

Integrated Minapadi (Rice-Fish) Farming System: Compost and Local Liquid Biofertilizer Based on Multiple Evaluation Criteria

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Abstract: Rice-fish cultivation, also known as Manipadi in Indonesia, is one of the many integrated farming systems where fish are grown concurrently with rice. However, this integrated system needs to be optimized by organic fertilizer. Application of organic fertilizer such as compost and local biofertilizer when implemented with integrated system can optimize the yield per land for both rice and fish. However, this combination must be evaluated systematically by multiple evaluation criteria and statistical analysis. Therefore, this study aimed to identify the combination of compost doses and/or local liquid biofertilizer concentrations based on multiple evaluation criteria in supporting the productivity of rice-fish integration agriculture. The experiment was carried out in the Wanuae farmer group of Barebbo District, Bone Regency, Indonesia between September 2018 and January 2019. The experiment employed a split plot design with a randomized complete block design (RCBD). The main plot consisted of compost (4 levels), and the subplot was the local biofertilizer source (4 levels). The results demonstrated that the number of fill grains was significantly affected by the compost treatment and the type of the local biofiller. The effect of compost dosing was more dominant in comparison to the biofiller character and its interactions. The compost dosage of 4 tons ha⁻¹ and the local biofertilizer sourced from soaked coconut fiber with bovine urine has been recommended as the combination treatments to optimize the rice yield potential. Moreover, the compost dosage in this Minapadi (rice-fish) study requires further exploration for better understanding.

Keywords: Coconut fiber, Compost dosage, Cow urine, Local biofertilizer, *Oryza sativa*

Citation: Yassi, A.; Farid, M.; Anshori, M.F.; Muchtar, H.; Syamsuddin, R.; Adnan, A. Integrated minapadi (Rice-Fish) farming system: Compost and local liquid biofertilizer based on multiple evaluation criteria.

Academic Editor: Firstname Lastname

Received: date
Accepted: date
Published: date

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1. Introduction

Rice is one the pivotal staple food crop and prime contributor in attaining food security (Sekaran et al. 2021; Tirtalistyani et al. 2022). The consumption of rice per capita of Indonesia for 2022 was 1.45 kg per week or 74.57 kg per capita per year (Annur 2022). This number is relatively higher in comparison to several other countries that are optimizing food diversification. The high demand for rice must be aligned with national rice productivity. In general, national rice production reaches 55.67 tons (Indonesian Statistics 2022). However, persistent growth population and overutilization of resources

are posing various challenges and impeding the yield. (Rumanti et al. 2018). Therefore, increasing productivity per unit of land is key to maintaining food stability in Indonesia.

In order to improve the rice productivity, one of the various efforts that are practiced is the consistent application of chemical fertilizers. Chemical fertilizers are known to provide optimal nutritional needs for rice cultivation (Kobua et al. 2021; Liu et al. 2021; Wan et al. 2021; Wang et al. 2021). However, habitual tendencies of excessive application of fertilizers including high planting intensity determinants a negative impact on soil stability, especially physically and biologically (Kakar et al. 2021; Wan et al. 2021). Several studies have reported the detrimental consequences of chemical fertilizers, few of which includes deleterious effect on the soil structure and soil porosity, affecting the soil to be more sticky when it rains and hard when it is dry (Xing et al. 2019; Iqbal et al. 2021; Wan et al. 2021; Kim et al. 2022). In addition, several studies have also reported that the application of excess chemical fertilizers and a decrease in soil organic matter due to intensive planting had an impact on reducing soil microorganisms (Iqbal et al. 2021; Kakar et al. 2021; Kim et al. 2022). This phenomenon will be more critical if there is no effective resolution. One gateway that can be optimized is the application of the integrated farming concept.

Integrated farming is an approach of optimizing agricultural products that considers sustainable concepts, from an ecological, social, and economic perspective (Peterson et al. 2020a; Fatimah et al. 2020; Freed et al. 2020; Paramesh et al. 2022). The concept focuses on maximizing the use of local resources with concurrent efforts to reduce the input costs for enhancing the land productivity and income (Kinkelaet al. 2017; Peterson et al. 2020b; Freed et al. 2020; Sekaran et al. 2021; Colazo et al. 2022). The theory of integrated agriculture can be practiced by harmonizing agriculture with other fields such as livestock (Peterson et al. 2020a,b; Sekaran et al. 2021; Colazo et al. 2022), fisheries (Nurhayati et al. 2016; Fatimah et al. 2020; Freed et al. 2020; Suryawati et al. 2021), and forestry (Hani et al. 2016; Baliton et al. 2020). One way to strategize this is by the incorporation of rice and fish, also known as Minapadi. Minapadi, a term coined in Indonesia for cross cultivation of rice and fish (Prasetyo et al. 2018; Fatimah et al. 2020; Artawan et al. 2021). Several reports have demonstrated the effectiveness of this combination in proliferating the economic income value of a land (Nurhayati et al. 2016; Kinkelaet al. 2017; Prasetyo et al. 2018; Fatimah et al. 2020). Manure from fish can be a good source of minerals for rice cultivation, while the paddy fields can be a great food reservoir for the fish in return (Kinkelaet al. 2017; Freed et al. 2020). However, the combination of the two is still considered to be ineffective in improving soil status, hence addition of organic fertilizer is essential for a productive Minapadi system. Organic fertilizers such as compost and local biofertilizers are considered effective in supporting plant productivity in a sustainable manner (Kadoglidou et al. 2019; Yu et al. 2019; Litardo et al. 2021; Wang et al. 2021).

Compost is the residue result of soil biological activity that are beneficial for improving physical, chemical, and biological properties (Azim et al. 2018; Brock et al. 2021). These improvements play a very important role in supporting crop growth and production (Brock et al. 2021; Medyńska-Juraszek et al. 2022). Several studies have

reported the effectiveness of compost use in supporting rice productivity (Razavipour et al. 2018; Kadoglidou et al. 2019; Litardo et al. 2021; Phares and Akaba 2021; Sultana et al. 2021; Sutardi et al. 2022). In general, compost is known for its beneficial role in improving soil structure, soil moisture, nutrient retention, and cation exchange capacity (Razavipour et al. 2018; Phares and Akaba 2021; Sultana et al. 2021). In addition, compost also functions as an organic material for microorganisms to be maximized in helping plant growth and productivity (Razavipour et al. 2018; Kadoglidou et al. 2019; Phares and Akaba 2021; Jin et al. 2021). Therefore, the use of compost is highly recommended to support sustainable crop productivity.

Similarly, local liquid biofertilizer is another recommendation in terms of sustainable agriculture prospects (Fasusi et al. 2021; Kumar et al. 2022). This fertilizer is more emphasized on the use of microorganisms that play a role in plant growth. These microorganisms enhance the plant metabolic processes, nutrient absorption, and disease resistance thereby contributing to plant development and productivity (Banayo et al. 2012; Fasusi et al. 2021; Liu et al. 2021; Kumar et al. 2022). Apart from that, this fertilizer also contains various nutrients, vitamins, and hormones that can stimulate an optimal environment for plant growth (Banayo et al. 2012; Zaini et al. 2022). The favorable incorporation of biofertilizers in rice cultivation has also been reported by Banayo et al. (2012), Hazra et al. (2022), Patriyawaty et al. (2022), and Simarmata et al. (2022). Therefore, the use of biofertilizers can be a complement to the Minapadi integrated farming concept.

Based on these potentials, optimizing the combination of compost and local liquid biofertilizer can be an additional input in integrated rice-fish farming (Minapadi). This combination needs to be equipped with optimal concentrations and/or doses of both, so that the evaluation of plantings on the input of compost and local liquid biofertilizer can be maximized. Optimization must be adjusted to the characteristics related to the main objective of the evaluation, namely the rice yield (Farid et al. 2022; Ulfa et al. 2022). However, an assessment that only focuses on the rice yield can result in an overestimated interpretation (Farid et al. 2021). This is based on the genetic constitution of the yield, which is polygenic, so the evaluation needs to involve other distinct characters that support productivity (Kassahun et al. 2013; Fellahi et al. 2018). In addition, the effectiveness of the interaction between rice yield and fish yield is also an important consideration in the optimization. Therefore, a systematic statistical approach is key in evaluating the combination of compost and local liquid biofertilizer in supporting the productivity of rice-fish integration agriculture. The purpose of this study was to identify the combination of compost doses and/or local liquid biofertilizer concentrations in accordance with multiple evaluation criteria in supporting land productivity based on rice-fish integration agriculture.

2. Materials and Methods

The experiment was carried out in the Wanuae farmer group in Barebbo District, Bone Regency (4° 13'–506' South Latitude and 119° 42'–120° 30' East Longitude), Indonesia during the month of September 2018 till January 2019. The study area receives an average

annual rainfall of 201.25 mm/year with 12 rainy days. The average air temperature ranges between 24.50°C–27.60°C and humidity varies between 77%–86%. This research was conducted by implementing the split plot design with randomized complete block design (RCBD). The principal plot of this study was the compost dose (C) that comprised of four levels, namely control without compost (C0), 2 ton ha⁻¹ (C1), 3 ton ha⁻¹ (C2), and 4 ton ha⁻¹ (C3). Meanwhile, the subplots of this study were a combination of local microorganisms with 4 types, namely, zero moles (m0), combination of cow urine with rice water (m1), combination of cow urine moles with water soaked coconut fiber (m2), and combination of cow urine and Maja fruit moles (m3), each randomly applied to the main plot. The collaboration of these factors resulted in 16 combinations which were repeated 3 times, adding total 48 experimental units.

2.1. Land preparation

Land preparation was carried out by repairing the bunds with 40 cm height, and maintaining the width of the base and upper bund at minimum 50 cm and 25 cm respectively. The ditches / kemalir were built 1 m wide and above 50 cm deep in order to protect fish from various threats. Ditches / kemalir were prepared both in the middle and on the surrounding edge of the rice field bunds along with a 70 cm deep storage tank to facilitate the fish harvesting during water draining process with an objective to optimize the ripening potential of rice grain. The description of the Minapadi concept is exhibited in Figure 1.

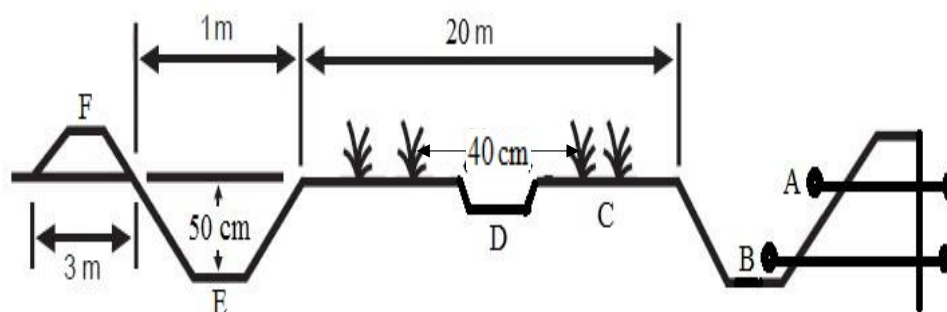


Figure 1. Construction of the Minapadi pond (cross section) Description: A) Water inlet channel, B) Lower water outlet channel, C) Rice plot, D) Middle kemalir, E) Main kemalir, F) Bunds

2.2. Maintenance of Rice Plants

The qualitative analysis of rice seeds was conducted by immersing the seeds in 3% salt solution or soaking them in ZA solution (225 g ZA/l water). The immersed seeds indicate their suitability for planting and were accordingly preselected for this experiment. Following which, the seeds were first soaked and then aged in sequence for 24 hours. The process of seeding was carried out by sowing the germinated seeds in the seeding plots. The nursery was fertilized with ponska NPK, Urea, and SP-36 each at 15 g/m². After the seedlings were 15 days old, the same were planted with 2 seeds per hole. The 2:1 row legowo cropping system was implemented with 40 cm for the largest inter-row spacing, 20 cm for the smallest inter-row spacing, and 10 cm in-row spacing. The planting

conditions are muddy to facilitate the process of making planting points. Then, the seeds were nurtured till the harvest.

Maintenance activities included replanting, weeding, fertilizing, irrigation, and controlling plant-disturbing organisms. Stitching was completed 7–10 days after planting (DAP). The field irrigation was regulated persistently in order to maintain the water level in accordance with the planting system. In the 2:1 legowo cropping system, the water level is maintained at 10 cm above the rice growth surface as the baseline. The first weeding was done at 20 DAP, then the second weeding at 40 DAP, and the third and last weeding at 70 DAP. Fertilizers ponska NPK, urea, and SP-36, were cautiously applied fifty percent below their recommended dose at 167, 100, and 31 kg ha⁻¹. All Chemical fertilizers are given as basic fertilizer to avoid fish growth disturbance caused by the accumulation of chemical fertilizers in the rice fields. In order to meet the nutrient requirements, both straw compost and Local biofertilizer (LB) fertilizer were also incorporated as a treatment in addition to chemical fertilizers. Compost was spread during the pre-planting period, whereas application of Local biofertilizer (LB) fertilizer was carried out once the plants attained 2 Mst. The fertilizer dilution of 1:10 was applied intermittently every 12 days by spraying on the leaves in the morning during stomatal opening. Meanwhile, pests and plant diseases were administered by using insecticides and fungicides rationally to not only avoid potential damage resulting in reduced yields but also to avert interference with the growth and development of fish.

2.3. Preparation of Local Biofertilizer and Compost Fertilizer

LB was resourcefully made by collecting materials surrounding the research location such as Maja fruit, clean water including rice washing, as well as, cow urine, and coconut fiber. The LB coconut coir is prepared by adding and pressing the coconut coir into a bucket already filled with water until fully submerged which is then closed and left for two weeks. Water that is already blackish brown is used as MOL. On the other hand, Maja fruit LB is prepared by blending Maja fruit (grinded) with coconut water and sugar that is stored in a closed container connected to a pipette filled with water for 2 weeks, eventually filtering it. Similarly, LB of rice water is made by storing it in a tightly closed container/bottle with sugar for 2 weeks. These ingredients are then mixed with cow urine in a ratio of 1:1 for each combination.

2.4. Fish Rearing

For this study, tilapia fish was chosen due to its high adaptability to the ecology of paddy fields and superior economic value (Puri et al. 2020; Jyoti et al. 2020). The seeds were selected for their uniform characteristics such as peaked survivability against the heat and their dark hue that functions as camouflage against predators' attacks. Before being spread, the baby fish are first weighed. The tilapia fish were spread in kemalir rice fields measuring 5 cm deep, 12 days post rice planting.

Tilapia was cultured on the rice field map by spreading the feed pellet on kemalir. The recommended amount of feed is 3% the biomass weight. A sample of 10 fish was weighed and averaged to determine the amount of feed. The average weight obtained was then multiplied by the total number of fish in the pond to calculate the biomass weight. The average weight of fish was measured at 246 grams and with total 41 fish, the weight of the biomass equaled to $246 \times 41 = 10,086$ g and accordingly the amount of feed per day

was corresponded to $3\% \times 10,086 \text{ grams} = 303 \text{ grams}$. This ration was fed twice per day. Simultaneously, the water volume was regulated by administering the water level persistently. If there is an increase in the volume of water caused by rain, excess water was removed from the paddy fields in the event of rainfall and conversely, was added from the irrigation channel, when the water volume dropped below the threshold. At the time of treatment, the water in the kemalir was still at a normal level so as not to interfere with the mobility of the fish. Other maintenance activities included monitoring and restricting disease and predator occurrences.

2.5. Harvesting Fish and Rice

Predominantly, rice harvesting is carried out when the seeds attain the ripen stage physiologically or when around 90%–95% of the panicles have turned yellow. Paddy fields require drainage for drying the plots prior to harvest to not only accelerates the panicle ripening but also to prevent the harvested stover from being exposed to water. Rice harvest is done manually by using a sickle and threshing of rice grains using a threshing machine. On other hand, fish harvesting is conducted 10 days before the rice fields are dried. It is done by gradually lowering the water discharge and herding the fish into the holding pond. At the discharge channel in the holding pond, a net is placed at the mouth of the outlet channel to convene fish in the direction of the draining water.

2.6. Parameter Observation and Data Analysis

The observed data included plant height, total tiller, productive tiller, chlorophyll content, stomata count, stomata length, panicle length, number of filled, unfilled as well as total grains, weight of 1000 grain, rice yield, and fish yield. All the data were analyzed by means of variance with an error of 5%, following which, the determination of the evaluation criteria was carried out by correlation and analysis of variance (Sakinah et al. 2022; Anshori et al. 2022). The results of both analyzes were followed by a polynomial structured test for compost concentration and interactions. Meanwhile, the significant effect on the type of LB material was tested by honest significant difference test analysis. The evaluation of fish yield was carried out using regression and 3D plot analysis (Farid et al. 2021).

3. Results and Discussion

The results of the variance show the diversified pattern of significance between characters to the source of the diversity. The compost treatment significantly affected the total tiller, productive tiller, chlorophyll content, number of stomata, stomata length, number of filled grains, number of unfilled grains, number of total grains, rice yield, and fish yield. LB significantly modulates the number of stomata, stomata length, panicle length, number of filled grains, number of unfilled grains, number of total grains, and rice yield. Meanwhile, the interaction of compost and LB has a significant effect on the number of stomata, stomata length, number of unfilled grains, and rice yield.

Table 1. Analysis of variance compost and local biofertilizer treatment of rice growth characters

Characters	Compost (C)	Local biofertilizer (B)	CxB	CV_C	CV_B
Plant height	36.96	149.81	284.71	5.53	5.98

Total tiller	141.66**	5.88	42.31	5.67	12.04
Productive tiller	80.11**	15.1	9.76	8.42	8.03
Chlorophyll content	0.0001**	0.00005	0.00016	7.39	6.88
Stomata count	31468.60**	31645.93**	182124.77**	6.37	6.00
Stomata length	0.0016**	0.0023**	0.0047**	13.19	11.79
Panicle Length	7.40	11.71**	4.91	5.23	2.99
Number of filled grains	2147.75*	2884.83**	948.17	10.79	8.56
Number of unfilled grains	320.60**	532.79**	103.30**	9.59	9.11
Number of total grains	2788.95**	3950.41**	1154.77	10.19	8.83
Weight of 1000 Grain	4.35	14.02	12.54	10.75	4.38
Rice yield	0.32*	0.62**	0.70**	5.56	4.13
Fish Yield	0.2157**	-	-	4.39	-

Notes: CV = coefficient of variation, ** significant effect at 1% error level, * significant effect at 5% error level

The results of the correlation analysis in Figure 2 show that rice yield has a significant correlation with the number of filled grains (0.74), number of unfilled grains (-0.69), number of total grains (0.66), total tiller (0.83), and productive tiller (0.89). The productive tiller character also showed a significant correlation to the number of filled grains (0.7), the number of total grains (0.69), and the total tiller (0.89). Meanwhile, the number of filled grains has a significant correlation with the number of unfilled grains (-0.89), the number of total grains (0.94).

The path analysis results focused on characters that correlated with the rice yield (Table 2). Based on this analysis, the number of total grains is the only character that has a direct negative effect on the rice yield (-0.51). In contrast, the characters of the total tiller (0.31), productive tiller (0.45), and number of filled grains (0.75) have a positive direct effect on the rice yield, although among the three, the number of filled grain characters is the only character with a significant direct effect on rice yield. Further tests of polynomial contrast of compost and LSD 0.05 local biofertilizer assays for the number of filled grains characters are shown in Figures 3A and 3B. Based on the compost treatment, the treatment combination showed linear regression with a determination value of 0.7748 and a gradient of 3.981. Treatment of 4 tons ha⁻¹ is the best compost treatment. Meanwhile, based on local biofertilizer treatment, treatment m3 (119.84a) is the best type of local biofertilizer and m0 is the lowest local biofertilizer treatment (98.33c).

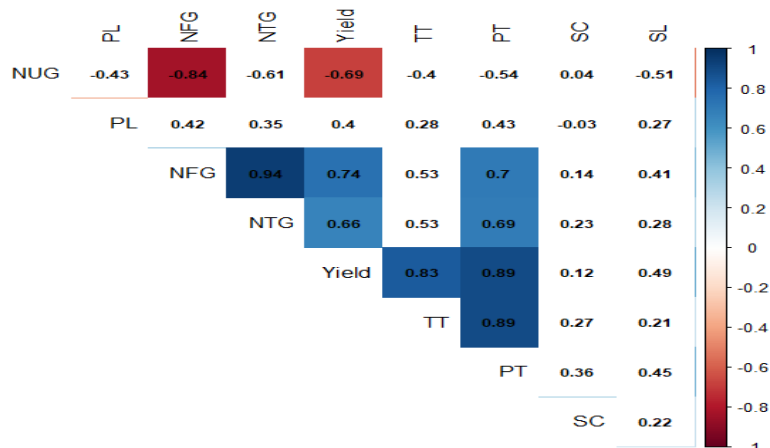


Figure 2. Correlation analysis of rice growth characters (notes: PH= plant height, TT= total tiller, PT= productive tiller, SC = stomata count, SL= stomata length, NFG = number of filled grains, NUG= number of unfilled grains, NTG = number of total grains, Yield = rice yield).

Table 2. Path analysis of several growth characteristics on the rice yield

Character	Direct Effect	Indirect Effect				Correlation
		TT	PT	NFG	NTG	
Total Tillers (TT)	0.31		0.4	0.4	-0.27	0.84
Productive Tillers (PT)	0.45	0.27		0.52	-0.35	0.89
Number of Filled Grains (NFG)	0.75**	0.16	0.31		-0.48	0.74
Number of Total Grains (NTG)	-0.51	0.16	0.31	0.7		0.66
Total Indirect effect		0.59	1.02	1.62	-1.1	

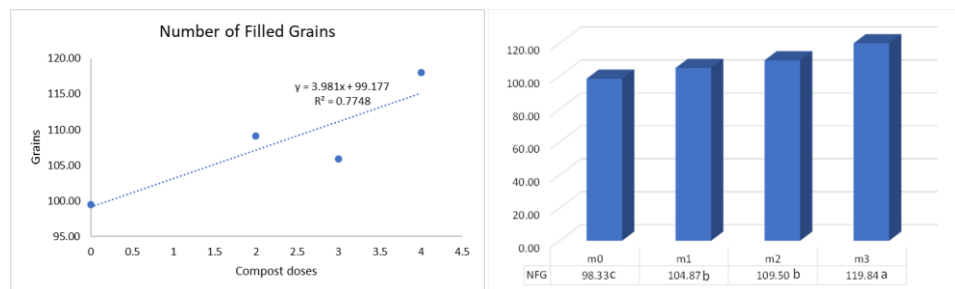
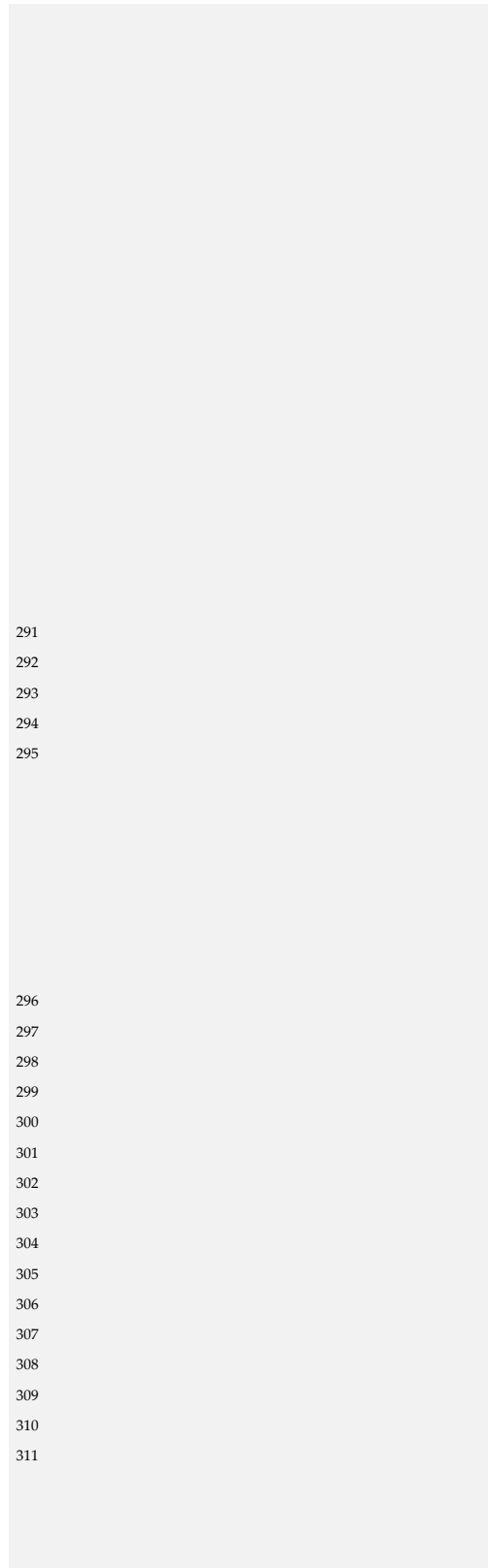


Figure 3. A) Regression analysis of the effect of compost on the number of filled grains B) Honest significant difference test of the effect of the type of local biofertilizer material on the number of filled grains.

The results of the orthogonal-polynomial interaction contrast test on rice yield characters are shown in Figure 4. The results of the analysis demonstrate that all local



biofertilizer treatments have a linear graph with a determination value above 0.9. The m1 biofertilizer treatment had the highest determination value of 0.9887. Based on the gradient value, m0 and m2 have gradient values above 0.3. Meanwhile, m² treatment is a local biofertilizer treatment with the highest gradient value of 0.39.

The results of the analysis of the polynomial contrast test on the fish yield character are shown in Figure 5. The analysis demonstrates that the compost treatment has a linear graph with a very high determination value (0.9988). The growth gradient on the fish yield graph is 0.00907. The results established that compost treatment with 4 ton ha⁻¹ is the most advantageous treatment for optimizing fish yield.

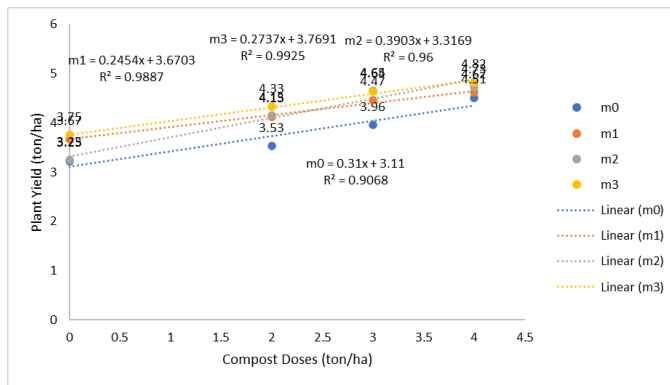


Figure 4. Polynomial-orthogonal interaction analysis of the rice yield character for the type of local biofertilizer (m) for the dose of compost

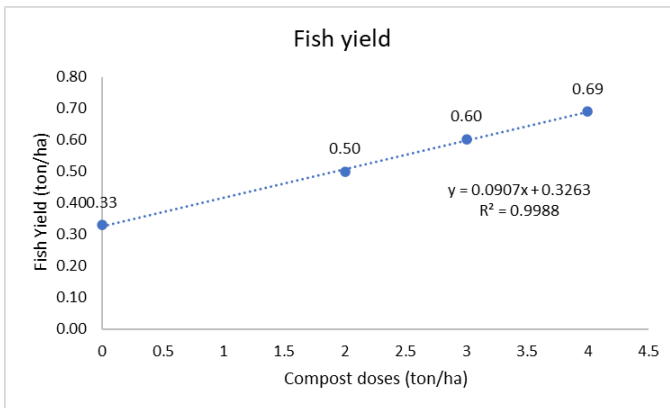
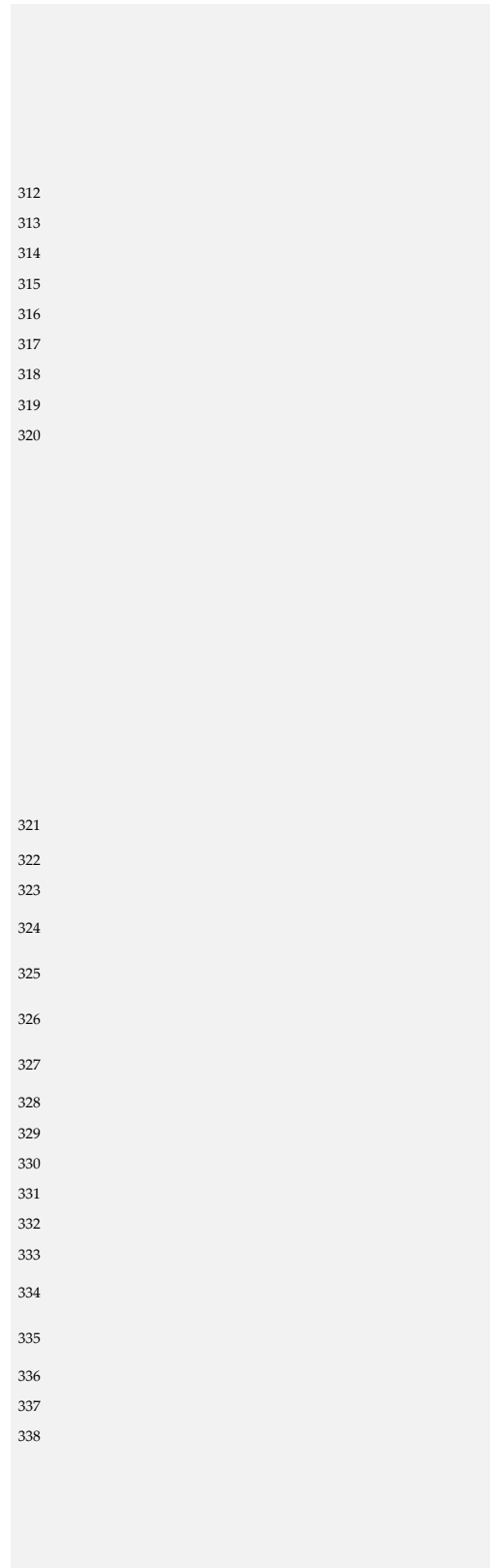


Figure 5. Regression analysis of the dose of compost on the increase in the yield of fish

The results of the 3D analysis plot analysis focused on the three main characters, namely, number of filled grains, rice yield, and fish yield (Figure 6). The combination of the three characters is focused on compost treatment. Based on this analysis, adding



compost (K1, K2, and K3) has a better combination index value than adding compost (K0). The 4-ton ha⁻¹ (K3) treatment is the treatment with the best index value and is found at the top end of the 3D plot. Meanwhile, the R/C ratio analysis is shown in Table 3. Based on this table, the best application of compost is at a compost dosage of 4 tons ha⁻¹. In contrast, the lowest R/C ratio was found in the control treatment (0 tons ha⁻¹).

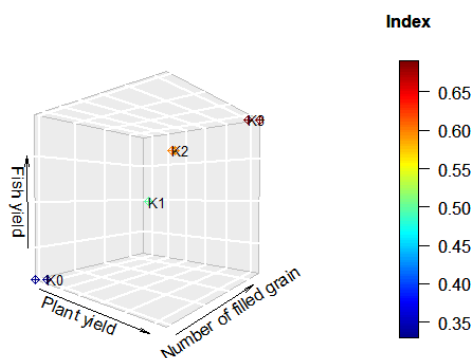


Figure 6. Analysis of 3D plots of the effect of compost based on the interaction of the number of filled grains, the fish yield, and the rice yield.

Table 3. Analysis of land income on compost treatment in Minapadi integration

Compost doses	Cost (C) (Rp)	Revenue (R) (Rp)	Profit (Rp)	R/C ratio
0 ton ha ⁻¹	10,087,478	41,999,800	31,912,322	4.16
2 ton ha ⁻¹	10,337,478	53,802,800	43,465,322	5.2
3 ton ha ⁻¹	10,437,478	59,701,600	49,264,122	5.72
4 ton ha ⁻¹	10,587,478	65,059,200	54,471,722	6.14

Discussion

The results of this study indicate that the effect of compost dosing is more dominant than the biofertilizer character and its interactions. The effects of compost include vegetative, physiological, and generative characteristics. This has been reported by Septiawan et al. (2021), Maninggir et al. (2019), and Sipayung et al. (2018). In contrast, the influence of the type of biofertilizer only plays a role in optimizing production components and stomatal characters. This effect was also reported by Subowo et al. (2010), Kalay et al. (2020), and Miranty (2020). The effect of interaction only modulates few characters. This indicates that each type of biofertilizer relatively has the same response changes to increasing compost doses so that interactions do not occur in some characters. Based on this, differences in patterns of diversity between factors will affect the interpretation of the evaluation in this study; hence the selection of the main parameters is the key to evaluating the technology package for rice growth in the Minapadi concept.

The combination of correlation and path analysis shows that the number of filled grains character is the only character that has a significant direct effect on the rice yield. The character, number of filled grains, can be recommended as the main parameter

supporting the rice yield. In general, the combination of the two analyzes is a multivariate analysis which is mostly used to identify the main parameters supporting production. This has also been reported by Sabouri et al. (2008), Khapte and Jansirani (2014), Kumar et al. (2014), Mustafa et al. (2019), and Akbar et al. (2019). In general, the results of correlation analysis are still influenced by distinct factors; hence the results of this analysis cannot be the main basis for identifying relationships between parameters. The use of cross-tracking is a more in-depth approach than correlation analysis. This analysis can divide the correlation value into direct and indirect effects (Bocianowski et al. 2016). This direct influence is the basis for how big a character's role is in influencing the total diversity of the main characters (Bocianowski et al. 2016; Anshori et al. 2022; Sakinah et al. 2022). However, the use of cross-prints on many characters is ineffective (Anshori et al. 2022), so the characters included need to be selected first through correlation analysis. Therefore, the combination of the two analyzes is considered effective for estimating the main parameters supporting productivity. Based on the analysis concept, the characters of the number of filled grains and the rice yield become reference parameters in the evaluation of organic fertilizer packages in the cultivation of Minapadi.

The number of filled grains is one of the characteristics that play a major role in determining crop production. This has also been reported by Rahmad et al. (2022), Fadhillah et al. (2021), and Asfaruddin et al. (2022). Based on the results of this study, the number of filled grains was significantly affected by the compost treatment and the type of LB. However, the interaction between the two did not affect this character, so the treatment evaluation was carried out individually for this character. Figure 2A displays the effect of compost treatment on the number of filled grains. The results of the analysis in the figure indicate that the compost treatment is relatively linear with a relatively high gradient. A high gradient indicates that the rate of increase in compost is still not close to the optimum level so that the study of compost dosage treatment still requires further exploration. This was also stated by Baba et al. (2021) and Harahap et al. (2020). Nevertheless, this figure already reflects the pivotal role of compost treatment on the number of filled grains character, especially at the compost dosage level of 4 tons ha⁻¹. Figure 2B shows the effect of the type of LB on the character of the number of filled grains, especially when compared to no biofertilizer treatment (m0). The figure recommends the treatment of cow urine and Maja fruit as the best LB. In general, cow urine has a higher nutrient content and contains IAA which can be used as a growth stimulant for growth regulators (Desiana et al., 2013; Pujati et al., 2015). In addition, this effectiveness is optimized with Maja fruit. Maja fruit gives better results in growth and production, containing 2.82% nitrogen, 1.62% phosphorus, 1.22% potassium, and 40.62% carbon (Pane and Marwazi, 2020; Dewi and Ainun, 2022). Based on this, the treatment of compost dosage of 4 tons ha⁻¹ and the local treatment of bovine urine in combination of Maja fruit biofertilizer are recommended treatments in optimizing the character of the number of filled grains.

The most commonly used main character employed in cropping evaluation is the rice yield (Farid et al. 2022; Ulfa et al. 2022). This character is strongly influenced by the

three existing sources of diversity, so the evaluation is based on the analysis of orthogonal-polynomial interactions in Figure 3. The results of the analysis in the figure demonstrate that the effect of compost is predominantly linear on the rate of increase in the rice yield. In addition, the LBs sources has a positive impact on increasing rice yield. However, this increase is very dependent on the difference in gradient between LBs toward increasing the dose of compost. It indicates that LBs produced from various sources have distinct types of microbes and preferences in optimizing the role of compost in the rice yield. This was also stated by Sulistyarningsih and Harsono (2017). Based on the yield interaction analysis, LB from the combination of cow urine with coconut fiber soaking water is highest gradient value of the LB source. This was also reported by Hayat et al. (2021), Rahim et al. (2016), and Bakri (2020). It indicates that the combination of m2 biofertilizer with higher doses of compost will proliferate the rice yield with increased compost dosages. Therefore, m2 LB source and 4-ton ha⁻¹ compost is recommended as the best treatment combination for optimizing rice yield potential. Although, the combined position of the LB of cow urine with Maja fruit showed higher (m3) than biofertilizer m2 at the number of filled grains and rice yield.

The fish yield in this study only focused on the effect of compost. This is because the LB is only applied to the plant canopy, so the effectiveness of the treatment does not directly affect fish yield. Based on Figure 4, the addition of compost significantly increases the fish yield potential in the rice-fish integration concept. This is seen in the very high determination value close to 1. In addition, a report by Parvez et al. (2019) and Jyoti et al. (2020) also stated that the addition of compost affected fish weight in the paddy-fish integration concept. In general, high doses of compost not only play a role in the process of increasing plant growth but also play a role in improving water quality (Kumar and Godara 2016). These improvements will provide a good environment for the growth of phytoplankton and other microbes. Phytoplankton are organisms similar to plants in water (Cloern et al. 2014), so adding compost will also increase the nutrient content required for the growth of phytoplankton in water (Hastuti et al. 2019). This indicates that increasing compost in a rice field will provide comfort for phytoplankton to grow and develop, so that fish can also thrive in rice fields. This environmental improvement is also in line with good habitat for tilapia. According to He et al. (2020), tilapia with the Minapadi integration system can improve the quality and production of fish meat. This is because the ecology of the rice fields has good water quality and lots of microbes making it suitable for maximal tilapia growth. Therefore, the addition of compost to the rice-fish integration system is required to augment the fish yield potential in rice fields.

The results of the three main characters illustrate that the application of compost affects the increase in the three characters linearly. However, since the interaction between the three traits cannot be detected, a 3D plot analysis is still essential. Based on the results of the 3D analysis, the compost treatment had a domino effect on the three characters. This is indicated by the large difference in spatial position between the control and the compost application. The position of the distant space indicates the degree of significance of a treatment, so it can be concluded that compost must be applied to the rice-fish integrated cropping system. This will have a large effect on increasing the potential income per paddy field. This potential has also been reflected in the R/C ratio shown in Table 3, where

the application of minimal compost provides a difference in R/C ratio of 1.04 in comparison to no compost treatment. This R/C ratio is a comparison between total revenue and total costs as an indicator in measuring business feasibility (Suratiah, 2015). Even though compost has a high dominance, it is also recommended to apply local biofertilizer to optimize the potential for increasing the R/C ratio. This refers to the potential interaction between compost and local biofertilizer on rice yield.

4. Conclusions

This research establishes that the application of compost plays a very important role in increasing the potential of Minapadi integrated agriculture. In addition, the concept of the multiple evaluation criteria through secondary character approach is effective for use in the evaluation of cultivation technology. An effective secondary character for this research is the number of filled grains. Based on the overall evaluation, the best dose of compost in this study was 4 tons/ha. This dose can increase the potential income per land with a difference in the R/C ratio of up to 2 points and is recommended to be increased again. Meanwhile, the compost dosage of 4 tons ha⁻¹ and the local biofertilizer from cow urine with coconut fiber soaking is recommended combination treatments in optimizing rice yield potential. Moreover, the compost dosage in this Minapadi (rice-fish) study also requires further exploration for better understanding.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, Amir Yassi, Muh Farid, Rajuddin Syamsuddin; methodology, Amir Yassi, Muh Farid, Hamdani Muchtar, Rajuddin Syamsuddin; validation, Muhammad Fuad Anshori; formal analysis, Muhammad Fuad Anshori; Hamdani Muchtar; Amir Yassi; investigation, Hamdani Muchtar, Adnan Adnan, and Muh Farid; resources, Muh Farid; Hamdani Muchtar; data curation, Hamdani Muchtar, and Muhammad Fuad Anshori; writing—original draft preparation, Amir Yassi, and Muhammad Fuad Anshori; writing—review and editing, Muh Farid, Adnan Adnan, Rajuddin Syamsuddin; visualization, Muhammad Fuad Anshori; supervision, Amir Yassi, Muh Farid, and Rajuddin Syamsuddin. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding

Data Availability Statement: Not applicable.

Acknowledgments: We are grateful to the publication management center of Hasanuddin University for providing the facilities, like workshop training and Enago proofreading for this article.

Conflicts of Interest: The authors declare no conflict of interest” and “The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results”.

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February 4, 2023

To
The Editor in Chief
Journal of “**Agronomy**”, MDPI

Dear Editor,

I am submitting an original article entitled “ Integrated Minapadi (Rice-Fish) Farming System: Compost and Local Liquid Biofertilizer Based on Multiple Evaluation Criteria” by Amir Yassi, Muh Farid, Muhammad Fuad Anshori, Hamdani Muchtar, Rajuddin Syamsuddin, and Adnan Adnan which I would like to submit for publication in Journal of “**Agronomy**”, MDPI.

We believe that this manuscript is appropriate for publication by Journal of “**Agronomy**”, MDPI because this paper is dealing with **Farming Sustainability** Section with the topic: **Cropping Systems and Agronomic Management Practices of Field Crops**. We discussed the combination of compost doses and/or local liquid biofertilizer concentrations based on multiple evaluation criteria in supporting the productivity of rice-fish integration agriculture. We found that the number of fill grains was significantly affected by the compost treatment and the type of the local biofiller. The effect of compost dosing was more dominant in comparison to the biofiller character and its interactions. The compost dosage of 4 tons ha⁻¹ and the local biofertilizer sourced from soaked coconut fiber with bovine urine has been recommended as the combination treatments to optimize the rice yield potential. Moreover, the compost dosage in this Minapadi (rice-fish) study requires further exploration for better understanding.

We confirm that this manuscript has not been published and is not under consideration for publication elsewhere. We also declare that all authors have approved the manuscript and also do not have any conflict of interest. We also declare that we do not have any issue related to the journal policy including ethical consent. We do really hope that this manuscript will gain your approval. Thank you for your consideration.

Finally, We would like to inform you that We also submit the proofreading proof in the submission system.

Sincerely yours,

Muh Farid

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¹ In case of any clarifications or questions please approach us at submit@enago.com

Dear Author:

Thank you for entrusting us with your manuscript and opting for our Language Check service. We have edited your assignment UNPMCW-69 for basic language and grammar, from the aspect of fluency, and would like to share our experience in editing your manuscript. Overall, we have made moderate revisions to the manuscript in terms of language and grammar. We have also made some sentence reconstructions and word choice changes for accuracy and enhanced clarity. We hope that the revisions meet your expectations from our service.

As a step toward finalization, we suggest that you check all changes/clarifications in the edited file, as this is important.

We wish you the very best and look forward to working with you again.

Sincerely,

Your Editor

Russell

¹Editor Message is a means of personal communication between the author and the editor through which the editor clarifies manuscript-related points, provides suggestions/improvements, and/or notifies the author about the next steps.

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Comment dan balasan kedua Reviewer**Table of Response****Reviewer: 1**

In general, we so thanks for your comment to improve our article. We have revised it as you suggested. Meanwhile, for English editing, we will use an English editing service from MDPI after our article has been accepted. The list of review comments and our response are shown in below:

Q1	What is the difference of local biofertilizer and compost fertilizer? If the authors can add some key nutrition information about these two fertilizers , it will be better.
A1	Thank you for your question. In our study, there were several local biofertilizers and compost fertilizers, namely (1) the local biofertilizer used was in a liquid state and was applied by spray. In contrast, compost in solid form is applied by sprinkling compost on paddy fields according to the treatment (2) local biofertilizer is made privately while compost is purchased at a farmer's shop with specific nutritional provisions, (3) local biofertilizer is focused on adding nutrients through leaves, increasing plant tolerance to pathogens, and induces plant hormones. Meanwhile, compost, besides acting as a nutrient provider, this fertilizer also plays a role in improving soil structure and soil biology. The biological properties of the soil and the nutrient content contained in the compost will also increase microorganisms and plankton, which are suitable for fish growth. The characteristic of local liquid biofertilizer and compost fertilizer has shown in Table 2 and Table 3, respectively.
Revision	Table 2 and 3, Lines 207-208

Q2	Whether the authors have analysed the nutrition concentration in the water from paddy field?
A2	Thank you for your question. We have analyzed the water parameter before and after the treatment application (Table 4). Besides that, we also add the soil status in our study field (Table 1).
Revision	Table 1 (line 167) and Table 4 (Line 242)

Q3	Why is it better for 4 ton local fertilizer per ha?
A3	Thank you for your question. Maybe you mean the compost fertilizer. The compost fertilizer has four levels, namely, 0 ton ha ⁻¹ , 2 ton ha ⁻¹ , 3 ton ha ⁻¹ , and 4 ton ha ⁻¹ . In our study, the compost fertilizer has an excellent linear regression to the rice and fish yield with a high gradient and determination value. Besides that, many studies have reported the effectiveness of high doses of compost on rice yield (Razavipour et al. 2018; Kadoglidou et al. 2019; Litardo et al. 2021; Phares and Akaba 2021; Sultana et al. 2021; Sutardi et al. 2022) and fish yield (Kumar and Godara 2016; Parvez et al. 2019; Jyoti et al. 2020). Therefore, we choose the high compost doses (4 tons ha ⁻¹) in this study.
Revision	-

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Q4	The format of the manuscript is not regular.
A4	Thank you very much for your suggestion. we have revised the manuscript format according to Agronomy guidelines
Revision	Almost in revised manuscript

Table of Response

Reviewer: 2

In general, we so thanks for your comment to improve our article. We have revised it as you suggested. The list of review comments and our response are shown in below:

Q1	A number of technical errors need to be corrected, you will surely have feedback from other reviews. For example, formatting errors point 2.6- wrong format, unit format unification,add information on fertilizers
A1	Thank you for your correction. We have revised the format, added the parameters unit, and added fertilizer information (Table 2 and Table 3).
Revision	Table 2 and Table 3 (lines 211-213) and subsection of <i>Parameter Observation and Data Analysis</i> (Lines 257-260)

Q2	The results section and the discussion then look better. The conclusion corresponds to the research. Perhaps the novelty of your ideas could be emphasized in the abstract.
A2	Thank you for your correction. We have added and sharpened our novelty in abstract section.
Revision	The compost dosage of 4 tons ha ⁻¹ and the local biofertilizer sourced from soaked coconut fiber with cow urine have been recommended as combination treatments to optimize the yield potential of rice and fish. The Minapadi (rice fish) with additional high compost effectively increased the farmer's outcome with a 2-point R/C ratio than without compost. Moreover, the compost dosage in this Minapadi study requires further exploration for better understanding (lines 28-32)

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Hasil Revisi Review 1

Article

Integrated Minapadi (Rice-Fish) Farming System: Compost and Local Liquid Biofertilizer Based on Multiple Evaluation Criteria

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Abstract: Rice-fish cultivation, also known as Manipadi in Indonesia, is one of the many integrated farming systems where fish are grown concurrently with rice. However, this integrated system needs to be optimized by organic fertilizer. Application of organic fertilizer such as compost and local bi-ofertilizer when implemented with integrated system can optimize the yield per land for both rice and fish. However, this combination must be evaluated systematically by multiple evaluation criteria and statistical analysis. Therefore, this study aimed to identify the combination of compost doses and/or local liquid biofertilizer concentrations based on multiple evaluation criteria in supporting the productivity of rice-fish integration agriculture. The experiment was carried out in the Wanuae farmer group of Barebbo District, Bone Regency, Indonesia between September 2018 and January 2019. The experiment employed a split plot design with a randomized complete block design (RCBD). The main plot consisted of compost (4 levels), and the subplot was the local biofertilizer source (4 levels). The results demonstrated that the number of fill grains was significantly affected by the compost treatment and the type of the local biofiller. The effect of compost dosing was more dominant in comparison to the local biofertilizer character and its interactions. The compost dosage of 4 tons ha⁻¹ and the local biofertilizer sourced from soaked coconut fiber with cowurine has been recommended as the combination treatments to optimize the rice and fish yield potential. The Minapadi (rice fish) with additional high compost effectively increased the farmer's outcome with a 2-point R/C ratio than without compost. Moreover, the compost dosage in this Minapadi study requires further exploration for better understanding.

Keywords: Agronomy; collaborator interaction; drought stress; image processing; mapping analysis; plant breeding

Citation: Yassi, A.; Farid, M.;

Anshori, M.F.; Muchtar, H.;

Syamsuddin, R.; Adnan, A. . . Integrated Minapadi (Rice-Fish) Farming System: Compost and Local Liquid Biofertilizer Based on Multiple Evaluation Criteria.

Academic Editor: Firstname Last-name

Received: date

Accepted: date

Published: date

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1. Introduction

Rice is one the pivotal staple food crop and prime contributor in attaining food security (Sekaran et al. 2021; Tirtalistyani et al. 2022). The consumption of rice per capita of Indonesia for 2022 was 1.45 kg per week or 74.57 kg per capita per year (Annur 2022). This number is relatively higher in comparison to several other countries that are optimizing

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food diversification. The high demand for rice must be aligned with national rice productivity. In general, national rice production reaches 55.67 tons (Indonesian Statistics 2022). However, persistent growth population and overutilization of resources are posing various challenges and impeding the yield. (Rumanti et al. 2018). Therefore, increasing productivity per unit of land is key to maintaining food stability in Indonesia.

In order to improve the rice productivity, one of the various efforts that are practiced is the consistent application of chemical fertilizers. Chemical fertilizers are known to provide optimal nutritional needs for rice cultivation (Kobua et al. 2021; Liu et al. 2021; Wan et al. 2021; Wang et al. 2021). However, habitual tendencies of excessive application of fertilizers including high planting intensity determinants a negative impact on soil stability, especially physically and biologically (Kakar et al. 2021; Wan et al. 2021). Several studies have reported the detrimental consequences of chemical fertilizers, few of which includes deleterious effect on the soil structure and soil porosity, affecting the soil to be more sticky when it rains and hard when it is dry (Xing et al. 2019; Iqbal et al. 2021; Wan et al. 2021; Kim et al. 2022). In addition, several studies have also reported that the application of excess chemical fertilizers and a decrease in soil organic matter due to intensive planting had an impact on reducing soil microorganisms (Iqbal et al. 2021; Kakar et al. 2021; Kim et al. 2022). This phenomenon will be more critical if there is no effective resolution. One gateway that can be optimized is the application of the integrated farming concept.

Integrated farming is an approach of optimizing agricultural products that considers sustainable concepts, from an ecological, social, and economic perspective (Peterson et al. 2020a; Fatimah et al. 2020; Freed et al. 2020; Paramesh et al. 2022). The concept focuses on maximizing the use of local resources with concurrent efforts to reduce the input costs for enhancing the land productivity and income (Kinkelaet al. 2017; Peterson et al. 2020b; Freed et al. 2020; Sekaran et al. 2021; Colazo et al. 2022). The theory of integrated agriculture can be practiced by harmonizing agriculture with other fields such as livestock (Peterson et al. 2020a,b; Sekaran et al. 2021; Colazo et al. 2022), fisheries (Nurhayati et al. 2016; Fatimah et al. 2020; Freed et al. 2020; Suryawati et al. 2021), and forestry (Hani et al. 2016; Baliton et al. 2020). One way to strategize this is by the incorporation of rice and fish, also known as Minapadi. Minapadi, a term coined in Indonesia for cross cultivation of rice and fish (Prasetyo et al. 2018; Fatimah et al. 2020; Artawan et al. 2021). Several reports have demonstrated the effectiveness of this combination in proliferating the economic income value of a land (Nurhayati et al. 2016; Kinkelaet al. 2017; Prasetyo et al. 2018; Fatimah et al. 2020). Manure from fish can be a good source of minerals for rice cultivation, while the paddy fields can be a great food reservoir for the fish in return (Kinkelaet al. 2017; Freed et al. 2020). However, the combination of the two is still considered to be ineffective in improving soil status, hence addition of organic fertilizer is essential for a productive Minapadi system. Organic fertilizers such as compost and local biofertilizers are considered effective in supporting plant productivity in a sustainable manner (Kadoglidou et al. 2019; Yu et al. 2019; Litardo et al. 2021; Wang et al. 2021).

Compost is the residue result of soil biological activity that are beneficial for improving physical, chemical, and biological properties (Azim et al. 2018; Brock et al. 2021). These improvements play a very important role in supporting crop growth and production (Brock et al. 2021; Medyńska-Juraszek et al. 2022). Several studies have reported the effectiveness of compost use in supporting rice productivity (Razavipour et al. 2018; Kadoglidou et al. 2019; Litardo et al. 2021; Phares and Akaba 2021; Sultana et al. 2021; Sutardi et al. 2022). In general, compost is known for its beneficial role in improving soil structure, soil moisture, nutrient retention, and cation exchange capacity (Razavipour et al. 2018; Phares and Akaba 2021; Sultana et al. 2021). In addition, compost also functions as an organic material for microorganisms to be maximized in helping plant growth and productivity (Razavipour et al. 2018; Kadoglidou et al. 2019; Phares and Akaba 2021; Jin et al. 2021). Therefore, the use of compost is highly recommended to support sustainable crop productivity.

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Similarly, local liquid biofertilizer is another recommendation in terms of sustainable agriculture prospects (Fasusi et al. 2021; Kumar et al. 2022). This fertilizer is more emphasized on the use of microorganisms that play a role in plant growth. These microorganisms enhance the plant metabolic processes, nutrient absorption, and disease resistance thereby contributing to plant development and productivity (Banayo et al. 2012; Fasusi et al. 2021; Liu et al. 2021; Kumar et al. 2022). Apart from that, this fertilizer also contains various nutrients, vitamins, and hormones that can stimulate an optimal environment for plant growth (Banayo et al. 2012; Zaini et al. 2022). The favorable incorporation of biofertilizers in rice cultivation has also been reported by Banayo et al. (2012), Hazra et al. (2022), Patriyawaty et al. (2022), and Simarmata et al. (2022). Therefore, the use of biofertilizers can be a complement to the Minapadi integrated farming concept.

Based on these potentials, optimizing the combination of compost and local liquid biofertilizer can be an additional input in integrated rice-fish farming (Minapadi). This combination needs to be equipped with optimal concentrations and/or doses of both, so that the evaluation of plantings on the input of compost and local liquid biofertilizer can be maximized. Optimization must be adjusted to the characteristics related to the main objective of the evaluation, namely the rice yield (Farid et al. 2022; Ulfa et al. 2022). However, an assessment that only focuses on the rice yield can result in an overestimated interpretation (Farid et al. 2021). This is based on the genetic constitution of the yield, which is polygenic, so the evaluation needs to involve other distinct characters that support productivity (Kassahun et al. 2013; Fellahi et al. 2018). In addition, the effectiveness of the interaction between rice yield and fish yield is also an important consideration in the optimization. Therefore, a systematic statistical approach is key in evaluating the combination of compost and local liquid biofertilizer in supporting the productivity of rice-fish integration agriculture. The purpose of this study was to identify the combination of compost doses and/or local liquid biofertilizer concentrations in accordance with multiple evaluation criteria in supporting land productivity based on rice-fish integration agriculture.

2. Materials and Methods

The experiment was carried out in the Wanuae farmer group in Barebbo District, Bone Regency (4° 13'–506' South Latitude and 119° 42'–120° 30' East Longitude), Indonesia during the month of September 2018 till January 2019. The study area receives an average annual rainfall of 201.25 mm/year with 12 rainy days. The average air temperature ranges between 24.50°C–27.60°C and humidity varies between 77%–86%. This research was conducted by implementing the split plot design with randomized complete block design (RCBD). The principal plot of this study was the compost dose (C) that comprised of four levels, namely control without compost (C0), 2 ton ha⁻¹ (C1), 3 ton ha⁻¹ (C2), and 4 ton ha⁻¹ (C3). Meanwhile, the subplots of this study were a combination of local microorganisms with 4 types, namely, control (m0), combination of cow urine with water of rice washing (m1), combination of cow urine moles with water-soaked coconut fiber (m2), and combination of cow urine and Maja fruit moles (m3), each randomly applied to the main plot. The collaboration of these factors resulted in 16 combinations which were repeated 3 times, adding total 48 experimental units.

2.1. Land preparation

Land preparation was carried out by repairing the bunds with 40 cm height and maintaining the width of the base and upper bund at minimum 50 cm and 25 cm respectively. The ditches were built 1 m wide and above 50 cm deep in order to protect fish from various threats. Ditches were prepared both in the middle and on the surrounding edge of the rice field bunds along with a 70 cm deep storage tank to facilitate the fish harvesting during water draining process with an objective to optimize the ripening potential of rice grain. The description of the Minapadi concept is exhibited in Figure 1. Meanwhile, the nutrition land in this study was shown with Table 1.

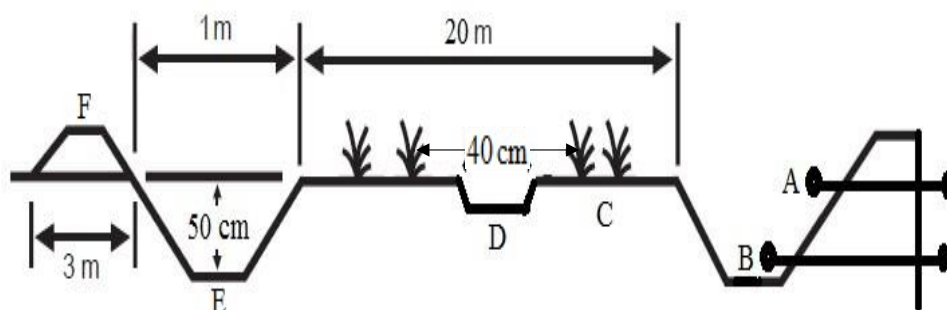


Figure 1. Construction of the Minapadi pond (cross section) Description: A) Water inlet channel, B) Lower water outlet channel, C) Rice plot, D) Middle ditches, E) Main ditches, F) Bunds.

Table 1. Soil status on study field

Parameter	unit	Value
Texture		Dusty Clay
Clay	%	38
dust	%	50
Sand	%	12
C-Organic	%	2.35
Total Nitrogen	%	0.11
C/N	ppm	21
P Olsen	ppm	6.6
K	cmol (+) kg ⁻¹	0.08
Ca	cmol (+) kg ⁻¹	6.03
Mg	cmol (+) kg ⁻¹	2.53
Na	cmol (+) kg ⁻¹	0.08
cation exchange capacity	me/100g	20.65

2.2. Maintenance of Rice Plants

The qualitative analysis of rice seeds was conducted by immersing the seeds in 3% salt solution or soaking them in ZA solution (225 g ZA/l water). The immersed seeds indicate their suitability for planting and were accordingly preselected for this experiment. Following which, the seeds were first soaked and then aged in sequence for 24 hours. The process of seeding was carried out by sowing the germinated seeds in the seeding plots. The nursery was fertilized with ponska NPK, Urea, and SP-36 each at 15 g/m². After the seedlings were 15 days old, the same were planted with 2 seeds per hole. The 2:1 row legowo cropping system was implemented with 40 cm for the largest inter-row spacing, 20 cm for the smallest inter-row spacing, and 10 cm in-row spacing. The planting conditions are muddy to facilitate the process of making planting points. Then, the seeds were nurtured till the harvest.

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Maintenance activities included replanting, weeding, fertilizing, irrigation, and controlling plant-disturbing organisms. Stitching was completed 7–10 days after planting (DAP). The field irrigation was regulated persistently in order to maintain the water level in accordance with the planting system. In the 2:1 legowo cropping system, the water level is maintained at 10 cm above the rice growth surface as the baseline. The first weeding was done at 20 DAP, then the second weeding at 40 DAP, and the third and last weeding at 70 DAP. Fertilizers ponska NPK, urea, and SP-36, were cautiously applied fifty percent below their recommended dose at 167, 100, and 31 kg ha⁻¹. All Chemical fertilizers are given as basic fertilizer to avoid fish growth disturbance caused by the accumulation of chemical fertilizers in the rice fields. In order to meet the nu-trient requirements, both straw compost and Local biofertilizer (LB) fertilizer were also incorporated as a treatment in addition to chemical fertilizers. Compost was spread during the pre-planting period, whereas application of Local biofertilizer (LB) fertilizer was carried out once the plants attained 2 Mst. The fertilizer dilution of 1:10 was applied intermittently every 12 days by spraying on the leaves in the morning during stomatal opening. Meanwhile, pests and plant diseases were administered by using insecticides and fungicides rationally to not only avoid potential damage resulting in reduced yields but also to avert interference with the growth and development of fish.

2.3. Preparation of Local Biofertilizer and Compost Fertilizer

LB was resourcefully made by collecting materials surrounding the research location such as, cow urine + water of rice washing, cow urine + coconut fiber. and cow urine + Maja fruit. The LB coconut coir is prepared by adding and pressing the coconut coir into a bucket already filled with water until fully submerged which is then closed and left for two weeks. Water that is already blackish brown is used as LB. On the other hand, Maja fruit LB is prepared by blending Maja fruit (grinded) with coconut water and sugar that is stored in a closed container connected to a pipette filled with water for 2 weeks, eventually filtering it. Similarly, LB of rice water is made by storing it in a tightly closed container/bottle with sugar for 2 weeks. These ingredients are then mixed with cow urine in a ratio of 1:1 for each combination. The nutrition component of each LB was shown in Table 2. Meanwhile, compost fertilizer was taken on farm shop with nutrient component list on Table 3.

Table 2. Analysis of nutrient content of local liquid biofertilizer

Local biofertilizer	Kjeldahl	Ekstrak HCl	
	N(%)	P2O5 (%)	K2O (%)
cow urine + water of rice washing	0.36	0.39	0.45
cow urine + coconut fiber	0.34	0.42	0.66
cow urine + Maja fruit	0.4	0.44	0.59

Table 3. Analysis of nutrient content of compost fertilizer

pH (H2O)	Walkley & Black	Kjeldahl N (%)	C/N	HNO3:HClO4	
	C (%)			P (%)	K (%)
6.86	15.25	0.55	28	0.15	0.32

2.4. Fish Rearing

For this study, tilapia fish was chosen due to its high adaptability to the ecology of paddy fields and superior economic value (Puri et al. 2020; Jyoti et al. 2020). The seeds were selected for their uniform characteristics such as peaked survivability against the heat and their dark hue that functions as camouflage against predators' attacks. Before being spread, the baby fish are first weighed. The tilapia fish were spread in kemalir rice fields measuring 5 cm deep, 12 days post rice planting.

Tilapia was cultured on the rice field map by spreading the feed pellet on kemalir. The recommended amount of feed is 3% the biomass weight. A sample of 10 fish was weighed and averaged to determine the amount of feed. The average weight obtained was then multiplied by the total number of fish in the pond to calculate the biomass weight. The average weight of fish was measured at 246 grams and with total 41 fish, the weight of the biomass equaled to $246 \times 41 = 10,086$ g and accordingly the amount of feed per day was corresponded to $3\% \times 10,086$ grams = 303 grams. This ration was fed twice per day. Simultaneously, the water volume was regulated by administering the water level persistently. If there is an increase in the volume of water caused by rain, excess water was removed from the paddy fields in the event of rainfall and conversely, was added from the irrigation channel, when the water volume dropped below the threshold. At the time of treatment, the water in the kemalir was still at a normal level so as not to interfere with the mobility of the fish. Other maintenance activities included monitoring and restricting disease and predator occurrences. Meanwhile, water status parameters in our study were shown in Table 4.

Table 4. Analysis of water quality in the study location of Bone Regency South Sulawesi.

Parameters	Unit	C1	C2	C3	C4
Before treatment					
Ammonia	ppm	0.006	0.009	0.007	0.001
Dissolved Oksigen (DO)	ppm	10.6	10	8.2	8.6
Carbon Dioxide (CO ₂)	ppm	8	10	9	9
After treatment					
Ammonia	ppm	0.018	0.019	0.021	0.051
Dissolved Oksigen (DO)	ppm	8.2	6	10.5	7.4
Carbon Dioxide (CO ₂)	ppm	9	10	10	9

2.5. Harvesting Fish and Rice

Predominantly, rice harvesting is carried out when the seeds attain the ripen stage physiologically or when around 90%–95% of the panicles have turned yellow. Paddy fields require drainage for drying the plots prior to harvest to not only accelerates the panicle ripening but also to prevent the harvested stover from being exposed to water. Rice harvest is done manually by using a sickle and threshing of rice grains using a threshing machine. On other hand, fish harvesting is conducted 10 days before the rice fields are dried. It is done by gradually lowering the water discharge and herding the fish into the holding pond. At the discharge channel in the holding pond, a net is placed at the mouth of the outlet channel to convene fish in the direction of the draining water.

2.6. Parameter Observation and Data Analysis

The observed data included plant height (cm), total tiller, productive tiller, chlorophyll content, stomata count, stomata length (mm), panicle length (cm), number of filled grains (grains), Number of unfilled grains (grains), Number of total grains (grains), weight of 1000 grain (g), rice yield (ton ha⁻¹), and fish yield. All the data were analyzed by means of variance with an error of 5%, following which, the determination of the evaluation criteria was carried out by correlation and analysis of variance (Sakinah et al. 2022; Anshori et al. 2022). The results of both analyzes were followed by a polynomial structured test for compost concentration and interactions. Meanwhile, the significant effect on the type of LB material was tested by honest significant difference test analysis. The evaluation of fish yield was carried out using regression and 3D plot analysis (Farid et al. 2021).

3. Results

The results of the variance show the diversified pattern of significance between characters to the source of the diversity. The compost treatment significantly affected the total tiller, productive tiller, chlorophyll content, number of stomata, stomata length, number of filled grains, number of unfilled grains, number of total grains, rice yield, and fish yield. LB significantly modulates the number of stomata, stomata length, panicle length, number of filled grains, number of unfilled grains, number of total grains, and rice yield. Meanwhile, the interaction of compost and LB has a significant effect on the number of stomata, stomata length, number of unfilled grains, and rice yield (Table 5).

The results of the correlation analysis in Figure 2 show that rice yield has a significant correlation with the number of filled grains (0.74), number of unfilled grains (−0.69), number of total grains (0.66), total tiller (0.83), and productive tiller (0.89). The productive tiller character also showed a significant correlation to the number of filled grains (0.7), the number of total grains (0.69), and the total tiller (0.89). Meanwhile, the number of filled grains has a significant correlation with the number of unfilled grains (−0.89), the number of total grains (0.94).

Table 5. Analysis of variance compost and local biofertilizer treatment of rice growth characters

Characters	Compost (C)	Local biofertilizer (B)	CxB	CV_C	CV_B
Plant height	36.96	149.81	284.71	5.53	5.98
Total tiller	141.66**	5.88	42.31	5.67	12.04
Productive tiller	80.11**	15.1	9.76	8.42	8.03
Chlorophyll content	0.0001**	0.00005	0.00016	7.39	6.88
Stomata count	31468.60**	31645.93**	182124.77**	6.37	6.00
Stomata length	0.0016**	0.0023**	0.0047**	13.19	11.79
Panicle Length	7.40	11.71**	4.91	5.23	2.99
Number of filled grains	2147.75*	2884.83**	948.17	10.79	8.56
Number of unfilled grains	320.60**	532.79**	103.30**	9.59	9.11
Number of total grains	2788.95**	3950.41**	1154.77	10.19	8.83
Weight of 1000 Grain	4.35	14.02	12.54	10.75	4.38
Rice yield	0.32*	0.62**	0.70**	5.56	4.13
Fish Yield	0.2157**	-	-	4.39	-

Notes: CV = coefficient of variation, ** significant effect at 1% error level, * significant effect at 5% error level

The path analysis results focused on characters that correlated with the rice yield (Table 6). Based on this analysis, the number of total grains is the only character that has a direct negative effect on the rice yield (−0.51). In contrast, the characters of the total tiller (0.31), productive tiller (0.45), and number of filled grains (0.75) have a positive direct effect on the rice yield, although among the three, the number of filled grain characters is the only character with a significant direct effect on rice yield. Further tests of polynomial contrast of compost and LSD 0.05 local biofertilizer assays for the number of filled grains characters are shown in Figures 3A and 3B. Based on the compost treatment, the treatment combination showed linear regression with a determination value of 0.7748 and a gradient of 3.981. Treatment of 4 tons ha^{−1} is the best compost treatment. Meanwhile, based on local biofertilizer treatment, treatment m3 (119.84a) is the best type of local biofertilizer and m0 is the lowest local biofertilizer treatment (98.33c).

The results of the orthogonal-polynomial interaction contrast test on rice yield characters are shown in Figure 4. The results of the analysis demonstrate that all local biofer-

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tilizer treatments have a linear graph with a determination value above 0.9. The m1 bio-fertilizer treatment had the highest determination value of 0.9887. Based on the gradient value, m0 and m2 have gradient values above 0.3. Meanwhile, m2 treatment is a local biofertilizer treatment with the highest gradient value of 0.39.

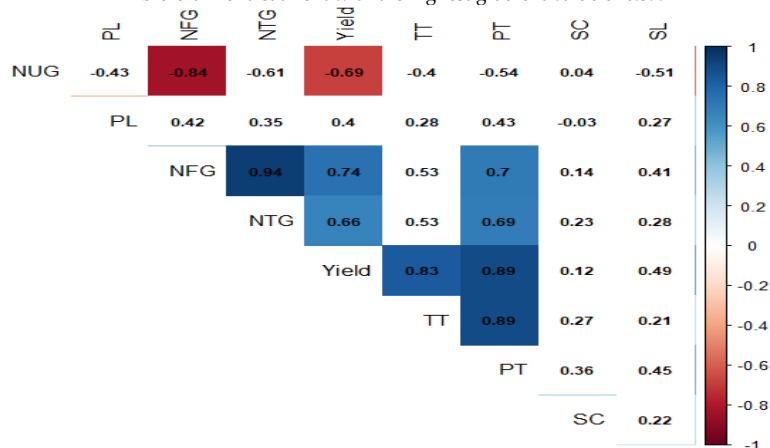


Figure 2. Correlation analysis of rice growth characters (notes: PH= plant height, TT= total tiller, PT= productive tiller, SC = stomata count, SL= stomata length, NFG = number of filled grains, NUG= number of unfilled grains, NTG = number of total grains, Yield = rice yield).

Table 6. Path analysis of several growth characteristics on the rice yield

Character	Direct Effect	Indirect Effect				Correlation
		TT	PT	NFG	NTG	
Total Tillers (TT)	0.31		0.4	0.4	-0.27	0.84
Productive Tillers (PT)	0.45	0.27		0.52	-0.35	0.89
Number of Filled Grains (NFG)	0.75**	0.16	0.31		-0.48	0.74
Number of Total Grains (NTG)	-0.51	0.16	0.31	0.7		0.66
Total Indirect effect		0.59	1.02	1.62	-1.1	

The results of the orthogonal-polynomial interaction contrast test on rice yield characters are shown in Figure 4. The results of the analysis demonstrate that all local biofertilizer treatments have a linear graph with a determination value above 0.9. The m1 biofertilizer treatment had the highest determination value of 0.9887. Based on the gradient value, m0 and m2 have gradient values above 0.3. Meanwhile, m2 treatment is a local biofertilizer treatment with the highest gradient value of 0.39.

The results of the analysis of the polynomial contrast test on the fish yield character are shown in Figure 5. The analysis demonstrates that the compost treatment has a linear graph with a very high determination value (0.9988). The growth gradient on the fish yield graph is 0.00907. The results established that compost treatment with 4 ton ha⁻¹ is the most advantageous treatment for optimizing fish yield.

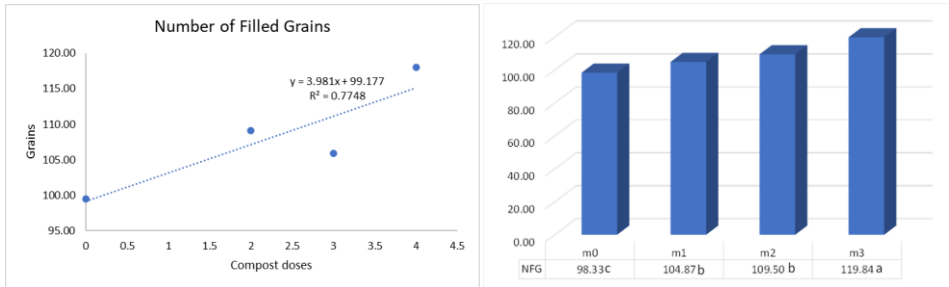


Figure 3. A) Regression analysis of the effect of compost on the number of filled grains B) Honest significant difference test of the effect of the type of local biofertilizer material on the number of filled grains.

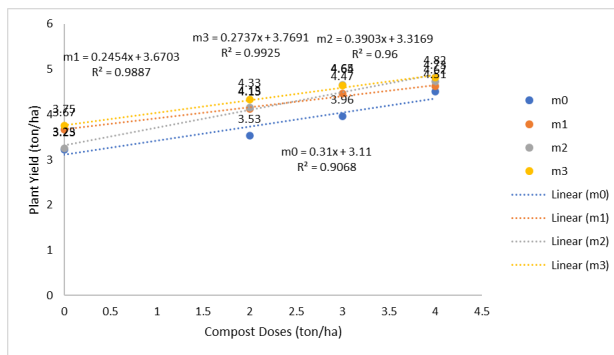


Figure 4. Polynomial-orthogonal interaction analysis of the rice yield character for the type of local biofertilizer (m) for the dose of compost

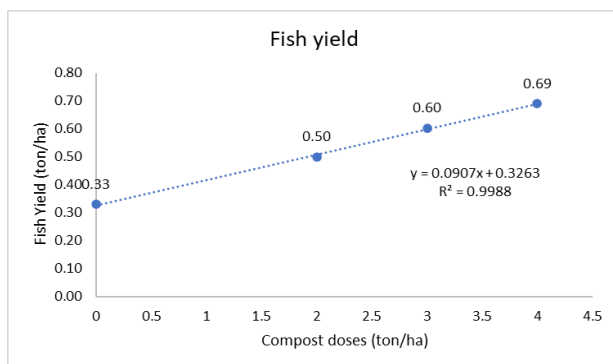


Figure 5. Regression analysis of the dose of compost on the increase in the yield of fish

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The results of the 3D analysis plot analysis focused on the three main characters, namely, number of filled grains, rice yield, and fish yield (Figure 6). The combination of the three characters is focused on compost treatment. Based on this analysis, adding compost (K1, K2, and K3) has a better combination index value than adding compost (K0). The 4-ton ha^{-1} (K3) treatment is the treatment with the best index value and is found at the top end of the 3D plot. Meanwhile, the R/C ratio analysis is shown in Table 7. Based on this table, the best application of compost is at a compost dosage of 4 tons ha^{-1} . In contrast, the lowest R/C ratio was found in the control treatment (0 tons ha^{-1}).

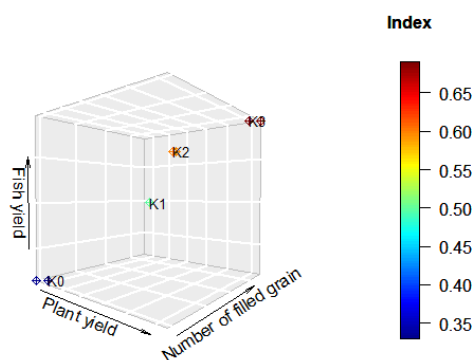


Figure 6. Analysis of 3D plots of the effect of compost based on the interaction of the number of filled grains, the fish yield, and the rice yield.

Table 7. Analysis of land income on compost treatment in Minapadi integration

Compost doses	Cost (C) (Rp)	Revenue (R) (Rp)	Profit (Rp)	R/C ratio
0 ton ha^{-1}	10,087,478	41,999,800	31,912,322	4.16
2 ton ha^{-1}	10,337,478	53,802,800	43,465,322	5.2
3 ton ha^{-1}	10,437,478	59,701,600	49,264,122	5.72
4 ton ha^{-1}	10,587,478	65,059,200	54,471,722	6.14

4. Discussion

The results of this study indicate that the effect of compost dosing is more dominant than the biofertilizer character and its interactions. The effects of compost include vegetative, physiological, and generative characteristics. This has been reported by Septiawan et al. (2021), Maninggir et al. (2019), and Sipayung et al. (2018). In contrast, the influence of the type of biofertilizer only plays a role in optimizing production components and stomatal characters. This effect was also reported by Subowo et al. (2010), Kalay et al. (2020), and Miranty (2020). The effect of interaction only modulates few characters. This indicates that each type of biofertilizer relatively has the same response changes to increasing compost doses so that interactions do not occur in some characters. Based on this, differences in patterns of diversity between factors will affect the interpretation of the evaluation in this study; hence the selection of the main parameters is the key to evaluating the technology package for rice growth in the Minapadi concept.

The combination of correlation and path analysis shows that the number of filled grains character is the only character that has a significant direct effect on the rice yield. The character, number of filled grains, can be recommended as the main parameter supporting the rice yield. In general, the combination of the two analyzes is a multivariate analysis which is mostly used to identify the main parameters supporting production. This has also been reported by Sabouri et al. (2008), Khapte and Jansirani (2014), Kumar

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et al. (2014), Mustafa et al. (2019), and Akbar et al. (2019). In general, the results of correlation analysis are still influenced by distinct factors; hence the results of this analysis cannot be the main basis for identifying relationships between parameters. The use of cross-tracking is a more in-depth approach than correlation analysis. This analysis can divide the correlation value into direct and indirect effects (Bocianowski et al. 2016). This direct influence is the basis for how big a character's role is in influencing the total diversity of the main characters (Bocianowski et al. 2016; Anshori et al. 2022; Sakinah et al. 2022). However, the use of cross-prints on many characters is ineffective (Anshori et al. 2022), so the characters included need to be selected first through correlation analysis. Therefore, the combination of the two analyzes is considered effective for estimating the main parameters supporting productivity. Based on the analysis concept, the characters of the number of filled grains and the rice yield become reference parameters in the evaluation of organic fertilizer packages in the cultivation of Minapadi.

The number of filled grains is one of the characteristics that play a major role in determining crop production. This has also been reported by Rahmad et al. (2022), Fadhillah et al. (2021), and Asfaruddin et al. (2022). Based on the results of this study, the number of filled grains was significantly affected by the compost treatment and the type of LB. However, the interaction between the two did not affect this character, so the treatment evaluation was carried out individually for this character. Figure 2A displays the effect of compost treatment on the number of filled grains. The results of the analysis in the figure indicate that the compost treatment is relatively linear with a relatively high gradient. A high gradient indicates that the rate of increase in compost is still not close to the optimum level so that the study of compost dosage treatment still requires further exploration. This was also stated by Baba et al. (2021) and Harahap et al. (2020). Nevertheless, this figure already reflects the pivotal role of compost treatment on the number of filled grains character, especially at the compost dosage level of 4 tons ha^{-1} . Figure 2B shows the effect of the type of LB on the character of the number of filled grains, especially when compared to no biofertilizer treatment (m0). The figure recommends the treatment of cow urine and Maja fruit as the best LB. In general, cow urine has a higher nutrient content and contains IAA which can be used as a growth stimulant for growth regulators (Desiana et al., 2013; Pujiati et al., 2015). In addition, this effectiveness is optimized with Maja fruit. Maja fruit gives better results in growth and production, containing 2.82% nitrogen, 1.62% phosphorus, 1.22% potassium, and 40.62% carbon (Pane and Marwazi, 2020; Dewi and Ainun, 2022). Based on this, the treatment of compost dosage of 4 tons ha^{-1} and the local treatment of bovine urine in combination of Maja fruit biofertilizer are recommended treatments in optimizing the character of the number of filled grains.

The most commonly used main character employed in cropping evaluation is the rice yield (Farid et al. 2022; Ulfa et al. 2022). This character is strongly influenced by the three existing sources of diversity, so the evaluation is based on the analysis of orthogonal-polynomial interactions in Figure 3. The results of the analysis in the figure demonstrate that the effect of compost is predominantly linear on the rate of increase in the rice yield. In addition, the LBs sources has a positive impact on increasing rice yield. However, this increase is very dependent on the difference in gradient between LBs toward increasing the dose of compost. It indicates that LBs produced from various sources have distinct types of microbes and preferences in optimizing the role of compost in the rice yield. This was also stated by Sulistyarningsih and Harsono (2017). Based on the yield interaction analysis, LB from the combination of cow urine with coconut fiber soaking water is highest gradient value of the LB source. This was also reported by Hayat et al. (2021), Rahim et al. (2016), and Bakri (2020). It indicates that the combination of m2 biofertilizer with higher doses of compost will proliferate the rice yield with increased compost dosages. Therefore, m2 LB source and 4-ton ha^{-1} compost is recommended as the best treatment combination for optimizing rice yield potential. Although, the combined position of the LB of cow urine with Maja fruit showed higher (m3) than biofertilizer m2 at the number of filled grains and rice yield.

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The fish yield in this study only focused on the effect of compost. This is because the LB is only applied to the plant canopy, so the effectiveness of the treatment does not directly affect fish yield. Based on Figure 4, the addition of compost significantly increases the fish yield potential in the rice-fish integration concept. This is seen in the very high determination value close to 1. In addition, a report by Parvez et al. (2019) and Jyoti et al. (2020) also stated that the addition of compost affected fish weight in the paddy-fish integration concept. In general, high doses of compost not only play a role in the process of increasing plant growth but also play a role in improving water quality (Kumar and Godara 2016). These improvements will provide a good environment for the growth of phytoplankton and other microbes. Phytoplankton are organisms similar to plants in water (Cloern et al. 2014), so adding compost will also increase the nutrient content required for the growth of phytoplankton in water (Hastuti et al. 2019). This indicates that increasing compost in a rice field will provide comfort for phytoplankton to grow and develop, so that fish can also thrive in rice fields. This environmental improvement is also in line with good habitat for tilapia. According to He et al. (2020), tilapia with the Minapadi integration system can improve the quality and production of fish meat. This is because the ecology of the rice fields has good water quality and lots of microbes making it suitable for maximal tilapia growth. Therefore, the addition of compost to the rice-fish integration system is required to augment the fish yield potential in rice fields.

The results of the three main characters illustrate that the application of compost affects the increase in the three characters linearly. However, since the interaction between the three traits cannot be detected, a 3D plot analysis is still essential. Based on the results of the 3D analysis, the compost treatment had a domino effect on the three characters. This is indicated by the large difference in spatial position between the control and the compost application. The position of the distant space indicates the degree of significance of a treatment, so it can be concluded that compost must be applied to the rice-fish integrated cropping system. This will have a large effect on increasing the potential income per paddy field. This potential has also been reflected in the R/C ratio shown in Table 3, where the application of minimal compost provides a difference in R/C ratio of 1.04 in comparison to no compost treatment. This R/C ratio is a comparison between total revenue and total costs as an indicator in measuring business feasibility (Suratiah, 2015). Even though compost has a high dominance, it is also recommended to apply local biofertilizer to optimize the potential for increasing the R/C ratio. This refers to the potential interaction between compost and local biofertilizer on rice yield.

4. Conclusions

This research establishes that the application of compost plays a very important role in increasing the potential of Minapadi integrated agriculture. In addition, the concept of the multiple evaluation criteria through secondary character approach is effective for use in the evaluation of cultivation technology. An effective secondary character for this research is the number of filled grains. Based on the overall evaluation, the best dose of compost in this study was 4 tons/ha. This dose can increase the potential income per land with a difference in the R/C ratio of up to 2 points and is recommended to be increased again. Meanwhile, the compost dosage of 4 tons ha⁻¹ and the local bio-fertilizer from cow urine with coconut fiber soaking is recommended combination treatments in optimizing rice yield potential. Moreover, the compost dosage in this Minapadi (rice-fish) study also requires further exploration for better understanding.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, Amir Yassi, Muh Farid, Rajuddin Syamsuddin; methodology, Amir Yassi, Muh Farid, Hamdani Muchtar, Rajuddin Syamsuddin; validation, Muhammad Fuad Anshori; formal analysis, Muhammad Fuad Anshori; Hamdani Muchtar; Amir Yassi; investigation, Hamdani Muchtar, Adnan Adnan, and Muh Farid; resources, Muh Farid; Hamdani Muchtar; data curation, Hamdani

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Muchtar, and Muhammad Fuad Anshori; writing—original draft preparation, Amir Yassi, and Muhammad Fuad Anshori; writing—review and editing, Muh Farid, Adnan Adnan, Rajuddin Syamsuddin; visualization, Muhammad Fuad Anshori; supervision, Amir Yassi, Muh Farid, and Rajuddin Syamsuddin. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding

Data Availability Statement: Not applicable.

Acknowledgments: We are grateful to the publication management center of Hasanuddin University for providing the facilities, like workshop training and Enago proofreading for this article..

Conflicts of Interest: The authors declare no conflict of interest” and “The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results”.

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Koment Reviewer Revisi 2 minor revision**Table of Response****Reviewer: 1**

In general, we so thanks for your comment to improve our article. The list of review comments and our response are shown in below:

Q1	There are still some mistakes in the manuscript. For example, DO should be dissolved oxygen, K ₂ O should be K ₂ O and so on. Therefore, the authors should be revised carefully at first, the manuscript can be accepted.
A1	Thank you for your suggestion. We have revised the manuscript according to your suggestion
Revision	Table 2, 3 and 4

Editor Comments

In this study, the so-called "local biofertilizers" corresponds to a mixture of organic materials collected at the surroundings of the the research location, such as cow urine + water of rice washing, cow urine + coconut fiber, and cow urine + Maja fruit, but enriched or inoculated microbial cultures are not mentioned. In my opinion this product should be named as a "local organic fertilizer", or something similar that highlights that specific organic wastes are valorized, since it does not correspond to the definition of biofertilizers provided above. I'm aware that there is no consensus on this issue and that the literature is often misleading, but by this rule conventional compost should also be classified as a biofertilizers. This is of course true when compost has been inoculated with specific microbial cultures, such as the suppressive fungus *Trichoderma*, but I would not use this term for all types of composts.

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Article

Integrated Minapadi (Rice-Fish) Farming System: Compost and Local liquid organic fertilizer Based on Multiple Evaluation Criteria

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Abstract: Rice-fish cultivation, also known as Manipadi in Indonesia, is one of the many integrated farming systems where fish are grown concurrently with rice. However, this integrated system needs to be optimized by organic fertilizer. Application of organic fertilizer such as compost and local bi-organic fertilizer when implemented with integrated system can optimize the yield per land for both rice and fish. However, this combination must be evaluated systematically by multiple evaluation criteria and statistical analysis. Therefore, this study aimed to identify the combination of compost doses and/or local liquid organic fertilizer concentrations based on multiple evaluation criteria in supporting the productivity of rice-fish integration agriculture. The experiment was carried out in the Wanuae farmer group of Barebbo District, Bone Regency, Indonesia between September 2018 and January 2019. The experiment employed a split plot design with a randomized complete block design (RCBD). The main plot consisted of compost (4 levels), and the subplot was the local bi-organic fertilizer source (4 levels). The results demonstrated that the number of fill grains was significantly affected by the compost treatment and the type of the local biofiller. The effect of compost dosing was more dominant in comparison to the local liquid organic fertilizer character and its interactions. The compost dosage of 4 tons ha⁻¹ and the local liquid organic fertilizer sourced from soaked coconut fiber with cowurine has been recommended as the combination treatments to optimize the rice and fish yield potential. The Minapadi (rice fish) with additional high compost effectively increased the farmer's outcome with a 2-point R/C ratio than without compost. Moreover, the compost dosage in this Minapadi study requires further exploration for better understanding.

Keywords: Agronomy; collaborator interaction; drought stress; image processing; mapping analysis; plant breeding

Citation: Yassi, A.; Farid, M.;

Anshori, M.F.; Muchtar, H.;

Syamsuddin, R.; Adnan, A. Integrated Minapadi (Rice-Fish) Farming System: Compost and Local liquid organic fertilizer Based on Multiple Evaluation Criteria.

Academic Editor: Firstname Last-name

Received: date

Accepted: date

Published: date

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1. Introduction

Rice is one the pivotal staple food crop and prime contributor in attaining food security [1,2]. The consumption of rice per capita of Indonesia for 2022 was 1.45 kg per week

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or 74.57 kg per capita per year [3]. This number is relatively higher in comparison to several other countries that are optimizing food diversification. The high demand for rice must be aligned with national rice productivity. In general, national rice production reaches 55.67 tons [4]. However, persistent growth population and overutilization of resources are posing various challenges and impeding the yield [5,6]. Therefore, increasing productivity per unit of land is key to maintaining food stability in Indonesia.

In order to improve the rice productivity, one of the various efforts that are practiced is the consistent application of chemical fertilizers. Chemical fertilizers are known to provide optimal nutritional needs for rice cultivation [7–10]. However, habitual tendencies of excessive application of fertilizers including high planting intensity determinants a negative impact on soil stability, especially physically and biologically [9,11]. Several studies have reported the detrimental consequences of chemical fertilizers, few of which includes deleterious effect on the soil structure and soil porosity, affecting the soil to be more sticky when it rains and hard when it is dry [11–14]. In addition, several studies have also reported that the application of excess chemical fertilizers and a decrease in soil organic matter due to intensive planting had an impact on reducing soil microorganisms [9,13,14]. This phenomenon will be more critical if there is no effective resolution. One gateway that can be optimized is the application of the integrated farming concept.

Integrated farming is an approach of optimizing agricultural products that considers sustainable concepts, from an ecological, social, and economic perspective [15–18]. The concept focuses on maximizing the use of local resources with concurrent efforts to reduce the input costs for enhancing the land productivity and income [1,17,19,20,21]. The theory of integrated agriculture can be practiced by harmonizing agriculture with other fields such as livestock [1,15,20,21], fisheries [16,17,22,23], and forestry [24,25]. One way to strategize this is by the incorporation of rice and fish, also known as Minapadi. Minapadi, a term coined in Indonesia for cross cultivation of rice and fish [16,26,27]. Several reports have demonstrated the effectiveness of this combination in proliferating the economic income value of a land [16,19,22,26]. Manure from fish can be a good source of minerals for rice cultivation, while the paddy fields can be a great food reservoir for the fish in return [17,19]. However, the combination of the two is still considered to be ineffective in improving soil status, hence addition of organic fertilizer is essential for a productive Minapadi system. Organic fertilizers such as compost and local liquid organic fertilizers (LLOF) are considered effective in supporting plant productivity in a sustainable manner [10,28–30].

Compost is the residue result of soil biological activity that are beneficial for improving physical, chemical, and biological properties [31,32]. These improvements play a very important role in supporting crop growth and production [32,33]. Several studies have reported the effectiveness of compost use in supporting rice productivity [27,29,34–37]. In general, compost is known for its beneficial role in improving soil structure, soil moisture, nutrient retention, and cation exchange capacity [34–36]. In addition, compost also functions as an organic material for microorganisms to be maximized in helping plant growth and productivity [27,34,35,38]. Therefore, the use of compost is highly recommended to support sustainable crop productivity.

Similarly, LLOF is another recommendation in terms of sustainable agriculture prospects [39,40]. This fertilizer is more emphasized on the use of microorganisms that play a role in plant growth. These microorganisms enhances the plant metabolic processes, nutrient absorption, and disease resistance thereby contributing to plant development and productivity [8,39–41]. Apart from that, this fertilizer also contains various nutrients, vitamins, and hormones that can stimulate an optimal environment for plant growth [41,42]. The favorable incorporation of biofertilizers in rice cultivation has also been reported by Banayo et al. [41], Hazra et al. [43], Patriyawaty et al. [44], and Simarmata et al. [45]. Therefore, the use of biofertilizers can be a complement to the Minapadi integrated farming concept.

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Based on these potentials, optimizing the combination of compost and LLOF can be an additional input in integrated rice-fish farming (Minapadi). This combination needs to be equipped with optimal concentrations and/or doses of both, so that the evaluation of plantings on the input of compost and LLOF can be maximized. Optimization must be adjusted to the characteristics related to the main objective of the evaluation, namely the rice yield [46,47]. However, an assessment that only focuses on the rice yield can result in an overestimated interpretation [48]. This is based on the genetic constitution of the yield, which is polygenic, so the evaluation needs to involve other distinct characters that support productivity [49,50]. In addition, the effectiveness of the interaction between rice yield and fish yield is also an important consideration in the optimization. Therefore, a systematic statistical approach is key in evaluating the combination of compost and LLOF in supporting the productivity of rice-fish integration agriculture. The purpose of this study was to identify the combination of compost doses and/or local liquid organic fertilizer concentrations in accordance with multiple evaluation criteria in supporting land productivity based on rice-fish integration agriculture.

2. Materials and Methods

The experiment was carried out in the Wanuae farmer group in Barebbo District, Bone Regency (4° 13'–506' South Latitude and 119° 42'–120° 30' East Longitude), Indonesia during the month of September 2018 till January 2019. The study area receives an average annual rainfall of 201.25 mm/year with 12 rainy days. The average air temperature ranges between 24.50°C–27.60°C and humidity varies between 77%–86%. This research was conducted by implementing the split plot design with randomized complete block design (RCBD). The principal plot of this study was the compost dose (C) that comprised of four levels, namely control without compost (C0), 2 ton ha⁻¹ (C1), 3 ton ha⁻¹ (C2), and 4 ton ha⁻¹ (C3). Meanwhile, the subplots of this study were a combination of local microorganisms with 4 types, namely, control (L0), combination of cow urine with water of rice washing (L1), combination of cow urine moles with water-soaked coconut fiber (L2), and combination of cow urine and calabash fruit moles (L3), each randomly applied to the main plot. The collaboration of these factors resulted in 16 combinations which were repeated 3 times, adding total 48 experimental units.

2.1. Land preparation

Land preparation was carried out by repairing the bunds with 40 cm height and maintaining the width of the base and upper bund at minimum 50 cm and 25 cm respectively. The ditches were built 1 m wide and above 50 cm deep in order to protect fish from various threats. Ditches were prepared both in the middle and on the surrounding edge of the rice field bunds along with a 70 cm deep storage tank to facilitate the fish harvesting during water draining process with an objective to optimize the ripening potential of rice grain. The description of the Minapadi concept is exhibited in Figure 1. Meanwhile, the nutrition land in this study was shown with Table 1.

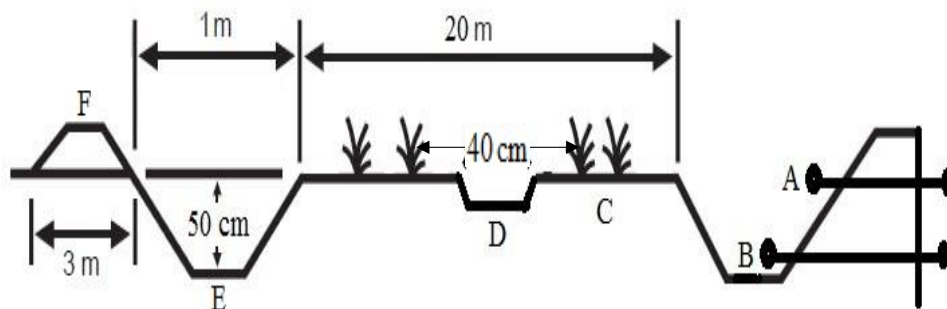


Figure 1. Construction of the Minapadi pond (cross section) Description: A) Water inlet channel, B) Lower water outlet channel, C) Rice plot, D) Middle ditches, E) Main ditches, F) Bunds.

Table 1. Soil status on study field

Parameter	unit	Value
texture		Dusty Clay
clay	%	38
dust	%	50
sand	%	12
C-Organic	%	2.35
total nitrogen	%	0.11
C/N	ppm	21
P Olsen	ppm	6.6
K	cmol (+) kg ⁻¹	0.08
Ca	cmol (+) kg ⁻¹	6.03
Mg	cmol (+) kg ⁻¹	2.53
Na	cmol (+) kg ⁻¹	0.08
cation exchange capacity	me/100g	20.65

2.2. Maintenance of Rice Plants

The qualitative analysis of rice seeds was conducted by immersing the seeds in 3% salt solution or soaking them in ZA solution (225 g ZA/l water). The immersed seeds indicate their suitability for planting and were accordingly preselected for this experiment. Following which, the seeds were first soaked and then aged in sequence for 24 hours. The process of seeding was carried out by sowing the germinated seeds in the seeding plots. The nursery was fertilized with ponska NPK, Urea, and SP-36 each at 15 g m⁻². After the seedlings were 15 days old, the same were planted with 2 seeds per hole. The 2:1 row legowo cropping system was implemented with 40 cm for the largest inter-row spacing, 20 cm for the smallest inter-row spacing, and 10 cm in-row spacing. The planting conditions are muddy to facilitate the process of making planting points. Then, the seeds were nurtured till the harvest.

Maintenance activities included replanting, weeding, fertilizing, irrigation, and controlling plant-disturbing organisms. Sticking was completed 7–10 days after planting (DAP). The field irrigation was regulated persistently in order to maintain the water level in accordance with the planting system. In the 2:1 legowo cropping system, the water level is maintained at 10 cm above the rice growth surface as the baseline. The first weeding was done at 20 DAP, then the second weeding at 40 DAP, and the third and last weeding at 70 DAP. Fertilizers ponska NPK, urea, and SP-36, were cautiously applied fifty percent below their recommended dose at 167, 100, and 31 kg ha⁻¹. All Chemical fertilizers are given as basic fertilizer to avoid fish growth disturbance caused by the accumulation of chemical fertilizers in the rice fields. In order to meet the nu-trient requirements, both straw compost and Local liquid organic fertilizer (LLOF) fertilizer were also incorporated as a treatment in addition to chemical fertilizers. Compost was spread during the pre-planting period, whereas application of LLOF was carried out once the plants attained 2 Mst. The fertilizer dilution of 1:10 was applied intermittently every 12 days by spraying

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on the leaves in the morning during stomatal opening. Meanwhile, pests and plant diseases were administered by using insecticides and fungicides rationally to not only avoid potential damage resulting in reduced yields but also to avert interference with the growth and development of fish.

2.3. Preparation of Local liquid organic fertilizer and Compost Fertilizer

LLOF was resourcefully made by collecting materials surrounding the research location such as, cow urine + water of rice washing, cow urine + coconut fiber. and cow urine + calabash fruit. The LLOF coconut coir is prepared by adding and pressing the coconut coir into a bucket already filled with water until fully submerged which is then closed and left for two weeks. Water that is already blackish brown is used as LLOF. On the other hand, calabash fruit LLOF is prepared by blending calabash fruit (grinded) with coconut water and sugar that is stored in a closed container connected to a pipette filled with water for 2 weeks, eventually filtering it. Similarly, LLOF of rice water is made by storing it in a tightly closed container/bottle with sugar for 2 weeks. These ingredients are then mixed with cow urine in a ratio of 1:1 for each combination. The nutrition component of each LLOF was shown in Table 2. Meanwhile, compost fertilizer was taken on farm shop with nutrient component list on Table 3.

Table 2. Analysis of nutrient content of local liquid organic fertilizer

Local liquid organic fertilizer	Ekstrak HCl		
	Kjeldahl N(%)	P ₂ O ₅ (%)	K ₂ O (%)
cow urine + water of rice washing	0.36	0.39	0.45
cow urine + coconut fiber	0.34	0.42	0.66
cow urine + calabash fruit	0.4	0.44	0.59

Table 3. Analysis of nutrient content of compost fertilizer

pH (H ₂ O)	Walkley & Black C (%)	Kjeldahl N (%)	C/N	HNO ₃ :HClO ₄	
				P (%)	K (%)
6.86	15.25	0.55	28	0.15	0.32

2.4. Fish Rearing

For this study, tilapia fish was chosen due to its high adaptability to the ecology of paddy fields and superior economic value [51,52]. The seeds were selected for their uniform characteristics such as peaked survivability against the heat and their dark hue that functions as camouflage against predators' attacks. Before being spread, the baby fish are first weighed. The tilapia fish were spread in kemalir rice fields measuring 5 cm deep, 12 days post rice planting.

Tilapia was cultured on the rice field map by spreading the feed pellet on kemalir. The recommended amount of feed is 3% the biomass weight. A sample of 10 fish was weighed and averaged to determine the amount of feed. The average weight obtained was then multiplied by the total number of fish in the pond to calculate the biomass weight. The average weight of fish was measured at 246 g and with total 41 fish, the weight of the biomass equaled to 246 × 41 = 10,086 g and accordingly the amount of feed per day was corresponded to 3% × 10,086 grams = 303 grams. This ration was fed twice per day. Simultaneously, the water volume was regulated by administering the water level persistently. If there is an increase in the volume of water caused by rain, excess water was removed from the paddy fields in the event of rainfall and conversely, was added from the irrigation channel, when the water volume dropped below the threshold. At the time of treatment, the water in the kemalir was still at a normal level so as not to interfere with the mobility of the fish. Other maintenance activities included monitoring and restricting

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disease and predator occurrences. Meanwhile, water status parameters in our study were shown in Table 4.

Table 4. Analysis of water quality in the study location of Bone Regency South Sulawesi.

Parameters	Unit	C1	C2	C3	C4
Before treatment					
ammonia	ppm	0.006	0.009	0.007	0.001
dissolved oxygen (DO)	ppm	10.6	10	8.2	8.6
carbon dioxide (CO ₂)	ppm	8	10	9	9
After treatment					
Ammonia	ppm	0.018	0.019	0.021	0.051
dissolved oxygen (DO)	ppm	8.2	6	10.5	7.4
carbon dioxide (CO ₂)	ppm	9	10	10	9

2.5. Harvesting Fish and Rice

Predominantly, rice harvesting is carried out when the seeds attain the ripen stage physiologically or when around 90%–95% of the panicles have turned yellow. Paddy fields require drainage for drying the plots prior to harvest to not only accelerates the panicle ripening but also to prevent the harvested stover from being exposed to water. Rice harvest is done manually by using a sickle and threshing of rice grains using a threshing machine. On other hand, fish harvesting is conducted 10 days before the rice fields are dried. It is done by gradually lowering the water discharge and herding the fish into the holding pond. At the discharge channel in the holding pond, a net is placed at the mouth of the outlet channel to convene fish in the direction of the draining water.

2.6. Parameter Observation and Data Analysis

The observed data included plant height (cm), total tiller, productive tiller, chlorophyll content, stomata count, stomata length (mm), panicle length (cm), number of filled grains (grains), Number of unfilled grains (grains), Number of total grains (grains), weight of 1000 grain (g), rice yield (ton ha⁻¹), and fish yield. All the data were analyzed by means of variance with an error of 5%, following which, the determination of the evaluation criteria was carried out by correlation and analysis of variance [53,54]. The results of both analyzes were followed by a polynomial structured test for compost concentration and interactions. Meanwhile, the significant effect on the type of LLOF material was tested by honest significant difference test analysis. The evaluation of fish yield was carried out using regression and 3D plot analysis [48](Farid et al. 2021).

3. Results

The results of the variance show the diversified pattern of significance between characters to the source of the diversity. The compost treatment significantly affected the total tiller, productive tiller, chlorophyll content, number of stomata, stomata length, number of filled grains, number of unfilled grains, number of total grains, rice yield, and fish yield. local liquid organic fertilizer (LLOF) significantly modulates the number of stomata, stomata length, panicle length, number of filled grains, number of unfilled grains, number of total grains, and rice yield. Meanwhile, the interaction of compost and LLOF has a significant effect on the number of stomata, stomata length, number of unfilled grains, and rice yield (Table 5).

The results of the correlation analysis in Figure 2 show that rice yield has a significant correlation with the number of filled grains (0.74), number of unfilled grains (−0.69), number of total grains (0.66), total tiller (0.83), and productive tiller (0.89). The productive

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tiller character also showed a significant correlation to the number of filled grains (0.7), the number of total grains (0.69), and the total tiller (0.89). Meanwhile, the number of filled grains has a significant correlation with the number of unfilled grains (−0.89), the number of total grains (0.94).

Table 5. Analysis of variance compost and local liquid organic fertilizer treatment of rice growth characters

Characters	Compost (C)	Local liquid organic fertilizer (B)	CxB	CV_C	CV_B
Plant height	36.96	149.81	284.71	5.53	5.98
Total tiller	141.66**	5.88	42.31	5.67	12.04
Productive tiller	80.11**	15.1	9.76	8.42	8.03
Chlorophyll content	0.0001**	0.00005	0.00016	7.39	6.88
Stomata count	31468.60**	31645.93**	182124.77**	6.37	6.00
Stomata length	0.0016**	0.0023**	0.0047**	13.19	11.79
Panicle Length	7.40	11.71**	4.91	5.23	2.99
Number of filled grains	2147.75*	2884.83**	948.17	10.79	8.56
Number of unfilled grains	320.60**	532.79**	103.30**	9.59	9.11
Number of total grains	2788.95**	3950.41**	1154.77	10.19	8.83
Weight of 1000 Grain	4.35	14.02	12.54	10.75	4.38
Rice yield	0.32*	0.62**	0.70**	5.56	4.13
Fish Yield	0.2157**	-	-	4.39	-

Notes: CV = coefficient of variation, * significant effect at 1% error level, ** significant effect at 5% error level

The path analysis results focused on characters that correlated with the rice yield (Table 6). Based on this analysis, the number of total grains is the only character that has a direct negative effect on the rice yield (−0.51). In contrast, the characters of the total tiller (0.31), productive tiller (0.45), and number of filled grains (0.75) have a positive direct effect on the rice yield, although among the three, the number of filled grain characters is the only character with a significant direct effect on rice yield. Further tests of polynomial contrast of compost and LSD 0.05 LLOF assays for the number of filled grains characters are shown in Figures 3A and 3B. Based on the compost treatment, the treatment combination showed linear regression with a determination value of 0.7748 and a gradient of 3.981. Treatment of 4 tons ha^{−1} is the best compost treatment. Meanwhile, based on LLOF treatment, treatment L3 (119.84a) is the best type of LLOF and L0 is the lowest LLOF treatment (98.33c).

The results of the orthogonal-polynomial interaction contrast test on rice yield characters are shown in Figure 4. The results of the analysis demonstrate that all LLOF treatments have a linear graph with a determination value above 0.9. The L1 biofertilizer treatment had the highest determination value of 0.9887. Based on the gradient value, L0 and L2 have gradient values above 0.3. Meanwhile, L2 treatment is a LLOF treatment with the highest gradient value of 0.39.

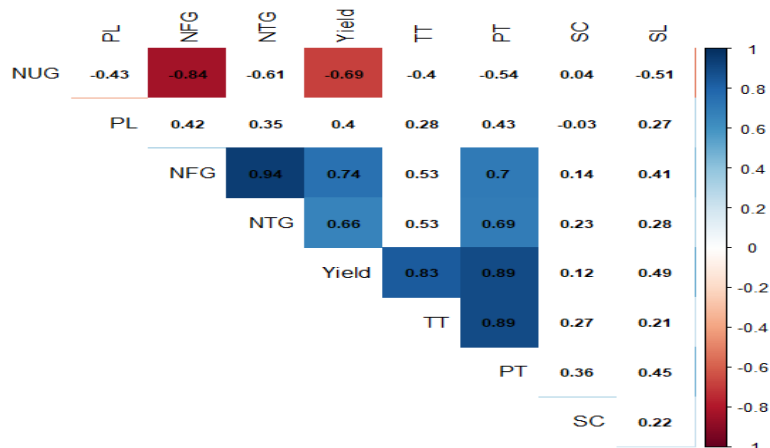


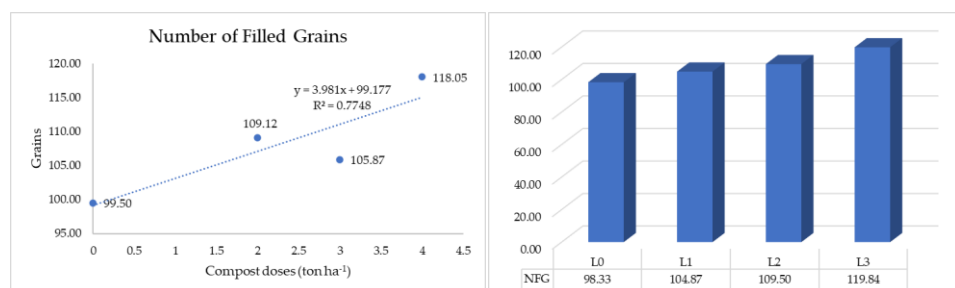
Figure 2. Correlation analysis of rice growth characters (notes: PH= plant height, TT= total tiller, PT= productive tiller, SC = stomata count, SL= stomata length, NFG = number of filled grains, NUG= number of unfilled grains, NTG = number of total grains, Yield = rice yield).

Table 6. Path analysis of several growth characteristics on the rice yield

Character	Direct Effect	Indirect Effect				Correlation
		TT	PT	NFG	NTG	
Total Tillers (TT)	0.31		0.4	0.4	-0.27	0.84
Productive Tillers (PT)	0.45	0.27		0.52	-0.35	0.89
Number of Filled Grains (NFG)	0.75**	0.16	0.31		-0.48	0.74
Number of Total Grains (NTG)	-0.51	0.16	0.31	0.7		0.66
Total Indirect effect		0.59	1.02	1.62	-1.1	

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The results of the analysis of the polynomial contrast test on the fish yield character are shown in Figure 5. The analysis demonstrates that the compost treatment has a linear graph with a very high determination value (0.9988). The growth gradient on the fish yield graph is 0.00907. The results established that compost treatment with 4 ton ha⁻¹ is the most advantageous treatment for optimizing fish yield.



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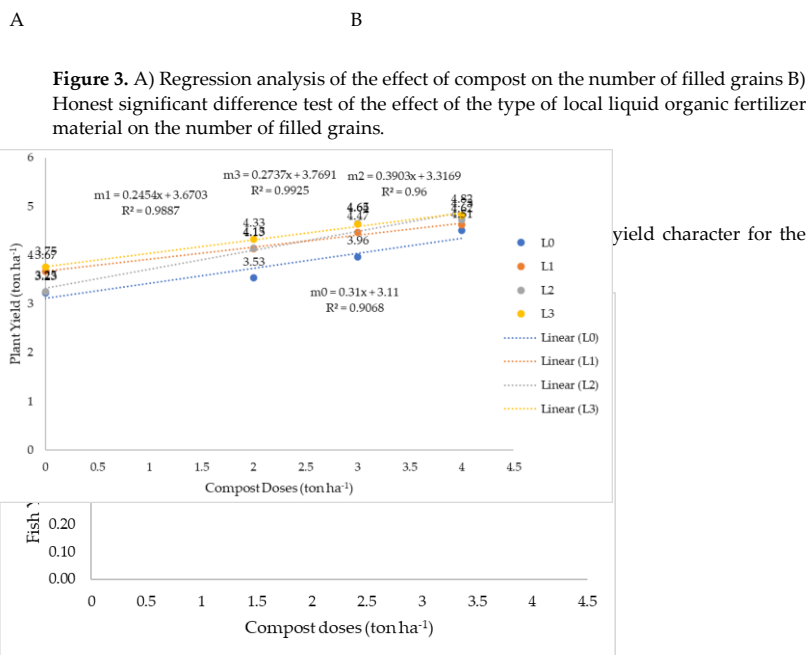
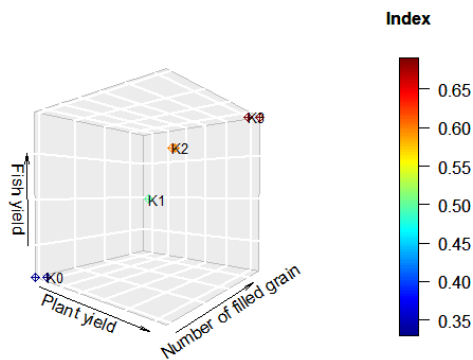


Figure 5. Regression analysis of the dose of compost on the increase in the yield of fish

The results of the 3D analysis plot analysis focused on the three main characters, namely, number of filled grains, rice yield, and fish yield (Figure 6). The combination of the three characters is focused on compost treatment. Based on this analysis, adding compost (K1, K2, and K3) has a better combination index value than adding compost (K0). The 4-ton ha⁻¹ (K3) treatment is the treatment with the best index value and is found at the top end of the 3D plot. Meanwhile, the R/C ratio analysis is shown in Table 7. Based on this table, the best application of compost is at a compost dosage of 4 tons ha⁻¹. In contrast, the lowest R/C ratio was found in the control treatment (0 tons ha⁻¹).



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Figure 6. Analysis of 3D plots of the effect of compost based on the interaction of the number of filled grains, the fish yield, and the rice yield.

Table 7. Analysis of land income on compost treatment in Minapadi integration

Compost doses	Cost (C) (Rp)	Revenue (R) (Rp)	Profit (Rp)	R/C ratio
0 ton ha ⁻¹	10,087,478	41,999,800	31,912,322	4.16
2 ton ha ⁻¹	10,337,478	53,802,800	43,465,322	5.2
3 ton ha ⁻¹	10,437,478	59,701,600	49,264,122	5.72
4 ton ha ⁻¹	10,587,478	65,059,200	54,471,722	6.14

4. Discussion

The results of this study indicate that the effect of compost dosing is more dominant than the biofertilizer character and its interactions. The effects of compost include vegetative, physiological, and generative characteristics. This has been reported by Septiawan et al. [55], Maninggir et al. [56], and Huang et al. [57]. In contrast, the influence of the type of local organic fertilizer only plays a role in optimizing production components and stomatal characters. This effect was also reported by Nabayi et al. [58], and Arianti [59]. The effect of interaction only modulates few characters. This indicates that each type of biofertilizer relatively has the same response changes to increasing compost doses so that interactions do not occur in some characters. Based on this, differences in patterns of diversity between factors will affect the interpretation of the evaluation in this study; hence the selection of the main parameters is the key to evaluating the technology package for rice growth in the Minapadi concept.

The combination of correlation and path analysis shows that the number of filled grains character is the only character that has a significant direct effect on the rice yield. The character, number of filled grains, can be recommended as the main parameter supporting the rice yield. In general, the combination of the two analyzes is a multivariate analysis which is mostly used to identify the main parameters supporting production. This has also been reported by Sabouri et al. [60], Murtaza et al. [61], and Akbar et al. [62]. In general, the results of correlation analysis are still influenced by distinct factors; hence the results of this analysis cannot be the main basis for identifying relationships between parameters. The use of cross-tracking is a more in-depth approach than correlation analysis. This analysis can divide the correlation value into direct and indirect effects [63]. This direct influence is the basis for how big a character's role is in influencing the total diversity of the main characters [53,54,63]. However, the use of cross-prints on many characters is ineffective [54], so the characters included need to be selected first through correlation analysis. Therefore, the combination of the two analyzes is considered effective for estimating the main parameters supporting productivity. Based on the analysis concept, the characters of the number of filled grains and the rice yield become reference parameters in the evaluation of organic fertilizer packages in the cultivation of Minapadi.

The number of filled grains is one of the characteristics that play a major role in determining crop production. This has also been reported by Sarwendah et al. [64], Abbasi et al. [65], and Hastini et al. [66]. Based on the results of this study, the number of filled grains was significantly affected by the compost treatment and the type of local liquid organic fertilizer (LLOF). However, the interaction between the two did not affect this

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character, so the treatment evaluation was carried out individually for this character. Figure 2A displays the effect of compost treatment on the number of filled grains. The results of the analysis in the figure indicate that the compost treatment is relatively linear with a relatively high gradient. A high gradient indicates that the rate of increase in compost is still not close to the optimum level so that the study of compost dosage treatment still requires further exploration. This was also stated by Amaral et al. [67] and Iqbal et al. [68]. Nevertheless, this figure already reflects the pivotal role of compost treatment on the number of filled grains character, especially at the compost dosage level of 4 tons ha⁻¹. Figure 2B shows the effect of the type of LLOF on the character of the number of filled grains, especially when compared to no biofertilizer treatment (L0). The figure recommends the treatment of cow urine and calabash fruit as the best LLOF. In general, cow urine has a higher nutrient content and contains IAA which can be used as a growth stimulant for growth regulators [69,70]. In addition, this effectiveness is optimized with calabash fruit. Calabash fruit gives better results in growth and production, containing 2.82% nitrogen, 1.62% phosphorus, 1.22% potassium, and 40.62% carbon [71,72]. Based on this, the treatment of compost dosage of 4 tons ha⁻¹ and the local treatment of bovine urine in combination of calabash fruit biofertilizer are recommended treatments in optimizing the character of the number of filled grains.

The most commonly used main character employed in cropping evaluation is the rice yield [46,47]. This character is strongly influenced by the three existing sources of diversity, so the evaluation is based on the analysis of orthogonal-polynomial interactions in Figure 3. The results of the analysis in the figure demonstrate that the effect of compost is predominantly linear on the rate of increase in the rice yield. In addition, the LLOFs sources has a positive impact on increasing rice yield. However, this increase is very dependent on the difference in gradient between LLOFs toward increasing the dose of compost. It indicates that LLOFs produced from various sources have distinct types of microbes and preferences in optimizing the role of compost in the rice yield. This was also stated by Sulistyarningsih and Harsono [73](2017). Based on the yield interaction analysis, LLOF from the combination of cow urine with coconut fiber soaking water is highest gradient value of the LLOF source. This was also reported by Hongpakdee and Ruamrungsri et al. [74], and Rahim et al. [75]. It indicates that the combination of L2 biofertilizer with higher doses of compost will proliferate the rice yield with increased compost dosages. Therefore, L2 LLOF source and 4-ton ha⁻¹ compost is recommended as the best treatment combination for optimizing rice yield potential. Although, the combined position of the LLOF of cow urine with calabash fruit showed higher (L3) than biofertilizer L2 at the number of filled grains and rice yield.

The fish yield in this study only focused on the effect of compost. This is because the LLOF is only applied to the plant canopy, so the effectiveness of the treatment does not directly affect fish yield. Based on Figure 4, the addition of compost significantly increases the fish yield potential in the rice-fish integration concept. This is seen in the very high determination value close to 1. In addition, a report by Parvez et al. [76] and Jyoti et al. [49] also stated that the addition of compost affected fish weight in the paddy-fish integration concept. In general, high doses of compost not only play a role in the process of increasing plant growth but also play a role in improving water quality [77]. These improvements will provide a good environment for the growth of phytoplankton and other microbes. Phytoplankton are organisms similar to plants in water [78], so adding compost will also increase the nutrient content required for the growth of phytoplankton in water [79]. This indicates that increasing compost in a rice field will provide comfort for phytoplankton to grow and develop, so that fish can also thrive in rice fields. This environmental improvement is also in line with good habitat for tilapia. According to He et al. [80], tilapia with the Minapadi integration system can improve the quality and production of fish meat. This is because the ecology of the rice fields has good water quality and lots of

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microbes making it suitable for maximal tilapia growth. Therefore, the addition of compost to the rice-fish integration system is required to augment the fish yield potential in rice fields.

The results of the three main characters illustrate that the application of compost affects the increase in the three characters linearly. However, since the interaction between the three traits cannot be detected, a 3D plot analysis is still essential. Based on the results of the 3D analysis, the compost treatment had a domino effect on the three characters. This is indicated by the large difference in spatial position between the control and the compost application. The position of the distant space indicates the degree of significance of a treatment, so it can be concluded that compost must be applied to the rice-fish integrated cropping system. This will have a large effect on increasing the potential income per paddy field. This potential has also been reflected in the R/C ratio shown in Table 3, where the application of minimal compost provides a difference in R/C ratio of 1.04 in comparison to no compost treatment. This R/C ratio is a comparison between total revenue and total costs as an indicator in measuring business feasibility [81]. Even though compost has a high dominance, it is also recommended to apply local liquid organic fertilizer to optimize the potential for increasing the R/C ratio. This refers to the potential interaction between compost and local liquid organic fertilizer on rice yield.

4. Conclusions

This research establishes that the application of compost plays a very important role in increasing the potential of Minapadi integrated agriculture. In addition, the concept of the multiple evaluation criteria through secondary character approach is effective for use in the evaluation of cultivation technology. An effective secondary character for this research is the number of filled grains. Based on the overall evaluation, the best dose of compost in this study was 4 tons/ha. This dose can increase the potential income per land with a difference in the R/C ratio of up to 2 points and is recommended to be increased again. Meanwhile, the compost dosage of 4 tons ha⁻¹ and the local liquid organic fertilizer from cow urine with coconut fiber soaking is recommended combination treatments in optimizing rice yield potential. Moreover, the compost dosage in this Minapadi (rice-fish) study also requires further exploration for better understanding.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, Amir Yassi, Muh Farid, Rajuddin Syamsuddin; methodology, Amir Yassi, Muh Farid, Hamdani Muchtar, Rajuddin Syamsuddin; validation, Muhammad Fuad Anshori; formal analysis, Muhammad Fuad Anshori; Hamdani Muchtar; Amir Yassi; investigation, Hamdani Muchtar, Adnan Adnan, and Muh Farid; resources, Muh Farid; Hamdani Muchtar; data curation, Hamdani Muchtar, and Muhammad Fuad Anshori; writing—original draft preparation, Amir Yassi, and Muhammad Fuad Anshori; writing—review and editing, Muh Farid, Adnan Adnan, Rajuddin Syamsuddin; visualization, Muhammad Fuad Anshori; supervision, Amir Yassi, Muh Farid, and Rajuddin Syamsuddin. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding

Data Availability Statement: Not applicable.

Acknowledgments: We are grateful to the publication management center of Hasanuddin University for providing the facilities, like workshop training and Enago proofreading for this article..

Conflicts of Interest: The authors declare no conflict of interest” and “The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results”.

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Proof Reading

Article

The Integrated Minapadi (Rice-Fish) Farming System: Compost and Local Liquid Organic Fertilizer Based on Multiple Evaluation Criteria

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Abstract: Rice-fish cultivation, also known as Manipadi in Indonesia, is one of the many integrated farming systems where fish are grown concurrently with rice. However, this integrated system needs to be optimized by organic fertilizer. The application of organic fertilizers, such as compost and local biofertilizers, when implemented into this integrated system, can optimize the yield per land for both rice and fish. However, this combination must be evaluated systematically by multiple evaluation criteria and statistical analyses. Therefore, this study aimed to identify the combination of compost doses and/or local liquid organic fertilizer concentrations, based on multiple evaluation criteria, that supports the productivity of rice-fish integration agriculture. The experiment was carried out in the Wanuae farmer group of the Barebbo District, Bone Regency, Indonesia, between September 2018 and January 2019. The experiment employed a split plot design with a randomized complete block design (RCBD). The main plot consisted of compost (four levels), and the subplot was the local biofertilizer source (four levels). The results demonstrated that the number of fill grains was significantly affected by the compost treatment and the type of local biofiller. The effect of the compost dosing was more dominant in comparison with the local liquid organic fertilizer character and its interactions. A compost dosage of four tons ha⁻¹ and a local liquid organic fertilizer, sourced from soaked coconut fiber with cow urine, has been recommended as the combination treatment to optimize the rice and fish yield potential. The Minapadi (rice fish) with additional high composting effectively increased the farmer's outcome with a 2-point R/C ratio, more so than those without composting. Moreover, the compost dosage in this Minapadi study requires further exploration for a better understanding.

Keywords: agronomy; collaborator interaction; drought stress; image processing; mapping analysis; plant breeding

Citation: Yassi, A.; Farid, M.; Anshori, M.F.; Muchtar, H.; Syamsuddin, R.; Adnan, A. Integrated Minapadi (Rice-Fish) Farming System: Compost and Local Liquid Organic Fertilizer Based on Multiple Evaluation Criteria. *Agronomy* **2023**, *13*, x. <https://doi.org/10.3390/xxxxx>

Academic Editor(s): Francisc Xavier Prenafeta Boldú, Albert Magrí, Jaume Boixadera

Received: 4 February 2023

Revised: 19 March 2023

Accepted: 20 March 2023

Published: date



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1. Introduction

Rice is one the pivotal staple food crops and a prime contributor to the attainment of food security [1,2]. The consumption of rice per capita in Indonesia for 2022 was 1.45 kg per week, or 74.57 kg per capita, per year [3]. This number is relatively higher in comparison to several other countries that are optimizing their food diversification. This high

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demand for rice must be aligned with the national rice productivity. In general, the national rice production reaches 55.67 tons [4]. However, a persistent growth in population and the overutilization of resources are posing various challenges, and impeding the rice yield [5,6]. Therefore, increasing its productivity per unit of land is key to maintaining food stability in Indonesia.

In order to improve rice productivity, one of the various efforts that is undertaken is the consistent application of chemical fertilizers. Chemical fertilizers are known to provide the optimal nutritional needs for rice cultivation [7–10]. However, the habitual tendencies of the excessive application of fertilizers, including high planting intensity determinants, has a negative impact on the soil stability, especially physically and biologically [9,11]. Several studies have reported the detrimental consequences of chemical fertilizers, a few of which include the deleterious effects on soil structure and soil porosity, causing the soil to be more sticky when it rains and harder when it is dry [11–14]. In addition, several studies have also reported that the application of excess chemical fertilizers and a decrease in the soil organic matter due to intensive planting had an impact on reducing the soil microorganisms [9,13,14]. This phenomenon will be more critical if there is no effective resolution. One gateway that can be optimized is the application of the integrated farming concept.

Integrated farming is an approach to optimizing agricultural products that considers sustainable concepts from ecological, social, and economic perspectives [15–18]. The concept focuses on maximizing the use of local resources, with concurrent efforts to reduce the input costs for enhancing the land productivity and income [1,17,19–21]. The theory of integrated agriculture can be practiced by harmonizing this agriculture with other fields, such as livestock [1,15,20,21], fisheries [16,17,22,23], and forestry [24,25]. One way to strategize this is through the incorporation of rice and fish, also known as Minapadi. Minapadi is a term coined in Indonesia for the cross-cultivation of rice and fish [16,26,27]. Several reports have demonstrated the effectiveness of this combination in proliferating the economic income value of land [16,19,22,26]. The manure from fish can be a good source of minerals for rice cultivation, while paddy fields can be a great food reservoir for the fish in return [17,19]. However, the combination of the two is still considered to be ineffective in improving the soil status; hence, the addition of organic fertilizer is essential for a productive Minapadi system. Organic fertilizers such as compost and local liquid organic fertilizers (LLOF) are considered to be effective in supporting plant productivity in a sustainable manner [10,28–30].

Compost is the residue result of the soil biological activity that is beneficial for improving physical, chemical, and biological properties [31,32]. These improvements play a very important role in supporting crop growth and production [32,33]. Several studies have reported the effectiveness of compost use in supporting rice productivity [27,29,34–37]. In general, compost is known for its beneficial role in improving soil structure, soil moisture, nutrient retention, and cation exchange capacity [34–36]. In addition, compost also functions as an organic material that helps microorganisms be maximized in the enhancement of plant growth and productivity [27,34,35,38]. Therefore, the use of compost is highly recommended to support sustainable crop productivity.

Similarly, LLOF is another recommendation in terms of its sustainable agriculture prospects [39,40]. This fertilizer has more emphasis on the use of the microorganisms that play a role in plant growth. These microorganisms enhance the plant's metabolic processes, nutrient absorption, and disease resistance, thereby contributing to the plant's development and productivity [8,39–41]. Apart from that, this fertilizer also contains various nutrients, vitamins, and hormones that can stimulate an optimal environment for plant growth [41,42]. The favorable incorporation of biofertilizers into rice cultivation has also been reported by Banayo et al. [41], Hazra et al. [43], Patriyawaty et al. [44], and Simarmata et al. [45]. Therefore, the use of biofertilizers can be a complement to the Minapadi integrated farming concept.

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Based on this potential, optimizing the combination of compost and LLOF can be an additional input for integrated rice–fish farming (Minapadi). This combination needs to be equipped with the optimal concentrations and/or doses of both, so that the evaluation of the impact of the plantings on the input of the compost and LLOF can be maximized. This optimization must be adjusted to the characteristics that are related to the main objective of the evaluation, namely, the rice yield [46,47]. However, an assessment that only focuses on the rice yield can result in an overestimated interpretation [48]. This is based on the genetic constitution of the yield, which is polygenic, so the evaluation needs to involve other distinct characters that support its productivity [49,50]. In addition, the effectiveness of the interaction between the rice yield and fish yield is also an important consideration in the optimization. Therefore, a systematic, statistical approach is key to evaluating this combination of compost and LLOF, in order to support the productivity of the rice–fish integration agriculture. The purpose of this study was to identify the best combination of compost doses and/or local liquid organic fertilizer concentrations, in accordance with multiple evaluation criteria, to support land productivity based on the rice–fish integration agriculture.

2. Materials and Methods

The experiment was carried out in the Wanuae farmer group in the Barebbo District, Bone Regency, South Sulawesi, (4° 13′–506′ south latitude and 119° 42′–120° 30′ east longitude), Indonesia, during the months of September 2018 until January 2019. The study area receives an average annual rainfall of 201.25 mm/year, with 12 rainy days. Its average air temperature ranges between 24.50 °C–27.60 °C, and its humidity varies between 77–86%. This research was conducted by implementing the split plot design with a randomized complete block design (RCBD). The principal plot of this study was the compost doses (C) that comprised four levels, namely, the control without the compost (C0), 2 ton ha⁻¹ (C1), 3 ton ha⁻¹ (C2), and 4 ton ha⁻¹ (C3). Meanwhile, the subplots of this study were a combination of the local microorganisms with 4 types, namely, the control (L0), a combination of cow urine with water for rice washing (L1), a combination of cow urine moles with water-soaked coconut fiber (L2), and a combination of cow urine and calabash fruit moles (L3), with each randomly applied to the main plot. The collaboration of these factors resulted in 16 combinations which were repeated 3 times, adding a total of 48 experimental units.

2.1. Land Preparation

The land preparation was carried out by repairing the bunds with 40 cm height and maintaining the width of the base and upper bund at a minimum of 50 cm and 25 cm, respectively. The ditches were built 1 m wide and above 50 cm deep, in order to protect the fish from various threats. The ditches were prepared both in the middle of and on the surrounding edges of the rice field bunds, along with a 70 cm deep storage tank to facilitate the fish harvesting during the water draining process, with an objective to optimize the ripening potential of the rice grain. The description of the Minapadi concept is exhibited in Figure 1. Meanwhile, the nutrition land in this study is shown in Table 1.

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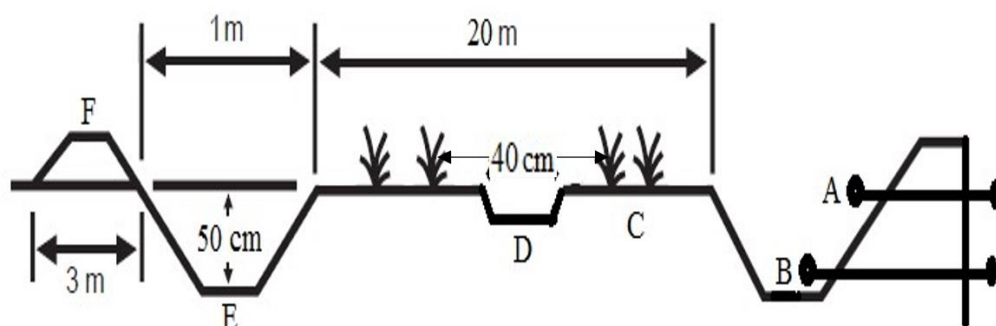


Figure 1. Construction of the Minapadi pond (cross section) description: (A) water inlet channel, (B) lower water outlet channel, (C) rice plot, (D) middle ditches, (E) main ditches, and (F) bunds.

Table 1. Soil status of study field.

Parameter	Unit	Value
texture		Dusty Clay
clay	%	38
dust	%	50
sand	%	12
C-Organic	%	2.35
total nitrogen	%	0.11
C/N	ppm	21
P Olsen	ppm	6.6
K	cmol (+) kg ⁻¹	0.08
Ca	cmol (+) kg ⁻¹	6.03
Mg	cmol (+) kg ⁻¹	2.53
Na	cmol (+) kg ⁻¹	0.08
cation exchange capacity	me/100 g	20.65

2.2. Maintenance of Rice Plants

The qualitative analysis of the rice seeds was conducted by immersing the seeds in a 3% salt solution or soaking them in a ZA solution (225 g ZA/l water). The immersed seeds indicated their suitability for planting and were, accordingly, preselected for this experiment. Following which, the seeds were first soaked and then aged in sequence for 24 h. The process of seeding was carried out by sowing the germinated seeds in the seeding plots. The nursery was fertilized with ponska NPK, urea, and SP-36, each at 15 g m⁻². After the seedlings were 15 days old, the same were planted, with 2 seeds per hole. The 2:1 row legowo cropping system was implemented, with 40 cm for the largest inter-row spacing, 20 cm for the smallest inter-row spacing, and 10 cm for the in-row spacing. The planting conditions were muddy, in order to facilitate the process of making planting points. Then, the seeds were nurtured until the harvest.

The maintenance activities included replanting, weeding, fertilizing, irrigation, and controlling the plant-disturbing organisms. The stitching was completed 7–10 days after the planting (DAP). The field irrigation was regulated persistently, in order to maintain the water level in accordance with the planting system. In the 2:1 legowo cropping system, the water level was maintained at 10 cm above the rice growth surface as the baseline. The first weeding was performed at 20 DAP, then the second weeding at 40 DAP, and the third and last weeding at 70 DAP. The fertilizers, ponska NPK, urea, and SP-36, were cautiously applied, fifty percent below their recommended doses at 167, 100, and 31 kg ha⁻¹. All the

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chemical fertilizers were provided as basic fertilizers to avoid a fish growth disturbance caused by the accumulation of the chemical fertilizers in the rice fields. In order to meet the nutrient requirements, both straw compost and local liquid organic fertilizer (LLOF) fertilizer were also incorporated as treatments, in addition to the chemical fertilizers. The compost was spread during the pre-planting period, whereas the application of the LLOF was carried out once the plants had attained 2 Mst. A fertilizer dilution of 1:10 was applied intermittently every 12 days, via spraying on the leaves in the morning during the stomatal opening. Meanwhile, pests and plant diseases were administered by using insecticides and fungicides rationally, not only to avoid potential damage that would result in reduced yields, but also to avert any interference with the growth and development of the fish.

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2.3. Preparation of Local Liquid Organic Fertilizer and Compost Fertilizer

The LLOF was resourcefully made by collecting the materials surrounding the research location, such as cow urine and water for rice washing, cow urine and coconut fiber, and cow urine and calabash fruit. The LLOF coconut coir was prepared by adding and pressing the coconut coir into a bucket that was already filled with water, until it was fully submerged, upon which the bucket was then closed and left for two weeks. Water that was already blackish brown was used as the LLOF. On the other hand, the calabash fruit LLOF was prepared by blending calabash fruit (grinded) with coconut water and sugar, which was stored in a closed container and connected to a pipette that was filled with water for 2 weeks, eventually filtering it. Similarly, the LLOF with rice water was made by storing it in a tightly closed container/bottle with sugar for 2 weeks. These ingredients were then mixed with cow urine in a ratio of 1:1 for each combination. The nutrition component of each LLOF is shown in Table 2. Meanwhile, the compost fertilizer was taken from a farm shop, with its nutrient component list shown in Table 3.

Table 2. Analysis of nutrient content of local liquid organic fertilizer.

Local Liquid Organic Fertilizer	Kjeldahl	Ekstrak HCl	
	N(%)	P ₂ O ₅ (%)	K ₂ O (%)
cow urine and water for rice washing	0.36	0.39	0.45
cow urine and coconut fiber	0.34	0.42	0.66
cow urine and calabash fruit	0.4	0.44	0.59

Table 3. Analysis of nutrient content of compost fertilizer.

pH (H ₂ O)	Walkley & Black	Kjeldahl	C/N	HNO ₃ :HClO ₄	
	C (%)	N (%)		P (%)	K (%)
6.86	15.25	0.55	28	0.15	0.32

2.4. Fish Rearing

For this study, tilapia fish was chosen, due to its high adaptability to the ecology of paddy fields and its superior economic value [51,52]. The seeds were selected for their uniform characteristics, such as a peaked survivability against the heat and their dark hue, which functions as a camouflage against predators' attacks. Before being spread, the baby fish were first weighed. The tilapia fish were spread in kemalir rice fields that measured 5 cm deep, 12 days after the rice planting.

The tilapia was cultured on the rice field map by spreading the feed pellets on the kemalir. The recommended amount of feed is 3% of the biomass weight. A sample of 10 fish was weighed and averaged to determine the right amount of feed. The average weight that was obtained was then multiplied by the total number of fish in the pond, in order to calculate the biomass weight. The average weight of the fish was measured at 246 g and, with total 41 fish, the weight of the biomass equaled to $246 \times 41 = 10,086$ g, and, accordingly, the amount of feed per day corresponded to $3\% \times 10,086 \text{ g} = 303$ g. This ration was fed twice per day. Simultaneously, the water volume was regulated by administering the water level persistently. If there was an increase in the volume of the water that was caused by rain, the excess water was removed from the paddy fields in the event of rainfall, and conversely, was added from the irrigation channel when the water volume dropped below the threshold. At the time of the treatment, the water in the kemalir was still at a normal level, so as not to interfere with the mobility of the fish. Other maintenance activities included monitoring and restricting the disease and predator occurrences. Meanwhile, the water status parameters in our study are shown in Table 4.

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Table 4. Analysis of water quality in the study location of Bone Regency South Sulawesi.

Parameters	Unit	C1	C2	C3	C4
Before treatment					
ammonia	ppm	0.006	0.009	0.007	0.001
dissolved oxygen (DO)	ppm	10.6	10	8.2	8.6
carbon dioxide (CO ₂)	ppm	8	10	9	9
After treatment					
ammonia	ppm	0.018	0.019	0.021	0.051
dissolved oxygen (DO)	ppm	8.2	6	10.5	7.4
carbon dioxide (CO ₂)	ppm	9	10	10	9

2.5. Harvesting Fish and Rice

Predominantly, rice harvesting is carried out when the seeds reach the ripening stage physiologically, or when around 90–95% of the panicles have turned yellow. Paddy fields require drainage for drying the plots prior to harvest, not only to accelerate the panicle ripening, but also to prevent the harvested stover from being exposed to water. Rice harvest is performed manually by using a sickle, and the threshing of rice grains is performed by using a threshing machine. On other hand, fish harvesting is conducted 10 days before the rice fields are dried. It is achieved by gradually lowering the water discharge and herding the fish into the holding pond. At the discharge channel in the holding pond, a net is placed at the mouth of the outlet channel to convene the fish in the direction of the draining water.

2.6. Parameter Observation and Data Analysis

The observed data included the plant height (cm), total tiller, productive tiller, chlorophyll content, stomata count, stomata length (mm), panicle length (cm), number of filled grains (grains), number of unfilled grains (grains), number of total grains (grains), weight of 1000 grain (g), rice yield (ton ha⁻¹), and fish yield. All the data were analyzed by means of variance with an error of 5%, following which, the determination of the evaluation criteria was carried out by a correlation and analysis of variance [53,54]. The results of both analyses were followed by a polynomial structured test for the compost concentration and interactions. Meanwhile, the significant effect on the type of LLOF material was tested by an honest significant difference test analysis. The evaluation of the fish yield was carried out using a regression and 3D plot analysis [48] (Farid et al. 2021).

3. Results

The results of the variance show the diversified pattern of significance between the characters to the source of the diversity. The compost treatment significantly affected the total tiller, productive tiller, chlorophyll content, number of stomata, stomata length, number of filled grains, number of unfilled grains, number of total grains, rice yield, and fish yield. The local liquid organic fertilizer (LLOF) significantly modulated the number of stomata, stomata length, panicle length, number of filled grains, number of unfilled grains, number of total grains, and rice yield. Meanwhile, the interaction of the compost and LLOF had a significant effect on the number of stomata, stomata length, number of unfilled grains, and rice yield (Table 5).

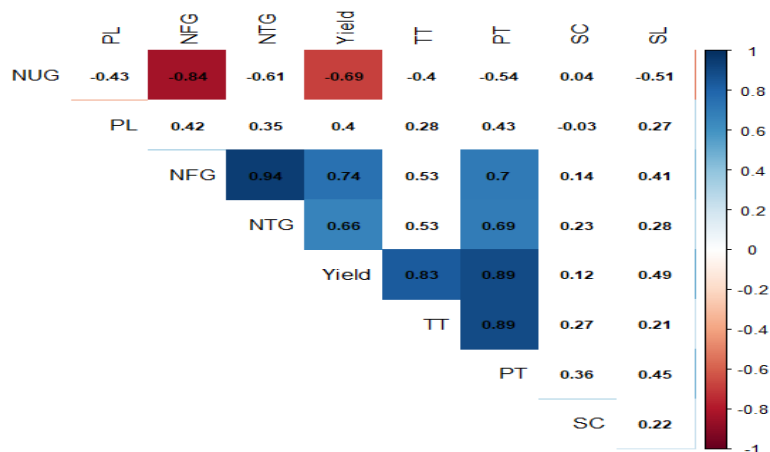
The results of the correlation analysis in Figure 2 show that the rice yield had a significant correlation with the number of filled grains (0.74), number of unfilled grains (−0.69), number of total grains (0.66), total tiller (0.83), and productive tiller (0.89). The productive tiller character also showed a significant correlation with the number of filled grains (0.7), the number of total grains (0.69), and the total tiller (0.89). Meanwhile, the number of filled grains had a significant correlation with the number of unfilled grains (−0.89) and the number of total grains (0.94).

Table 5. Analysis of variance compost and local liquid organic fertilizer treatment of rice growth characters.

Characters	Compost (C)	Local Liquid Organic Fertilizer (B)	CxB	CV_C	CV_B
Plant height	36.96	149.81	284.71	5.53	5.98
Total tiller	141.66 **	5.88	42.31	5.67	12.04
Productive tiller	80.11 **	15.1	9.76	8.42	8.03
Chlorophyll content	0.0001 **	0.00005	0.00016	7.39	6.88
Stomata count	31,468.60 **	31,645.93 **	182,124.77 **	6.37	6.00
Stomata length	0.0016 **	0.0023 **	0.0047 **	13.19	11.79
Panicle length	7.40	11.71 **	4.91	5.23	2.99
Number of filled grains	2147.75 *	2,884.83 **	948.17	10.79	8.56
Number of unfilled grains	320.60 **	532.79 **	103.30 **	9.59	9.11
Number of total grains	2,788.95 **	3,950.41 **	1154.77	10.19	8.83
Weight of 1000 Grain	4.35	14.02	12.54	10.75	4.38
Rice yield	0.32 *	0.62 **	0.70 **	5.56	4.13
Fish yield	0.2157 **	-	-	4.39	-

Notes: CV = coefficient of variation, * significant effect at 1% error level, and † significant effect at 5% error level.

The path analysis results focused on the characters that correlated with the rice yield (Table 6). Based on this analysis, the number of total grains was the only character that had a direct negative effect on the rice yield (-0.51). In contrast, the characters of the total tiller (0.31), productive tiller (0.45), and number of filled grains (0.75) had a positive direct effect on the rice yield, although among the three, the number of filled grain characters was the only character with a significant direct effect on the rice yield. The further tests of the polynomial contrast of the compost and the LSD 0.05 LLOF assays for the number of filled grains characters are shown in Figure 3A,B. Based on the compost treatment, the treatment combination showed a linear regression with a determination value of 0.7748 and a gradient of 3.981. The treatment of four tons ha⁻¹ was the best compost treatment. Meanwhile, based on the LLOF treatment, treatment L3 (119.84a) was the best type of LLOF, and L0 was the lowest LLOF treatment (98.33c).



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Figure 2. Correlation analysis of rice growth characters (notes: PH = plant height, TT = total tiller, PT = productive tiller, SC = stomata count, SL = stomata length, NFG = number of filled grains, NUG = number of unfilled grains, NTG = number of total grains, and yield = rice yield).

Table 6. Path analysis of several growth characteristics on the rice yield.

Character	Direct Effect	Indirect Effect				Correlation
		TT	PT	NFG	NTG	
Total Tillers (TT)	0.31		0.4	0.4	-0.27	0.84
Productive Tillers (PT)	0.45	0.27		0.52	-0.35	0.89
Number of Filled Grains (NFG)	0.75 **	0.16	0.31		-0.48	0.74
Number of Total Grains (NTG)	-0.51	0.16	0.31	0.7		0.66
Total Indirect effect		0.59	1.02	1.62	-1.1	

Note: ** significant effect at 1% error level

The results of the orthogonal-polynomial interaction contrast test on the rice yield characters are shown in Figure 4. The results of the analysis demonstrate that all the LLOF treatments had a linear graph with a determination value above 0.9. The L1 biofertilizer treatment had the highest determination value of 0.9887. Based on the gradient value, L0 and L2 had gradient values above 0.3. Meanwhile, the L2 treatment was the LLOF treatment with the highest gradient value of 0.39.

The results of the analysis of the polynomial contrast test on the fish yield characters are shown in Figure 5. This analysis demonstrates that the compost treatment had a linear graph with a very high determination value (0.9988). The growth gradient on the fish yield graph was 0.0907. These results established that the compost treatment with four ton ha⁻¹ was the most advantageous treatment for optimizing the fish yield.

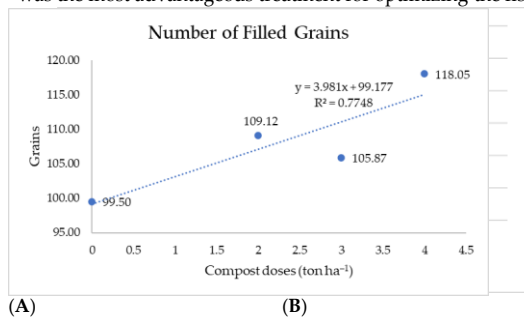
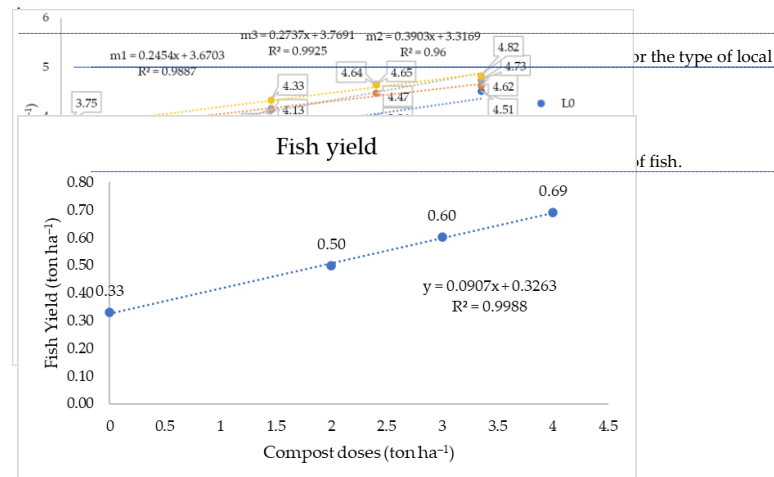


Figure 3. (A) Regression analysis of the effect of compost on the number of filled grains, and (B) honest significant difference test of the effect of the type of local liquid organic fertilizer material on the number of filled grains.



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The results of the 3D plot analysis focused on the three main characters, namely, the number of filled grains, rice yield, and fish yield (Figure 6). The combination of the three characters was focused on the compost treatment. Based on this analysis, adding compost (K1, K2, and K3) had a better combination index value than adding compost (K0). The four ton ha⁻¹ (K3) treatment was the treatment with the best index value and is found at the top end of the 3D plot. Meanwhile, the R/C ratio analysis is shown in Table 7. Based on this table, the best application of the compost was at a compost dosage of four tons ha⁻¹. In contrast, the lowest R/C ratio was found in the control treatment (0 tons ha⁻¹).

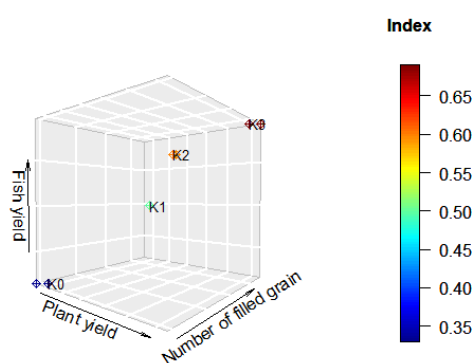


Figure 6. Analysis of 3D plots of the effect of compost based on the interaction of the number of filled grains, the fish yield, and the rice yield.

Table 7. Analysis of land income on compost treatment in Minapadi integration.

Compost Doses	Cost (C) (Rp)	Revenue (R) (Rp)	Profit (Rp)	R/C Ratio
0 ton ha ⁻¹	10,087,478	41,999,800	31,912,322	4.16
2 ton ha ⁻¹	10,337,478	53,802,800	43,465,322	5.2
3 ton ha ⁻¹	10,437,478	59,701,600	49,264,122	5.72
4 ton ha ⁻¹	10,587,478	65,059,200	54,471,722	6.14

4. Discussion

The results of this study indicate that the effect of compost dosing is more dominant than the biofertilizer character and its interactions. The effects of the compost include vegetative, physiological, and generative characteristics. This has been reported by Septiawan et al. [55], Maninggir et al. [56], and Huang et al. [57]. In contrast, the influence of the type of local organic fertilizer only plays a role in optimizing the production components and stomatal characters. This effect was also reported by Nabayi et al. [58] and Arianti [59]. The effect of this interaction only modulates a few characters. This indicates that each type of biofertilizer has relatively the same response changes to increasing the compost doses, so that interactions do not occur in some characters. Based on this, differences in the patterns of diversity between the factors will affect the interpretation of the evaluation in this study; hence, the selection of the main parameters is the key to evaluating the technology package for rice growth within the Minapadi concept.

The combination of the correlation and path analyses shows that the character for the number of filled grains is the only character that has a significant direct effect on the rice yield. The character of the number of filled grains can be recommended as the main parameter supporting the rice yield. In general, this combination of the two analyses is a multivariate analysis, which is mostly used to identify the main parameters supporting production. This has also been reported by Sabouri et al. [60], Murtaza et al. [61], and

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Akbar et al. [62]. In general, the results of the correlation analysis are still influenced by distinct factors; hence, the results of this analysis cannot be the main basis for identifying the relationships between the parameters. The use of cross-tracking is a more in-depth approach than a correlation analysis. This analysis can divide the correlation value into direct and indirect effects [63]. This direct influence is the basis for how big a character's role is in influencing the total diversity of the main characters [53,54,63]. However, the use of cross-prints on many characters is ineffective [54], so the characters that are included need to be selected first through a correlation analysis. Therefore, the combination of the two analyses is considered to be effective for estimating the main parameters that support productivity. Based on this analysis concept, the characters of the number of filled grains and the rice yield become the reference parameters in the evaluation of organic fertilizer packages for the cultivation of Minapadi.

The number of filled grains is one of the characteristics that play a major role in determining the crop production. This has also been reported by Sarwendah et al. [64], Ab-basi et al. [65], and Hastini et al. [66]. Based on the results of this study, the number of filled grains was significantly affected by the compost treatment and the type of local liq-uid organic fertilizer (LLOF). However, the interaction between the two did not affect this character, so its treatment evaluation was carried out individually. Figure 2A displays the effect of the compost treatment on the number of filled grains. The results of the analysis in the figure indicate that the compost treatment is relatively linear, with a relatively high gradient. A high gradient indicates that the rate of increase in the compost is still not close to the optimum level, so the study of the compost dosage treatment still requires further exploration. This was also stated by Amaral et al. [67] and Iqbal et al. [68]. Nevertheless, this figure already reflects the pivotal role of the compost treatment on the number of filled grains character, especially at the compost dosage level of four tons ha^{-1} . Figure 2B shows the effect of the type of LLOF on the character of the number of filled grains, espe-cially when compared with no biofertilizer treatment (L0). The figure recommends the treatment of cow urine and calabash fruit as the best LLOF. In general, cow urine has a higher nutrient content and contains IAA, which can be used as a growth stimulant for growth regulators [69,70]. In addition, this effectiveness is optimized with calabash fruit. Calabash fruit provides better results for growth and production, containing 2.82% nitro-gen, 1.62% phosphorus, 1.22% potassium, and 40.62% carbon [71,72]. Based on this, the treatment of the compost dosage of four tons ha^{-1} , and the local treatment of bovine urine in combination with calabash fruit biofertilizer, are the recommended treatments for op-timizing the character of the number of filled grains.

The most commonly used main character that is employed in cropping evaluation is the rice yield [46,47]. This character is strongly influenced by the three existing sources of diversity, so its evaluation is based on the analysis of the orthogonal-polynomial interac-tions in Figure 3. The results of the analysis in the figure demonstrate that the effect of the compost is predominantly linear on the rate of the increase in the rice yield. In addition, the LLOF sources have a positive impact on increasing the rice yield. However, this in-crease is very dependent on the difference in the gradients between the LLOFs towards increasing the dose of the compost. It indicates that the LLOFs that are produced from various sources have distinct types of microbes and preferences in optimizing the role of the compost in the rice yield. This was also stated by Sulistyarningsih and Harsono [73] (2017). Based on the yield interaction analysis, the LLOF from the combination of cow urine with the coconut fiber soaking water has the highest gradient value of all the LLOF sources. This was also reported by Hongpakdee and Ruamrungsri et al. [74] and Rahim et al. [75]. It indicates that the combination of the L2 biofertilizer with higher doses of the compost will proliferate the rice yield with increased compost dosages. Therefore, the L2 LLOF source and the four ton ha^{-1} compost dose are recommended as the best treatment combination for optimizing the rice yield potential. However, the combined position of the LLOF of cow urine with calabash fruit showed higher (L3) than the biofertilizer L2 for the number of filled grains and rice yield.

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The fish yield in this study only focused on the effect of the compost. This is because the LLOF is only applied to the plant canopy, so the effectiveness of the treatment does not directly affect the fish yield. Based on Figure 4, the addition of compost significantly increases the fish yield potential in the rice-fish integration concept. This is seen from the very high determination value close to 1. In addition, a report by Parvez et al. [76] and Jyoti et al. [49] also stated that the addition of compost affected the fish weight in the paddy-fish integration concept. In general, high doses of compost not only play a role in the process of increasing plant growth, but also play a role in improving water quality [77]. These improvements will provide a good environment for the growth of phytoplankton and other microbes. Phytoplankton are organisms that are similar to the plants in water [78], so adding compost will also increase the nutrient content that is required for the growth of phytoplankton in water [79]. This indicates that increasing the compost in a rice field will provide comfort for the phytoplankton to grow and develop, so that fish can also thrive within these rice fields. This environmental improvement is also in line with a good habitat for tilapia. According to He et al. [80], tilapia within the Minapadi integration system can improve the quality and production of the fish meat. This is because the ecology of the rice fields has a good water quality and lots of microbes that make it suitable for maximal tilapia growth. Therefore, the addition of compost into the rice-fish integration system is required to augment the fish yield potential in rice fields.

The results of the three main characters illustrate that the application of compost affects the increase in the three characters linearly. However, since the interaction between the three traits cannot be detected, a 3D plot analysis is still essential. Based on the results of the 3D analysis, the compost treatment has a domino effect on the three characters. This is indicated by the large difference in the spatial position between the controls and the compost applications. The position of the distant space indicates the degree of significance of a treatment, so it can be concluded that the compost must be applied to the rice-fish integrated cropping system. This will have a large effect on increasing the potential income per paddy field. This potential has also been reflected in the R/C ratio that is shown in Table 3, where the application of minimal compost provides a difference in the R/C ratio of 1.04, in comparison with no compost treatment. This R/C ratio is a comparison between the total revenue and total costs as an indicator of measuring the business feasibility [81]. Even though the compost has a high dominance, it is also recommended to apply a local liquid organic fertilizer to optimize this potential for increasing the R/C ratio. This refers to the impact of the potential interaction between the compost and local liquid organic fertilizer on the rice yield.

5. Conclusions

This research establishes that the application of compost plays a very important role in increasing the potential of Minapadi integrated agriculture. In addition, the concept of the multiple evaluation criteria through a secondary character approach is effective for use in the evaluation of cultivation technology. An effective secondary character for this research is the number of filled grains. Based on the overall evaluation, the best dose of the compost in this study was four tons/ha. This dose can increase the potential income per land with a difference in the R/C ratio of up to two points, and is recommended to be increased again. Meanwhile, the compost dosage of four tons ha⁻¹ and the local liquid organic fertilizer from cow urine with coconut fiber soaking are the recommended combination treatments for optimizing the rice yield potential. Moreover, the compost dosage from this Minapadi (rice-fish) study also requires further exploration for a better understanding.

Author Contributions: Conceptualization, A.Y., M.F., R.S.; methodology, A.Y., M.F., H.M., R.S.; validation, M.F.A.; formal analysis, M.F.A., H.M., A.Y.; investigation, H.M., A.A., and M.F.; resources, M.F.; H.M.; data curation, H.M., and M.F.A.; writing—original draft preparation, A.Y., and M.F.A.;

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writing—review and editing, M.F., A.A., R.S.; visualization, M.F.A.; supervision, A.Y., M.F. and R.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: We are grateful to the publication management center of Hasanuddin University for providing the facilities, like workshop training and Enago proofreading for this article.

Conflicts of Interest: The authors declare no conflicts of interest and the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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The Integrated Minapadi (Rice-Fish) Farming System: Compost and Local Liquid Organic Fertilizer Based on Multiple Evaluation Criteria

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Agronomy 2023, 13(4), 978; <https://doi.org/10.3390/agronomy13040978>

Received: 4 February 2023 / Revised: 19 March 2023 / Accepted: 20 March 2023 / Published: 25 March 2023

(This article belongs to the Special Issue Bio-Based Fertilizers in Agriculture: New Opportunities and Challenges)

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