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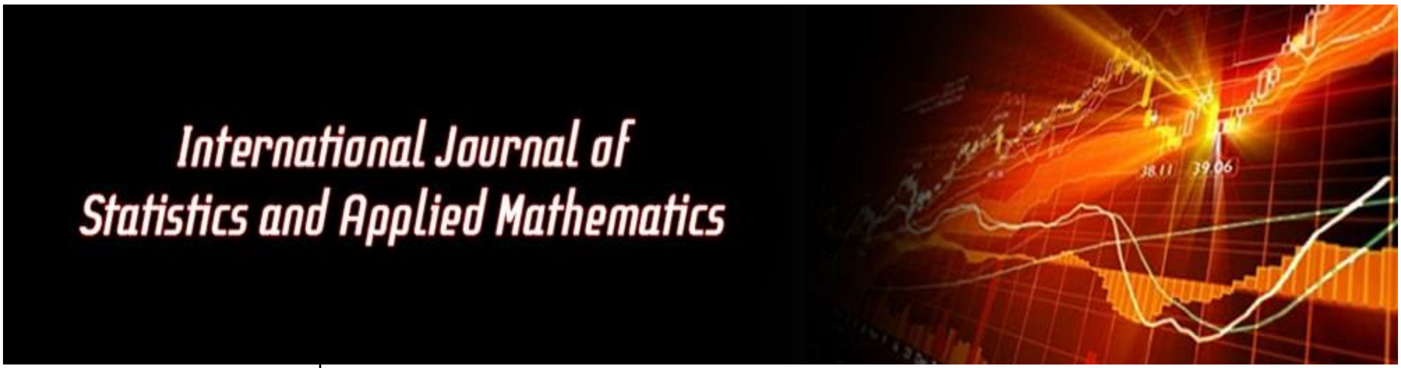

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Growth, yield attributes and yield of aerobic rice under organic and inorganic sources nutrient management

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Abstract
A field study was taken up to evaluate the influence of organic sources of nutrients and fertility levels in aerobic rice during *kharif* 2017 and kharif 2018 at Indian Institute of Rice Research, Rajendra Nagar, Hyderabad. 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 $^{-1}$] and four subplots with graded doses of fertilizers viz; S 1 :Control; S 2 :50% RDF; S 3 :75% RDF and S 4 :100% RDF (120-60-40). It was observed that higher plant height, dry matter production and tillers m -2 were recorded under M 2 [vermicompost 2 t ha -1] followed by M 3 [goat manure 5t ha ha $^{-1}$]. Among the graded doses of fertilizers S 4 :100% RDF recorded taller plants, drymatter production and tillers m -2 followed by S 3 :75% RDF and shorter plants, lowest drymatter production and tillers m -2 were recorded under control treatment(S 1 : 0% RDF). Higher panicle length (25.6), panicle weight (3.4), total grains per panicle (125) and filled grains per panicle (116) under M 2 [vermicompost 2 t ha $^{-1}$], followed by M 3 : Goat manure @ 5 t ha -1 (panicle length -25.3, panicle weight - 3.3, total grains per panicle - 125 and filled grains perpanicle-114.), and among the graded doses of fertilizers S 4 :100% RDF recorded higher panicle length (26.6), panicle weight (3.4), total grains per panicle (126)and filled grains per panicle (119) followed by S 3 : (75%RDF) with panicle length- 25.3 cm, panicle weight - 3.1g, total grains per panicle - 124 and filled grains per panicle -113 and lowest panicle length (22.7 cm), panicle weight (2.8 g), total grains per panicle (103) and filled grains per panicle (84) were recorded under control (S 1 : 0%). M 2 treatment [vermicompost 2t ha $^{-1}$] accrued higher grain yield of 4248 kg ha $^{-1}$ which was statistically at par with M 3 (4141 kg ha $^{-1}$). Lowest grain yield of 3066 kg ha $^{-1}$ was obtained with M 1 (neem leaf manure 6t ha $^{-1}$).100% RDF (S 4) yielded 4712 kg ha $^{-1}$ followed by 75% RDF (S 3). The highest straw yield (5374 kg ha $^{-1}$) was obtained with M 2 (vermicompost 2t ha $^{-1}$) followed by M 3 (Goat manure 5 t ha $^{-1}$) (5268 kg ha $^{-1}$). S 4 (100%) RDF produced the highest straw yield of 5894 kg ha $^{-1}$ followed by S 3 (5530 kg ha $^{-1}$).

Keywords: Aerobic rice, organic nutrient sources and inorganic nutrient levels

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 M t and productivity of 4661 kg ha $^{-1}$ (FAO, 2019-20). In India, rice occupies an area of 43.7 M ha with an average production of 118.9 M t and with productivity of 2423 kg ha $^{-1}$. Rice bran rich in proteins and vitamins and is used as animal feed and for extraction of rice bran oil. In Telangana, the area of rice is 3.19 M ha with production of 11.12 M t and productivity of 3483 kg ha $^{-1}$ (CMIE, 2019-20). In terms of global rice productivity, irrigated lowland rice comprises of 55 and 75% of area and production, respectively (Mahender *et al*., 2019) [6]. Tuong and Bouman (2005) [17] estimated that by 2025, 15-20 M ha of irrigated rice is estimated to suffer from some degree of water scarcity. Further, increasing demand for water from various other sectors threatens the sustainability of irrigated rice production and needs a major shift in rice cultivation system. Aerobic rice is an alternative and contingent rice production system (Sreedevi *et al*., 2019) [12]. Here, rice crop is cultivated under non-puddled and non-saturated soil conditions. It is mainly

suited for irrigated lowlands, water scarce areas and uplands (Belder *et al.,* 2005) [2]. Aerobic rice avoids the risk of transplanting shock and hastens physiological maturity thereby reducing vulnerability to late season drought and reduced methane emission (Wassmann *et al*., 2004) [19]. According to Chandrapala *et al.* (2010) [3], aerobic rice production system 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 has been found to have positive implications on succeeding maize (Chandrapala *et al*., 2010) [3]. Rice-Maize systems exist in all climates ranging from tropical to sub-tropical to warm temperates. Rice–maize double cropping is gaining popularity in many Asian countries including India and currently occupies around 3.5 million ha in Asia (Timsina *et al*., 2010) [16]. The development of short duration rice varieties coupled with high yielding maize hybrids provided an opportunity for increasing the area under Rice–Maize cropping in India. Rice-Maize system is also gradually gaining importance in canal and tank irrigated areas of Telangana. Timsina *et al.* (2010) [16] hypothesized that sowing maize under reduced or no tillage conditions by retaining crop residues and adopting improved nutrient management and establishment methods could help to conserve soil organic matter and maintain soil fertility.

Cropping of two nutrient exhaustive cereals like rice and maize would drain a substantial quantity of nutrients from soil during continuous cropping round the year, envisaging the need for adoption of efficient nutrient management practices for sustained soil health and improving system productivity (Surekha *et al*., 2016) [13]. Proper nutrient management not only ensures adequate supply of fertilizers but also minimize losses and maximize the nutrient use efficiency. In this context, integrated nutrient management including organic manures and biofertilizers hold prominence. Integrated nutrient management improves soil fertility besides sustaining the desired levels of crop production and productivity through optimization of benefits from all possible sources of plant nutrients. It entails the conjunctive use of organic and inorganic fertilizers to achieve sustainable yields and improves the bio-physico-chemical properties. Therefore, suitable combination of chemical fertilizers, organic manures and biofertilisers need to be developed for Rice-Maize cropping system to enhance system and soil productivity. Recently, ICAR- IIRR has developed a consortium of plant growth promoting rhizobacteria (PGPR) constituting *Methylobacterium fujisawaense, Gluconacetobacter diazotrophicus* and *Bacillus subtilis*. These have been reported to colonize plant roots and enhance plant growth through nitrogen fixation, Phosphorus solubilization and making them available to host plant.

In the light of above, an experiment was planned to evaluate various nutrient management practices in aerobic rice for yield maximisation and their residual effect on succeeding maize sown under zero till conditions.

Materials and Methods

Experimental site, climate and soil characteristics

Field experiments were conducted for two consecutive years *viz.* 2017-18 and 2018-19 during the two seasons 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 zone. The soil of the experimental field at the start of the experiment had Sandy clay loam texture, with apH of 8.05, organic carbon (0.91%), available N (208 kg ha^{-1}), available P (26.3 kg ha^{-1}) and available K (382.2 kg ha^{-1}).

Experimental design, layout and crop management

The experiment was laid out in split-plot design with organic sources of nutrients as main plot and 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}] and four subplots with graded doses of fertilizers *viz*; S_1: Control; S_2:50% RDF; S_3 :75% RDF and S_4:100% RDF (120-60-40). 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. For rice crop, Nitrogen fertilizer (Urea) was applied in three split doses, 50% at sowing, 25% at maximum tillering stage and 25% at panicle initiation stage. The P fertiliser (DAP) 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.

Sampling and measurement

At tillering (TL) and flowering (FL) stages, five hills were selected randomly from each plot and tagged to measure agronomic parameters, which included tillers m^{-2}, dry biomass accumulation by shoot (g m^{-2}) and leaf area index (LAI). During the tillering (TL) and panicle initiation (PI) stages, tillers were counted from each hill at three fixed locations in each plot and biomass was sampled by collecting the fresh shoots with the help of a quadrat (0.25 x 0.25 m) from three locations. The measurement of yield attributes viz. Panicles m^{-2}, panicle weight, grain weight, filled grain percentage and yield was carried out according to the recommended procedure. Physiological maturity was determined when 80% of the grains had turned into golden-yellow colour. Panicle density was determined with a quadrat (0.25 m × 0.25 m) placed randomly in each plot at four locations. Dried seed samples were drawn randomly from each treatment plot produce and 100 grains were counted and their weight was recorded. Before harvest, yield components such as, fertility % and 1000 grain weight (g) were determined. 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 then at 0% moisture for calculating N uptake indices. Straw obtained from each net plot area after threshing was sun dried for four days and then weighed and expressed in t ha^{-1} at 0% moisture content. Harvest index was calculated as the ratio of dry grain yield to total biomass at crop harvest.

Statistical analyses

The data was subjected to analysis of variance to determine the influence of treatments (Gomez and Gomez, 1984). 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. The relationships between different attributes were assessed using correlation analysis.

Results and Discussion

Growth attributes

yPlant height increased linearly under different organic sources at all the growth stages of crop. M_2 [vermicompost 2 t ha^{-1}] produced significantly taller plants (69.3 and 83.9 cm) at maximum tillering and panicle initiation which was on par with M_3 [goat manure 5t ha^{-1}] (64.2 and 79.6 cm), followed by M_4 [microbial consortium]. However, among sub plots, S_4 [100%] produced significantly taller plants of 73.9 and 91.5 cm at maximum tillering and panicle initiation stage and was closely followed by S_3 [75% RDF] and S_2 [50% RDF].while S_1 [Control] had lowest plant height at maximum tillering and panicle initiation stage (39.2 and 46.3 cm).

The dry matter production was statistically significant in relation to organic nutrient sources and graded fertilizer doses. The dry matter accumulation increased linearly from sowing to harvest. The M_2 treatment *i.e.*2t ha^{-1} through vermicompost accumulated maximum dry matter at MT (5312 kg ha^{-1}) and PI (6469 kg ha^{-1}) stage and was on par with M_3 [goat manure 5t ha^{-1}] (5023 and 6178 kg ha^{-1}).Lowest dry matter production (3847 and 4508 kg ha^{-1}) was noticed with M_1 [neem leaf manure]. Among the four sub plots, S_4, *i.e.*100% RDF generated the higher dry matter at MT (5728 kg ha^{-1}) and PI (6821 kg ha^{-1}) stage followed by S_3 (75% RDF) andS_2 (50% RDF). The lowest dry matter was accrued by S_1 [Control].

Highest number of tillers m^{-2} were recorded with vermicompost @ 2t ha^{-1}*i.e.* M_2 produced significantly higher no. of tillers m^{-2} at MT and PI stage (320 and 346) which was statistically similar with goat manure @ 5 t ha^{-1} *i.e.* M_3 (305 and 330) and superior to M_4 [Microbial consortia @ ST 4 g kg^{-1} & SA @ 4 kg ha^{-1}]. The minimum number of tillers were recorded with M_1 [neem leaf manure @ 6 t ha^{-1}] treatment. Among the nutrient levels, application of 100% RDF {S_4} resulted in significant increase in the number of tillers m^{-2} (335 and 364) over rest of treatments at all the stages followed by 75% RDF and 50% RDF. The least number of tillers m^{-2} were recorded with control [S_1] *i.e.* 0% RDF. These results are in close collaboration with the findings of Siddaram (2009) [10], Tejaswini (2016) [15], and Jana (2020) [5].

Superior performance of vermicompost, goat manure treated plots in producing better growth parameters might be attributed to continuous steady release of nutrients which might have enabled the higher rate of cell division, elongation and various metabolic processes resulting increase in plant height, tillers favouring higher photosynthetic rate which in turn, could have led to higher production of dry matter, thus the results were in conformity with the findings reported by the findings agree with Enhanced nutrient application resulted in significant increase in plant height, tillers m^{-2}and higher dry matter production as athigher doses of fertilizers might have helped in inducing higher vegetative growth leading to better interception of photosynthetically active radiation and greater photosynthesis by the crop was responsible for profuse tillering and ultimately higher plant DMP. These findings are in accordance with the reports of Shekara *et al.* (2010) [9], and Malla Reddy *et al.* (2013) [7], Anil (2014) [1].

Yield attributes

Higher values of panicles m^{-2}, total no. of grains panicle^{-1}, total no. of filled grains panicle^{-1}, panicle length (cm), panicle weight (g), test weight (g), grain yield, straw yield and harvest index were observed during *kharif* 2018 as compared to *kharif* 2017. Higher yields during the second season were attributed to favourable mean bright sunshine hours of 5.33h compared to 4.33h in 2017. Significant differences in panicles m^{-2}, total no. of grains panicle^{-1}, total no. of filled grains panicle^{-1}, panicle length (cm), panicle weight (g), test weight (g), grain and straw yield and harvest index were seen when different nutrient sources and levels were used. However, test weight (g) did not alter considerably when different nutrient sources were used. The results revealed that M_2 (310) produced considerably more panicle m^{-2} and was statistically similar to M_3 (297) followed by M_4. The least no. of panicles m^{-2} was found with M_1 (206). Among the nutrient levels, S_4 (100% RDF) resulted in highest no. of panicles m^{-2} (339).

Yield

Grain yield was significantly influenced with nutrient sources treatments. M_2 treatment [vermicompost @ 2t ha^{-1}] accrued higher grain yield of 4248 kg ha^{-1} which was statistically at par with M_3 (4141 kg ha^{-1}). Lowest grain yield of kg ha^{-1} was obtained with M_1 *i.e.* neem leaf manure @ 6t ha^{-1}. Nutrient levels exerted a significant variation on grain yield. 100% RDF (S_4) yielded 4712 kg ha^{-1}followed by 75% RDF (S_3) and 50% RDF (S_2).

Straw yield of 5374 kg ha^{-1}was recorded with vermicompost @ 2 t ha^{-1} (M_2) and was at par with goat manure @ 5 t ha^{-1} (5268 kg ha^{-1}) and lowest was recorded with M_1 [neem leaf @ 6t ha^{-1}]. Among nutrient levels S_4 (100%) RDF produced the highest straw yield of 5894 kg ha^{-1} followed by S_3 (5530 kg ha^{-1}). The findings are similar to the results of Anil (2014) [1], where higher yield attributes and yield of aerobic rice was recorded.

Application organic sources of nutrients *viz*. of vermicompost @ 2t ha^{-1} or goat manure @ 5t ha^{-1} increased grain yield might be due to higher nitrogen content in vermicompost and goat manure which is much readily available as compared to other organic manures, Since the yield of the crop is a function of several yield components which are dependent on the complementary interaction between the vegetative and reproductive growth of the crop. Increased nutrient availability and uptake with organic nitrogen had increased photosynthetic rate and net assimilation rate, which has resulted in more grain yield. Similar observations were reported by Siddaram (2006) [10], Jana *et al*. (2012) [5].

Improvement in yield attributes *viz:* panicle length, effective tilers, panicle weight, total grains per panicle and test weight in organic manuring with vermicompost and goat manures was due to better nutrient availability and uptake by crop to match the crop nutritional requirement at log phase wherein, the critical processes related to cell division, cell differentiation and cell elongation takes place at a higher rate. Higher sink capacity consequent to longer panicle length, more number of total grains per panicle, and better test weight resulting in significantly higher grain yield, straw yield and HI% was observed in several studies. Similar findings of enhancement in yield attributing traits was reported by Swikar Karki *et al*. (2017) [14] and Pandit *et al*. (2020) [8] both reported similar findings.

Application of fertilizer at optimum doses at critical growth stages resulted in increased availability of nutrients to rice crop which enabled to produce longer panicle length, more number of effective tilers, higher panicle weight, total grains per panicle and test weight. The findings are consistent with those of Sowmya *et al*. (2017) [11] and Swikar *et al*. (2017) [14]

impacted in significant enhancement in grain yield, straw yield and HI%.

Table 1: Growth attributes of aerobic rice at different growth stages as influenced by organic nutrient sources and fertility levels

Treatment	Plant height (cm)		Dry matter production (kg ha^{-1})		Tillers (no. m^{-2})	
	Maximum tillering	Panicle initiation	Maximum tillering	Panicle initiation	Maximum tillering	Panicle initiation
Organic nutrient sources (M)						
M_1: Neem leaf manure @ 6 t ha^{-1}	51.7	64.6	3847	4508	238	257
M_2: Vermicompost @ 2t ha^{-1}	69.3	83.9	5312	6469	320	346
M_3: Goat manure @ 5 t ha^{-1}	64.2	79.6	5023	6178	305	330
M_4: Microbial consortia @ 4g /kg seed & 4kg ha^{-1} soil application	57.9	72.4	4323	5348	266	286
Sem±	1.16	1.22	105	206	6.2	7.2
CD (P=0.05)	4.02	4.21	362	714	21.5	25.0
Inorganic nutrient levels(S)						
S_1:0% RDF	39.2	46.3	2790	3521	219	232
S_2:50%RDF	61.3	76.9	4523	5589	269	290
S_3:75%RDF	68.6	85.8	5465	6573	307	333
S_4: 100%RDF	73.9	91.5	5728	6821	335	364
Sem±	0.73	1.01	131	99	5.6	5.8
CD (P=0.05)	2.14	2.95	381	289	16.4	16.8
MXS						
Sem±	1.25	1.27	261	198	11.2	11.5
CD (P=0.05)	NS	NS	NS	633	NS	36.8
SXM						
Sem±	1.02	1.05	205	280	10.3	11.3
CD (P=0.05)	NS	NS	NS	897	NS	35.2

Table 2: Yield attributes and yield of aerobic rice as influenced by organic nutrient sources and fertility levels

Treatment	Effective Tillers (no. m^{-2})	Panicle length (cm)	Panicle weight (g)	Total grains per panicle	Filled grains per panicle	Test weight (g)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest Index
Organic sources of nutrients (M)									
5M_1: Neem leaf manure @ 6 t ha^{-1}	206.4	23.3	3.1	107.7	90.9	22.9	3066.8	4053.7	43.0
M_2: Vermicompost @ 2t ha^{-1}	310.6	25.6	3.4	125.7	116.5	22.9	4248.7	5374.9	43.9
M_3: Goat manure @ 5 t ha^{-1}	297.4	25.3	3.3	124.1	114.9	23.0	4141.8	5268.4	43.8
M_4: Microbial consortia @ 4g /kg seed&kg ha^{-1} soil application	264.2	24.4	2.8	114.1	99.8	23.1	3511.3	4642.6	42.8
Sem±	6.3	0.16	0.08	2.72	1.02	0.3	117.9	121.2	0.35
CD (P=0.05)	21.8	0.55	0.27	9.41	3.12	NS	408.1	419.5	NS
Inorganic nutrient levels (S)									
S_1:0% RDF	182.7	22.7	2.8	103.0	84.9	22.3	2202.4	3008.9	42.2
S_2:50%RDF	255.5	24.0	3.3	117.5	104.4	22.8	3702.5	4905.6	42.9
S_3:75%RDF	300.8	25.3	3.1	124.4	113.9	23.0	4351.4	5530.9	44.0
S_4: 100%RDF	339.7	26.6	3.4	126.7	119	23.7	4712.3	5894.2	44.4
Sem±	5.6	0.38	0.11	2.98	1.29	0.4	69.2	89.4	0.40
CD (P=0.05)	16.3	1.12	0.33	8.69	3.06	NS	201.9	260.8	1.16
MXS									
Sem±	11.2	0.8	0.35	3.12	2.14	0.55	138.3	178.7	0.79
CD (P=0.05)	35.7	NS	NS	NS	NS	NS	442.6	571.8	NS
SXM									
Sem±	10.3	0.51	0.23	3.02	2.02	0.51	167.4	184.5	0.64
CD (P=0.05)	33.0	NS	NS	NS	NS	NS	535.7	590.1	NS

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