sons; 1984.
12. Sudhakar C. Integrated nutrient management in rice-maize cropping system Thesis submitted to the Acharya NG. Ranga Agricultural University; 2011.
13. Padmanabhan M. Effect of different organic manures on growth and yield of transplanted rice in coastal Karnataka (Doctoral dissertation, University of Agricultural Sciences, GKVK); 2013.
14. Chesti MH, Kohli A, Mujtaba A, Sofi JA, Qadri TN, Peer QJA, Dar MA, Bisati IA. Effect of integrated application of inorganic and organic sources on soil properties, yield and nutrient uptake by rice (*Oryza sativa* L.) in intermediate zone of Jammu and Kashmir. Journal of the Indian Society of Soil Science. 2015;63(1) :88-92.
15. Karthika N, Ramanathan SP. Effect of drip fertigation on growth, physiological parameters and grain yield of rice grown in Cauvery new delta zone of Tamil Nadu. International Journal of Chemical Studies. 2019;7(3):2758-276.
16. Ajmal KK. Optimization of nitrogen dose and time of application for semi dry rice. M. Sc (Ag.) Thesis. Professor Jayashankar Telangana State Agricultural University, Hyderabad, India; 2020.
17. Devi RB, Yashwant Singh. Nutrient uptake and yield of direct seeded rice as influenced by nitrogen and weed management practices. International Journal of Pure and Applied Bioscience. 2018;6(5):34-40.
18. Binoy C, Sinha AC. Moisture Conservation and Nutrient Management Practices on Growth and Yield of Maize (*Zea mays* L.). Current Agriculture Research Journal. 2019;7(3):2347-4688.
19. Dibakar Ghosh, Koushik Brahmachari, Marian Brestic, Peter Ondirisik, Akbar Hossain, Milan Skalicky, Sukamal Sarkar, Debojyoti Moulick, Nirmal Kumar Dinda, Anupam Das, Biswajit Pramanick, Sagar Maitra, Richard W. Bell. Integrated Weed and Nutrient Management Improve Yield. 2020. Nutrient Uptake and Economics of Maize in the Rice-Maize Cropping System of Eastern India. Agronomy. 2020; 10(12):1906-1915.
20. Naher UA, Biswas JC, Maniruzzaman M, Khan FH, Sarkar MIU, Jahan A, Hera MHR, Hossain MB, Islam A, Islam MR and Kabir MS. Bio-Organic Fertilizer: A Green Technology to Reduce Synthetic N and P Fertilizer for Rice Production. Front. Plant Sci. 2021;12:602052.
DOI: 10.3389/fpls.2021.602052
21. Abdullah MA. Seston and nitrogen effects on yield and N, P uptake of rice (*Oryza sativa* L. cv. Hasanii). Scientific Journal of King Faisal University. 2004;5(1): 93-101.
22. Cavigelli MA, Thien SJ. Phosphorous bioavailability following incorporation of green manure crops. Soil Science Society of America Journal. 2003;67:1186-1194.
23. Kaur A, Kumar M. Growth, crop phenology and PAR interception in kharif maize (*Zea mays* L.) as influenced by planting methods and nitrogen levels. Crop Research (0970-4884). 2019;53.
24. Mandal SS, Mandal TK, Dandapat S, Sarkar S. Effect of sulphur bearing fertilizers in conjunction with FYM on growth, productivity and nutrient uptake of rice. Indian Journal of Agronomy. 1994; 39(1):116-118.
25. Kumar AK, Mathew J. Timing of green leaf manuring in presence and absence of liming on growth, yield and nutrient uptake in transplanted rice. Indian Journal of Agronomy. 1994;39(4): 630-633.

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