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Qualitative assessment of black rice under an organic ecosystem of Northeast India

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Abstract
An agronomic investigation was carried out at Instructional-cum-Research Farm of Assam Agricultural University, Jorhat, Assam, during *kharif* season of 2019-2020 and 2020-2021 to assess the quality parameters of black rice under organic ecosystem of north east India. The topography of experimental field was uniform and fairly levelled. The farm is located at 26° 47'N latitude and 94° 12'E longitudes at an elevation of about 86.6 m above mean sea level. The experiment was laid out in a Randomized Block Design (RBD) with three replications. The soil of experimental plot was brownish to yellowish brown color with fair drainage and sandy loam in texture with acidic in pH, low in available nitrogen, phosphorous but medium in available potassium. The experimental data recorded during both successive years revealed that there were no significant results observed in relation to length, breadth, L/B ratio, Brown rice recovery (%), Milled rice recovery (%) and Head rice recovery (%) of grain of black rice. However, the results also showed the significant Protein content (7.96 and 7.98%), with application of RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}) (T_6). Amylose content (6.48 and 6.68%), and micronutrient content *i.e.* Cu (0.54 and 0.59 mg/100 g), Mn (3.72 and 3.75 mg/100 g), Fe (3.42 and 3.57 mg/100 g), and Zn (5.36 and 5.42 mg/100 g). Were found highest with application of RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1}) (T_8) during 2019-2020 and 2020-2021, respectively.

Keywords: Black rice, bio inputs, micronutrients, quality studies, milling quality

1. Introduction

More over half of the world's population consumes rice (*Oryza sativa* L.) as a staple food. With a yield of 117.47 million tons, it is grown across 43.86 million hectares in India (DAC&FW, 2019-20). It has a big impact on the economy of the country. There are various varieties of rice, distinguished by the size, texture, aroma, maturity period, growth conditions, and color (polished, black, red, purple, and brown). The kinds of colored rice are said to have many health advantages. The violet or dark purple hue of black rice (*Oryza sativa* L. indica) is due to the very high levels of anthocyanin pigments in the aleurone layer compared to white and red rice (Hou *et al*., 2013) [43]. Black rice, often referred to as "Chakhao" in local dialect and meaning "delicious rice," is mostly grown by Meitei farmers in Manipur. In Manipur, black rice comes in four landrace varieties: Chakhao amubi, Chakhao angouba, Chakhao poireiton, and Chakhao pungdol amubi. Black rice has a low-fat level of 0.07%, a high protein content of 8.16%, and antioxidant activity that is nearly six times higher (Thomas *et al*., 2013) [44] when compared to other types of rice, is naturally cleaner, gluten-free, and has numerous medical benefits (Jha *et al*., 2017) [45]. Tryptophan, lysine, and other important amino acids are found in black rice, along with useful lipids, dietary fiber, vitamins B1, B2, and E, folic acid, and phenolic compounds (γ-oryzanols, tocopherols, and tocotrienols). When cooked, it takes on a little sticky texture and tastes mildly nutty. It has little calories and is high in macro and micronutrients including iron, zinc, calcium, phosphorus, and selenium. When compared to other rice varieties growing in northeast India, black rice has a higher protein and nutritional content. Before cooking, it is frequently used with white rice to improve flavor, quality, and palatability. Its higher fiber content makes it harder to digest, requires longer cooking times than white rice, and gives you a rubbery feeling when you chew it.

In order to get around this, black rice is parboiled, which shortens the cooking time and enhances the texture of the grains but may also cause color loss. Its many health benefits have led to its current popularity in food, cosmetic, nutraceutical, and pharmaceutical uses. Because of its high anthocyanin content, which serves as a significant bioactive component, it is not eaten as a staple food but rather as a functional food. Rice grains become black due to the accumulation of anthocyanins (Cyanidin-3-glucoside, Cyanidin-3-rutinoside, and Peonidin-3-glucoside) in the pericarp, tegmen, and aleurone layer. The water-soluble pigment known as anthocyanins gives black rice its anti-inflammatory and antioxidant qualities. It might be incorporated into the formulation of functional or nutraceutical foods. One variety of rice with color is called black rice. Black bran covers the endosperm of the rice kernel in black rice, a form of colored rice. Due to its many health benefits, the aromatic and colored black rice type known as Chakhao is becoming more and more popular in India and throughout the world. Both upland and lowland rice ecosystems use rainfed black rice cultivation. It is pigmented rice variety popular in Asia, whose demand and consumption is increasing day by day in India as well as in the world due to its numerous health benefits. Black rice is grown under rainfed condition in both upland and lowland rice ecosystem. Compared to brown rice, black and red rice are more pest- and insect-resistant. Compared to dark fruits including blueberries, blackberries, dark grapes, and dark cherries, black rice has higher concentrations of anthocyanins. As a result, it provides more antioxidants than blueberries (Kushwaha, 2016) [47]. According to a recent study, the pigmentation in black rice is caused by the Kala4 gene, which is required for the synthesis of anthocyanins (Pratiwi *et al.*, 2017) [49].

Since inorganic fertilizers and chemicals are used in relatively small amounts, the North Eastern Region of India is by default regarded as organic. The average NPK fertilizer use in the NER is reported to be 51.67 kg ha^{-1} against the country's average of 144.33 kg ha^{-1} (Anon, 2019) [9]. All NER states, with the exception of Sikkim and Tripura, have a larger percentage of their land used for food grain production than the 65 percent national average.

Assam basically a rice centric state mainly due to the fact that during *kharif* season this state receives heavy rainfall resulting in waterlogging in the low and medium land situations. Under waterlogged condition, rice is the best suitable crop which provides the advantage of less weed menace. Besides this, majority of the people of the state consume rice as staple food. Hence, under favourable agro-climatic condition, farmers of the state cultivate both traditional and high yielding varieties of non-aromatic, aromatic and glutinous rice during the *kharif season.* In Assam, rice occupies 4.16 million hectares of land under gross cropped area covering three rice growing seasons of the state *viz.*, *sali* or winter rice, *ahu* or autumn rice and *boro* and early *ahu* or summer rice. Rice alone contributes 96% of food grain production of the state of Assam. The state produces 51.25 million tonnes of rice annually, with an average productivity of 2087 kg ha^{-1} (Anon., 2019) [10].

More focus on recent agronomic intervention like System of Rice Intensification may open new avenue for boosting rice production under organic ecosystem with the traditional varieties. The growth, yield and quality advantages under SRI system may be explored to give organic rice production a new momentum. A shift from traditional to scientific cultivation of organic black rice may enhance the productivity of rice and thereby increase income of farmers. Potassium (K) is an essential macro-nutrient needed for proper growth and development of plants. Commonly known as the "quality nutrient", K improves resistance to several plant diseases. It is also essential for water regulation and maintaining cell wall strength. Growth may be inhibited and yield may be decreased if K is lacking or not delivered in sufficient amounts.

In organic farming, proper management of K is very crucial for better crop production, protection and quality of organic foods. It is necessary to supplement the required K through various organic sources so that plants do not have to suffer from deficiency symptoms throughout their growth period. The target of higher yield from traditional black rice may be achieved by adoption of SRI technique along with proper K management practices under organic ecosystem.

2. History

Throughout ancient times, people in Asian nations including China, Korea, and Japan have enjoyed black rice. Black rice is said to have higher antioxidant activity than white rice. During the imperial era, the people in China and Indonesia were not permitted to harvest, store, or consume black rice without official authorization. Black rice was only used as a tribute dish by royals and other prominent figures in Asia. Black rice was once thought to be extremely uncommon and excellent since it was thought to lengthen a king's life and promote good health.

Rich with micronutrients and antioxidants, black rice is also referred to as treasured rice, purple rice, paradise rice, royal rice, king's rice, and forbidden rice (Kushwaha, 2016) [47]. Nowadays, numerous nations grow and use black rice. Traditional farmers in Manipur, India, produce black rice on a small scale. China has the greatest reserves of black rice (62%), with Sri Lanka (8.6%), Indonesia (7.2%), India (5.1%), Bangladesh (4.1%), and a little amount in Malaysia following (Chaudhary, 2003) [34]. 52 of the 200 types that have been created thus far are high producing variants.

3. Material and Methods

3.1 Experimental site description

The experiment was conducted at certified organic block of the Instructional-Cum Research (ICR) Farm of the Assam Agricultural University, Jorhat during *kharif* season of 2019 and 2020 under rainfed medium land situation. The farm is located at 26° 47'N latitude and 94° 12'E longitudes at an elevation of about 86.6 m above mean sea level. The topography of experimental field was uniform and fairly levelled. The representative soil samples from 0 to 30 cm depth were taken from randomly selected plots all over the experimental field before laying out the experiment. The soil of the experimental site was sandy loam in texture with pH 5.3, low in available nitrogen (246.45 kg ha^{-1}), phosphorus (21.02 kg ha^{-1}) and available potassium (144.80 kg ha^{-1}) and medium in organic carbon (0.72%). (Table 4.) The total rainfall received was 110.6 mm. in 2019 and 1272.1 mm in 2020 during the cropping period. The cropping history of certified organic experimental plot for last three years is presented in Table 1.

3.2 Experimental details

Twelve different treatments were used in the experiment: Control (T_1), Potash solubilizing bacteria (KSB) @ 3.5 kg ha^{-1} as root dip treatment (T_2), RDK through azolla incorporation (T_3), RDK through water hyacinth incorporation (T_4), RDK through banana pseudo stem vermicompost (T_5), RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1} (T_6), RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1} (T_7), RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1} (T_8), RDK through azolla incorporation + Potash solubilizing bacteria (KSB) @ 3.5 kg ha^{-1} as rood dip treatment (T_9), RDK through water hyacinth incorporation + Potash solubilizing bacteria (KSB) @ 3.5 kg ha^{-1} (T_{10}), RDK through banana pseudo stem vermicompost + Potash solubilizing bacteria (KSB) @ 3.5 kg ha^{-1} (T_{11}), Indigenous traditional knowledge (T_{12}). The experiment was laid out in a Randomized Block Design (RBD) with three replications. The gross size of the area was 563.75 m^2 and net area was 432 m^2. The seeding was raised on nursery bed and after 14 days the seeding was transplanted in to main field by keeping 25 cm x 25 cm spacing between plant to plant and between row to row. The individual plant size was 4 m x 3 m. Sowing was done under system of rice intensification. The organic inputs were incorporated into each experimental plot before one month.

3.3 Climatic conditions of experimental field

The Jorhat experimental site is located in Assam's Upper Brahmaputra Valley Agro-Climatic Zone.

The region is known for its subtropical climate, which features hot, humid summers and comparatively dry, chilly winters. Situated in the south-west monsoon zone, it receives approximately 2014 mm of total mean precipitation per year. With pre-monsoon showers from mid-March to April, the monsoon rains typically begin in June and last through September. Occasionally, they extend to the first week of October. The intensity of rainfall decreases from mid of September reaching minimum or zero during December-January. The relative humidity of this zone is high (above 80 per cent) during the *kharif season* as the region is located in sub-tropical humid region. In summer, the temperature ranges from 34 to 37 °C, while in winter, the lowest temperature is from 8 to 10 °C. In the first year of experimentation, the mean maximum bright sunshine hours (hours/day) were as high as 8.2 hours /day in the 49 SMW (3 Dec -9 Dec, 2019). The lowest bright sunshine hours were recorded as 1.8 hours/day in the 30 SMW (23-29 July, 2019). The corresponding values for the second year (2020) of experimentation were 7.4 hours/day in the 34 SMW (20 Aug -26 Aug) and 0.9 hours/day in the 29 SMW (16 July - 22 July).

Table 1: Cropping history of experimental field

Year	*Kharif*	*Rabi*	Summer
2016-17	Rice	Rice	Fallow
2017-18	Rice	Rice	Fallow
2018-19	Rice	Rice	Fallow
2019-20	Present investigation	Fallow	
2020-21	Present investigation	Fallow	

Table 2: Quantification of N, P and K content in different organic sources (dry weight basis)

Organic sources (Inputs)	Moisture (%)	N (%)	P (%)	K (%)	Quantity (kg ha$^{-1)}$ (Dry weight basis)
i. Azolla	35	2.29	1.00	2.01	770
ii. Water hyacinth	35	0.75	0.32	2.27	685
iii. Banana pseudo stem compost	40	1.54	1.10	2.45	685
iv. Mustard Oil cake	8.75	3.15	1.35	1.00	22
v. Wood ash	6.18	1.40	1.24	2.64	410
vi. Fish wash water	-	0.23	0.12	0.026	10 Lit

Table 3: The classified description of the treatments with corresponding symbol is shown below:

Sl. No.	Treatment	Symbol
1.	Control (No organic nutrient input)	T_1
2.	KSB @ 3.5 kg ha^{-1} as root dip treatment	T_2
3.	RDK through azolla incorporation	T_3
4.	RDK through water hyacinth incorporation	T_4
5.	RDK through banana pseudo vermicompost	T_5
6.	RDK through azolla incorporation + Mustard oil cake @ 20 kg ha^1	T_6
7.	RDK through water hyacinth incorporation + Mustard oil cake @ 20 kg ha^{-1}	T_7
8.	RDK through banana pseudo vermicompost + Mustard oil cake @ 20 kg ha^{-1}	T_8
9.	RDK through azolla incorporation + KSB @ 3.5 kg ha^{-1}	T_9
10	RDK through water hyacinth incorporation + KSB @ 3.5 kg ha^{-1}	T_{10}
11	RDK through banana pseudo stem vermicompost + KSB @ 3.5 kg ha^{-1}	T_{11}
12	ITK (Wood ash + Fish washing water application)	T_{12}

Table 4: Initial soil status of experimental plot

Sl. No	Properties	Composition (Value)	Textural class / stats	Methods adopted
A	**Physical properties**			
i	Texture			
ii	Sand (%) Silt (%) Clay (%)	59.00 22.12 17.61	Sandy loam	International pipette Method (Piper,1966) [50]
iii	Bulk density (g cc^{-1})	1.26		Core Sampler Method (Piper,1966) [50]
iv	Water holding capacity (%)	36.31		Ken Rackzowaski Box Method (Piper. 1966) [50]
B	**B Chemical properties**			
i	pH (Soil reaction)	5.75	Acidic	Glass electrode pH Meter (Jackson,1973) [46]
ii	Electrical conductivity (EC dsm^{-1})	0.05	Normal	Solubridge Method (Black, 1965)
iii	CEC (meq per 100 of soil)	6.54	Medium	Distillation method (Jackson,1973) [46]
iv	Organic carbon (%)	0.71	Medium	Walkley and Black's Titration Method (Jackson, 1973) [56]
v	Available N (kg ha^{-1})	244.45	Low	Kjeldahl Method (Jackson, 1973) [46]
vi	Available P2O5 (kg ha^{-1})	19.81	Low	Bray's I Method (Jackson, 1973) [46]
vii	Available K2O (kg ha^{-1})	142.70	Medium	Flame photometric method (Jackson, 1973) [46]
C	**Microbial properties**			
i	Microbial biomass carbon (µg/g dry soil)	558.7		Chloroform fumigation extraction technique (Vance *et al.*, 1987) [54]
ii	Dehydrogenase activity (µg TPF/g/day)	50.64		Reduction of TTC to TPF (Casida *et al.*,1964) [31]

4. Quality parameter analysis of black rice grain
The samples were collected for quality analysis after harvesting of plant from each treatment. In order to estimate the micronutrient content of the plant sample, 0.5 mg of the sample was taken and placed in a digestion flask. The sample was then mixed with the digestion mixture and digested with 25 ml of H_2SO_4 until a bluish liquid formed.
Using an atomic absorption spectrophotometer, the iron, copper, manganese, and zinc contents of plant samples were ascertained following the appropriate dilution of di-acid extract.

4.1 Crude protein content
By multiplying the nitrogen percentage by a factor of 6.25, the protein percentage was determined (Piper, 1966) [50].

4.2 Amylose content
The amylase content was determined using the protocol proposed by Sadasivam and Manickam (1996) [53].

4.3 Calcium and magnesium content
The EDTA method as described by Jackson (1973) [46] was used for determination of Ca and Mg.

4.4 Fe, Zn, and Mn content
Iron (mg/100 g), Zn (mg/100 g) and Mn (mg/100 g) content in grain was determined by atomic Absorption Spectrophotometer using DTPA (diethylene triamine pentra acetic acid) method (Lindsay and Norvell, 1978) [48].

4.5 Brown rice recovery (%)

$$\text{Brown rice recovery (\%)} = \frac{\text{Weight of brown rice (Dehusked)}}{\text{Weight of sample}} \times 100$$

4.6 Milled rice recovery (%)
Brown rice was put into standard miller/polisher and weight of milled rice was recorded.

$$\text{Milled rice recovery (\%)} = \frac{\text{Weight of polished rice (Milled)}}{\text{Weight of sample}} \times 100$$

4.7 Head rice recovery (%)
The head rice recovery was recorded by taking a ¾ and entire kernel from the milled rice. Whole and broken rice were sorted, and the weight of each was noted.

Head rice recovery is calculated by the following formula

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of head rice}}{\text{Weight of sample}} \times 100$$

4.8 Length and breadth of grain (mm)
Ten grains were taken randomly from each plot. Their length and breadth were measured by using Digital caliper. The mean for both the length and breadth were calculated and recorded.

Digital caliper

4.9 L/B ratio
L/B ratio was calculated by dividing the length of grain with breadth of the same grain.

4.10 Statistical analysis
The information related to every character was examined using the analysis of variance (ANOVA) method, as recommended by Gomez, K.A. and A.A. Gomez. John Wiley and Sons, New York, Statistical techniques for agricultural research, 2nd ed., 1984, p. 704.

5. Incorporation of organic inputs
5.1Application of vermicompost by banana pseudo stem
Vermicomposting is the breaking down of organic material

through the use of worms, bacteria and fungi. Instead of using regular organic waste material, banana pseudo stem is used as a substrate along with cow dung. This is a nutrient rich organic substance that can be added to soil to increase its organic matter content and available nutrients. For making banana pseudo stem vermicompost, some locally available banana plants were collected and those plants were chopped with small pieces. After chopping those chopped pieces were dried under shade at A.A.U Vermicomposting unit. The semi dried chopped banana pieces were used for making banana pseudo stem vermicompost. So, after that vermicompost made from banana pseudo stem compost were incorporated into treatment allotted plot well before one month of transplanting.

5.2 Incorporation of water hyacinth

The free-floating, invasive aquatic plant known as water hyacinth is native to South America's Amazon Basin. Since 1800, it has mostly migrated to the tropics and subtropics. In the United States since 1984, Africa since early 1900, Asia since 1902, and Europe since 1930, water hyacinth has been regarded as an invasive aquatic plant. After being removed from AAU's water pond, the water hyacinth was dried in the shade. A month before to transplanting, the water hyacinth was gathered, chopped into little pieces, and then added to the field.

5.3 Incorporation of Azolla

The azolla species *A.Coroliniana* was collected from Azolla production unit of Assam Agricultural University, Jorhat. The collected azolla was sun dried and after drying that dried azolla was incorporated in field just before one month of transplanting.

5.4 Incorporation of Mustard oil cake (MOC)

The mustard oil cake was brought from an organic farmer from Majuli district of Assam with the help of KVK Jorhat. The organic MOC so collected was processed in the laboratory of Agronomy Department for grinding and subsequent nutrient analysis. The powder form of MOC was applied to the experimental field as per treatment before one month of transplanting.

5.5 Application of wood ash as ITK

The wood ash was collected from a local village Jamukudi, Jorhat. Utmost care was taken to make the wood ash free from foreign materials and inorganic compounds. The collected wood ash was sieved to separate out large objects. The powder form of wood ash was incorporated in the field as per treatment just one month ahead of transplanting.

5.6 Application of fish wash water as ITK

As one of the treatments of present research work, fish washing water was applied to rice at PI stage as foliar spray. Local fish was collected from Majuli district purely reared organically in farm pond without any contaminated water. After collection, fishes were dressed and washed clearly with 1:3 ratio of fish to water and that washed water was collected and stored for one week. The water so collected was sprayed in respective treatment at P.I stage of rice after analysis of nutrient content in the Agronomy laboratory. Traditionally, many farmers and farm women apply wood ash and fish washing water to their kitchen gardens with the believe that they may promote growth of crop with protection from insect pest infestation. Some researchers are also of the opinion that fish washing water and ash may contain high level of K which may have growth promoting effect as believed by traditional farmers. These two ITKs were combined in the treatment to validate their combined effects in organic rice cultivation.

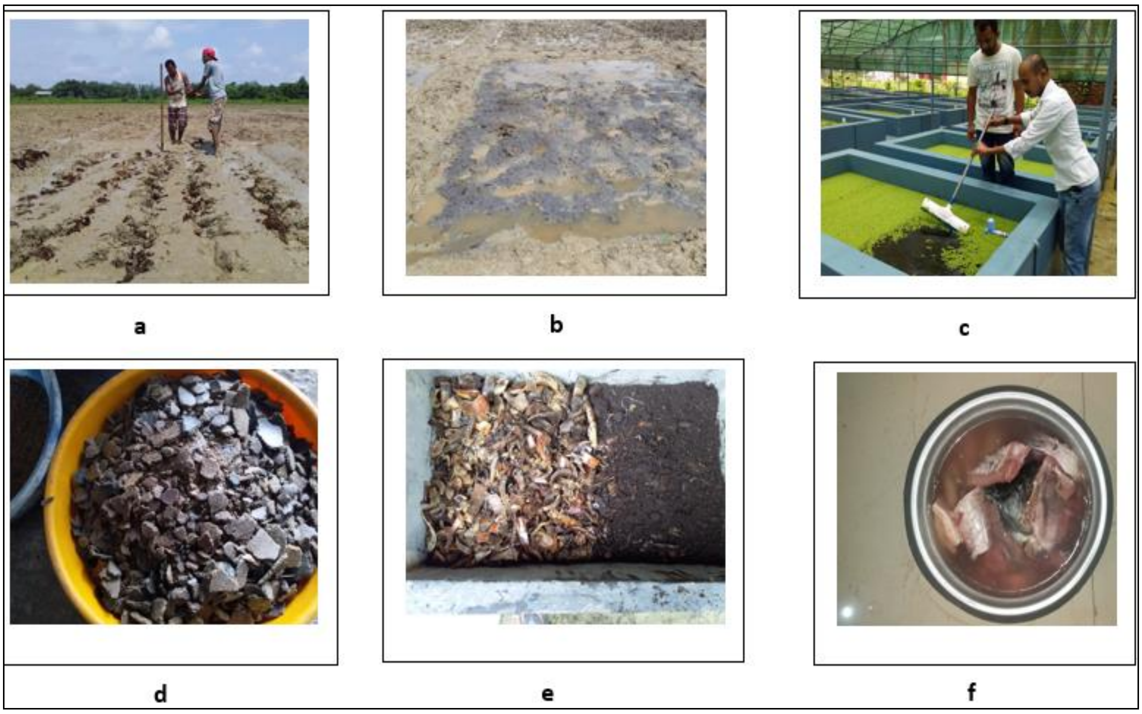

Fig 1: a) Before sowing (Azolla incorporation). b) Wood ash incorporation. c) Azolla production. d) Mustard oil cake. e) Banana pseudo stem vermicompost. f) Fish wash water

6. Results and Discussion

Length and breadth of grain, L/B ratio, protein content of grain, aroma, milling of rice and micronutrient content were considered as the quality parameters of the black rice.

6.1 Length of grain (mm)

The variation in length of grain of black rice kernel due to organic nutrient management practices was found not significant during both the years However, the longest grain length 10.67

mm during 2019 and 10.73 during 2020 were recorded under T_8 treatment with application of RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1}) and the shortest grain of 7.19 and 7.26 mm was recorded in the control during both the years of experimentation. The higher in treatment T_8 may be due to more supply of nutrients.

6.2 Breadth of grain (mm)

The variation in breadth of grain of black rice kernel due to organic nutrient management practices was found not significant during both the years. However, the longest grain breadth 2.79 mm during 2019 and 2.83 during 2020 were recorded under T_8 treatment with application of RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1}) compost and the shortest breadth of 2.42 and 2.45 mm was recorded in the control during both the years of study.

6.3 L/B ratio of grain

The data pertaining to L/B ratio of black rice grain under different organic treatments was recorded and furnished in Table 5. The result showed no significant variation in L/B ratio of grain. However, the highest L/B ratio of black rice grain 3.83 mm and 3.79 were recorded under T8 treatment with application of RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha1) and the lowest L/B ratio of 2.97 mm and 2.97 mm were recorded T_1 (Control). As a whole, the L/B ratio indicated the class of grain was to be of short-slender--grain type as per quality specification.

6.4 Intensity of aroma

The aroma of black rice grain under different organic treatments was measured by qualitative method (Olfaction) and the data are presented in Table 5. There was no significance difference in aroma of black rice grain found, all treatment shown strong (+++) aroma of black rice grain.

6.5 Protein content (%)

The data pertaining to protein content of black rice grain as influenced by different K management practices are presented in Table 5 and reported that, various organic inputs significantly influenced protein content during both the years of study. The highest protein content was recorded under T_6 treatment with application of RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}) that was 7.96, 7.98 and 7.97 per cent during 2019, 2020 and in the pooled data, respectively while, the lowest protein content percentage was recorded under T_1 (Control) that was 6.40, 6.48 and 6.44 per cent which was remained at par with T_9 (RDK through azolla incorporation + potash solubilising bacteria @ 3.5 kg ha^{-1}), T_3 (RDK through azolla incorporation) and T_8 (RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1}) during both the years of study and in pooled data. The highest protein content in T_6 treatment may be due to supply of more nitrogen through azolla.

6.6 Brown rice recovery (%)

The perusal of data in Table 6. Revealed the effect of various organic inputs on brown rice recovery was not found significant during 2019 and 2020. However, the highest value 71.2 and 71.38% were reported during both the years in respect to brown rice recovery due to the application of RDK through banana pseudo stem vermicompost along with mustard oil cake @ 20 kg ha^{-1} in T_8 treatment and the lowest pooled value (59.43%).

6.7 Milled rice recovery (%)

The data on milled rice recovery of black rice are presented in Table 6. The data revealed that the influence of various organic inputs on black rice milled rice recovery was not found significant during both the years of study. However, under T_8 treatment produced highest pooled value of milled rice recovery i.e. 68.56%, followed by T_6 treatment i.e. 66.36% and lowest value reported in T_1 treatment (Control).

6.8 Head rice recovery (%)

The head rice recovery is an important quality parameter of black rice which determines the quality as well as final economic price in market. The head rice recovery of black rice was not significantly influenced by different K management practices. However, treatment T_8 shown highest pooled head rice recovery per centage (42.66%) due to the application of RDK through banana pseudo stem vermicompost along with mustard oil cake @ 20 kg ha^{-1} and lowest was recorded in T_1 treatment (Control).

6.9 Amylose content (%)

The data pertaining to amylose content in black rice are presented in Table 7. Variation in the amylose content of black rice was not reported significant by organic inputs, however highest amylose content was reported under T_8 treatment during both the years of study respectively *i.e.* 6.48 and 6.68%.

6.10 Cu content (mg/100 g)

The data on copper content in black rice grain are influenced by various organic inputs and are presented in Table 7. The copper content in black rice grain differed significantly due to the organic nutrient management practices in both the years of study. The highest copper content in grain of black rice was reported in T8 treatment (0.54 mg/100 g in 2019 and 0.59 mg/100 g in 2020) which was found statistically at par with T6 (RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}), T7 (RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1}) and T11 (RDK through banana pseudo stem vermicompost + Potash solubilising bacteria @ 3.5 kg ha^{-1} as root dip treatment). These results are in confirmation with Bora, *et al*., (2014) [14] and Yadav, *et al*., (2013) [55].

6.11 Mn content (mg/100 g)

The data on manganese content in black rice grain are influenced by various organic inputs and are presented in Table 7. The manganese content in black rice grain differed significantly due to the organic nutrient management practices in both the years of study. The highest manganese content in grain of black rice was reported in T_8 treatment (3.72 mg/100 g in 2019 and 3.75 mg/100 g in 2020) which was found statistically at par with T_6 (RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}), T_7 (RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1}) and T_{11} (RDK through banana pseudo stem vermicompost + Potash solubilising bacteria @ 3.5 kg ha^{-1} as root dip treatment). The results resemble the findings of by Bora, *et al*., (2014) [14] and Yadav, *et al*., (2013) [55] Showed that addition of higher amount of organic inputs favored increase in manganese content in black rice.

6.12 Fe content (mg/100 g)

The data pertaining to Iron content in black rice grain are influenced by various organic inputs and are presented in Table 7. The Iron content in black rice grain differed significantly due to the organic nutrient management practices in the both the years of study. The highest Iron content in grain of black rice was reported in T8 treatment (3.42 mg/100 g in 2019 and 3.57

mg/100 g in 2020). This was found significantly superior over rest of the treatments. The lowest Iron content was reported under T1 treatment (Control). Similar results were earlier reported by Bora, *et al*., (2014) [14], and Yadav, *et al*., (2013) [55].

6.13 Zn content (mg/100 g)

In the present study, the zinc content in black rice grain was influenced by various organic inputs during 2019 and 2020 are presented in Table 7. The data indicate that zinc content in black rice grain varied from 5.36 to 4.01 and 5.46 to 4.08 during 2019 and 2020 respectively. The highest zinc content in black rice grain was recorded under the treatment T8 (RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1}) followed by treatment T6 (RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}),T7 (RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1}),T11 (RDK through banana pseudo stem vermicompost + potash solubilising bacteria @ 3.5 kg ha^{-1} root dip treatment), T9 (RDK through azolla incorporation + potash solubilising bacteria @ 3.5 kg ha^{-1}) and T10 (RDK through water hyacinth incorporation + potash solubilising bacteria @ 3.5 kg ha^{-1} root dip treatment). The highest values under treatment T8 with respect to Cu, Mn, Fe and Zn content in black rice grain may be attributed due to application of RDK through banana pseudo stem vermicompost along with mustard oil cake @ 20 kg ha^{-1} which are good sources of many elements. Similar kinds of finding were also reported by Bora, *et al*., (2014) [14], and Yadav, *et al*., (2013) [55].

Table 5: K management practices as influenced on grain quality of black rice

Treatment	Length (mm)		Breadth (mm)		L/B Ratio		Intensity of aroma*		Protein content (%)		
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	Pooled
T_1	7.19	7.26	2.42	2.45	2.97	2.97	+++	+++	6.40	6.48	6.44
T_2	8.26	8.36	2.51	2.54	3.30	3.29	+++	+++	6.71	6.71	6.71
T_3	8.70	8.77	2.56	2.59	3.40	3.40	+++	+++	7.65	7.71	7.68
T_4	8.53	8.60	2.54	2.58	3.36	3.34	+++	+++	6.92	6.98	6.95
T_5	8.90	9.01	2.57	2.62	3.46	3.44	+++	+++	7.31	7.35	7.33
T_6	10.50	10.57	2.75	2.79	3.81	3.79	+++	+++	7.96	7.98	7.97
T_7	10.23	10.32	2.71	2.77	3.77	3.73	+++	+++	7.04	7.13	7.08
T_8	10.67	10.73	2.79	2.83	3.83	3.79	+++	+++	7.56	7.60	7.58
T_9	9.60	9.65	2.67	2.71	3.59	3.57	+++	+++	7.71	7.81	7.76
T_{10}	9.33	9.39	2.64	2.68	3.53	3.51	+++	+++	6.98	7.04	7.01
T_{11}	9.85	9.89	2.70	2.75	3.65	3.60	+++	+++	7.38	7.42	7.40
T_{12}	9.03	9.09	2.60	2.64	3.47	3.45	+++	+++	7.10	7.17	7.14
S.Ed(±)	0.18	0.19	0.17	0.17	0.08	0.08	-	-	0.27	0.27	0.25
CD at 5%	NS	NS	NS	NS	NS	NS	-	-	0.55	0.58	0.56
CV (%)	6.38	5.62	10.96	10.95	6.72	6.87	-	-	6.55	6.44	5.98

+++ Strong aroma
NS: Non-significant

Table 6: Effect of different K management practices on milling quality of black rice

Treatment	Brown rice recovery (%)			Milled rice recovery (%)			Head rice recovery (%)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1	59.38	59.48	59.43	58.19	58.40	58.30	34.18	34.48	34.33
T_2	60.88	60.94	60.91	59.18	59.42	59.30	35.48	35.74	35.61
T_3	61.94	62.14	62.04	60.76	60.84	60.80	36.41	36.69	36.55
T_4	60.98	61.06	61.02	60.38	60.57	60.48	36.12	36.52	36.32
T_5	62.81	63.05	62.93	61.32	61.54	61.43	36.78	37.05	36.92
T_6	70.42	70.64	70.53	66.36	66.68	66.52	41.15	41.68	41.42
T_7	69.98	70.10	70.04	65.13	65.61	65.37	40.24	40.58	40.41
T_8	71.24	71.38	71.31	68.41	68.71	68.56	42.51	42.81	42.66
T_9	65.92	66.12	66.02	63.41	63.79	63.60	38.62	38.86	38.74
T_{10}	64.76	65.08	64.92	62.74	62.88	62.81	38.28	38.59	38.44
T_{11}	68.54	68.66	68.60	64.72	65.05	64.89	40.16	40.51	40.34
T_{12}	63.48	63.69	63.59	62.69	62.78	62.74	37.64	37.84	37.74
S.Ed(±)	4.11	4.12	4.12	3.97	3.98	3.97	2.41	2.43	2.42
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	10.96	10.96	10.96	10.94	10.94	10.94	10.93	10.93	10.93

NS: Non-significant

Table 7: Effect of different K management practices on quality attributes of organic black rice

Treatment	Amylose content (%)		Cu (mg/100 g)		Mn (mg/100 g)		Fe (mg/100 g)		Zn (mg/100 g)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T_1	4.67	4.79	0.31	0.34	3.00	3.07	2.05	2.09	4.01	4.08
T_2	4.72	4.86	0.33	0.36	3.11	3.13	2.08	2.10	4.09	4.13
T_3	5.14	5.29	0.36	0.40	3.21	3.24	2.14	2.21	4.58	4.62
T_4	5.02	5.27	0.34	0.38	3.16	3.20	2.12	2.18	4.12	4.17
T_5	5.32	5.48	0.38	0.43	3.24	3.28	2.24	2.33	4.64	4.68
T_6	6.18	6.37	0.52	0.57	3.68	3.71	2.78	2.86	5.31	5.39
T_7	6.10	6.28	0.50	0.54	3.59	3.63	2.65	2.74	5.24	5.31
T_8	6.48	6.68	0.54	0.59	3.72	3.75	3.42	3.57	5.36	5.46
T_9	5.58	5.74	0.46	0.49	3.54	3.58	2.51	2.63	4.88	4.92
T_{10}	5.48	5.64	0.43	0.47	3.51	3.54	2.48	2.58	4.82	4.86
T_{11}	5.64	5.81	0.48	0.52	3.55	3.59	2.56	2.68	5.18	5.23
T_{12}	5.38	5.54	0.41	0.44	3.48	3.52	2.39	2.46	4.78	4.81
S.Ed(±)	0.35	0.36	0.03	0.03	0.17	0.15	0.15	0.16	0.30	0.30
CD at 5%	0.87	0.90	0.08	0.09	0.49	0.45	0.45	0.46	0.88	0.89
CV (%)	10.96	10.95	10.95	10.94	8.48	7.80	10.83	10.82	10.93	10.93

NS: Non-significant

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