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Field Performance and Profitability of Bingawan Black Rice (*Oryza sativa L.*) Grown Under Various Production Systems

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ABSTRACT

The growing trend towards healthy lifestyle among consumers led to the production of nutritious and organic staples. Black rice (*Oryza sativa* L. Bingawan cultivar) is known to be both. While most studies on rice are conducted through conventional approach, this experiment aimed to assess the response of black rice to various organic production systems on productivity and marginal analysis. A Randomized Complete Block Design (RCBD) was used with 4 replications and 3 treatments; T_1 = UPLB's best bet organic production system, T_2 = optimized organic production system in Leyte, and T_3 = conventional production system in Leyte. Leyte's optimized organic production system (T_2) promoted the heading and maturity of black rice comparable to the conventional production system in Leyte (T_3). The UPLB's best bet organic production system (T_1) produced heavier fresh straw yield and total biomass, more productive tillers, filled and unfilled grains per panicle, heavier grains per hill, and high grain yield. However, it generated a lower net margin than the conventional production system in Leyte (T_3). When sold unmilled, black rice has comparable net margins irrespective of the production systems. The markedly higher yield in T_1 failed to compensate for the higher production cost, resulting in a lower net margin. It is worth noting, however, that organic rice commands a relatively higher prevailing price, unmilled and milled, than those produced in the conventional system.

Keywords: Black rice, field performance, organic production systems, and profitability

INTRODUCTION

Rice (*Oryza sativa L.*) is one of the most important food crops globally that feed more people than any other crop. In Asia, rice or "palay "accounts for 46 % of calorie intake and 35 % of protein consumption (FAO 2008).

Polished rice is the main staple food of Filipinos in the Philippines. However, a healthy lifestyle trend and growing health awareness of consumers led to producing nutritious and organic crops. For instance, consuming black rice

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reduces the risk of chronic diseases such as cardiovascular disease, type II diabetes, obesity, and cancer due to the bioactive pigments in the bran layer of its grains (Okarter & Liu, 2010). This rice type is becoming a popular substitute for white rice due to higher amounts of proteins, vitamins, and minerals, including health-promoting and chronic-disease-preventing properties (Chiang et al 2006; Suzuki et al 2004; Wang et al 2007).

The production of black rice in the Philippines ranks fifth globally, making it a potential crop for export. However, the country's black rice production is constrained by low yield and high production costs, which need to be addressed. Conventional or inorganic production system boosts crop growth and yield performance, yet farmers cannot always afford the necessary inputs. If not judiciously done, the continuous application of chemical inputs may cause ill effects on the environment, soil, and human health.

Organic farming is one of the options for sustaining soil fertility, productivity, and food security. Roder et al (2006) reported that the most promising practice to optimize yields includes using locally available manures, crop residues, weed biomass, green leaf manuring, legume integration, etc. Although grain yield obtained from organic farming is usually lower than that from conventional farming, it is resilient to extreme weather conditions like drought (Röös et al 2018). Recent findings also indicated that organic farming systems are more profitable than conventional systems (Quion 2018), especially if organic rice is sold at premium prices (Gaurana & Ratilla 2020).

Though organic farming requires more labor and costs, it helps restore nutrients in the soil, mitigating the greenhouse effect and global warming through sequestering carbon in the soil. In addition, consuming organic foods is more nutritious and healthier than conventional food due to the lower contamination of harmful components.

The current organic production system has proven more profitable than the conventional system. However, under these production system, trial on black rice is still limited. Hence, this study evaluated the practicality of growing black rice in an organic production system in the field and its profitability performance.

Objectives of the Study

This study aimed to evaluate the growth and yield performance of Bingawan black rice under various production systems; and determine the gross margin of growing Bingawan black rice under various production systems in VSU conditions.

Time and Place of the Study

The study was conducted in the experimental area of the Department of Agronomy, Visayas State University, Visca, Baybay City, Leyte, from December 22, 2018 to April 12, 2019.

MATERIALS AND METHODS

Land Preparation

The experimental area was already set up for six croppings for a collaborative project between VSU and UPLB. After the project's termination, the area was fallowed for six months and used for this study. The same plots were subjected to organic production systems (UPLB's best bet and Leyte farmers' practice) and conventional systems. The field was flooded with water for five days at a depth of 5 cm before plowing and harrowing. It was plowed and harrowed twice using a hand tractor at weekly intervals, retaining the previous croppings' established plots. Dikes around the experimental plot were fixed and cleaned. Canals were cleaned and maintained to facilitate water management. The final puddling was done a week before transplanting, leaving 2.5 cm of standing water.

Green Leaf Manuring in T1

For the UPLB's best bet organic production system (T_1), kakawate (*Gliricidia sepium*) leaves were applied at a rate of two kg m^{-2} or at 20 tons ha^{-1}as green leaf manure and were incorporated into the soil two weeks before transplanting to allow decomposition.

Field Layout and Experimental Design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three treatments replicated four times for a total of 12 treatment plots with a dimension of 6 m x 5 m or 30 m^2 $plot^{-1}$. Alleyways between replications (2 m) and treatment plots (1 m) of the previous cropping were maintained to facilitate farm operation and data gathering. The treatments used in this study were as follows:

T_1 – UPLB's best bet organic production system (5 t ha^{-1} Vermicast + kakawate leaves 2 kg m^{-2} + FPJ (kakawate leaves) + Vermitea + FFJ (banana) + Panyawan extract)

T_2 – Optimized organic production system in Leyte (2.5 t ha^{-1} vermicast + FPJ (kakawate leaves) + Vermitea + FFJ (banana) + Panyawan extract)

T_3 – Conventional production system in Leyte (urea + complete fertilizers + Lannate a.i. methomyl)

Seedbed and Seedling Preparation

Three seedbeds were established, each measuring 4.8 m x 1.0 m. Two beds were intended for organic production and one plot for the conventional treatment. Black rice seeds (Bingawan) weighing 0.48 kg were sown on each bed based on the seeding rate of 40 kg ha^{-1}. Seeds were soaked in tap water for 24 hours and incubated for 36 hours. The seedbeds for T_1 and T_2 were applied with 4.8 kg vermicast, while T_3 was applied with 9.6 tbsp. of 14-14-14. Seedlings were grown and maintained for 21 days before transplanting.

Soil Sampling and Analysis

For the initial soil analysis, three soil samples from each treatment plot were randomly collected before land preparation from the ground surface up to 20 cm deep using a soil auger. The collected soil samples were composited, air dried, pulverized, and sieved using 2-mm wire mesh. These were submitted to the Central Analytical Service Laboratory (CASL), PhilRootCrops, Visayas State University, Visca, Baybay City, Leyte for the determination of soil pH, organic matter (Modified Walkley-Black Method), total N (Modified Kjeldahl Method, PCARR 1980), available phosphorous (Bray P2, PCARR 1980) and exchangeable potassium (Ammonium acetate extraction method, ISRIC 1995) contents. For the final analysis, soil samples were collected from each treatment plot right after harvest, processed, and analyzed for the aforementioned soil parameters.

Transplanting

Seedlings were transplanted 21 days after sowing at a distance of 20 cm x 20 cm. Replanting of missing hills was done five days after transplanting to maintain the desired population of 750 hills per plot (250,000 hills ha^{-1}).

Fermented Plant Juice (FPJ) and Fermented Fruit Juice (FFJ) Preparation

Fermented plant juice was prepared from kakawate leaves. The leaves were chopped, added with molasses at a 2:1 ratio, and mixed thoroughly in a clean container. The mixture was covered with manila paper and kept for 7 days in a cool shaded place to facilitate the fermentation process. The resulting plant juice was extracted, strained, and placed in a clean container.

On the other hand, fermented fruit juice was prepared using ripe bananas. The ripe bananas were mashed, added with molasses at a 1:1 ratio (by weight), and placed in a clean container covered with manila paper. The container was also placed for 7 days in a cool, dry, shaded place to allow fermentation. The resulting juice was strained to separate the liquid from the residue.

Vermitea Preparation

Vermitea was prepared using 2 kg of vermicast mixed with 30 L of water and 1 kg of molasses. The mixture was brewed in a brewer for 72 hr. After brewing, the resulting liquid was collected and stored in a clean container.

Fertilizer and its Application

Conventional treatment (T_3) was applied with inorganic fertilizer at a rate of 105 – 45.5 – 45.5 kg ha^{-1} N, P_2O_5, and K_2O. The recommendation was satisfied by applying 975 g $plot^{-1}$ complete fertilizer plus 88.05 g $plot^{-1}$ of urea at 15 days after transplanting. Urea was again top-dressed at a rate of 300 g $plot^{-1}$ 55 days after transplanting. On the other hand, vermicast was applied for treatments 1 and 2 before transplanting at 5,000 and 2,500 kg ha^{-1}, respectively.

Treatments 1 and 2 were also applied with fermented plant juice (FPJ), fermented fruit juice (FFJ), and vermitea at specified concentration and timing as indicated in the treatment (Appendix Tables 1 & 2). Treatment 1 was sprayed with vermitea one week after transplanting and alternately with a 10 % solution of fermented plant juice (kakawate) per L of water (100 mL of FPJ to 900 mL water) at weekly intervals until the flowering stage. Vermitea spray was prepared by diluting 1 L vermitea with 15 L of water. Treatment 2 was applied with a mixture of FPJ (kakawate) and vermitea at weekly intervals starting two weeks after transplanting until the flowering stage at a rate of 100 mL of each foliar supplement per L of water (Appendix Table 2). At panicle initiation (55 DAT), fermented fruit juice was sprayed in Treatments 1 and 2 at 100 mL per L of water at 7 days intervals until two weeks before harvest. Spraying of foliar supplements was done at 4 o'clock in the afternoon.

Analysis of Organic Fertilizer and Nutrient Solutions

One hundred (100) grams of vermicast samples were submitted to the Central Analytical Service Laboratory (CASL), PhilRootCrops, Visayas State University, Visca, Baybay City, Leyte, for the analysis of pH, OM, total N, P, and K contents. For fermented juices (plant and fruit) and vermitea, 100 mL of each juice was also submitted for analysis of pH, total N, P, and K contents.

Table 1 shows the analysis results of vermicast, vermitea, fermented fruit, and plant juices. Among the organic supplements, vermicast had the highest total nitrogen (1.72) and available P (0.56) than the nutrient solutions. Vermitea had the highest pH (7.90), but the lowest in total N, available P, and exchangeable K among sources of organic supplements. Fermented juices were more acidic but contained slightly higher total N, available P, and exchangeable K than vermitea. It was noted that fermented fruit juice had the highest exchangeable K among the organic supplements.

Table 1. pH, organic matter, total N, available P, and exchangeable K contents of nutrient sources

Fertilizers	pH (1:2.5)	OM (%)	Total N (%)	Available P (%)	Exchangeable K (%)
Vermicast	6.66	21.97	1.72	0.56	0.36
Vermitea	7.90		0.05	0.04	0.14
Fermented fruit juice (FFJ)	5.00		0.31	0.13	12.72
Fermented plant juice	3.85		0.32	0.25	0.84

Weed Management

Rotary weeding was done 14 days after transplanting. Hand weeding followed five days later to remove weeds around each hill. Weeds in the dikes were also controlled by under brushing using a sharp sickle.

Water Management

Five days after transplanting, the experimental area was irrigated to a depth of 2.5 cm to hasten the recovery of newly transplanted seedlings. Intermittent irrigation was employed until the panicle initiation stage. Water depth was increased to 5 cm at the panicle initiation stage and was drained two weeks before harvest to facilitate harvesting.

Control of Insect Pests and Diseases

In organic production systems (T_1 and T_2), *Tinospora rumphii Boerl* or panyawan extract was applied to control insect pests and disease incidence. The organic pesticide was applied using a knapsack sprayer by diluting 1 L of panyawan extract in 15 L of water at the heading stage of black rice. For the conventional treatment (T_3), methomyl (Lannate) was sprayed at the heading stage (25 gm per 16 L water) to control rice bugs. A plastic enclosure was built around the conventional treatment to prevent contamination of chemical pesticides with the other treatments during spraying.

Furthermore, rat baiting was done during the reproductive stage until the soft dough stage. Racumin bait was placed on covered banana bracts and was strategically distributed in dikes around the experimental plot.

Harvesting

Plants were harvested when 85 % of the grains in each panicle had ripened as indicated by its golden yellow color and firm grains. The panicles were cut at the plant base using a sharp sickle. All the panicles within the harvestable area (12 m^2, excluding five border rows in each side of the plot, were threshed and cleaned. Sun drying of grains was done for two days to attain a 14 % MC prior to storage and milling.

Data Gathered

A. Agronomic Characteristics of Black Rice

These included days from sowing to heading, days from sowing to maturity, plant height, and fresh straw yield. The fresh straw yield was converted to per hectare using the formula:

$$\text{Fresh straw yield (t ha}^{-1}\text{)} = \frac{\text{Plot straw yield (kg)}}{\text{Harvestable area (12 m}^2\text{)}} \times \frac{10{,}000 \text{ m}^2 \text{ ha}^{-1}}{1{,}000 \text{ kg t}^{-1}}$$

$$\frac{\text{Plot grain yield (kg)}}{\text{Harvestable area (12 m}^2\text{)}} \times \frac{10{,}000 \text{ m}^2 \text{ ha}^{-1}}{1{,}000 \text{ kg t}^{-1}}$$

B. Yield and Yield Components of Black Rice

The yield components comprised the number of productive tillers hill^{-1}, the number of filled and unfilled grains panicle^{-1}, percentage filled spikelets panicle^{-1}, the weight of grains per hill (g), and weight of 1,000 grains (g), and panicle length. Grain yield in t ha^{-1} was determined by weighing the dried, cleaned grains from panicles within each treatment plot's harvestable area (12 m^2). The weight per plot was converted into tons per hectare using this formula:

Grain yield (t ha^{-1}) =

Total biomass (t ha^{-1}) was determined by adding the total grain yield and total straw yield as shown below:

Total biomass (t ha^{-1}) = grain yield (t ha^{-1}) + straw yield (t ha^{-1})

C. Harvest index (HI)

Dry weight of grains (g) (3 sample hills)

This is the ratio of the dry weight of filled grains (economic yield) to the dry weight of the straw plus the dry weight of filled grains (biological yield). The harvest index indicates the plant's efficiency in converting the absorbed nutrients and the products of photosynthesis into grains. A higher harvest index indicates that the crop produced a higher grain yield than straw yield. Low harvest index means the straw yield is higher in proportion to the grains formed. Three sample plants per plot were collected and oven-dried at 70 ^{0}C for 72 hours before weighing. HI was computed using the formula:

$$\text{HI} = \frac{\text{Economic Yield}}{\text{Biological Yield}}$$

D. Gross Margin Analysis

The gross margins among various production systems were determined by subtracting the total variable costs from the gross income. The total variable cost was determined by recording all the expenses incurred from land preparation up to harvesting and milling. These include seeds, fertilizers, chemicals, materials, and labor. The gross income was calculated using the formula:

Gross income = Yield (kg ha^{-1}) x current price kg^{-1}

Variable cost = Price of a particular input x quantity of input used

Total variable cost = is the sum of all variable costs or cost per unit x total number of units

E. Meteorological Data

Data on weekly rainfall (mm), weekly minimum and maximum temperatures (^{0} C), and relative humidity (%) throughout the conduct of the study were taken from the records of the Philippine Atmospheric Geophysical and Astronomical Services (PAGASA) Station, Visayas State University, Visca, Baybay City, Leyte.

F. Statistical Analysis

Data were consolidated, tabulated, and analysis of variance (ANOVA) was done using STAR version 2.0.1. Significant differences among treatment means were determined using Tukey's HSD test at a 5 % significance level.

RESULTS AND DISCUSSION

General Observation

The average weekly rainfall (mm), average weekly minimum and maximum temperature (^{0}C), and average weekly relative humidity (%) throughout the experiment were taken from the records of the Philippine Atmospheric,

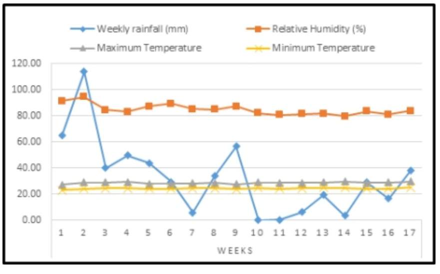

Figure 1. Weekly rainfall (mm), weekly minimum and maximum temperature (^{0}C) and weekly relative humidity (%) throughout the duration of the experiment

The average minimum and maximum temperatures recorded from planting to harvesting were 24.28 ^{0}C to 28.61 ^{0}C, wherein the highest minimum and maximum weekly temperature ranged from 23.24 ^{0}C (week 1) to 29.64 ^{0}C (week 17). Luh (1998) reported that the temperature requirement for normal vegetative growth and reproductive development of lowland rice from planting to harvesting ranges from 20 ^{0}C to 38 ^{0}C. This indicated that the temperature level during the conduct of the study was favorable for rice growth and development. Weekly relative humidity ranged from 79.50 % to 94.29 %.

Golden snail (*Pomacea canaliculata* L.) infestation was observed in the experimental area after transplanting. However, the damage was minimized by handpicking the adults, crashing the eggs, and draining the water within treatment plots. Missing hills were replanted five days after transplanting using the remaining seedlings in the seedbed. Irrigation to a depth of 2.5 cm was done to control and minimize the emergence of weeds and enhance tillers' growth. The water was gradually increased to 5 cm depth at the reproductive stage.

Echinochloa colona L. and *Ludwigia* sp. were the prevalent weed species observed. These were controlled by rotary weeding ten days after transplanting, followed by hand weeding seven days later. A slight infestation of stem borer (*Scirpophaga innota*) was noted at the heading stage, as indicated by the presence of white heads. Spraying of *Tinospora rumphii B.* "panyawan" extracts was done in organic plots (T_1 and T_2) at 1 L per 15 L knapsack sprayer to minimize insect pests' damage. Furthermore, control of rice bugs (*Leptocarisa acuta*) and other pests present in T_3 (conventional production system in Leyte) was done by spraying Lannate (powder) at a rate of 25 gm per 16 L of water. Slight damage of field rats (*Rattus argentiventer*) was observed in conventional plots (T_3); however, this was controlled by baiting with racumin.

More natural enemies like damselflies, lady beetles, spiders, grasshoppers, and water bugs were observed on organic plots. Frogs and bird's nests were also noted on these plots indicating that biodiversity existed.

Soil Analysis

The results of soil analysis before planting and after harvest are presented in Table 2. These revealed that the initial soil pH, organic matter, total nitrogen, available P, and exchangeable K ranged from 5.40-5.45, 3.27-3.94 %, 0.17-0.21 %, 1.07-1.54 mg kg^{-1} and 0.19-0.29 meq 100 g^{-1}, respectively. These indicated that the soil as strongly acidic, with low organic matter, total N, available P, and exchangeable K contents based on Landon's (1991) indices.

After harvest, soil analysis results showed a decrease in pH along with total N relative to its initial analysis. However, organic matter, available P, and exchangeable K slightly increased in all production systems. Likewise, a higher increase in OM, available P, and exchangeable K was noted in T_1. The increment of these nutrients was due to organic-based fertilizer and supplements.

The decrease in soil pH might be due to the release of organic acids upon decomposition of crop stubbles and added residues. Similarly, the decrease in total N after harvest might be due to crop uptake and losses brought by surface run-off and leaching.

Table 2. Soil test results before planting and after harvest of Bingawan black rice grown under various production systems

Treatment	pH (1:2.5)	OM (%)	Total N (%)	Available P (mg/kg)	Exchangeable K (meq/100g)
Initial (before planting)					
T_1	5.42	3.94	0.21	1.54	0.29
T_2	5.45	3.27	0.19	1.07	0.26
T_3	5.40	3.33	0.17	1.09	0.19
Mean	5.42	3.51	0.19	1.23	0.25
Final (after harvest)					
T_1	4.98	4.16	0.19	7.06	0.53
T_2	4.99	3.61	0.11	4.59	0.65
T_3	4.77	3.92	0.14	5.45	0.35
Mean	4.91	3.90	0.15	5.70	0.51

Legend: T_1 – UPLB's best bet organic production system (5 t ha^{-1} Vermicast + kakawate leaves 2 kg m^{-2} + FPJ (kakawate leaves) + Vermitea + FFJ (banana) + Panyawan extract)
T_2 – Optimized organic production system in Leyte (2.5 t ha^{-1} vermicast + FPJ (kakawate leaves) + Vermitea + FFJ (banana) + Panyawan extract)
T_3 – Conventional production system in Leyte (urea + complete fertilizers + Lannate a.i . methomyl)

Agronomic Characteristics of Lowland Black Rice

Table 3 shows the agronomic parameters of Bingawan black rice as influenced by various production systems. The results revealed that the number of days to heading and maturity, plant height, fresh straw yield, and total biomass differ significantly among production systems.

Black rice grown under an optimized organic production system in Leyte (T_2) headed and matured earlier than the best bet organic production system (T_1) but comparable to the conventional production system in Leyte (T_3). The results indicated that optimizing the current organic farmers' practice in Leyte (T_2) promoted early heading and maturity comparable to the conventional production system. It conforms to the findings of Quion (2018) and Gaurana (2016) that lowland rice under prevailing organic farmers' practice in Leyte (T2) headed and matured earlier than other production systems.

The best bet organic production system (T_1) induced heavier fresh straw yield and total biomass comparable to the conventional production system in Leyte (T3). These findings conform to Gaurana and Ratilla's (2020) observations that the higher amount of nutrients in T_1 and T_3 resulted in taller plants with bigger LAI and heavier biomass. It indicated that this organic production system (T_1) could substitute the conventional system and appear superior to Leyte's optimized organic production system (T_2). The vigorous growth of rice in T_1 and T_3 could be attributed to higher nutrient contents that promoted cell enlargement and the production of more leaves during its vegetative and reproductive stages.

T_1 approximately supplied about 86-28-18 kg N, P, K ha^{-1} from vermicast aside from nutrients derived from foliar supplements at 0.21-0.12-5.12 L N, P, K ha^{-1} plus the contributions of green leaf manure, which was not quantified. On the other hand, T_2 provided only half of what T_1 did at 43-14-9 kg N, P, K ha^{-1} from vermicast yet with a similar amount of nutrients from the weekly spray of vermitea and other foliar supplements. T_3 supplied the highest amount of nutrients at 105–45.5–45.5 kg ha^{-1} N, P_2O_5, and K_2O from inorganic fertilizers, which enabled plants to produce significantly taller plants than those applied with organic fertilizers (T_1& T_2).

Table 3. Agronomic parameters of Bingawan black rice as influenced by various production systems

Treatment	Number of Days from sowing to		Plant Height (cm)	Fresh Straw Yield (t ha^{-1})	Total biomass (t ha^{-1})
	Heading	Maturity			
T_1 = UPLB's best bet organic production system	78.00^a	111.00^a	97.62^b	18.09^a	27.59^a
T_2 = Optimized organic production system in Leyte	76.50^b	108.50^b	88.83^b	10.11^b	15.91^b
T_3 = Conventional production system in Leyte	76.50^b	108.75^b	107.03^a	18.05^a	27.29^a
Mean	77.00	109.42	97.83	15.42	23.60
C.V. (%)	0.75	0.46	5.40	18.56	13.16
Pr>F	0.016	0.001	0.008	0.011	0.003

Treatment means within each column followed by a common letter are not significantly different at 5 % level, HSD test

Grain Yield and Yield Components of Black Rice

Yield and yield components of Bingawan black rice grown under various production systems are presented in Tables 4 and 5. The results revealed that the number of productive tillers hill^{-1}, panicle length, number of filled, unfilled, and percent filled grains panicle^{-1}, weight of grains hill^{-1}, and grain yield were significantly influenced by various production systems except for the weight of 1,000 grains and harvest index.

More productive tillers, longer panicles, more and heavier filled grains hill^{-1}, and consequently higher grain yield were obtained from the best bet organic production system (T_1) than the optimized organic production system in Leyte (T_2). The former was comparable to the conventional production system in Leyte (T_3) except for panicle length and filled grains per panicle. Rice grown under an optimized organic production system in Leyte (T_2) obtained the least number of productive tillers, filled and unfilled grains per panicle, and the lowest grain yield than the rest of the production systems. The optimized organic production system in Leyte (T_2) only showed superiority over the conventional production system in

Leyte (T_3) in terms of percent filled spikelet panicle^{-1}. The number of productive tillers and weight of grains per hill could have highly influenced grain yield in this study. Li et. al. (2003) reported that tiller production is one of the most important parameters determining grain yield.

More productive tillers, longer panicles, more and heavier filled grains hill^{-1}, and higher grain yield was obtained from the best bet organic production system (T_1). The high nutrient content, especially N, in treatments T_1 and T_3 enhanced crop growth and production. The study by Gebrekidan and Seyoum (2006) and Yoseftabar (2013) revealed that nitrogen increased panicle length, especially if applied at the panicle initiation stage.

The results showed that Bingawan black rice grown in T_1 is superior to T_2, implying that the latter treatment might further be optimized to increase yield. Moreover, the conventional production system in Leyte (T_3) performed better among the production systems, often similar to T_1. This result further suggests that this optimization level of the organic production system in Leyte (T_2) needs to be further improved. However, it produced far better than the national average yield of 3.87 t ha^{-1} in 2019.

Table 4. Number of productive tillers, panicle length, filled and unfilled grains, and percent filled grains per panicle of Bingawan black rice under different production systems

Treatment	No. of productive tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}		% filled spikelet panicle^{-1}
			Filled	unfilled	
T_1 = UPLB's best bet organic production system	15.07^{a}	23.53^{a}	164.85^{a}	25.43^{a}	86.6^{b}
T_2 = Optimized organic production system in Leyte	10.43^{b}	20.56^{b}	114.20^{c}	13.45^{b}	89.65^{a}
T_3 = Conventional production system in Leyte	13.85^{a}	21.34^{b}	142.00^{b}	24.02^{a}	85.54^{b}
Mean	13.12	21.81	140.35	20.97	87.27
C.V. (%)	9.22	2.92	6.17	14.33	1.79
Pr>F	0.004	0.002	0.001	0.003	0.024

Treatment means within each column followed by a common letter are not significantly different at 5% level, HSD test

Table 5. Weight of grains hill^{-1}, weight of 1000 grains, grain yield, and harvest index of Bingawan black rice under various production systems

Treatment	Weight of grains hill^{-1} (g)	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Harvest index
T_1 = UPLB's b est bet organic production system	32.90 ^{a}	27.00	9.14 ^{a}	0.58
T_2 = Optimized organic production system in Leyte	20.65 ^{b}	25.75	5.59 ^{b}	0.55
T_3 = Conventional production system in Leyte	33.08 ^{a}	25.50	8.86 ^{a}	0.54
Mean	**28.88**	**26.08**	**7.87**	**0.56**
C.V. (%)	12.80	7.69	6.96	3.51
Pr>F	0.005	0.560	0.000	0.076

Treatment means within each column followed by a common letter and those without letters are not significantly different at 5% level, HSD test

Gross Margin Analysis

The gross margin analysis of unmilled and milled Bingawan black rice grown under various production systems is presented in Tables 6 and 7, respectively. Results revealed that black rice showed a comparable gross margin or profit if sold as unmilled rice based on the prevailing market price of Php 22.00 per kilo (organic rice) and Php 15.00 per kilo (inorganic rice)(Table 6). It indicates that black rice grown in any of the three different production systems earned statistically the same. The highest gross income recorded in T_1 was due to higher grain yield produced yet costly, thus, affecting its gross margin.

Table 6. Gross margin analysis of unmilled Bingawan Black rice production under various production systems

Treatment	Grain Yield (tha^{-1})	Gross Income (Php ha^{-1})	Total Variable Cost (Php ha^{-1})	Gross Margin (Php ha^{-1})
T_1 = UPLB's b est bet organic production system	9.14 ^{a}	201,080.00 ^{a}	127,427.20 ^{a}	73,652.80
T_2 = Optimized organic production system in Leyte	5.59 ^{b}	122,925.00 ^{b}	59,133.50 ^{b}	63,791.50
T_3 = Conventional production system in Leyte	**8.86 ^{a}**	**132,937.50 ^{b}**	**51,880.00 ^{b}**	**81,057.00**
Mean	7.87	152,314.17	79,480.23	72,833.77
C.V. (%)	6.96	6.79	1.50	15.07
Pr>F	0.000	0.0001	0.0000	0.3938

*Based on the prevailing market price of unmi lled organic black rice @ Php 22 .00 kg $^{-1}$ and inorganic black rice @ Ph p 15.00 kg $^{-1}$

Table 7. Gross margin analysis of milled Bingawan Black rice production under various production systems

Treatment	Milled Grain (t ha^{-1})	Gross Income (Php ha^{-1})	Total Variable Cos (Php ha^{-1})	Gross Margin (Php ha^{-1})
T_1 = UPLB's best bet organi production system	5.59^{a}	279,658.75^{a}	129,712.20^{a}	149,946.55^{b}
T_2 = Optimized organic production system in Leyte	3.73^{b}	186,500.00^{c}	60,531.00^{b}	125,969.00^{c}
T_3 = Conventional productio system in Leyte	5.71^{a}	239,701.25^{b}	54,095.90^{c}	185,605.35^{a}
Mean	5.01	235,286.67	81,446.37	153,840.30
C.V. (%)	3.52	3.48	0.047	5.31
Pr>F	0.0000	0.0000	0.0000	0.000

*Based on the prevailing market price of milled organic black rice @ Php 50.00 kg^{-1} and inorganic black rice @ Php 42.00 kg^{-1}

Moreover, if black rice was sold as milled rice, gross income, total variable cost, and gross margin per hectare differ significantly (Table 7). The conventional production system in Leyte (T_3) showed the highest profit over the two production systems (T_1 and T_2), amounting to Php 185,605.35 ha^{-1} when milled rice was sold at Php 42.00 per kilo. It was followed by the best bet organic production system (T_1), amounting to Php 149,946.55 ha^{-1} based on the prevailing market premium price of organic milled black rice at Php 50 per kilo. Leyte's optimized organic production system (T_2) had the least net margin, generating Php 125,969.00 ha^{-1}. Though the best bet organic production system in UPLB (T_1) resulted in the highest gross income among the production systems, it incurred the highest production cost, hence a lower gross margin. In addition, even the conventional production system in Leyte (T3) got significantly lower gross income than T_1. Still, the latter had markedly higher total variable cost comparable to the optimized production system (T_2), resulting in a comparable gross margin incurred among the production systems. It shows that organic rice can demand a premium price that can be enhanced further if the government continuously supports organic certification standards (Gaurana & Ratilla 2020). Moreover, Hazra et al (2016) stated that organic rice offers a healthy food alternative and can sustain the environment.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The results of the study showed that the growth, yield, and yield components of Bingawan black rice grown under various production systems differed significantly except for the weight of 1000 seeds and harvest index. UPLB's best bet organic production system obtained the highest yield of Bingawan black rice (9.14 t ha^{-1}) comparable to the conventional production system in Leyte. Black rice grown in an optimized production system though inferior in growth performance, showed superiority over the conventional production system in Leyte for percent filled spikelet panicle^{-1}. Marginal analysis of black rice under different production systems earned statistically the same if sold as unmilled rice at PhP 22.00 kg^{-1} (organic price) and PhP 15.00 kg^{-1} (inorganic price). Milled black rice in the conventional system is more profitable than the other two organic production systems due to its lower production cost. However, if the farmer can readily avail of the organic resources in the farm, production cost can highly be reduced implying that the organic production system can be a viable option for resource-poor farmers.

Recommendations

The optimization level for organic production in Leyte can be further improved to increase yield. It is recommended to sell black rice when already milled rather than unmilled considering the relatively higher prevailing market price of the former than the latter. Organic rice also commands a higher price than those produced from the conventional production system. A similar study must be conducted in areas of different agro-climatic conditions.

REFERENCES

Hazra KK, Swain DK, Bohra A, Singh SS, Kumar N & Nath CP. 2016. Organic rice: potential production strategies, challenges, and prospects. Organic Agriculture. Springer. DOI 10.1007/s13165-016-0172-4

Bouman BAM and Tuong TP. 2001. Field water management to save water and increase its productivity in irrigated lowland rice. Agricultural Water Management Journal. 49(1): 11-30.

Chiang AN, Wu HL, Yeh HI, Chu CS, Lin HC & Lee WC. 2006. Antioxidant effects of black rice extract through the induction of superoxide dismutase and catalase activities. Lipids, 41(8), 797-803.

Ethan S, Odunze AC, Abu ST & Iwuafor E. 2011. Effect of water management and nitrogen rates on Fe concentration and yield in lowland rice. Agric. Bio. J. N. Am. 2(4): 622–629.

FAO (Food and Agriculture Organization). 2008. Food security statistics. htttp://www.fao.org/econoci/ess/food-security-statistics/en/ (Accessed August 31, 2019).

Gaurana M. 2016. Field performance and sensory attributes of lowland rice (*Oryza sativa* L. var PSB Rc18) under various organic production systems (MS thesis). Visayas State University, Leyte. Philippines.

Gaurana ML and Ratilla BC. 2020. Agronomic response, nutrient uptake, and profitability of PSB Rc18 lowland rice under organic production systems. Phil. Jour. of Crop Science, 45(1):46-55.

Gberekidan H and Seyoum M. 2006. Effects of mineral N and P fertilizers on yield and yield components of flooded lowland rice on vertisols of Fogera plain, Ethiopia. Journal of Agriculture and Rural Development in Tropics and Sub-tropics. 107(2):161-176.

IRRI. 1993. Rice Almanac. College, Los Banos Laguna, Philippines. 91 pp.

ISRIC (International Soil Reference and Information Center). 1995. Procedures for Soil Analysis (L.P. Van Reuwijk, Editor) Wageningen, The Netherlands. 106p.

Landon JC. 1991. Booker Tropical Soil Manual. Longman Scientific and Technical Essex, England. 474 pp.

Leghari SJ, Wahocho NA, Laghari GM, Hafeez Laghari A, Mustafa Bhabhan G, Hussain Talpur KK, Bhutto TA, Wahocho SA, Lashari AA. 2016. Role of nitrogen for plant growth and development: A review. Adv. Environ. Biol. 10(9):209-219.

Li XY, Qian Q, Fu ZM, Wang YH, Xiong DL, Zheng DL, Wang XQ, Liu XF, Teng S, Hiroshi F, Yuan M, Luo D, Han B, J & Li, L. 2003. Control in tillering in rice. Nature 422:618-621.

Luh, BS.1998. Rice production and utilization. Westport, Conn. USA. AVI Pub. Connecticut, USA. 153 pp.

Norkaew O, Boontakham P, Dumri K, Noenplab ANL, Sookwong P & Mahatheeranon. 2017. Effect of post-harvest treatment on bioactive phytochemicals of Thai black rice. Food Chemistry. 217(1): 98-105.

Okater O. and Liu RH. 2010. Health benefits of whole grain phytochemicals. Critical Reviews in Food Science and Nutrition. 50(3): 193-208.

PCARR. 1980. Standard Methods of Analysis for Soil, Plant Tissue, Water and Fertilizer. Los Baños, Laguna. vii, 194 pp.

Quion, K. 2018. Physiological and field performance of lowland rice (Oryza sativa L. var. PSB Rc18) and soil organic carbon dynamics in different production system under VSU condition (Masteral Thesis). Visayas State University, Leyte, Philippines.

RööS E, Mie A, Wivstad M, Salomon E, Johansson B, Gunnarsson S & Watson CA. 2018. Risks and opportunities of increasing yields in organic farming. A review. Agronomy for Sustainable Development, 38(2): pp. 14.

Roder W, Schürmann S, Chittanavanh P, Sipaseuth K & Fernandez M. 2006. Soil fertility management for organic rice production in the Lao PDR. Renewable Agriculture and Food Systems. 21(4): 253-260.

Suzuki M, Kimura T, Yamagishi K, Shinmoto H & Yamaki K. 2004. Comparison of mineral contents in 8 cultivars of pigmented brown rice. Journal of the Japanese Society for Food Science and Technology (Japan). Accessed from: http://agris.fao.org/agris-search/search.do?record.ID=JP2005001785. on June 2018.

Wang Q, Han PH, Zhang MW, Xia M, Zhu HL, Ma J & Ling WH. 2007. Supplementation of black rice pigment fraction improves antioxidant and anti-inflammatory status in patients with coronary heart disease. Asia Pacific Journal of Clinical Nutrition, 16(S1), 295-301.

Yoseftabar S. 2013. Effect of nitrogen management on panicle structure and yield of rice (*Oryza sativa L.*) International Journal of Agricultural Crop Science. 5(11):1224-1227.