



Nutrient analysis and sensory qualities of black, red, and white rice (*Oryza sativa* L.) cultivars grown under different nutrient management in strongly alkaline soil

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Abstract

Appropriate nutrient management could influence the eating and grain qualities, and physicochemical properties of rice cultivars. The study aims to determine the grain yield and yield components, and nutrient content of black, red, and white rice cultivars as influenced by nutrient management under strongly alkaline soil. Evaluating the sensory qualities of different rice cultivars as influenced by nutrient management under strongly alkaline soil, and determines the suitable rice cultivar for optimum grain productivity. The study was laid out in a split-plot arranged in a Randomized Complete Block Design (RCBD) with rice cultivars as the main plot and nutrient management as the subplot. Statistical analysis revealed that black rice gave relatively higher crude fat and ash content with the same amount of nitrogen to red rice, however much lower to nitrogen, sugar, and starch content than white rice under strongly alkaline conditions. Application of pure poultry litter, inorganic fertilizer, or a combination of both does not enhance crude fat and starch content of all rice cultivar except the unfertilized plants (T₁). Application of pure inorganic (T₂) and combined application (T₄) increased N and sugar than unfertilized control (T₁). Texture and general acceptability were significantly affected by rice cultivars tested where red and black rice are comparably perceived as "like very much" than white rice, which is perceived to be "like slightly." No significant differences in other physical attributes such as color, aroma, and taste. All physical characteristics of sensory analysis were not influenced by nutrient management applied.

Keywords: Alkaline soil; eating quality; nutrient content; rice cultivars; sensory evaluation.

1. Introduction

Rice (*Oryza sativa* L.) is a staple crop of the majority of the human populace worldwide. This crop is mainly grown in the lowlands, especially under irrigated lowland ecosystems. Rice plants can grow best under a soil pH of 5.5 since soil pH affects many physical, chemical, and biological properties of the soil, which in turn also affect the growth of lowland rice (Yu, 1991). However, rice production nowadays is greatly affected by some reasons. One of those reasons is low productivity due to soil alkalinity that hampered its growth and development. One

of the most noticeable constraints in alkaline soils is generally the non-availability of iron. There are instances that the non-solubility of iron is present in abundant quantities and would therefore be made unavailable for plant utilization. The availability of phosphorus, including micronutrients; zinc, copper, and manganese, is reduced at high pH values. The problem can be more harmful by climate change; thus, planting alkaline-tolerant rice varieties and proper nutrient management must be used and managed more efficiently. There are potential rice varieties that might tolerate the presence of soil alkalinity. Red rice, black rice, and white rice are those selected rice cultivars that might solve low productivity in alkaline soils. In as much as appropriate nutrient management strategies through an

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integrated approach might also be a useful alternative for enhancing rice growth and development under such conditions. Thus, proper nutrient management and suitable rice cultivars may improve crop productivity in these areas. Applying poultry litter and supplemental application with inorganic fertilizer can be an option for conventional inorganic rice production. This organic manure may provide nutrient elements that are limited to inherently alkaline soil.

The studies have shown that agricultural practices can influence the nutrient composition of rice grains. Results found that soil nitrogen, solar radiation, maturity, and integrated nutrient management like poultry litter and other inorganic fertilizers influence chemical composition or protein content in rice (Juliano and Bechtel, 1985). It also improves rice grain quality in terms of chemical composition, cooking quality, and a high score of sensory evaluation (Sangeetha *et al.*, 2013)

Application of poultry litter and its combination with inorganic fertilizer may provide nutrient elements hampered under inherently alkaline soil, which can be an option for conventional inorganic rice production. With the adoption of appropriate nutrient management and rice cultivar in rice production under alkaline soils, achieving good eating and grain quality of rice as the primary concern of every consumer can be made possible. Hence, this study aimed to determine the grain yield and yield components, and nutrient content of black, red, and white rice cultivars as influenced by nutrient management under strongly alkaline soil. Evaluate the sensory qualities of black, red, and white rice cultivars as influenced by nutrient management under strongly alkaline soil; determine the suitable rice cultivar for optimum grain productivity under strongly alkaline soil.

2. Materials and Methods

2.1. The study site and land preparation

The study was conducted in a lowland rice field in Brgy. Pomponan, Baybay City, Leyte, the Philippines from December 21, 2018, until April 24, 2019, with Himayangan clay loam

soil series (Armecin *et al.*, 2011), which is inherently alkaline with a soil pH of 7.89. The specific experimental site has a geographical coordinate of 10° 41' N and 124° 48' E (Maplandia.com. 2021) under type four climate wherein rainfall is evenly distributed throughout the year (Lantican, 2001; Kintanar, 1984). An area of 699.2 m² was prepared using a two-wheeled hand tractor, which three times tractor operations were done until the area was ready for transplanting.

2.2. Soil sampling

Before transplanting, soil samples were randomly collected in the experimental area. The samples were submitted to analyze soil pH adopting the Potentiometric Method at a 1:1 soil-water ratio (PCARR, 1980). The total N through Kjeldahl Method (Nelson and Sommers, 1982), available P through Olsen Method (Olsen *et al.*, 1954), exchangeable K through extraction method using atomic absorption spectrophotometry (ISRIC, 1995). The soil pH, total N, available P, exchangeable K, available Na, Mg, Mn Ca, Fe, and Zn was analyzed at the Central Analytical Service Laboratory (CASL), PhilRootcrops, Visayas State University (VSU), Visca, Baybay City, Leyte, Philippines. Another set of soil samples were collected separately from each treatment plot right after harvesting. Samples collected per plot were composited and analyzed for the same soil parameters mentioned above.

2.3. Experimental design, layout, and treatments

The experiment was laid out in a split-plot arranged in a Randomized Complete Block Design (RCBD) with three replications. Rice cultivar was designated as the main plot and the different nutrient management as the subplot. Each subplot measured 4 m x 3 m with 15 rows per plot. Replication and treatment plots were separated by two-meter and 0.70 m alleyways, respectively, to prevent contamination of treatments and facilitate farm operations and data gathering. The different main plot treatments (Rice cultivars) were M₁- Black rice (Ballatinao cultivar), M₂- Red rice (Red 64 cultivar), and M₃- White rice (NSIC Rc216).

The subplot treatments relative to nutrient management were no fertilizer application - control (T₁), 120-60-60 kg ha⁻¹ N, P₂O₅, K₂O (T₂), 5 t ha⁻¹ poultry litter (T₃), and 2.5 t ha⁻¹ poultry litter + 60-30-30 kg ha⁻¹ N, P₂O₅, K₂O (T₄).

2.4. Rice cultivars used

White rice (NSIC RC216 – Tubigan 17), an inbred lowland rice variety is a good source of energy and various nutrients and minerals preferred by most people (DA-PhilRice, 2021). However, it may cause humans to develop diabetes mellitus and other disorders due to immoderate consumption. Both black (Ballatinao cultivar) and red rice (Red 64 cultivar) types were known worldwide as the best substitute for white rice, mainly consumed for their additional health benefits. It helps prevent diabetes mellitus, improves digestive health, and had anticancer effects due to anthocyanin and tannin pigments on its pericarp (Kushwaha, 2016). Both rice cultivars also have much higher fiber than white rice, found to be suitable for people with cardiovascular diseases as it can significantly lower blood cholesterol.

2.5. Crop establishment and cultural management

Twenty-day-old rice seedlings were uniformly transplanted in all varieties at one to two seedlings per hill at a planting distance of 20 cm × 20 cm between hills and between rows. Replanting was done seven days after transplanting (DAT), while rotary weeding was manipulated at 15 DAT. After that, hand weeding was done at 25-30 DAT, while spot weeding to remove weeds around each hill was also undertaken. For the full inorganic fertilizer treatment, complete fertilizers (14-14-14) and urea (46-0-0) were applied to satisfy the fertilizer recommendation of 120-60-60 kg ha⁻¹ N, P₂O₅, K₂O ha⁻¹. Complete fertilizer (14-14-14) amounting to 514.28 g treatment plot⁻¹ applied ten days after transplanting. The remaining N requirement was satisfied by broadcasting urea at 156.52 g treatment plot⁻¹ during the panicle initiation stage. For the combined application of inorganic and organic

fertilizer treatment (T₄) and purely applied poultry litter (T₃), poultry litter was used and applied seven days before transplanting. The inorganic fertilizer for T₄ was satisfied using complete fertilizer at 257.15 g plot⁻¹ and applied through broadcast method at ten DAT. The remaining N requirement was met by broadcasting urea at 78.26 g plot⁻¹ at the panicle initiation stage. For water management, intermittent irrigation was imposed from panicle initiation until two weeks before harvest to facilitate harvesting.

Handpicking of Golden Apple Snail-GAS (*Pomacea canaliculata* L.) was done a day before transplanting and were followed after another two days. Then, twenty-five grams of methomyl insecticide was sprayed to control insect pests like rice ear bug (*Leptocorisa oratoria*) and case worm (*Paraponyx stagnalis*) during vegetative to reproductive growth stages. Rat baiting using slow acting rodenticide was done one week before transplanting as a preventive measure and repeated during panicle initiation and heading stage.

2.6. Harvest and postharvest management

Plants within the harvestable area (8.32 m²) were harvested when 85 % of the grains in each treatment plot's panicles were ripened. The panicles within the harvestable area were cut at the base using a sharp sickle. The sample panicles were threshed, dried for three days to attain 14 % moisture content, and were cleaned before gathering all the necessary data.

2.7. Seed preparation for nutrient analysis and sensory evaluation

The 500 g composite sample grains from each treatment were oven-dried at 70° C for 72 hours as part of nutrient analysis. The sample grains were ground into fine particles and submitted to the Central Analytical Services Laboratory (CASL) at PhilRootcrops, VSU, Visca, Baybay City, Leyte, Philippines; for the analysis of the total nitrogen, ash, fiber, crude fat, sugar, and starch.

The sensory attributes of cooked rice from different treatments were evaluated using quality description combined with the nine-

point Hedonic scale. The milled sample grains from each treatment plot weighing 500 g were boiled for 40 to 45 minutes. The cooked rice was submitted to evaluate the sensory quality and acceptance tests to the Department of Food Science and Technology, VSU, Visca, Baybay City, Leyte, Philippines. Six trained panelists evaluated each sample relative to color, aroma, taste, texture, flavour, and general acceptability. The sensory evaluation outputs were subjected to a two-way analysis of variance using the computer software Statistical Tools for Agricultural Research (STAR). The mean comparison was done using the Least Significant Difference (LSD) test.

2.8. Data gathered

The data gathered were mainly focused on the number of productive tiller hill^{-1} , grain weight hill^{-1} , and grain yield (t ha^{-1}) and on the nutrient analysis of rice grains. The nutrient analysis gathered were nitrogen, ash, fiber, crude fat, sugar, and starch. However, rice grains' sensory quality and acceptance tests include color, aroma, taste, texture, flavour, and general acceptability evaluation were also taken into consideration in data gathering.

3. Results and discussion

3.1. Soil chemical properties

The initial soil analysis result showed that the soil had a pH of 7.89 with 2.15 % organic matter, 0.15 % total N, 9.48 mg kg^{-1} available P, 0.0101 me 100 g^{-1} exchangeable K, 5,111.07 me 100 g^{-1} Ca, 342.66 me 100 g^{-1} Mg, a trace amount of Na, 1.58 mg kg^{-1} Fe, 8.04 mg kg^{-1} Mn, 3.24 mg kg^{-1} Cu, and 1.46 mg kg^{-1} Zn (Table 1). These imply that the soil is strongly alkaline, with low amounts of organic matter, total N, and available P, very low amount of exchangeable K, low amounts of Fe and Zn, a moderate amount of Cu, a high amount of Mn, and very high amounts of Ca and Mg (Landon, 1991). After harvest, the final analysis results revealed a slight decrease in soil pH from a strongly alkaline to a moderately alkaline level. However, a slight increase in OM, total N, and exchangeable K was observed, especially in treatment plots applied with 5 t ha^{-1} poultry

litter (T_3), mainly attributed to the high contents of nutrient elements poultry litter applied (Table 1). The result aligns with Hamed *et al.* (2011) and Amanullah *et al.* (2007) that poultry manure serves as a source of N and P and provides nutrients such as Ca Mg, S, and Fe. A decrease in Ca, Mn, Zn, and P's available amount were due to plants' utilization of the said elements, especially those without fertilizer. On the other hand, the different subplot treatments increased to Mg, Fe, and Cu while the amount of Ca decreases indicating the decline in pH, especially in those plots applied with pure inorganic fertilizer at the rate of 120-60-60 kg ha^{-1} N, P_2O_5 , K_2O (T_2).

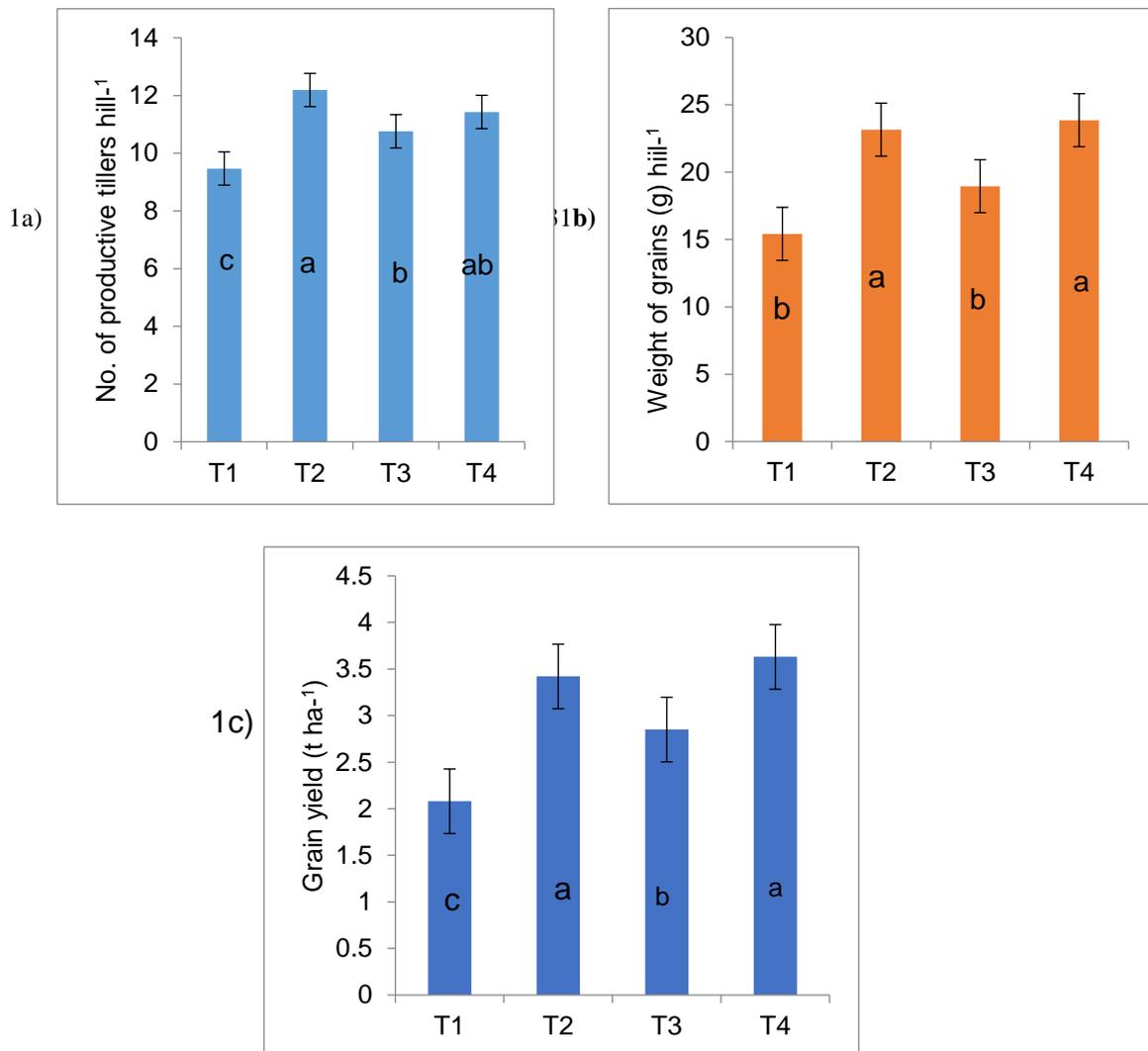
3.2. Number of productive tillers hill^{-1} , grain weight (g) hill^{-1} , and grain yield (t ha^{-1}) as influenced by nutrient management under strongly alkaline soil

Statistical analysis showed that the number of productive tillers hill^{-1} , grain weight hill^{-1} , and grain yield (t ha^{-1}) were significantly affected by nutrient management adopted (Figures 1a, 1b 1c). Regardless of rice cultivar, plants applied with 2.5 t ha^{-1} poultry litter + 60-30-30 kg ha^{-1} N, P_2O_5 , K_2O (T_4) significantly produced more productive tillers (11.43) comparable to those plants applied with 120-60-60 kg ha^{-1} N, P_2O_5 , K_2O (T_2) (Fig. 1a). Rice plants applied with pure poultry litter at 5 t ha^{-1} (T_3) and unfertilized control (T_1) had few numbers of productive tillers. Thereby, the combined application of poultry litter and inorganic fertilizer resulted in a significant increase in rice tillers due to its synergistic effect of increasing levels of nitrogen and phosphorus in the soil, which in turn promotes tillering (Belefant, 2007).

Table 1. Soil test results before planting and after harvest of black, red, and white rice (*Oryza sativa* L.) cultivars as influenced by nutrient management under strongly alkaline soil

	MACRONUTRIENTS							MICRONUTRIENTS				
	pH	OM (%)	Total N (%)	Available P (mg kg ⁻¹)	Exchangeable (me 100 g ⁻¹)			Extractable (mg kg ⁻¹)				
					K	Ca	Mg	Na	Fe	Mn	Cu	Zn
	Initial Soil Analysis											
Composite Sample	7.89	2.15	0.15	9.48	0.0101	5,111.07	342.65	trace	1.58	8.04	3.24	1.46
	Final Soil Analysis											
Treatment												
T ₁	7.54	2.98	0.19	2.32	0.0105	4,779.23	384.43	trace	5.67	3.63	4.39	0.90
T ₂	7.60	2.92	0.17	3.17	0.0151	4,533.65	485.78	trace	6.80	5.07	4.78	1.02
T ₃	7.60	3.25	0.19	7.29	0.0202	4,912.50	508.00	trace	6.22	3.51	4.83	1.68
T ₄	7.57	3.03	0.18	2.89	0.0193	4,921.20	437.00	trace	6.41	4.73	4.84	1.13
Mean	7.58	3.05	0.18	3.92	0.016	4,786.64	453.80	trace	6.28	4.24	4.71	1.18

Legend:T₁ = No fertilizer application (control)T₂ = 120-60-60 kg ha⁻¹N, P₂O₅, K₂OT₃ = 5 t ha⁻¹ poultry litterT₄ = 2.5 t ha⁻¹ poultry litter + 60-30-30 kg ha⁻¹ N, P₂O₅, K₂O



Treatment means with the same and without letter designations are not significantly different at 0.05 LSD.

Legend:

T₁ = No fertilizer application (control)

T₂ = 120-60-60 kg ha⁻¹N, P₂O₅, K₂O

T₃ = 5 t ha⁻¹ poultry litter

T₄ = 2.5 t ha⁻¹ poultry litter + 60-30-30 kg ha⁻¹ N, P₂O₅, K₂O

Figure. 1a, 1b, 1c. Number of productive tillers, the weight of grains (g) hill⁻¹, and grain yield (t ha⁻¹) of rice (*Oryza sativa* L.) cultivars as influenced by nutrient management under strongly alkaline soil

For the weight of grains per hill (Fig. 1b) and grain yield (t ha^{-1}) (Fig. 1c), plants applied with 2.5 t ha^{-1} poultry litter + $60\text{-}30\text{-}30 \text{ kg ha}^{-1}$ N, P_2O_5 , K_2O (T_4) significantly achieved heavier grains hill^{-1} of 23.86 g compared to those plants applied with pure poultry litter at 5 t ha^{-1} (T_3) and unfertilized plants (T_1) (Fig. 1b). However, T_4 plants were comparable to those plants that received pure inorganic fertilizer (T_2). A similar trend was also noted to its grain yield wherein rice plants applied with 2.5 t ha^{-1} poultry litter + $60\text{-}30\text{-}30 \text{ kg ha}^{-1}$ N, P_2O_5 , K_2O (T_4) significantly obtained higher grain yield (3.63 t ha^{-1}) than those plants under T_3 (2.85 t ha^{-1}) and unfertilized control (T_1) with only 2.08 t ha^{-1} but comparable to those plants that received pure inorganic fertilizer at the rate of $120\text{-}60\text{-}60 \text{ kg ha}^{-1}$ N, P_2O_5 , K_2O (T_2) with 3.42 t ha^{-1} . This result corroborates with the findings of Hasanuzzaman *et al.* (2010) that application of poultry litter at 4 t ha^{-1} + 50 % of recommended NPK produced the highest grain yield of rice.

3.3. Nutrient analysis of rice grains

The awareness of rice's nutritive value and health benefits is a vital undertaking to increase rice consumption in the human daily diet (Verma and Srivastav, 2017). The result of grain analysis of lowland rice as influenced by rice cultivar and nutrient

management under strongly alkaline soil was reflected in Table 2.

The results showed that under alkaline conditions, red rice and black rice gave relatively higher crude fat and ash content. Red rice gave the same amount of nitrogen as black rice, while white rice obtained relatively higher nitrogen, sugar, and starch content. The high nitrogen content can be attributed to the amount of nitrogen present in the soil, as amended by different nutrient management. For pure poultry litter application, purely inorganic fertilizer and combined organic and inorganic application did not enhance the crude fat and starch content of all rice cultivars except the unfertilized plants (T_1), which contains a higher amount of crude fat and starch. The result is associated with the high amount of sugar and carbohydrates as a good source of energy and the primary source of a range of nutrients for the human diet (Weininger *et al.*, 2018). Relative to plants under T_4 , application of 2.5 t ha^{-1} poultry litter + $60\text{-}30\text{-}30 \text{ kg ha}^{-1}$ N, P_2O_5 , K_2O higher value in nitrogen and sugar content of rice. In terms of ash content, plants applied with $120\text{-}60\text{-}60 \text{ kg ha}^{-1}$ N, P_2O_5 , K_2O (T_2) contained a relatively higher amount of ash of 0.199 %.

Table 2. Nutrient content on grains of lowland rice (*Oryza sativa* L.) as influenced by rice cultivar and nutrient management under strongly alkaline soil

Treatment	TOTAL (%)				
	Crude Fat	Ash	Nitrogen	Sugar	Starch
Rice cultivars					
M ₁ = Black rice	0.610	0.199	0.933	0.955	64.588
M ₂ = Red rice	0.593	0.124	0.933	0.655	61.938
M ₃ = White rice	0.491	0.162	0.968	1.278	65.978
Mean	0.560	0.160	0.940	0.960	64.170
Nutrient management					
T ₁ -No fertilizer application (control)	0.737	0.149	0.879	0.761	67.452
T ₂ -120-60-60 kg ha ⁻¹ N, P ₂ O ₅ , K ₂ O	0.342	0.199	1.162	1.001	65.132
T ₃ -5 t ha ⁻¹ poultry litter	0.609	0.166	0.527	0.723	61.561
T ₄ -2.5 t ha ⁻¹ poultry litter + 60-30-30 kg ha ⁻¹ N, P ₂ O ₅ , K ₂ O	0.566	0.132	1.211	1.365	62.526
Mean	0.56	0.16	0.94	0.96	64.17

Means in a column with a similar letter and no letter designation are not significantly different based on a 5% level of significance in (LSD).

3.4. Sensory analysis

The texture is an essential attribute of food acceptance by consumers (Meullenet *et al.*, 2000). Sensory analysis of black, red, and white rice cultivars as influenced by nutrient management under alkaline soil was observed (Table 3). The sensory analysis result revealed that texture and general acceptability were significantly affected by the different rice cultivars tested, but no significant differences in other physical attributes such as color, aroma, and taste. However, all physical characteristics of sensory analysis were not influenced by nutrient management applied. Red and black

rice cultivars achieved significantly higher texture with 7.56 and 7.26, respectively, while remarkably higher general acceptability for red rice (7.10) and black rice (6.96) when compared with white rice with only 6.15.

Red and black rice are comparably perceived as "like very much" to white rice, which is perceived as "like slightly." (Table 4). The same trend was noted for general acceptability wherein red, and black rice was consistently perceived as "like very much" comparing white rice, which was perceived as "like slightly."]

Table 3. Sensory analysis of lowland rice (*Oryza sativa* L.) as influenced by rice cultivar and nutrient management under strongly alkaline soil

Rice cultivars	Color	Aroma	Taste	Texture	General acceptability
M ₁ = Black rice	6.26	6.28	6.01	7.20 ^a	6.96 ^a
M ₂ = Red rice	6.19	5.91	6.09	7.56 ^a	7.10 ^a
M ₃ =White rice	6.18	6.08	6.00	5.94 ^b	6.15 ^b
Nutrient management					
T ₁ -No fertilizer application (control)	6.80	6.77	6.50	6.92	6.85
T ₂ -120-60-60 kg ha ⁻¹ N, P ₂ O ₅ , K ₂ O	5.64	5.63	5.53	5.93	5.75
T ₃ -5 t ha ⁻¹ poultry litter	5.82	5.57	5.60	5.86	5.72
T ₄ -2.5 t ha ⁻¹ poultry litte + 60-30-30 kg ha ⁻¹ N, P ₂ O ₅ , K ₂ O	5.91	5.52	5.62	5.91	5.67
C.V. (a)%	9.48	4.93	7.91	4.43	4.21
C.V. (b)%	6.35	4.53	4.53	2.98	1.84

Means in a column with a similar letter and no letter designation are not significantly different based on a 5% level of significance in (LSD).

Table 4. Sensory evaluation acceptability level test of lowland rice (*Oryza sativa* L.) as influenced by rice cultivar and nutrient management under strongly alkaline soil

Color	Aroma	Taste	Texture	General Acceptability
1-Slightly Black/Red/White	0- no perceptible aroma	0- no sweetness	1-(cheese) extremely soft	1- dislike extremely 2- dislike very much
2-Moderately Black/Red/White	1- slightly perceptible aroma	1- slightly sweet	2- (egg white) soft 3- (sausage) just	3- dislike moderately 4- dislike slightly
3- Intense Black/Red/White	2- moderately perceptible aroma	2- moderately sweet	right 4- (peanuts) slightly	5- neither like nor dislike 6- like slightly
	3-very perceptible aroma	3- very sweet	hard	7- like very much
	4-extremely perceptible aroma	4- extremely sweet		8-like very much 9- like extremely

This study conformed with the findings of Juliano *et al.* (1965) and Lorieux *et al.* (1996), which revealed that genetic variability, environment, and cultural practices affect the texture of the cooked rice. However, this undertaking contradicts Champagne *et al.* (2007) findings that nutrient management can affect rice grain and physicochemical characteristics.

The result indicated that rice cultivars have profound variation in terms of texture and general acceptability. The product supports Srisawas and Jindal's (2007) findings that acceptability scores were strongly correlated with cooked rice's textural properties. Pratiwi and Purwestri (2017) mentioned that variations in varieties might have implications in understanding various rice phenotypes and their potential uses as a functional food.

4. Conclusion

Based on the results obtained, red and black rice cultivars achieve a higher amount of crude fat, and ash, while white rice receives a higher amount of percent nitrogen, sugar, and starch. Regarding rice cultivars, fertilizer application increases the amount of percent nitrogen and starch of lowland rice under strongly alkaline soil. Red and black rice cultivars obtained good eating quality in terms of texture and general acceptability than that of white rice.

Recommendation

Black rice recommends massive planting due to its significantly higher grain yield (3.26 t ha⁻¹), good eating quality regarding texture and general acceptability, and high nutritional content (crude fat and ash content) when applied with combined application of poultry litter + 60-30-30 kg ha⁻¹ N, P₂O₅, K₂O (T₄).

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