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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

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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 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.

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.

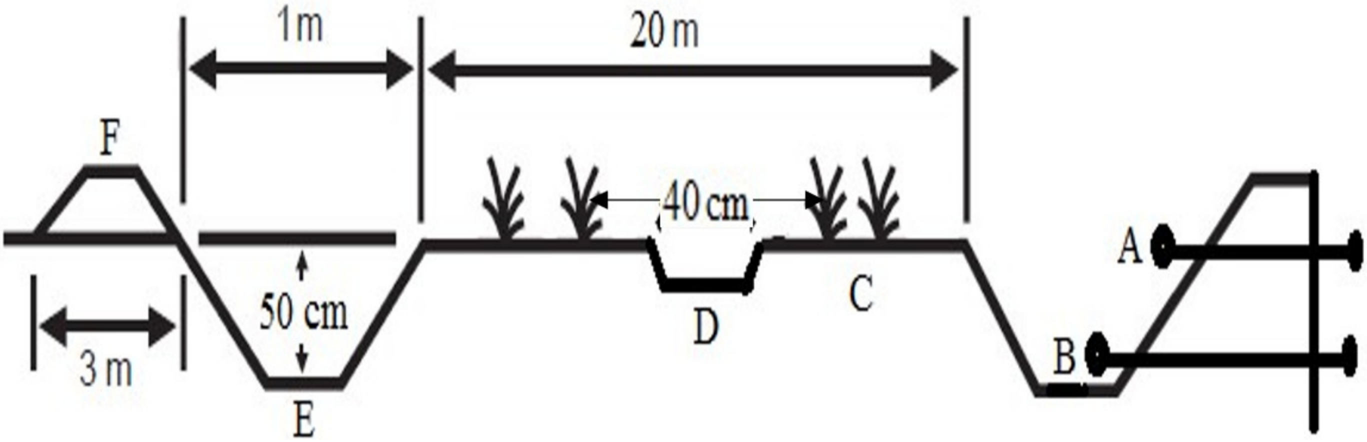

Figure 1. Construction of the Minapadi pond (cross section) description: (**A**) water inlet channel, (**B**) lower water outlet channel, (**C**) rice plot, (**D**) middle ditches, (**E**) main ditches, and (**F**) bunds.

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 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.

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_2O_5 (%)	K_2O (%)
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_2O)	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 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 × 41 = 10,086 g, and, accordingly, the amount of feed per day corresponded to 3% × 10,086 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.

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).

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 *	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, and * significant effect at 5% error level.

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).

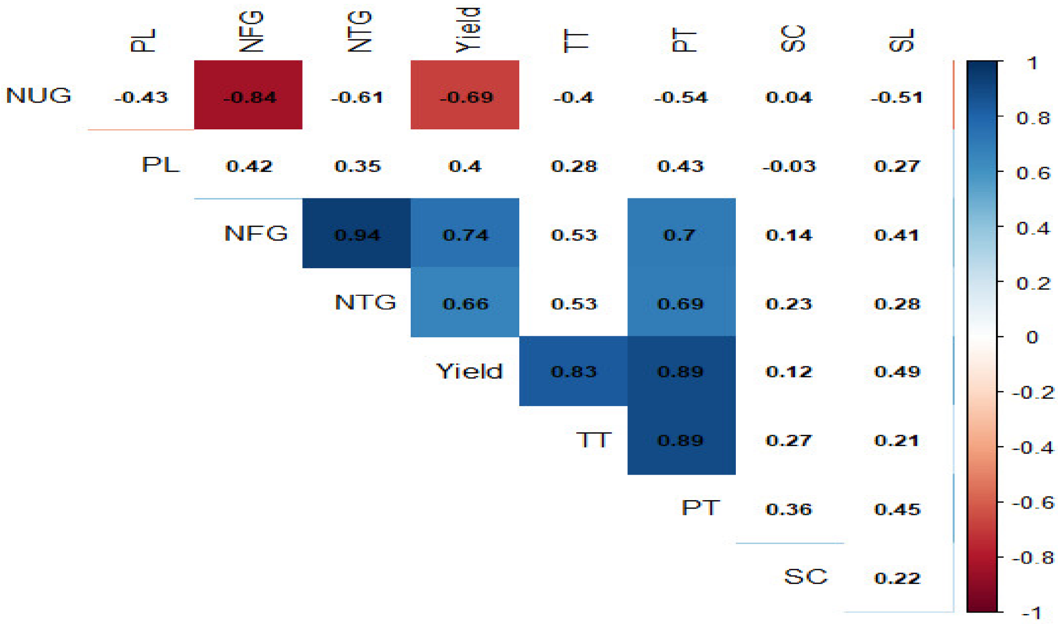

Figure 2. Correlation analysis of rice growth characters (notes: PH = plant height, TT = total tiller, PT = productive tiller, SC = stomata count, SL = stomata length, NFG = number of filled grains, NUG = number of unfilled grains, NTG = number of total grains, and yield = rice yield).

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).

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.

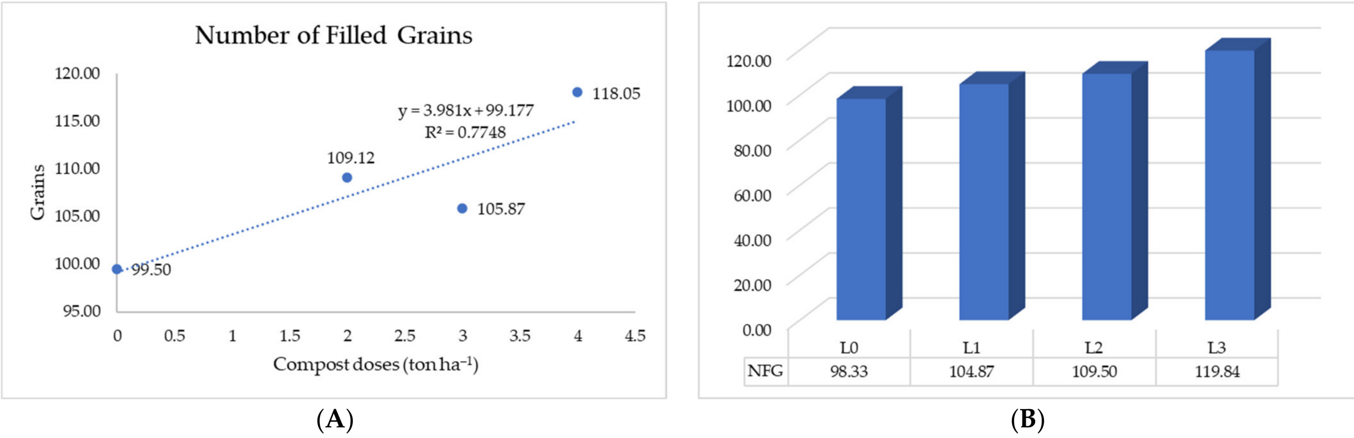

Figure 3. (**A**) Regression analysis of the effect of compost on the number of filled grains, and (**B**) honest significant difference test of the effect of the type of local liquid organic fertilizer material on the number of filled grains.

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.

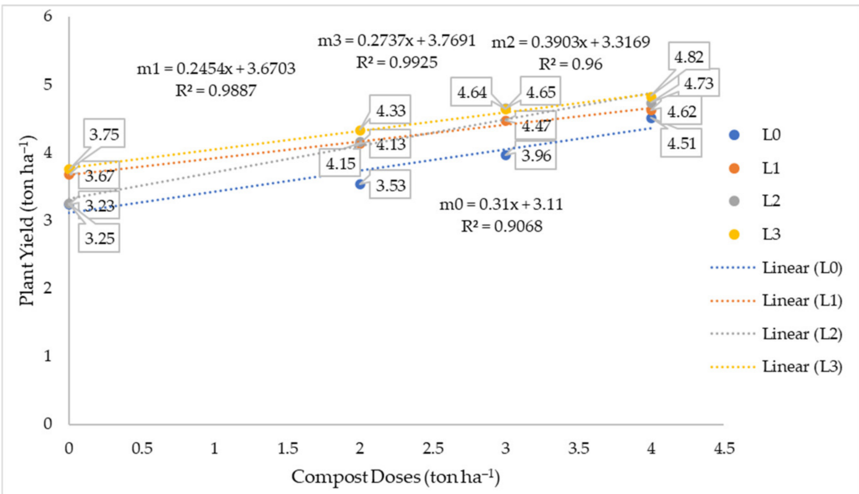

Figure 4. Polynomial–orthogonal interaction analysis of the rice yield character for the type of local liquid organic fertilizer (L) for the dose of compost.

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 0.00907. These results established that the compost treatment with four ton ha^{-1} was the most advantageous treatment for optimizing the fish yield.

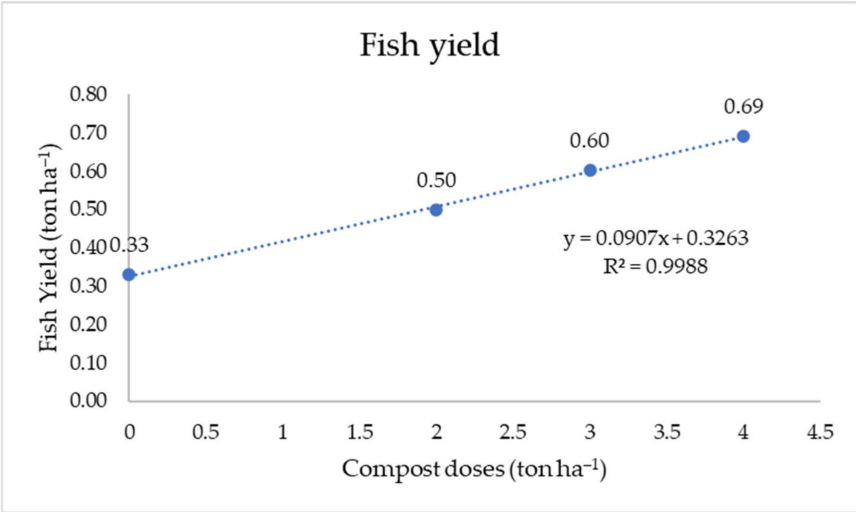

Figure 5. Regression analysis of the dose of compost on the increase in the yield of fish.

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}).

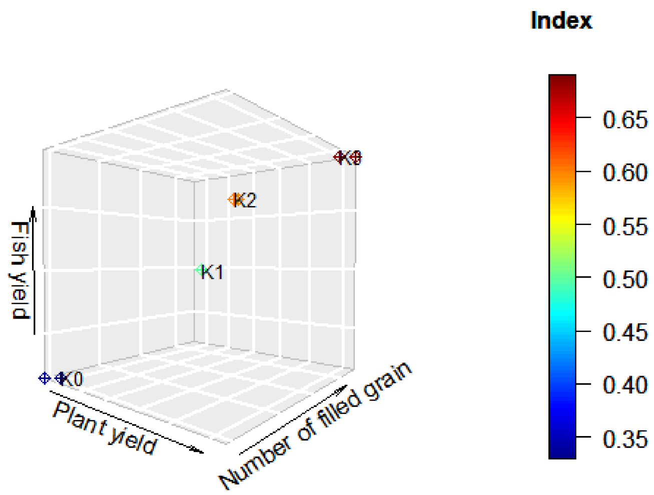

Figure 6. Analysis of 3D plots of the effect of compost based on the interaction of the number of filled grains, the fish yield, and the rice yield.

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 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], 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 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, especially 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% nitrogen, 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 optimizing 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 interactions 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 increase 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 Sulistyaningsih 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.

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.

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