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Research Communication

Effect of organic nutrient management on yield, quality, nutrient uptake and economics of aromatic rice (*Oryza sativa*) in hill zone of West Bengal

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ABSTRACT

A field experiment was conducted during the rainy (*kharif)* season of 2021 at the Uttar Banga Krishi Viswavidyalaya, Kalimpong, West Bengal, to study the response of 2 aromatic rice cultivars ('Kalture' and 'Kalonunia') under 4 organic nutrient management (cowdung manure @ 5 t/ha, vermicompost @ 1.5 t/ha, mustard-cake @ 0.5 t/ha, and leaf mould @ 1 t/ha). 'Kalonunia' exhibited greater tiller production (435/m^2), leaf-area index (3.08) and dry-matter accumulation (452 g/m^2) at 63 days after planting (DAT), and 'Kalture' showed taller plants (137.1 cm) and lodging susceptibility (score 4.0) at maturity. 'Kalonunia' performed significantly better in terms of grain yield (3.32 t/ha), non-lodging habit, protein content (7.25%) and net income (₹57,043/ha) than 'Kalture' cultivar. Although the application of vermicompost @ 1.5 t/ha resulted in the maximum grain yield (3.22 t/ha) and nutrient uptake (44.6 kg N, 16.4 kg P and 39.0 kg K/ha), mustard-cake @ 0.5 t/ha could be an alternative option owing to near-maximum grain yield (3.11 t/ha) with high protein content (7.1%), medium aroma (score 1.7), maximum net income (₹51,040/ha) and benefit: cost ratio (2.01) in hill zone of West Bengal.

***Key words*:** Aromatic rice, Cultivar, Growth, Organic nutrient management, Quality, Yield

The Sikkim-Darjeeling Himalayas having extreme climatic and edaphic conditions represents one of the unique reservoirs of rice (*Oryza sativa* L.) genetic resources in the country. Among diverse rice landraces in the region, 'Kalture', having medium-slender aromatic grain, is cultivated by the farmers in the hills of Kalimpong and Darjeeling districts of West Bengal for a long time (Mondal *et al*., 2021). Another popular scented 'Kalonunia', also reported as *Kala nenia* or *Kala nina* or *Kala nooniah*, is traditionally cultivated in foothills (*tarai*) and plains of hill zone of North Bengal for hundreds of years (Ghosh *et al*., 2021). The word 'Kalonunia' had two parts: '*Kalo*' meaning black in Bengali represented black-husked grain, and '*nuni*a' indicated local rice group of the region. The earliest record of 'Kalonunia' rice could be found as *aman* paddy under *nenia* group in Darjeeling District (Hunter, 1876), and during that time it was known to the Europeans as a table rice by its export from the region. It was considered as the 'Prince of Rice' being highly regarded by the *Maharaj* of Cooch Behar because of its use for preparation of traditional dishes of winter celebrations like *payesh* (sweet rice), *bhog* (pulse intermixed rice), *polao*, *pitha* (home-made cake), *selroti* (ring-shaped sweet bread) etc. in the region.

In Himalayan hilly region of West Bengal, farmers grow rice landraces following traditional practices with either little or no nutrient-management practices. Therefore, a suitable approach of nutrient management is required to keep up the production of aromatic rice with desired quality and maintenance of soil health. Cowdung manure is commonly used in rice cultivation since ancient times in the state, while vermicompost is gaining importance in crop production in recent times and mustard-cake has been using by a small-group of farmers in short-grained aromatic rice cultivation in South Bengal (Ghosh, 2019). On the other hand, leaf mould, the locally-available decomposed material of forest leaves, is used as a nutrient input in garden and orchid cultivation in hilly areas of West Bengal. However, there is no report on use of leaf mould in high-value rice cultivation in the foothills of Himalayas in West Bengal till date. In the context, it is also understood that the

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use of organic manures either conventional, locally-available and/or non-conventional untested ones may help in sustenance of productivity and quality of traditional scented rice in gravelly-loam soil. Besides, the demand for organic aromatic rice is increasing in recent times, which initiates the sporadic production of organic 'Basmati' in north India, organic 'Joha' in Assam and organic 'Gobindabhog' in southern part of West Bengal during last 2 decades. Hence, the present study was undertaken to find out the appropriate organic nutrient source(s) for better growth, yield, quality and economics of traditional aromatic rice cultivars during rainy (*kharif*) season in hill zone of West Bengal.

A field experiment was conducted at the Regional Research Station Farm (27°05'94" N, 88°46'95" E and 1,140 m altitude) of the Uttar Banga Krishi Viswavidyalaya (UBKV), Kalimpong, West Bengal, India during rainy (*kharif)* season of 2021. The soil of the field was classified as Lithic, Order Alfisol, gravely-loam in texture on steep slide slopes, grayish-brown, acidic (*p*H 5.1), high in organic carbon (8.5 g/kg) and available nitrogen (211.5 kg/ha), low in phosphorus (19.2 kg/ha) and potassium (112.9 kg/ha). The experiment was laid out in a split-plot design with 3 replications, which consisted of 2 traditional aromatic rice cultivars ('Kalture', and 'Kalonunia') in main plots and 4 organic nutrient-management practices (cowdung manure @ 5 t/ha, vermicompost @ 1.5 t/ha, mustard cake @ 0.5 t/ha and leaf mould @ 1 t/ha) in subplots. The nutrient content in different sources based on dry-weight basis was as follow: cowdung manure (0.5, 0.2 and 0.5%), vermicompost (1.3, 1.2 and 0.9%) mustard-cake (4.8, 1.0 and 1.0%) and leaf mould (2.2, 0.5 and 1.3%). 25 days old seedlings @ 2-3/hill were transplanted manually at a spacing of 20 cm × 15 cm. Two hand-weedings were done at 20 and 40 days after transplanting (DAT) in all the plots. The crop was raised with south–west monsoon rainfall (1730.8 mm), but it received scanty rainfall (2.3 cm) during post-flowering and grain-development stage in November.

The growth attributes of scented rice like plant height, tillering habit, dry-matter (DM) production at different stages were noted, while yield components and grain yield were determined at maturity. The rating of lodging of plants in each plot was done at hard dough stage following the scale mentioned in Standard Evaluation System for Rice (IRRI, 1996). The grain quality parameters like protein content (total N × 5.95), gelatinization temperature by alkali digestibility test (Little *et al.,* 1958) and aroma (Nagaraju *et al*., 1991) were determined at the Aromatic Rice Laboratory of BCKV, and the economics of cultivation was calculated as per local rates. The variability in cost of seed was recorded as ₹800/ha for 'Kalture' (20 kg/ha and ₹40 kg/ha) and ₹1,000/ha for 'Kalonunia' (20 kg/ha and ₹50/kg). On the other hand, the variable costs for organic manures were ₹15,900/ha for cowdung manure, ₹18,900/ha for vermicompost, ₹10,900/ha for mustard-cake, and ₹14,900/ha for leaf mould.

Benefit: cost ratio was calculated. The nutrient content (N, P and K) in grain and straw were determined in Chemical Analysis Laboratory. The data obtained in the study were analyzed using on-line OPSTAT software (*www.hau.ernet.in/opstat.html*) following standard statistical procedures.

The plant height, tillering pattern and dry-matter (DM) accumulation of both rice cultivars were gradually increased at varied rate toward maturity. 'Kalture' had taller plants (137.1 cm) at harvesting and lodging (Table 1) susceptibility (score 4.0) at hard dough stage, while 'Kalonunia' did not show lodging. The rice crop treated with cowdung manure @ 5 t/ha or vermicompost @ 1.5 t/ha became susceptible to lodging and most of the plants (>50 %) lodged slightly (score 3.0) at hard dough stage. But less lodging was noted in the plots receiving mustard-cake @ 0.5 t/ha (score 2.4) or leaf mould @ 1.0 t/ha (score 1.7). It could be assumed that cowdung manure and vermicompost might have less effect on the stiffness of stem developed at tillering phase of tall-indica rice.

'Kalture' had early tillering habit, but 'Kalonunia' produced greater number of tillers in unit area (434.8/m^2) at 63 DAT. The tillering pattern indicated that, both the cultivars produced >12 tillers/hill at the foothills of Himalayas in West Bengal. The LAI was significantly influenced at 63 DAT only, where 'Kalonunia' had more leaf area (3.08) than 'Kalture' (2.72). The use of cowdung manure @ 5 t/ha resulted in the maximum dry-matter yield (453.1 g/m^2) at 63 DAT owing to its slow release of nutrients to make available to the crop for a longer period even at later stage.

With regard to yield components, 'Kalture' produced < 10 panicles/hill, < 80 filled spikelets/panicle, straw-coloured grain with purple spot at tip and test weight of > 16 g; while 'Kalonunia' had < 11 panicles/hill, > 90 filled grains/panicle, black-coloured grain with medium-long black awn and 1,000-seed weight of < 13 g. 'Kalonunia' gave greater grain yield (3.32 t/ha) owing to significant improvement in number of panicles/m^2 (356.2) and filled grains/panicle (90.1) than 'Kalture' (2.86 t/ha). However, lower grain yield of 'Kalonunia' rice was reported as 2.98 t/ha (Sarkar *et al*., 2020) when grown in New Alluvial Zone of West Bengal. Both the scented rice cultivars, being tall-indica type, had straw yield of > 6.0 t/ha and harvest index of < 35.0%. The application of vermicompost @ 1.5 t/ha resulted in higher grain yield (3.22 t/ha), being at par with mustard-cake @ 0.5 t/ha (3.11 t/ha), while the lowest yield (2.88 t/ha) was obtained with cowdung

Table 1. Effect of organic manures and cultivars on growth and yield of traditional aromatic rice in hill zone of West Bengal

Treatment	Plant height (cm)	Tillers/m^2 at 63 DAT	LAI at 63 DAT	Dry-matter accumulationat 63 DAT (g/m^2)	CGR (g/m^2/day) at 42–63 DAT	Panicles/ m^2	Filled grains/ panicle	1,000-grain weight (g)	Grain yield (t/ha)	Lodging (score)
Cultivar										
'Kalture'	137.1	402	2.72	421	12.5	325	77.4	16.09	2.86	4.0
'Kalonunia'	126.9	435	3.08	452	14.0	356	90.1	12.87	3.23	1.0
SEm±	0.82	4.0	0.05	1.2	0.23	2.3	0.8	0.05	0.01	0.07
CD (P=0.05)	5.04	24.4	0.32	7.1	1.44	14.4	4.7	0.29	0.06	0.43
Organic nutrient management										
Cow dung manure @ 5 t/ha	126.5	410	3.03	453	14.7	335	79.5	14.57	2.88	3.0
Vermicompost @ 1.5 t/ha	134.1	438	2.85	419	11.9	366	85.6	14.68	3.22	3.0
Mustard cake @ 0.5 t/ha	131.6	415	2.87	438	12.9	339	84.9	14.69	3.11	2.4
Leaf mould @ 1 t/ha	135.8	412	2.83	434	13.5	323	85.0	13.98	2.97	1.7
SEm±	1.71	5.6	0.06	2.4	0.32	7.6	1.17	0.32	0.07	0.23
CD (P=0.05)	5.26	17.3	NS	7.3	0.97	23.5	3.60	NS	0.21	0.69

DAT, Days after transplanting; CGR, crop-growth rate

Table 2. Effect of organic manures and cultivars on grain quality, nutrient uptake and economics of traditional aromatic rice of in hill zone of West Bengal

Treatment	Protein content (%)	Alkali spreading (score)	Aroma (score)	Nutrient uptake (kg/ha)			Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net income (₹/ha)	Benefit: cost ratio
				N	P	K				
Cultivar										
'Kalture'	6.72	5.7	1.6	43.1	15.6	38.1	52,301	89,378	37,077	1.71
'Kalonunia'	7.25	6.0	1.8	44.5	16.5	39.0	52,501	104,545	57,044	2.09
SEm±	0.04	0.18	0.15	0.05	0.05	0.06		264.3	264.5	0.01
CD (P=0.05)	0.23	NS	NS	0.34	0.28	0.34		1,630.6	1,632.0	0.04
Organic nutrient management										
Cowdung manure @ 5 t/ha	6.66	5.8	1.58	43.8	15.9	38.4	52,276	94,537	42,262	1.81
Vermicompost @ 1.5 t/ha	7.08	6.0	1.58	42.8	15.8	38.3	55,276	104,038	48,762	1.88
Mustard-cake @ 0.5 t/ha	7.14	6.3	1.72	44.6	16.4	39.0	50,776	101,816	51,040	2.01
Leaf mould @ 1 t/ha	7.06	5.3	1.88	44.0	16.0	38.7	51,276	97,454	46,178	1.90
SEm±	0.04	0.21	0.14	0.09	0.04	0.05		1,937.4	1,937.3	0.04
CD (P=0.05)	0.11	0.63	NS	0.26	0.12	0.16		5,968.4	5,968.4	0.11

Cost of cowdung manure (₹3/kg), vermicompost (₹12/kg), mustard-cake (₹27/kg); leaf mould (₹14/kg)
Price of grain: 'Kalture' (₹27/kg), 'Kalonunia' (₹30/kg); price of straw: 'Kalture' 'Kalonunia' (₹2/kg)

manure @ 5 t/ha. The maximum grain yield obtained owing to application of vermicompost @ 1.5 t/ha could be attributed to greater number of panicles/m^2 (366), number of filled grains/panicle (85.6) and 1,000- grain weight (14.68 g). Although the nutrient content in mustard-cake and leaf mould was higher than vermicompost, but the quantity applied for the latter one was much more to supply the similar dose of nutrients. Moreover, vermicompost, having bulky nature and rich source of macro- and micro-nutrients, vitamins, plant-growth regulators, beneficial microflora, might have better effect on improvement in growth and yield of traditional aromatic rice in hilly soil of West Bengal.

Although both aromatic rice cultivars had medium-slender (MS) white kernels, 'Kalonunia' had higher protein content (7.25%), alkali spreading value (score 6.0) and aroma (score 1.78) than 'Kalture' (6.72%, score 5.68 and score 1.6). The alkali score indicated that 'Kalture' had intermediate-low gelatinization temperature (GT), while 'Kalonunia' could be categorized into low GT (55–69°C) category. However, Ghosh *et al*. (2021) recorded medium GT or ASV (score 3.9) of 'Kalonunia' rice in New Alluvial Zone of West Bengal. Among organic nutrient management practices, the use of mustard-cake resulted in the maximum protein content (7.14%) and moderate aroma (score 1.7). The protein content in grains obtained from mustard-cake-applied plots could be supported by the higher N content in grain as observed in N uptake values (Table 2). On the contrary, Prakash *et al*. (2002) reported higher protein content in Pusa Basmati 1 owing to application of FYM compared to commercial manures (processed city waste, vermicompost, and oil cake pellets and chemical fertilizers).

With regard to N, P and K uptake, 'Kalonunia' recorded the higher values for grain, straw and total uptake after harvesting compared to 'Kalture', except K uptake in straw in our study. Mean cultivar total N, P and K uptake was 43.8, 16.1 and 38.6 kg/ha, which were less than that reported for 'Kalonunia' rice in Coochbehar district of West Bengal by Heisnam *et al.* (2020). Among the 4 organic nutrient management practices, the application of mustard-cake @ 0.5 t/ha resulted in the highest total N (44.6 kg/ha) uptake (16.4 kg/ha) and K uptake (39.0 kg/ha) in the plants at maturity, but the maximum N and K uptake in straw and P uptake in grains were noted with the plants grown in vermicompost-applied plots.

The common expenditure incurred irrespective of cultivar and organic nutrient management was calculated as ₹36,376/ha, but variable cost included the cost of seeds and manures as per treatment schedule. Thus, total cost of cultivation varied between mustard cake applied plot (₹50,176/ha) and vermicompost-based nutrient-management (₹55,276/ha). But Paul *et al*. (2021) reported less cultivation cost for 'Kalonunia' rice under farmers' practice (₹35,580/ha) and integrated nutrient management (₹36,235–38,225/ha) in Jalpaiguri district within the native region of West Bengal. 'Kalonunia' recoded higher net income (₹57,044/ha) and benefit: cost ratio (2.09) owing to its greater yield and higher selling price than 'Kalture' (₹37,077/ha and 1.71). With regard to net income, 4 organic sources could be arranged as: mustard-cake (₹51,040/ha)> vermicompost (₹48,762/ha)> leaf mould (₹46,178/ha) > cowdung manure (₹42,261/ha). The application of mustard-cake @ 0.5 t/ha could result in B : C ratio of >2.0, but the other 3 organic nutrient management recorded B : C ratio <2.0 (1.81–1.90). However, Banerjee (2011) reported that the combined application of FYM and mustard-cake to a traditional rice (cv. 'Gobindabhog') resulted in the highest net return (₹19,190/ha) and higher B : C ratio (1.87) in New Alluvial Zone of West Bengal. In another study, Kumari *et al*. (2013) observed that scented rice ('Birsamati') receiving *dhaincha* (*Sesbania* sp.) green-manuring @ 5 t/ha and farmyard manure @ 10 t/ha was found to be most appropriate organic nutrient-management system for higher productivity as well as profitability.

It can be concluded that, 'Kalonunia' performed better in terms of grain yield, non-lodging habit, protein content and net income than 'Kalture' in our study. Among four organic nutrient management practices, mustard-cake @ 0.5 t/ha might be a good option owing to near-maximum yield with higher protein content moderate aroma, maximum net income and B : C ratio in Hill Zone of West Bengal.

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