Indian Journal of Agricultural Sciences **95** (9): 1133–1137, September 2025/Short Communication
https://doi.org/10.56093/ijas.v95i9.163332

Productivity and profitability of rice (*Oryza sativa*) varieties grown and nurtured organically on a 5-year old zero chemical applied soil base

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Received: 6 January 2025; Accepted: 21 August 2025

Keywords: *Bijamrutha*, EM solution I, FYM, *Jeevaamrutha, Panchagavya*, Vermicompost

Chemical-led agriculture involving technology packages, though led to green revolution successfully and also met the food requirement of burgeoning population, later proved to be impersonation of agriculture and ecology, and threatened the agriculture ecosystem and their adverse effect on soil quality indices raised a question mark on perpetuity of healthy agricultural production system unbalancing the food security policies over the world (Prasad 2015). Organic farming has attracted the agricultural scientists because of its importance in restoring the soil health through aggregate stabilization and C storage, besides increased consumer's preference and the policies of the central government. Varietal response under conventional farming is well established, however, the information on their response to organic nutrient management strategies as sole source is scantly available even from the soils nurtured with normal practices. The pattern of nutrient release from organic source is quite slow, and addressed contritely in contrast to a well-defined and well understood pattern as under inorganic sources. With these constraints in mind, an experiment involving traditional and high yielding rice (*Oryza sativa* L.) varieties were undertaken during wet season solely under organic nutrition to assess their response on a site not applied with any chemicals for the last 5 years at Agricultural Research Station.

A field experiment was conducted during rainy (*Kharif*) season 2022 at Agricultural Research Station, Siksha 'O' Anusandhan, Bhubaneswar, Odisha. Treatment consisted of six rice varieties, viz. V_1, Maundamani; V_2, Kamal (Green Rice); V_3, Poornabhog; V_4, Nua Chinikamini; V_5, Naveen and V_6, Kalinga Dhan 1201 (variety V_1, V_5 and V_6 are high yielding and variety V_2 ,V_3 and V_4 are traditional varieties). These were allocated to main plots. Basic varietal characters are given in Supplementary Table 1. Four organic management practices such as M_0, No manuring (Control); M_1, 50% of recommended dose of nitrogen (RDN) as per variety through 50% each from FYM and vermicompost; M_2, Full dose of RDN (as per variety) through 50% each from FYM and vermicompost and M_3, Organic formulation application having *Bijamrutha*, *Jeevamrutha*, *Panchagavya* and EM solution I. The textural class of surface soil of experimental site having received no chemical for preceding 5-years (Table 1) was loamy sand (sand 84.84%, silt 2% and clay 13.6%) with a bulk density of 1.45 g/cc, total soil

Table 1 Cropping history of the experimental site

Year	*Kharif*	*Rabi*	Summer
2017	Rice (seed treatment with *Bijamrutha* and applied with FYM @5 t/ha + soil application of *Jeevanmrutha* + foliar application of *Panchagavya*)	Fallow	Green manuring with Sesbania
2018	Rice (seed treatment with *Bijamrutha* and applied with FYM @5 t/ha + soil application of *Jeevanmrutha* + foliar application of *Panchagavya*)	Fallow	Green manuring with Sesbania
2019	Rice (*Bijamrutha* and applied with FYM @5 t/ha + soil application of *Jeevanmrutha* + foliar application of *Panchagavya*)	Fallow	Green manuring with Sesbania
2020	Rice (*Bijamrutha* and applied with FYM @5 t/ha + soil application of *Jeevanmrutha* + foliar application of *Panchagavya*)	Moong	Green manuring with sunhemp
2021	Rice (*Bijamrutha* and applied with FYM @5 t/ha + soil application of *Jeevanmrutha* + foliar application of *Panchagavya*)	Fallow	Moong and cowpea
2022	Present study with different rice varieties		

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porosity of 43.6%, available soil moisture 1.9 cm/15 cm soil depth, soil *p*H 5.67 and organic carbon 0.55%. The available nitrogen, phosphorus and potash were 215, 22.8 and 165.47 kg/ha, respectively. Crop growing period received 1210 mm rain in 65 rainy days. Method of preparation and application schedule is given in Supplementary Table 2. Microbial count in bio formulations was carried out using standard method (Olsen and Bakken 1987) and it was 8, 1.7, 5.5 and 2.1 ($\times 10^6$) CFU per ml in *Bijamritha*, EM solution I, *Jeevaamrutha* and *Panchagavya*, respectively. Quantity of farm yard manure and vermincompost was calculated as per the available nitrogen content. It was 0.45 and 1.8 % in FYM and vermicompost, respectively. Accordingly, their quantity was calculated for different manurial treatments based on N requirement of respective varieties. The recommended dose of nitrogen for Maundamani and Kamal is 80 and 40 kg N/ha, respectively while it is 60 kg N/ha for Poornabhog, Nua Chinkamini, Naveen and Kalinga Dhan 1201. Twenty five days old seedlings were transplanted in rectangular geometry of 20 cm row to row and 10 cm plant to plant. Data were collected on different parameters and subjected to analysis at 5% level of significance in split plot design (SPD). Before sowing in nursery beds, thousand grain weight of each variety was taken for comparison.

Findings revealed that height of all the varieties were statistically on par and ranged from 108.5–119.9 cm except Kalinga Dhan 1201 which measured significantly the shortest plants (86.4 cm). Comparative heights between the measured and basic varietal character (Table 2) would reveal that traditional varieties like Kamal and Nua Chinikmini, and high yielding varieties like Maundamani and Naveen measured slightly higher plant heights than their character (Supplementary Table 1). All the varieties showed maximum rate of increase in height, leaf numbers and Leaf Area Index (LAI) between 30–60 days after planting that decreased appreciably towards harvest. On an average, the rate was little higher in high yielding varieties. High yielding varieties have a proven record of having more vigour than the local or traditional varieties when grown under conventional practices. But trend indicates that high yielding varieties are equally adaptive to organic nutrition, on the other hand, Poornabhoog was equally competitive in vertical growth. All the varieties recorded more number of leaves/hill at 60 DAT and ranged from 35.3–45.5. The trend with respect to manure treatments was more or less similar with M_2 counted more leaves. All the varieties noted more LAI at 90 DAT except Maundamadi. Both highest and lowest values of leaf area index at 90 DAT were found in traditional variety Poornabhog and Kamal, respectively**.** Among the high yielding varieties, Naveen showed highest LAI of 5.4 with significant difference over V_1 and V_6 (Table 2). Treatment M_2 showed highest LAI at 90 DAT indicating their effectiveness in photosynthetic activities which is also reflected in highest HI which might have resulted in higher yield of grain (Table 3). Further, application of organic liquid formulations (M_3) showed stimulating effect on LAI as reflected through significantly higher LAI over M_0. Growth is genetically induced character of variety which in turn is influenced by environment and management practices. The application of nitrogen through organics as under M_1 and M_2 did favoured growth over M_0 treatment. The varying response due to variety is indicative of their nutrient uptake ability under organic environment. Varietal differences in growth parameters have also been reported by Das *et al.* (2019). Similarly, positive response on growth parameters due to application of farm yard manure and vermicompost

Table 2 Periodic plant height (cm), leaf number/hill and leaf area index of rice varieties under organic manure treatments

Treatments	Plant height (DAT)					Leaf number/hill				Leaf area index		
	30	60	90	Harvest	Var. char.	30	60	90	Harvest	30	60	90
Variety												
V_1	49.9	80.6	109.7	111.7	105	27	39	36	35	2.10	5.60	5.10
V_2	53.4	83.6	112.8	112.0	110	21	35	35	34	1.20	3.80	4.60
V_3	53.1	88.1	109.8	111.2	120	35	40	39	38	2.30	4.70	5.70
V_4	53.2	75.2	96.5	117.3	105	42	46	43	43	2.70	4.20	4.70
V_5	54.2	90.8	102.3	108.6	105	33	39	39	39	3.0	3.90	5.40
V_6	47.4	67.1	81.9	86.4	110	38	45	40	44	2.40	3.60	4.80
LSD (*p*=0.05)	1.71	2.43	4.02	12.03	-	1.32	1.42	1.71	1.58	0.53	1.36	0.18
Manures												
M_0	49.6	76.2	100.2	104.4	-	27	36	36	36	1.70	3.50	4.40
M_1	51.6	82.0	103.0	111.9	-	35	41	40	40	2.50	4.80	5.00
M_2	56.1	85.6	104.3	110.7	-	37	43	45	42	2.80	4.60	5.70
M_3	50.5	79.9	101.1	109.8	-	32	39	40	38	2.10	4.20	5.10
LSD (*p*=0.05)	1.10	1.99	2.33	8.34	-	0.89	0.84	0.88	0.89	0.54	0.66	0.25

Refer to Methodology for treatment details.

Table 3 Yield attributes, yield, economic return and efficiency indices at harvest as influenced by variety and manure treatments

Treatments	EBT/m^2	FG/p	Chaff/ panicle	Panicle wt (g)	Panicle length (cm)	Test wt (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	HI (%)	NR (₹/ha)	B:C
Variety											
V_1	201	111	36	2.5	23.3	21.7	2768.7	4033.3	40.4	68877	1.11
V_2	169	107	37	2.4	24.6	16.3	2505.9	3816.7	39.5	93649	1.6
V_3	234	114	34	2.8	25.5	19.7	3250.1	5783.3	35.7	133703	2.2
V_4	175	102	39	2.1	21.7	13.1	2007.2	4825.0	29.4	61175	1.1
V_5	217	11.4	35	2.5	23.6	21.4	2908.8	3958.3	40.3	79763	1.4
V_6	210	94.1	49	2.3	21.0	22.4	2663.0	3758.3	37.6	68584	1.2
LSD (p=0.05)	15.15	5.08	1.95	0.35	2.85	0.11	254.98	331.74	-	642	0.11
Manure											
M_0	194	105	40	2.3	23.8	20.1	2274.0	4472.2	34.0	73904	1.6
M_1	195	109	39	2.5	22.4	19.0	2691.2	4405.6	37.6	81098	1.3
M_2	211	108	36	2.5	24.7	19.2	3235.0	4383.3	40.4	94514	1.3
M_3	203	105	38	2.4	22.2	18.0	2535.4	4188.9	37.9	87718	1.5
LSD (p=0.05)	7.68	2.84	0.99	0.13	1.78	0.19	134.48	164.57	-	55311	0.23

EBT, Ear bearing tillers; FG, Filled grains; HI, Harvest index; NR, Net return; BC, Benefit:Cost ratio; LSD, Least significant difference. Refer to Methodology for treatment details.

(Mahmud *et al*. 2016) has also been reported. Application of organic manures might have improved microbial biomass and thereby growth characters. A comparison on duration of the varieties from seed to seed indicated that all the varieties did not show appreciable difference from their basic characters except Kalinga Dhan 1201 that took 10 days less than the basic character (Supplementary Table 1).

Among the traditional varieties, Poornabhog exhibited significantly higher values of EBT/m^2 and number of filled grains/panicle over Nua Chinikamini and Kamal by 33.3 and 38%, and 11.3 and 6.2 %, respectively. Length of panicle was statistically at par of V_3 and V_2 and both were significantly superior over Nua Chinicamini. Among the high yielding varieties, Naveen had an edge over other two varieties with respect to all above characters. Test weight is generally a genotype dependant trait, though it was higher with high yielding varieties compared to traditional ones. Further, the test weight values observed in experiment was nearly same to that of the values noted from the seeds of respective varieties at the time of sowing (Supplementary Table 1). Trend with regards to weight of panicle was similar to that of panicle length. Poornabhog and Maundamani, counted the lowest number of chaffs panicle while Nua Chinicamini and Naveen counted the highest. Application of 100% RDN as under M_2, counted higher EBT/ m^2, panicle length and number of filled grains/ panicle and lowest number of chaffs/panicle.

Data on productivity (Table 3) indicated that traditional variety Poornabhog recorded significantly the highest yield of grain over all other varieties. No significant difference was observed among the three high yielding varieties. Differences in yield due to varieties under Palampur conditions, has also been reported by Saini *et al*. (2023).Two factor interactions was significant and all the varieties produced higher yield when applied with 100 % RDN through FYM and vermicompost (Fig. 1). Further, application of organic liquid formulation could increase the yield significantly to the tune of 11.5% over no manure treatment (control). Aulakh *et al.* (2013) concluded that *Beejamrutha* and *Jeevamrutha* help to enrich native soil microorganisms N-fixers, P- solubilizer and some fungi and actinomycetes. The differences in yield traits and the yield of high yielding and traditional varieties have also been reported by Rashid *et al.* (2017). Mastiholi *et al.* (2023) reported that application of organic manure helps in improving the nutrient status including micro nutrients in soil. Combined application of FYM and vermicompost increases the population of rhizosphere microorganisms as it is the outcome from microbial composting through earthworm and contain enough organic matter (Aechra *et al*. 2022). Data on economic indices showed variety Poornabhog was superior in terms of net return and B-C ratio with values of ₹1,33,703/ha and 2.2, respectively. Application of full dose of RDN registered highest net return of ₹94,514/ha, however, the B-C ratio of 1.6 was higher under M_0 treatment (Table 3). Student's t test was carried out to compare the mean values of two independent variable that is high yielding and traditional rice varieties. The mean values were obtained across the manuring interventions. The test was performed to see whether the two groups of variable differ with each other significantly or not. Data presented in Table 4 revealed no significant difference in different characters in their mean values such as grain yield, straw yield, EBT/m^2, test weight and panicle weight. It indicated that the traditional varieties can performed equally well and

Table 4 Student's t test with equal variance of traditional varieties and high yielding varieties across the manuring treatments

Attributes	Mean		t- Test	
	High yielding varieties	Traditional varieties	Calculated value	Tabulated value
Grain yield	2780.14	2587.73	0.43	2.07
Straw yield	3916.67	4808.33	0.003	2.07
EBT/m^2	210.19	195.76	0.25	2.09
Filled grains/panicle	105.35	107.52	0.53	2.07
Test weight	21.78	16.36	2.45E-05	2.07

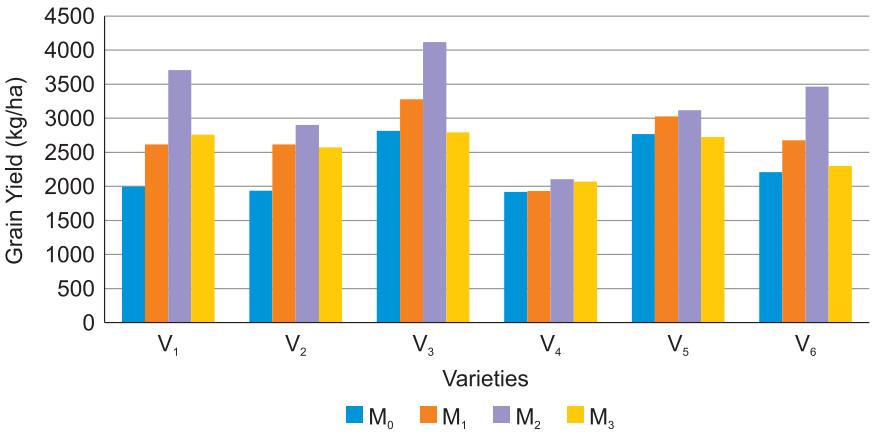

Fig. 1 Interaction effect of variety and organic manuring on grain yield. Refer to Methodology for treatment details.

are comparable with high yielding varieties when grown in organically nurtured soil.

Partial factor productivity (PPF) is a useful index to compare the varieties across the management practices and is an aggregate index related to nitrogen which integrates indigenous 'N' supply from the soil and that applied from external sources, and it generally decreases with increase in 'N' application (Dobermonn 2007) (Table 5). Similar trend with respect to PFP under grain yield was obtained in the present study when varietal comparison was made with that of 'N' application dose (Table 4). Application of 50% of N recorded higher PFP of 130.3 kg/kg in V_2 with minimum of 65.4 kg/kg in V_1. The corresponding values under 100% N application were 72.5 and 46.3 kg/kg. Singh and Pun (2020) also reported similar trend with PFP of 168.7 kg grain at lower level of nitrogen and 76.1 kg grain/kg nitrogen at higher N level. On the other hand, recovery efficiency is a good measure of N-use and aims to achieve more economic yield. It varied from 6.5–39% under M_1 and 8.8–31.8% in M_2 but the response due to varieties was inconsistent. The present results are in conformity with that of Cassman *et al. (*1993) who reported that recovery efficiency in rice generally ranges from 20–80%.

Table 5 Partial factor productivity and recovery efficiency of different rice varieties under manure application

Variety	Partial factor productivity (kg/kg)		Recovery efficiency (%)	
	Grain			
	M_1	M_2	M_1	M_2
V_1	65.38	46.32	6.5	24.6
V_2	130.7	72.55	38.5	32.7
V_3	96.73	68.59	8.0	19.0
V_4	64.46	35.10	39.0	14.0
V_5	100.87	51.59	17.6	8.8
V_6	89.27	115.50	19.0	31.8

Refer to Methodology for treatment details.

Traditional varieties Poornavog was found to be superior with respect to productivity and profitability. Among the high yielding varieties, Naveen responded well to organic manuring. Both the groups of variety performed at par when the mean value was compare through Student's t test. Among the manurial treatments, each variety performed well when provided with recommended dose of nitrogen 50% each through FYM and vermicompost. Foliar application of organic liquid formulation showed positive effect over no manuring treatments.

SUMMARY

A field experiment entitled "Productivity and profitability of rice varieties grown and nurtured organically on a 5-year old zero chemical applied soil base" was conducted at Agricultural Research Station, Siksha 'O' Anusandhan, Bhubaneswar, Odisha in rainy (*Kharif*) season 2022. Application of manures was based on recommended dose of nitrogen (RDN) of respective varieties with 50% N (M_1) and 100% N (M_2) applied half each through FYM and vermicompost. Treatment M_3 was devoted to application of organic liquid formulations. Across the treatments, variety Poornbhog was significantly superior with respect to grain yield (3250.1 kg/ha) and associate characters, viz. EBT/m^2 (234), number of filled grains (114), panicle length (25.5 cm) and panicle weight (2.8 g) along with highest net return (₹1,33,703/ha) and B-C (2.2). Among the HYV Naveen was significantly superior over Kalinga Dhan 1201. Student's t test showed no significant difference in mean yield of

varieties of both the groups. Treatment M_3 produced significantly higher yield (3235.1 kg/ha) along with maximum NR (₹ 94,514/ha) over others. All the varieties under organics showed almost similar plant height, test weight and duration though, Poornabhog and Kalinga Dhan 1201 matured earlier by 10 days than their basic varietal characters. Interaction was significant and all the varieties produced their best under M_2 treatments. Application of organic liquid formulations showed favourable effect on yield over M_0. Partial factor productivity and recovery efficiency was higher at lower level of N application.

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