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Isek variety of black rice: its performance on organic and inorganic fertilizer application

Jovita V. Valmores*[1], Florentino P. Orpilla[1], Renato F. Limon[2]

[1]Research Unit, Don Mariano Marcos Memorial State University, North La Union Campus, Bacnotan, La Union, Philippines

[2]College of Agriculture, Don Mariano Marcos Memorial State University, North La Union Campus, Bacnotan, La Union, Philippines

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Abstract

Black rice is native rice grown by farmers under upland and rain-fed conditions. This open-pollinated rice is increasingly attractive due to its high value and having a high level of anthocyanin compared to white rice. Hence, the study was conducted at the DMMMSU Research and Production Farm from the 2016 to 2019 cropping season; to determine the growth and yield of black rice (var. Isek) fertilized with inorganic and organic fertilizers, to determine which of the inorganic and organic fertilizer combinations would maximize the yield potential of black rice grown during the wet season and to determine the cost and return analysis based on three cropping seasons with the following treatments: T1 - Recommended Rate (100%), T2 - 50% RR + 5t vermicompost + Bio-N, T3 - 25% RR+10t vermicompost + Bio-N and T4 - 15t vermicompost + Bio-N + Foliar fertilizer. Results of the study revealed that 25 – 50% RR fertilization when added with 5-10 tons/ha vermicompost + Bio-N was found comparable to 100% RR using inorganic fertilizer in terms of plant height at harvest, number of productive tillers, weight of 1000 grains and grain yield (t/ha). However, applications of organic and inorganic fertilizer combinations did not influence panicle length due to black rice inherent characteristic of being short variety. Hence, the use of 25-50% RR combined with 5-10 t/ha vermicompost as organic fertilizer maximized the yield potential of black rice.

* **Corresponding Author:** Jovita V. Valmores ✉ jvalmores@dmmmsu.edu.ph

Introduction

The demand for black rice has increased, especially to affluent and health-conscious consumers because of its health benefits, especially for its antioxidant properties. Black rice has a high level of anthocyanin, known to be a powerful antioxidant. Black rice (var. Isek) is open-pollinated rice that is popularly grown by farmers under upland rice culture and rain-fed conditions. Compared to improved rice varieties, black rice has a much lower yield due to its inherent characteristics as native rice. Only a few farmers are willing to cultivate black rice because of low yield. Nevertheless, black rice has been increasingly attractive as a high value-added and it can be grown under rain-fed conditions in both upland and lowland environments. However, low productivity becomes a problem to fulfill community demand so it needs a cultivation technique that can improve productivity.

Black rice as a native rice variety is of short and medium characteristics with an approximate height ranging from 95 to 98 cm with a panicle length of 20 – 23 cm. Benoya (2019) claimed that plant height and panicle length are more or less constant through her periodic cropping of native rice at Lipay Proper, San Gabriel, La Union, Philippines. Yapyapan (2019) also reported that this native black rice produces 10 -13 productive tillers per hill which is much lower than improved rice varieties under upland rice culture. This is further supported by other common farmers Bomogao (2019) from San Gabriel, La Union who stated that black rice has an average yield of 2 – 3 tons per hectare under upland or rainfed rice culture. He further stressed that the addition of fertilizer has little effect on the increase of yield in semi-irrigated conditions.

Fertilizer is the major input and one of the most important factors in rice production. Good fertilizer management can increase rice yield and reduce production costs. It is required to supply the nutrient requirements for plants and to attain high performance in the rice plant. The gradual introduction on the use of organic fertilizers with that of chemical use is encouraged to lessen the impact of chemical fertilizers on environmental quality. For sustainable crop production, integrated use of chemical and organic fertilizers has been demonstrated to mitigate the deficiency of many secondary and micronutrients in fields that continuously received only N, P, and K fertilizers for a few years, without any micronutrient or organic fertilizer (Bokhtiar and Sakurai, 2005; Chand *et al.*, 2006;). The combined use of organic fertilizers and chemical fertilizers, compared to the addition of organic fertilizers alone, had a higher positive effect on microbial biomass and hence soil health (Dutta *et al.*, 2003). Organic fertilizers usually come from vermicompost, plants, animals or minerals that contain a variety of nutrients to enhance the soil ecosystem. Organic fertilizer adds valuable micronutrients, growth hormones, and vitamins which help disease tolerance, and reduce plant stress from drought (Victore, 2014). However, they release their nutrients more slowly in the soil. On the other hand, foliar fertilization using liquid fertilizer is an efficient way to guarantee the availability of nutrients to rice for obtaining higher yield (Shaygany *et al.*, 2012) due the quick absorption of nutrients, the quick addressing of nutrient deficiencies and a reduction in the amount of fertilizer needed as compared to soil application and in the amount of fertilizer wasted.

Bio-N is a solid inoculant in powder form that contains two important strains of bacteria (*Azospirillum*) that were isolated from the two roots of talahib, *Saccharum spontaneum* L, which have been screened for their effectiveness against a variety of agricultural crops and capable of converting atmospheric nitrogen (N2) into a usable form by rice, corn and vegetable crops. Compared with unfertilized plants, maintains the natural soil properties and fertility. Hence, this study was conducted to maximize the yield potential of black rice through the application of combined inorganic and organic fertilizers to achieve optimum growth and yield.

Gangmei and George (2017) investigated the response of black rice to organic and inorganic sources of nutrients, particularly on growth, yield and grain

protein content. They found out that integrated use of organic and inorganic sources of nutrients is the best method to increase black rice productivity. Sarkar *et al.* (2003) added that both organic and inorganic fertilizers have an effect of rice productivity. They noticed that on the first yield in rice. However, application of organic materials such as wheat straw and farmyard manure gave higher grain yields of rice from seventh year onwards. Furthermore, Marwanto *et al.* (2018) also observed a considerable effect of combining the application of cow manure and inorganic nitrogen fertilizer on growth, yield and nitrogen uptake of black rice. Overall, the researchers discovered that the combined use of inorganic nitrogen fertilizer (urea) and cow manure as an equivalence promoted growth and yield of black rice by improving nitrogen uptake. Such combination of organic and inorganic fertilizers is also applicable on soil fertility and increased crop productivity under mustard-cowpea-rice cropping sequence (Babar & Dongale, 2013).

Material and methods

Research design

The study was laid out following the Randomized Complete Block Design (RCBD) with three (3) blocks. Treatments used in the experiment were randomly assigned in each block and they were as follows:

T_1 – Recommended Rate (100 %)

T_2 – 50% RR + 5t Vermicompost + Bio-N

T_3 – 25% RR + 10t Vermicompost + Bio-N

T_4 – 15t Vermicompost + Bio-N + Crop Giant Foliar Fertilizer (15-15-15- + ME)

Preparation of plots/paddies

The study was conducted at the Research Production Farm of DMMMSU-NLUC located in Barangay Casiaman, Bacnotan, La Union, Philippines which serves as a research area where new technologies of different crops are tested and verified. It was implemented from 2016 to 2019 cropping season with an area of 149.625 square meters and was subdivided into 12 small paddies (plots) measuring 3m long x 3m wide with a height of 10 cm. A 50 cm alley was made between the blocks that served as a trail for maintenance activities.

Raising of seedlings

One month before sowing the upland black rice variety Isek seeds, a seedbed with a dimension of 1m x 10m was prepared and was properly cleared to ensure that it was free from off-type rice varieties. Rice seeds were raised through “dapog” method.

Transplanting

Transplanting of 21-day-old seedlings was done in the month of July during the wet season. Prior to transplanting, seedlings were dipped in a Bio-N solution whereas one (1) pack (200g) Bio-N fertilizer diluted with four (4) liters of water for at least 30 minutes before transplanting for treatments 2, 3, and 4.

Fertilizer application

Vermicompost was incorporated into the soil following the corresponding amount per treatment before transplanting with the use of a rake. Complete fertilizer (14-14-14) at the rate of 289 grams and 29.3 grams of urea (46-0-0) per plot were applied in T_1, 144.5 grams of complete fertilizer (14-14-14) and 14.65 grams of urea (46-0-0) + 4.5 kgs of vermicompost per plot in T_2 and 72.25 grams of complete fertilizer and 7,325 grams of urea (46-0-0) + 9 kgs of vermicompost per plot in T_3. Crop Giant (15-15-15 + ME) foliar fertilizer was applied at the rate of 4 – 6 tablespoons/16 liters of water at 45 days after transplanting and repeated every 10-14 days intervals + 13.5 kgs of vermicompost per plot in T_4.

Weed control

For the control of grass weeds, spraying of post-emergence herbicide (2, 4-D) was applied at the rate of 5 tablespoons/16 liters of water at 21 days after transplanting. Other broadleaved weeds were controlled by manual weeding during the vegetative period at 45 days after transplanting.

Insect pest and disease control

Decis 2.5 EC was sprayed at the rate of 1.5 tablespoons per 16 liters of water to control various insect pests such as rice stem borers, leafhoppers, and rice bugs. Dithane M-45 at the rate of 3-5 tablespoons per 16 liters of water sprayed once to control the leaf spot.

Harvesting/ threshing

Harvesting was done manually with the use of a sickle when the grains of the whole panicle had 85% matured which was 110 days from seed sowing. Threshing was done by the use of pedaled rice thresher. Sun-drying of grains was done for three (3) consecutive days.

Data gathering

The following data were gathered:

1. Plant height was measured from the base of the plants to the tip of the panicle using a meter stick at 110 days after sowing.
2. Length of panicle (cm) – The length of the panicle was measured from the last node of the panicle to the tip of the panicle using a meter stick.
3. The tillers with filled grains were counted and recorded.
4. The filled grains in every panicle were counted and recorded.
5. Number of unfilled grains per panicle – the unfilled grains in the panicle were counted and recorded
6. Weight of 1000 grains (g) - measured using a calibrated digital weighing scale.
7. Yield in tons per hectare

Yield (tons)/hectare = {weight (kg)/ (area/plot)} × {plot/area (m2)} × {10,000m2/1ha} × (ton/1000kg)
ROI (%) = (Net Income/Cost of Production) × 100

Analysis of data

The gathered data were tabulated, summarized using means, and analyzed using the Analysis of Variance (ANOVA) for Randomized Complete Block Design (RCBD). Tukeys HSD was used in the comparison among treatment means.

Results and discussion

Plant height at harvest

The average plant height of black rice (var. Isek) as affected by organic and inorganic fertilization is presented in Table 1. Results showed that black rice fertilized with 100% recommended rate were the tallest measuring 97.73 cm followed by those of 25-50% RR with 5-10 t vermicompost and Bio-N fertilization. The shortest (94.40 cm) was obtained from those fertilized with zero inorganic fertilizer with 15t vermicompost per hectare, Bio-, N, and foliar using crop giant.

Analysis of variance revealed highly significant results. Comparison among treatment means further revealed that fertilization of 100% RR using inorganic fertilizer was found comparable to reduced RR of 25% - 50% + 5t-15t vermicompost + Bio-N. The use of 15t vermicompost + Bio-N + foliar (T_4) significantly reduced plant height at harvest. This finding implies that black rice is responsive to inorganic fertilizer from 25% to 50% RR could be used provided that such reduction is supplemented with organic fertilizer using 5t-15t vermicompost + Bio-N.

Moreover, this finding could be supported by Benoya (2019) who reported that black rice could attain plant height ranging from 95-98 cm. For sustainable crop production, the application of organic and inorganic fertilizers will be done to mitigate the deficiency of many secondary and micronutrients in fields with NPK fertilizers only for a few years (Bokhtiar and Sakurai, 2005; Chand *et al.,* 2006). The combined use of organic fertilizers and inorganic fertilizers compared to the addition of organic fertilizer alone had a higher positive effect on microbial biomass and hence soil health (Dutta *et al.,* 2003). Organic fertilizer from vermicompost adds valuable micronutrients, growth hormones, and vitamins (Victore, 2014).

Panicle length at harvest

The average panicle length of black rice as affected by inorganic and organic fertilization at harvest is presented in Table 1. Results showed that all fertilization combinations resulted no insignificant effects on panicle length. This finding conformed to the result of the study by Benoya (2019) that black rice could attain panicle length of 20 – 23 cms which is due to its inherent agronomic characteristic.

Number of productive tillers

Table 1 presents the average number of productive tillers per hill on black rice as affected by combined inorganic and organic fertilization. Analysis of variance revealed no significant differences among the treatments ranging from 10.07 to 12.90 tillers.

Table 1. Mean plant height (cm) at harvest, mean panicle length and mean number of productive tillers on black rice as affected by organic and inorganic fertilization

Treatment	Mean plant height (cm) at harvest **	Mean panicle length	Mean number of productive tillers
T_1 – Recommended Rate (100%)	97.73 a	22.58	12.90
T_2 – 50% RR + 5t vermicompost + Bio-N	97.23 a	22.82	12.00
T_3 – 25% RR + 10t vermicompost + Bio-N	96.70 a	21.92	11.10
T_4 – 15t vermicompost + Bio-N + Foliar	94.40 b	22.17	10.07

**All means followed by the same letter are not significantly different at 0.05 level (DMRT)

Table 2. Mean number of filled and unfilled grains per panicle on black rice

Treatment	Filled grain	Unfilled grain
T_1 – Recommended Rate (100%)	118.17	16.67
T_2 – 50% RR + 5t vermicompost + Bio-N	123.40	15.37
T_3 – 25% RR + 10t vermicompost + Bio-N	111.90	15.80
T_4 – 15t vermicompost + Bio-N + Foliar	104.53	14.30

Table 3. Weight of 1000 grains (g) and yield (t/ha) on black rice

Treatment	Wt. of 1000 grains (g) **	Yield (t/ha) **
T_1 – Recommended Rate (100%)	29.67 a	3.04 a
T_2 – 50% RR + 5t vermicompost + Bio-N	28.00 a	3.02 a
T_3 – 25% RR + 10t vermicompost + Bio-N	27.67 ab	2.87 a
T_4 – 15t vermicompost + Bio-N + Foliar	24.67 b	2.34 b

Table 4. ROI (%) Analysis of black rice production/ha based on three cropping season (2016 -2019)

Treatment	Gross income (₱)	Cost of production (₱)	Net income (₱)	ROI (%)
T_1 – Recommended Rate (100%)	76,000.00	25,114.25	50,885.75	202.62
T_2 – 50% RR + 5t vermicompost + Bio-N	75,500.00	33,343.78	42,156.22	126.43
T_3 – 25% RR + 10t vermicompost + Bio-N	71,750.00	45,922.42	25,827.58	56.24
T_4 – 15t vermicompost + Bio-N + Foliar	57,250.00	34,393.67	22,856.33	66.45

Estimated cost of production, income and ROI of black rice production/ha based on three cropping season (2017-2019)

Number of filled and unfilled grains per panicle

Table 2 presents the number of filled and unfilled grains per panicle as affected by inorganic and organic fertilization on black rice. Results showed that all treatment combinations of organic and inorganic fertilization have comparable effects on the number of filled and unfilled grains per panicle. The number of filled grains per panicle ranged from 104.53 to 123.40 grains while the unfilled ranged from 14.30 to 16.67 grains. This finding could be due to the inherent characteristics of this native black rice even though there is application of combined inorganic and organic fertilizer.

Yield and yield components

Table 3 presents the weight of 1000 grains and production yield as affected by inorganic and organic fertilization on black rice. Results showed that the application of 100% RR using inorganic fertilizer resulted in the heaviest weight of grains and the highest grain yield of 3.04 t ha^{-1}. However, reduction at 25% to 50% RR but with combined 5 –10t vermicompost + Bio-N as sources of organic fertilizer resulted to a comparable weight of 1000 grains and yield. This suggests that black rice is very responsive to inorganic and organic fertilizers using 5 – 10t vermicompost. The absence of inorganic fertilizer greatly resulted in a significant reduction of yield and yield components on black rice. Furthermore, the maximum application of vermicompost at 15 t/ha is not enough to sustain crop productivity although there is a combined application of Bio-N and foliar fertilizer. This means that vermicompost at 15 t/h could not meet the NPK requirement supplied by inorganic/chemical fertilizer although there is further supplementation of BIO-N and foliar fertilizer.

This finding conformed to the previous study of Bomogao (2019) that black rice has an average of 2-3 t/ha when grown under upland or rainfed rice culture.

Cost and return analysis

Table 4 shows the cost and return analysis of black rice production per hectare. Results revealed that pure inorganic fertilizer (100% RR) has the highest income (P50,885.75) with an ROI of 202.62%, which was due to its low cost of production (P25,114.25). The other treatment combinations resulted in lower income ranging from P22,856.33 to P42,156.22 with corresponding ROI from 56.45% to 126.43% respectively, which was due to high production costs ranging from P33,433.78 to P45,922.43, respectively. The estimated cost of production includes vermicompost, inorganic fertilizer, Bio-N, and foliar fertilizer Crop Giant (15-15-15 + ME).

Conclusion

1. The black rice applied with the recommended rate was the tallest but comparable to those applied with a combination of inorganic, organic, and biofertilizers.
2. The application of inorganic, organic, and biofertilizers to black rice has:
   a. Comparable effect to the length of panicles, number of productive tillers, number of filled grains, and unfilled grains.
   b. The black rice applied with the recommended rate of inorganic fertilizer has the heaviest weight of 1000 grains and yield per hectare, but comparable to those applied with a combination of inorganic, organic, and biofertilizers.
3. The black rice applied with a 100% recommended rate of inorganic fertilizer has the highest income and ROI.

Recommendation(S)

The application of 100% of the recommended rate of inorganic fertilizer and the combination of inorganic, organic and biofertilizers is recommended to attain higher yield and income.

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