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RESEARCH ARTICLE
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Optimization of Growth, Production and Seeding of Black Rice through a Combination of Compost and Liquid Fertilizer Based on Multivariate Analysis

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ABSTRACT

The development of black rice requires the optimization of organic fertilizers, such as compost and liquid organic fertilizer, to support their production and seeding. In addition, the optimization of organic fertilizers also requires a systematic concept in estimating the evaluation criteria, such as multivariate analysis. Therefore, the study aims to 1) identify the criteria for practical evaluation and response patterns to compost doses and liquid organic fertilizer concentrations and 2) determine the best combination of the two treatments in supporting the growth, productivity, and seed quality of black rice. This research was designed using a split-plot design. The main plot was the dose of compost (three doses), and the subplots were liquid organic fertilizer concentrations (four concentrations) repeated three times. Based on these results, the number of tillers, flag leaf length, flag leaf width, panicle length, and yield were appropriate characters for evaluation criteria. Based on these criteria, the combination of compost doses of 6tons ha^{-1} and liquid organic fertilizer concentration of 60mL L^{-1} is the best in supporting the growth, productivity, and seeding of black rice of the Jeliteng variety. This combination is recommended for application in the production and cultivation of black rice.

Keywords: Black rice, Healthy trend, Organic farming, Oryza sativa, Seed production

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INTRODUCTION

Black rice (*Oryza sativa* L.) is a type of rice consumed as a valuable local food source rich in antioxidants, and it is helpful to increase the body's immunity (Pratiwi & Purwestri, 2017; Yamuangmorn & Prom-u-Thai, 2021; Rahim et al., 2022). However, the planting area is not extensive. It is caused by several factors: long plant life, high habitus, uncomfortable taste and texture, and relatively low productivity. In addition, black rice is also local and only planted in certain areas, so this rice is relatively closely related to traditional ceremonies (Borah et al., 2018). However, with the increasingly rapid trend of healthy living, the demand for high anthocyanin rice (black rice) continues to increase (Zhang et al., 2023). Therefore, improvements in black rice cultivation technology are expected to support the potential for black rice production, especially in Indonesia.

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Applying organic fertilizers, such as compost and liquid organic fertilizer (LOF), in black rice cultivation aligns with the concept of optimizing the quality of the rice. Compost is one of the solid organic fertilizers resulting from the decomposition of agricultural waste (Merhabi, 2020; Devianti et al., 2021; Waqas et al., 2023). This waste will undergo natural or artificial weathering or fermentation processes to produce nutrients for plants (Chojnacka et al., 2020; El-Beltagi et al., 2022; Waqas et al., 2023). Compost will improve the soil's physical properties by improving soil porosity, KTA, and CEC. These properties will support the development of plant roots, which is correlated with shoot production (Khalil et al., 2015; Tajima, 2021; Lynch et al., 2021). In addition, this decomposition contains a variety of good microbes for planting so that the ecosystem of the planting area becomes more sustainable (Dlamini et al., 2022; Koza et al., 2022). However, using compost alone is still not optimal, so other organic fertilizers are needed as support.

Liquid organic fertilizer (LOF) is organic fertilizer in liquid form, which consists of several nutrients, hormones, and microbes as a result of the decomposition and fermentation of organic materials (Gunawan et al., 2021; Husaini et al., 2022). This liquid organic fertilizer has various benefits, including being able to overcome nutrient deficiencies, containing certain substances such as microorganisms which are rarely found in solid organic fertilizers in dry form, and increasing plant adaptation under stress (Maintang et al., 2021; Bahri et al., 2022; Hariyadi et al., 2009). These advantages are expected to support the effect of compost in increasing black rice production and seedlings. Several reports have reported the effectiveness of combining the two treatments (Simarmata et al., 2017; Lidya et al., 2018). However, this effectiveness must also be supported by effective evaluation criteria, one with the multivariate analysis.

Multivariate analysis can reduce a large dimension with many parameters to be simpler and more focused so that this approach can determine critical evaluation criteria effectively. The use of this approach has also been reported by Anshori et al. (2022), Padjung et al. (2021) and Farid et al. (2022). Based on this, the aims of this study were 1) to identify the criteria for practical evaluation and the pattern of response to compost doses and LOF concentrations based on multivariate analysis and 2) to determine the best combination of the two treatments in supporting the growth, productivity, and seed quality of the black rice.

MATERIALS & METHODS

Experimental Design

This research was conducted in Apala Village, Barebbo District, Bone Regency (4°36'47.0" S 120°17'52.0" E), from August to December 2022 (Fig. 1). The black rice variety used in this study was Jeliteng. This study employed a split-plot design with a dose of compost (C) as the main plot consisting of 3 levels, namely: D0: Without compost or 0tons ha^{-1}; D1: 3tons ha^{-1} compost; D2: 6tons ha^{-1} compost. Meanwhile, the concentration of liquid organic fertilizer (LOF) was the subplots (K) consisting of 4 levels, namely: L0: Without fertilizer or 0mL L^{-1} LOF; L1: 20mL L^{-1} LOF; L2: 40mL L^{-1} LOF, and L3: 60mL L^{-1} LOF. Based on the combination of treatments, there were 12 packages of dose of compost, and the concentration of LOF combination was repeated three times.

Manufacture of Compost and LOF

Making compost begins with evenly mixing the materials used, namely, 60kg of roasted husks, 30kg of cow manure, 30kg of chicken manure, and 30kg of rice bran (2:1:1:1:1). After that, the mixture of ingredients was moistened with molasses and 1 liter of local microorganisms which are dissolved in water evenly so that the fertilizer is in moist condition. Afterward, the fertilizer can stand and cover using a tarp for two weeks. Stir the fertilizer every two days. The characteristics of compost content were shown in Table 1.

Making LOF begins with mixing the ingredients into a bucket, namely, 10L of coconut water, 10L of rice water, 5L of cow urine, 1L of molasses, 1L of MOL, and 2kg of chopped fruit and vegetables. The ingredients are mixed evenly, and the bucket is closed until no air enters. The perforated lid is then connected to a plastic bottle filled with water using a ¼ inch hose. LOF is left for two weeks, and stirring is done every two days. LOF is considered successful when it produces an aroma like the aroma of fermentation. The characteristics of LOF were shown in Table 2.

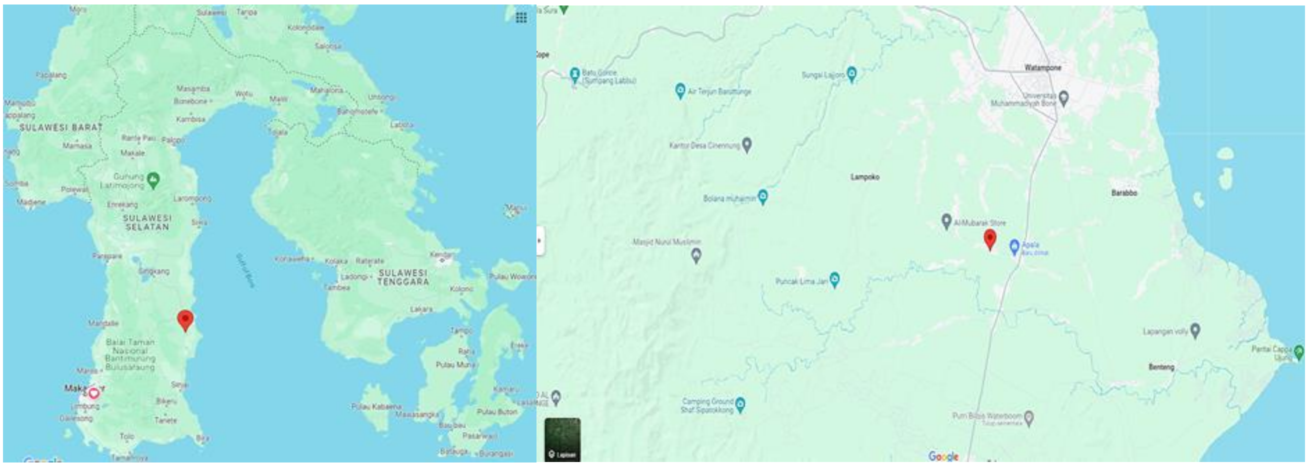


Fig. 1: Map location of the study in Apala Village, Barebbo District, Bone Regency.

Table 1: The nutrient characteristics of compost

Characteristic	Value
pH-water	7.32
C organic matter (%)	32.83
N (%)	2.1
C/N (%)	16.6
P_2O_5 (%)	0.86
K (%)	1.23

Table 2: The nutrient characteristics of liquid organic fertilizer

Characteristic	Value
pH-water	7.10
C organic matter (%)	0.55
N (%)	0.24
C/N (%)	2.34
P_2O_5 (%)	0.60
K (%)	0.46

Implementation of Cultivation

The cultivation process begins with processing the land. Processing starts with flooding the land before plowing by flooding it for two days. After that, piracy was repeated to optimize the even distribution of puddling. Rice seeds are soaked in a bucket filled with clean water for 24 hours and then fermented in a sack for 24 hours. After that, the seeds were sown in nursery plots and then transferred to the research field after about two weeks of age. Planting is done by transplanting black rice seedlings 14 days old after spreading to the experimental plots. The planting system used is a 30x30cm tile planting system with a plot size of 4.5x13.8m (62.1m^2) and a plot size of 4.5x2.7m.

The maintenance process follows the cultivation process. There are several maintenance stages: embroidery, fertilizing, weed control, irrigation, and pest and disease control, adapted to Akbar et al. (2021)—fertilization using compost, LOF, and NPK. Compost fertilizer was given one week before planting according to the dose of each main plot, while LOF fertilizer was given two weeks after transplanting. LOF was given every two weeks according to the concentration of each subplot. Meanwhile, chemical fertilizers are divided evenly over the land using Phonska fertilizer of as much as 1kg plot^{-1} and urea of 300g plot^{-1}, divided into two increments. The last activity is harvesting. Harvesting occurs when 80% of the rice grains have entered the physiological ripening phase (yellow straw) and the rice grains at the base of the panicles have hardened. Harvesting is done in stages according to plant conditions.

Observation and Data Analysis

Observations were made on 5 sample plants per plot. Parameters observed included plant height (cm), number of tillers (stems), number of productive tillers (stems), flag leaf length (cm), flag leaf width (cm), days to flowering (days, days to harvesting (days), length panicle (cm), Number of grain per panicle (grain), Density of panicle (grain cm^{-1}), Number of panicle branches (branches), length of grain (mm), Percentage of filled grain per panicle (%), Weight of 1000-grains (g), Production per clump (g), Grain production per hectare (ton ha^{-1}), Germination capacity (%) every week after harvest.

The observed data were analyzed using ANOVA (analysis of variance). Significant characters were followed by Pearson correlation analysis and path analysis. The results of the analysis determine the selected evaluation criteria. The selected evaluation criteria are followed by further testing. The additional test used is the least significant difference (LSD), at a 95% confidence level or α 0.05. Meanwhile, germination characteristics were analyzed using the concept of time series from week 1 to week 4.

RESULTS

The variance analysis showed that the variation coefficient for all growth characters was low, below 20% (Table 3). The two single effects, compost dosage, and LOF concentration, significantly affected almost all growth characters, except grain length, in the LOF concentration treatment. The interaction between the two treatments also dominantly influenced the growth characteristics of black rice significantly, except for plant height, flag leaf length, flag leaf width, harvest age, and panicle density. Overall growth data was followed by correlation analysis.

Table 3: Analysis of variance in growth, agronomy, and plant physiological traits in black rice

Characters	Mean Square			CV C (%)	CV LOF (%)
	C	LOF	C x LOF		
PH	212.50**	67.38**	5.69ns	5.16	2.17
NT	182.96**	206.56**	29.88**	13.37	10.67
NPT	94.44**	94.57**	11.88**	13.00	7.93
FLL	134.54*	50.40**	5.92ns	12.60	7.65
FLW	0.025*	0.059**	0.003ns	3.65	3.50
LCI	171.68**	100.27**	41.51**	13.50	11.07
DF	17.33**	33.66**	2.52**	1.76	1.50
DH	23.03**	24.63**	1.88ns	1.73	1.23
PL	19.22**	9.60**	1.83*	3.69	3.32
NG	182.20**	833.62**	93.29**	4.18	4.63
PD	0.13**	0.44**	0.05ns	4.64	4.13
NB	2.34**	3.35**	0.40**	6.55	4.30
GL	0.009**	0.006ns	0.014**	0.98	0.71
PFG	0.008**	0.014**	0.001**	2.53	2.07
1000GW	14.21**	4.92**	0.96**	4.38	2.17
Yield	1.61**	0.96**	0.14*	8.14	6.26

Notes: *: significant effect on 5% error level, **: very substantial effect on 1% error level, ns: no significant effect, PH: plant height, NT: number of tillers, NPT: number of productive tillers, FLL: flag leaf length, FLW: flag leaf width, LCI: leaf chlorophyll index, DF: days to flowering, DH: days to harvest, PL: panicle length, NG: number of grains, PD: panicle density, NB: number of branches, GL: grain length, PFG: percentage of filled grains, 1000GW: 1000 grain weight.

The results of the correlation analysis focused on black rice productivity (Table 4). Based on this correlation, productivity correlates with plant height, number of tillers, number of productive tillers, flag leaf length, flag leaf width, panicle length, total grain number, percentage of filled grain, and 1000-grain weight. The nine characters also show a positive correlation with each other. This is the basis for cross-finding. Based on the results of the path analysis (Table 5), the number of tillers (1.49), flag leaf length (2.50), flag leaf width (2.23), and panicle length (3.9) showed a dominant positive direct effect. The character of the percentage of filled grain shows a shallow positive direct effect (0.24). On the other hand, plant height (-0.37), number of productive tillers (-1.76), total grain number (-2.57), and 1000grain weight (-1.42) showed a negative direct effect.

Table 4: Correlation analysis of the black rice growth parameters

	PH	NT	NPT	FLL	FLW	LCI	DF	DH	PL	NG	PD	NB	GL	PFG	1000GW	Yield
PH	1.00															
NT	0.67*	1.00														
NPT	0.83**	0.86**	1.00													
FLL	0.90**	0.64*	0.90**	1.00												
FLW	0.85**	0.70*	0.85**	0.79**	1.00											
LCI	0.64*	0.25ns	0.54ns	0.77**	0.64*	1.00										
DF	-0.78**	-0.78**	-0.92**	-0.85**	0.82**	-0.66*	1.00									
DH	-0.79**	-0.85**	-0.97**	-0.88**	-0.81**	-0.63*	0.95**	1.00								
PL	0.83**	0.66*	0.75**	0.89**	0.72**	0.70*	-0.74*	0.79**	1.00							
NG	0.64*	0.68*	0.75**	0.77**	0.78**	0.61*	-0.77**	-0.79**	0.87**	1.00						
PD	0.14ns	0.44ns	0.45ns	0.30ns	0.56ns	0.29ns	-0.49ns	-0.48ns	0.34sn	0.76**	1.00					
NB	0.73**	0.69**	0.75**	0.83*	0.61*	0.63*	-0.78**	-0.78**	0.96**	0.93**	0.56ns	1.00				
GL	0.36ns	0.33ns	0.43ns	0.42ns	0.24ns	0.52ns	-0.32ns	-0.40ns	0.40ns	0.41ns	0.32ns	0.38ns	1.00			
PFG	0.83**	0.80**	0.88**	0.80**	0.80**	0.40ns	-0.87**	-0.88**	0.72*	0.69**	0.39ns	0.62*	0.33**	1.00		
1000GW	0.81**	0.76**	0.77**	0.83**	0.71**	0.60*	-0.73**	-0.80**	0.94**	0.78**	0.25ns	0.88**	0.27**	0.70*	1.00	
Yield	0.85**	0.70*	0.87**	0.94**	0.78**	0.72**	-0.82**	-0.86**	0.96**	0.85**	0.38ns	0.93**	0.51ns	0.81**	0.90**	1.00

Notes: *: significant effect on 5% error level, **: very significant impact on 1% error level, ns: no significant effect, PH: plant height, NT: number of tillers, NPT: number of productive tillers, FLL: flag leaf length, FLW: flag leaf width, LCI: leaf chlorophyll index, DF: days to flowering, DH: days to harvest, PL: panicle length, NG: number of grains, PD: panicle density, NB: number of branches, GL: grain length, PFG: percentage of filled grains, 1000GW: 1000 grain weight.

Table 5: Path analysis among the correlated black rice growth parameters to the yield

Characters	Direct effect	Indirect effect									Correlation
		PH	NT	NPF	FLL	FLW	PL	NG	PFG	1000GW	
PH	-3.07		1.00	-1.46	2.25	1.90	2.83	-1.64	0.20	-1.15	0.85
NT	**1.49**	-2.06		-1.51	1.60	1.56	2.25	-1.75	0.19	-1.08	0.70
NPF	-1.76	-2.55	1.28		2.25	1.90	2.55	-1.93	0.21	-1.09	0.87
FLL	**2.50**	-2.76	0.96	-1.58		1.76	3.03	-1.98	0.19	-1.18	0.94
FLW	**2.23**	-2.61	1.05	-1.50	1.98		2.45	-2.00	0.19	-1.01	0.78
PL	**3.40**	-2.55	0.99	-1.32	2.23	1.61		-2.23	0.17	-1.33	0.96
NG	-2.57	-1.96	1.02	-1.32	1.93	1.74	2.96		0.17	-1.11	0.85
PFG	0.24	-2.55	1.19	-1.55	2.00	1.78	2.45	-1.77		-0.99	0.81
1000WG	-1.42	-2.48	1.14	-1.36	2.08	1.58	3.20	-2.00	0.17		0.90

Note: PH: plant height, NT: number of tillers, NPF: number of productive tiller, FLL: flag leaf length, FLW: flag leaf width, PL: panicle length, NG: number of grain, PFG: percentage of filled grain, 1000WG: 1000 weight grain, the bold number and label in the table are selected characters as supporting characters with a high direct effect to the yield

The results of the polynomial-polynomial interaction test results of the number of tillers on compost dosage and LOF concentration are shown in Fig. 2. The advanced test result showed that compost dosage and LOF concentration treatments had a dynamic quadratic response interaction. The determination of the response reaches 0.679. In general, increasing the dose of compost with a high LOF dose will support a dynamic increase in the number of tillers. Meanwhile, the best treatment supporting the number of tillers was a dose of 6-ton ha^{-1} compost with a LOF concentration of 60mL L^{-1} with a value of 38.73 tillers.

Further test results on the effect of a single dose of compost and LOF concentration on flag leaf length are shown in Fig. 2A and 2B, respectively. Based on Fig. 3A, the increase in leaf length to the dose of compost shows a linear response with a determination value of 0.34. The best compost dose in this study was 6tons ha^{-1}, with a value of 36.68 cm. Meanwhile, based on Fig. 3B, an increase in leaf length to LOF concentration also shows a linear response with a determination value 0.2012. The best LOF concentration in this study was 60mL L^{-1} with a value of 35cm.

Further test results on the effect of a single dose of compost and LOF concentration on flag leaf width are shown in Fig. 4, respectively. Based on Fig. 4A, the increase in leaf width to the dose of compost shows a linear response with a determination value of 0.16. The best compost dose in this study was 6tons ha^{-1} with a value of 1.495cm. Meanwhile, based on Fig. 3B, an increase in leaf width to LOF concentration shows a linear response with a determination value 0.42. The best LOF concentration in this study was 60mL L^{-1} with a value of 1.52cm.

The results of the polynomial-polynomial interaction test of panicle length on compost dosage and LOF concentration are shown in Fig. 5. The advanced test results showed that compost dosage and LOF concentration treatments had a sloping quadratic response interaction with panicle length. The determination of the response reaches 0.719. In general, an increase in the dose of compost with a high LOF dose will support a static increase in panicle length. Meanwhile, the best treatment for supporting panicle length was a dose of 6-ton ha^{-1} compost with a LOF concentration of 60mL L^{-1} with a value of 26.55cm.

The results of the polynomial-polynomial interaction test results of the yield on compost dosage and LOF concentration are shown in Fig. 6. The advanced test results showed that compost dosage and LOF concentration treatments had a dynamic quadratic response interaction concerning yield. The determination of the response reaches 0.424. In general, an increase in the dose of compost with a high LOF dose will support a drastic increase in the yield. Meanwhile, the best treatment supporting the yield was a dose of 6-ton ha^{-1} compost with a LOF concentration of 60mL L^{-1} with a value of 5.78t ha^{-1}.

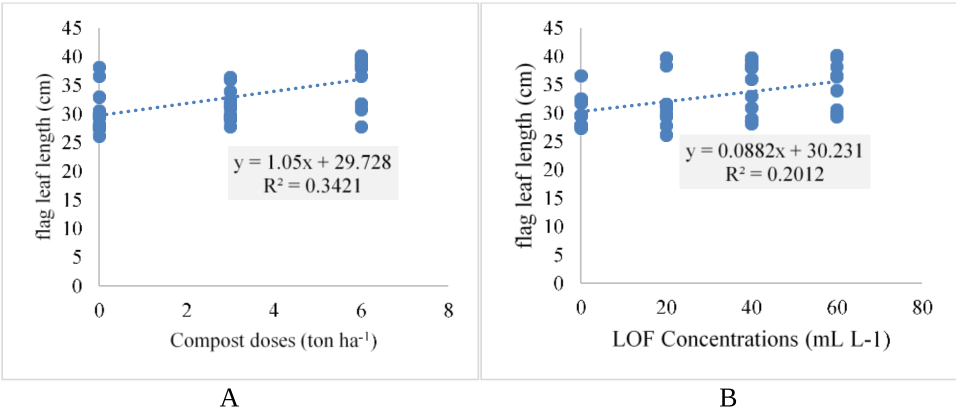


Fig. 2: Graphs showing the relationship between A) compost dosage and flag leaf length and B) LOF concentration and flag leaf length.

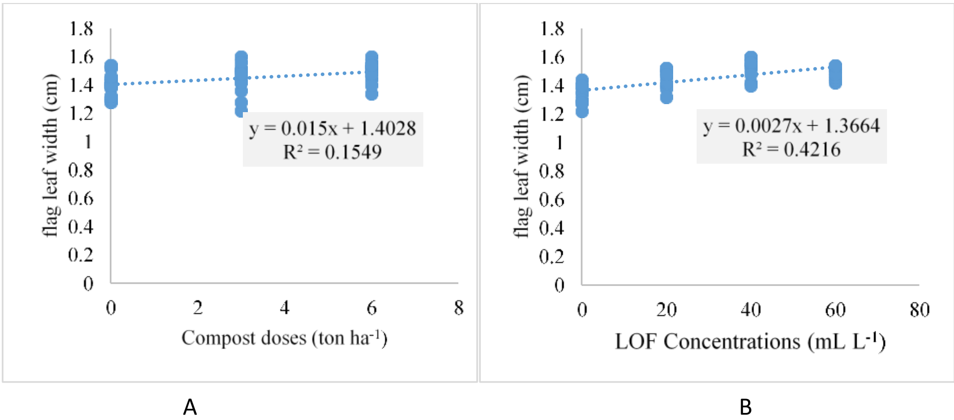


Fig. 3: Graph the relationship between compost dosage A) and flag leaf width B) LOF concentration relationship graph with flag leaf width character.

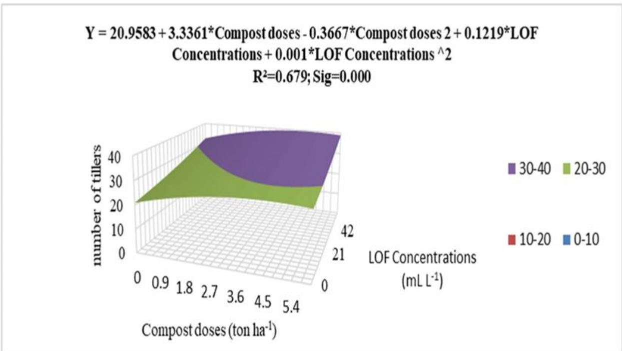


Fig. 4: Graph of the interaction between compost dosage and LOF concentration with the number of tillers.

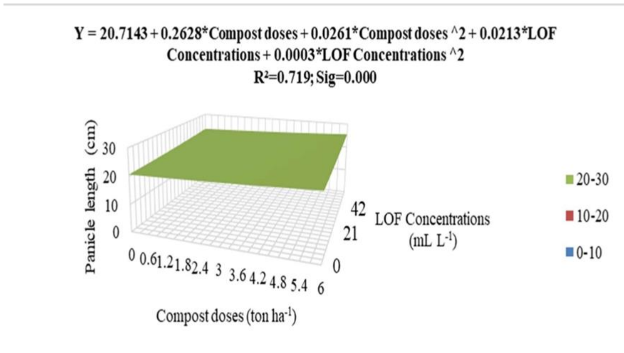


Fig. 5: Graph of interaction between compost dosage and LOF concentration with panicle length characters.

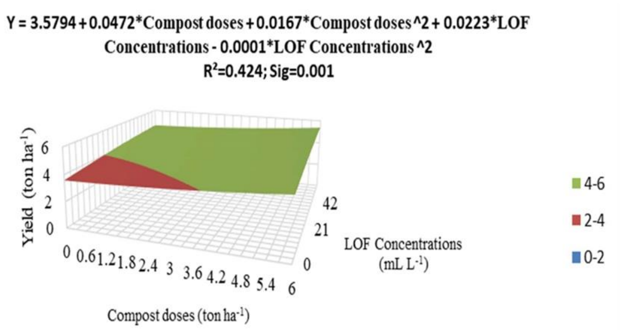
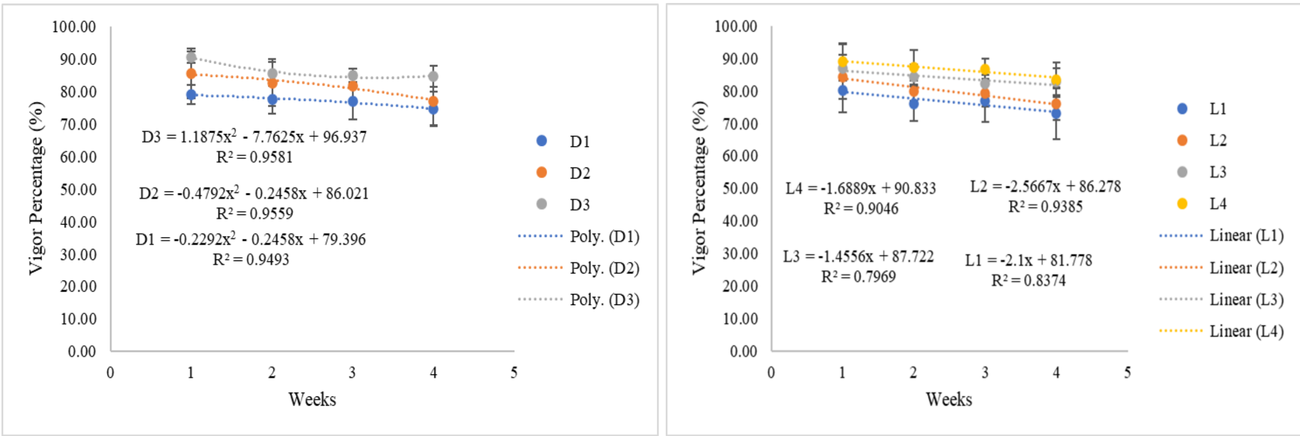


Fig. 6: Graph of interaction between compost dosage and LOF concentration with the yield characters per hectare.

The results of the seed vigor test within four weeks after harvest on the effects of compost and LOF are shown in Fig. 7. Based on this Figure, the compost dosage and LOF concentrations experienced a linear decrease with a constant high determination every week on germination power. Fig. 7A shows that the compost dose of 6tons ha^{-1} is consistently the best every week. Conversely, the dose of 0 ton ha^{-1} is consistent as the lowest dose level every week. Fig. 7B shows the LOF concentration of 60mL L^{-1}, consistently being the best weekly concentration. In contrast, the LOF concentration of 0mL L^{-1} was consistent as the lowest concentration level every week.

DISCUSSION

The analysis of variance showed that the doses of compost, LOF concentrations, and their interactions significantly affected the vegetative, physiological, and generative characters of the black rice Jeliteng variety. However, the interaction has an insignificant effect on several characters. This indicates that several characters constantly change from a low dose to a high dose or vice versa, so the two treatments affect growth characteristics



A ` B

Fig. 7: Graph the relationship between compost dose and seed vigor character A) and LOF concentration relationship graph with seed vigor character B).

independently (Crossa et al, 2015; Abduh et al., 2021). In general, analysis of significant variance can be the initial basis for selecting essential characters in evaluating technology packages on growth and production. This concept has been reported by Abduh et al. (2021) and Farid et al. (2022) on corn. Although this study had several insignificant interaction effects, these characters directly influenced the two single variations. Therefore, all characters can still be evaluated further with a more profound analysis.

Critical character evaluation can be determined by correlating supporting characters and the main character (production per hectare). However, in several studies, the use of correlations needs to be supported by path analysis, especially in the value of the direct effect. This concept has also been reported by Padjung et al. (2021) and Akbar et al. (2021). This is based on the correlation coefficient but cannot show a causal relationship between characters. Correlation can only show the general closeness between two variables, which is still crude, so cross-finding is needed to find out causal relationships by calculating the contribution of the direct influence of a character to the main character (Akbar et al., 2021; Anshori et al., 2022). However, path analysis on many characters must first be screened through a significant correlation analysis of the main characters (Anshori et al., 2022; Fadhilah et al., 2022). This will streamline the process of evaluating essential evaluation criteria in a study. Based on the two analyses, the number of tillers, flag leaf length, flag leaf width, and panicle length had an excellent direct influence on the character of production per hectare. This was also reported by Sabri et al. (2020) on the number of tillers, Faysal et al. (2022) on flag leaf characters, Sabri et al. (2020), and Manasa et al. (2022) on panicle length. Therefore, these four characters can be used as supporting characters for the main character (the yield).

The length and wide characters of flag leaf were significantly influenced by single variations of compost dose and LOF concentration, so the two evaluations were carried out separately. Based on Fig. 1A, 1B, 2A, and 2B, the effect of compost dosing and LOF concentration showed a linear increase in flag leaf length and width. This indicates that the higher the compost dose and the LOF concentration, the width and length of flag leaf characters will increase. This phenomenon is closely related to optimizing plant nutrients, so essential growth characteristics, such as flag leaves, experience a significant increase (Moe et al., 2019a,b). Flag leaves generally have identical photosynthetic potential that fills rice grains (Fabre et al., 2016; Huang et al., 2021). Increasing the length and width of the leaves will affect the area of the capture of solar energy by flag leaves, thereby indirectly contributing to increased productivity (Fabre et al., 2016; Moe et al., 2019b). However, based on this study, the two treatments did not influence flag leaf growth. This indicates that the increase in flag leaf is static or additive, so the combination of treatments cannot suppress each other or spur an increase in flag leaf in general. Even so, this increase directly affects black rice yield, so both results remain a reference in the evaluation process. Based on this, a compost dose of 6tons ha^{-1} and a LOF concentration of 60mL L-1 are the best compost dosages, and the LOF concentration supports the increase in the leaf area of Jeliteng black flag rice.

The characteristics of the number of tillers, panicle length, and production per hectare were significantly affected by multiple doses of compost, LOF concentration, and the interaction between the two. Fig. 3 to 5 reflect the interaction effect of compost dosing and LOF concentration on the number of tillers, panicle length, and yield, respectively. The equations of the three curves show a quadratic graph. However, the number of tillers and the yield show a dynamic quadratic, while panicle length shows a sloping quadratic graph. A positive value in all equation components on the panicle length character indicates this. The dynamic quadratic has an optimal peak point in increasing the number of tillers and the yield. Hence, increasing the dose of compost and LOF beyond the optimal point is no longer effective. However, based on the graph, the total number of tillers curve is more dynamic with the yield. This is different from the panicle length, which has not yet reached the optimal point in the equation, so the increase in compost and LOF can still be carried out beyond the levels in this study. This increase can indirectly optimize the yield potential, where the panicle length character is the character with the most significant direct influence. Based on the three graphs, the compost dosage of 6tons ha^{-1} and the concentration of LOF 60mL L^{-1} is the best combination to support the increase in the number of tillers, panicle length, and the yield of black rice of the Jeliteng variety. This is also in line with research by Yassi et al. (2023), which shows a dynamic linear curve at the dose of compost 0-4tons ha^{-1}. This curve indicates that giving more than 4tons ha^{-1} can still support rice's growth potential and productivity, including black rice. In addition, the research by Bahua and Gubali (2020) also shows a linear graph of LOF concentrations with a range of 0-40mL L^{-1}. This indicates that the addition of concentrations exceeding 40mL L^{-1} can still optimize the potential of rice productivity, including the black rice variety Jeliteng. Therefore, both combinations of compost dosage levels of 6tons ha^{-1} and LOF concentrations of 60mL L^{-1} are recommended for use in rice cultivation, especially the Jeliteng variety of black rice. Meanwhile, increasing the dose of compost and LOF concentration can still be considered in further research.

Based on Fig. 6A and 6B, the effect of compost dosing and LOF concentration showed a linear decrease in seed vigor. However, this decrease was constant, and no interaction occurred, especially in weeks 2, 3 and 4. In general, seed vigor was affected by seed storage time and related to changes in physiological properties. Changes in the physiological properties of seeds, such as the seeds, the seed's initial viability, and the seed's moisture content, cause a slow and irreversible decline in seed quality (Waterworth et al., 2019; Xing et al., 2023). This indicates that seed quality is primarily determined by the initial seeding process, namely the seed's filling. If the seed filling process goes well with complete nutrition, it will correlate with the seed germination process. However, the seeds are stored for several weeks after harvest. This is also indicated by the level of compost dosage of 6tons ha^{-1} and LOF concentration of 60mL L^{-1}, which stably becomes the best compost dose and LOF concentration each week. These results indicate that the application of compost and LOF can also improve the seed quality of the black rice variety Jeliteng. Therefore, combining the two is recommended for producing and seeding black rice of the Jeliteng variety.

Conclusion

The results of this study indicate that the number of tillers, flag leaf length, flag leaf width, panicle length, and yield are suitable for evaluation criteria in evaluating the growth of black rice of the Jeliteng variety. Based on the evaluation of these criteria, combining compost doses of 6tons ha^{-1} and LOF concentration of 60mL L^{-1} is the best combination for supporting the growth and productivity of black rice of the Jeliteng variety. In addition, the two combinations also helped improve the seed quality of the Jeliteng black rice variety. Based on this, the combination of compost doses of 6tons ha^{-1} and LOF concentration of 60mL L^{-1} is recommended for application in the production and seed cultivation of black rice of the Jeliteng variety.

Conflict of Interest

The authors declare there is no conflict of interest.

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Author's Contribution

RR was the lead researcher, conception, and design of the study. MF, AM, and IR provided advice and direction on the research. MFA and ANF provided analysis and interpretation of data in the study. AFA and AML investigated data in the field. MFA, ANF, and FF helped with the data study and manuscript draft. RR and MF helped improve the article's writing.

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