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Growth and yield of the Indonesian local rice variety (*Oryza sativa* cv. Mentik Susu) cultivated organically with the application of cow manure and rice husk biochar

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Abstract

The research was aimed to obtain the role of cow manure (CM) and rice husk biochar (RHB) on the performance of one of Indonesian local varieties that was rice cv. Mentik Susu. A 3x3 split plot experiment with a completely randomized block design was used throughout the study. The main plot consisted of three levels of CM, CM-0 = no added-CM; CM-36 and CM-72 were added 36 and 72 ton CM/ha, respectively. The sub plot was three RHB levels, RHB-3, RHB-6 and RHB-9, respectively for 3, 6 and 9 ton RHB/ha. This research was conducted from June to September 2021, experimentally in the rice fields of Ketapang Village, Susukan Sub-District, Semarang District, Central Java Province, Indonesia. It is located at coordinates 7°24'22"S - 110°36'33"E at an altitude of 613 meters above sea level. The activity of observing destructive plant samples was carried out at the Ecology and Plant Production Laboratory, Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Indonesia, located at 6°50'-7°10' S - 109°35'-110°50' E. The parameters observed were plant height, number of tillers, leaf greenness, leaf chlorophyll content, carotenoid content, plant growth rate, plant dry weight, percentage of productive tillers, rice yield per hectare, and weight of 1000 grains. The data obtained were analyzed using Analysis of Variance (ANOVA). Treatments that showed a significant effect on the observed parameters were further tested using the Honestly Significant Difference (Tukey HSD) with a confidence level of 95%. The results showed that the application of 36 tons of CM/ha and 9 tons of RHB/ha was a treatment combination that provides optimal results. However, because the rice yield between the 36 ton CM/ha and 9 ton RHB/ha treatments was not significantly different to the rice yield in the 36 ton CM/ha and 3 ton RHB/ha treatment, therefore, the 36 ton CM/ha and 3 ton RHB/ha treatments can be recommended to be applied on organically rice cultivation, especially rice cv. Mentik Susu.

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Introduction

Rice (*Oryza sativa* L.) is a cereal crop that is important for human life throughout the world, especially for people in Asia and Africa. Therefore, to support human needs for rice, large enough land is needed for rice cultivation considering that more than 50% of the world's population consumes rice. However, in the last few decades there has been a decline in the quality of paddy fields due to the implementation of intensive agriculture (FAO, 2009; Wang *et al.,* 2019). Cultivating the land 3 to 4 times/year, excessive use of artificial chemical fertilizers, use of straw as feed and minimal use of organic fertilizer in paddy fields result in a decrease in organic carbon content or soil organic carbon (SOC).

The Indonesian government has continues to produce superior varieties of food crops, especially rice, to meet national needs, but due to the increasing population, the increase in rice production is still not able to meet national needs. Many strategies have been used to meet national rice needs, but it is still difficult to be fulfilled. Apart from efforts to obtain superior varieties such as rice cv. Situ Bagendit (Widjajanto *et al.,* 2023), there is the opportunity to develop superior local varieties of rice such as rice cv. Mentik Susu to be cultivated continously as it is one of the superior local varieties that has excellent production performance (Widjajanto *et al.,* 2021).

Changes in SOC content result in physical, chemical and biological changes in the soil. Soil organic matter (SOM) contains 58% SOC so that changes in SOC content result in changes in the biomass of soil microorganisms, increasing SOC will increase water absorption and retention and reduce the compactness of soil particles (Blanco-Canqui *et al.,* 2013). A decrease in the population and diversity of soil microbes will have an impact on the availability of nutrients because the availability of nutrients in the rhizosphere is closely related to the activity of microorganisms. The solution that can be implemented is the application of organic farming significantly by increasing the SOC content in rice fields as has been done by several farmer groups in Central Java such as in Pati District (Supriyadi *et al.,* 2020), Wonogiri District (Supriyadi *et al.,* 2021) and Semarang District (Haryuni *et al.,* 2021; Mustofa and Widjajanto, 2021).

Organic farming has a positive long-term impact on farmers and agricultural land. Organic farming implementations prioritize the use of local resources to increase farmers' income through the use of cheaper local resources. Local resources that can be utilized include cow manure (CM) and rice husk biochar (RHB). Cow manure is very abundant in rural areas as Central Java Province, because farmers generally raise livestock, especially cows. The number of beef cattle raised by farmers is distributed as follows: 5-10 heads (65%), 1-4 heads (18.33%) and >10 heads (16.66%) (Mulyo *et al.,* 2012). The use of manure at a dose of 45 tons/ha in the 4th year significantly increased the number of tillers, plant height, panicle length, shoot dry weight, root dry weight and weight of 1000 rice grains compared to the first year (Zhang *et al.,* 2021).

Another amendment that can be used to improve soil quality as well as the growth and production of rice plants is RHB. The application of 2.8 tons RHB/ha effectively increased plant height, plant production, total carbon, total nitrogen, available K and available Mg in the soil during 4 years of observation compared to without biochar application (Nan *et al.,* 2020). Providing RHB at planting effectively increases shoot dry weight, number of filled grains, total grain number, weight of filled grains, total grain weight and weight of 1000 grains compared to without adding RHB (Butnan and Vityakon, 2023). Therefore, this research was conducted with the aim of assessing the role of CM and RHB on the growth and yield of organically cultivated rice cv. Mentik Susu.

Materials and methods

Experiment was conducted from June to September 2021, experimentally in the rice fields of Ketapang Village, Susukan Sub-District, Semarang District, Central Java Province, Indonesia with coordinates 7°24'22"S - 110°36'33"E at an altitude of 613 meters

above sea level. The activity of observing destructive plant samples was carried out at the Ecology and Plant Production Laboratory, Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Indonesia.

A split plot design prepared using a completely randomized block design was used throughout out the experiment. The main plot consisted of CM doses, respectively were 0, 36 and 72 tons CM/ha. The subplots consisted of three consequtive RHB doses that were 3, 6, and 9 tons/ha. The local variety of rice cv. Mentik Susu was investigated during the experiment. The rice cultivation was carried out organically by applying CM and RHB one week before planting.

The experiment consisted of 9 treatment combinations with 3 blocks as replications. For each treatment combination, a 2 m x 3 m plot of experimental land was used with a rice planting distance of 25 cm x 25 cm. The parameters observed were plant height, number of tillers, leaf greenness, leaf chlorophyll content, carotenoid content, plant growth rate, plant dry weight, percentage of productive tillers, rice yield per hectare, and weight of 1000 grains. Destructive sampling was carried out twice, at 21 day after planting (DAP) and 63 DAP. Destructive sample observations to determine chlorophyll and carotenoids were carried out at maximum vegetative time when the rice population had entered the generative phase.

The data obtained were analyzed using Analysis of Variance (ANOVA). Treatments that showed a significant effect on the observed parameters were further tested using the Honestly Significant Difference (Tukey HSD) with a confidence level of 95%.

Results and discussions

The height of rice plants in the 36 ton CM/ha (CM-36) was significantly higher than in the control (CM-0) and 72 ton CM/ha (CM-72). Meanwhile, it in the 72 tons CM/ha (CM-72) was not significantly different from the control (CM-0) (Table 1). Plant height in the 36 ton CM/ha (CM-36) treatment increased significantly compared to plant height in the control treatment by 29.7%, while plant height in the 36 ton CM/ha (CM-36) treatment decreased significantly by 26.0% in the 72 ton CM/ha (CM-72) treatment.

Table 1. Plant height and number of tillers at various doses of CM and RHB

Treatments	Plant height (cm)	Number tillers
Cow Manure, CM (ton/ha)		
CM-0	102.52 b	23.24
CM-36	132.93 a	27.67
CM-72	98.33 b	25.37
Rice Husk Biochar, RHB (ton/ha)		
RHB-3	111.56	25.98
RHB-6	111.26	26.56
RHB-9	110.96	23.74

The increased in plant height of up to 29.7% from the control treatment to the 36 ton/ha manure treatment was not in accordance with the results of previous research Sudarsono *et al.* (2014). They found that the height of rice plants applied manure increased by only 5.6% compared to those were not added manure. The difference in the increased in plant height achieved in this study compared to the research of Sudarsono *et al.* (2014) was probably due to the use of manure in this study as much as 36 and 72 tons CM/ha, whereas in Sudarsono *et al.* (2014) only 7.5 to 10 tons CM/ha. In another study, Khanafi *et al.* (2018) found that superior rice varieties including rice cv. IR-64 and rice cv. Ciherang which were cultivated with balanced fertilizer between bioslurry and artificial chemical fertilizers showed that plant height and number of tillers when applied only with bioslurry organic fertilizer up to 8.5 tons/ha were not significantly different compared to plant height and number of tillers at 550 kg NPK/ha. This means that bioslurry organic fertilizer may be used as a substitute for the use of artificial chemical fertilizers up to 100%.

Manure contains organic materials that may improve soil conditions as well as macro nutrients such as N, P and K so that plants may use them for the plant growth (Padmanabha *et al.,* 2014). However, the number of tillers in this study could not be increased by applying manure up to 72 tons/ha. The average number of tillers formed on rice plants was 25.4 tillers. Meanwhile, the application of RHB did not show a significant effect on plant height and number of tillers on rice plants.

There was a significant interaction between the doses of CM and RHB on the greenness of rice plant leaves (Table 2). The combination of 36 tons CM/ha (CM-36) with 6 tons RHB/ha (RHB-6) showed that the greenness of the rice plant leaves was not significantly different from the combination of 36 tons CM/ha (CM-36) with 9 tons RHB/ha (RHB-9). However, both treatments were significantly higher than the other treatments. The combination of a manure dose of 36 tons CM/ha (CM-36) with 6 tons RHB/ha (RHB-6) was able to increase the greenness of plant leaves by 111.87% compared to the combination treatment of 0 tons CM/ha (CM-0) with 3 tons RHB/ha (RHB-3). Then there was a decrease in leaf greenness by 59.91% when the manure dose was increased to 36 tons CM/ha (CM-36) with 9 tons RHB/ha (RHB-9)

Table 2. Greeness of leaves at various doses of CM and RHB

Treatments	Rice Husk Biochar, RHB (ton/ha)			Average
	RHB-3	RHB-6	RHB-9	
Cow Manure, CM (ton/ha)				
CM-0	16.60 cd	13.67 d	14.07 d	14.78
CM-36	24.80 bc	35.17 a	27.37 ab	29.11
CM-72	19.17 bcd	21.17 bcd	14.10 d	18.14
Average	20.19	23.33	18.51	(+)

The dose of manure has a significant effect on the growth rate of rice plants (Table 3). The growth rate of rice plants in the 36 ton/ha treatment increased by 78.9% compared to the treatment without manure application. Meanwhile, when the manure dose was increased to 72 tons/ha, the growth rate of rice plants decreased by 29.1% compared to the growth rate of rice plants in the 36 tons/ha manure.

The manure treatment did not show a significant effect on leaf chlorophyll levels, but did have a significant effect on the caroteoid levels of rice plant leaves (Table 3). Rice leaf carotenoid levels decreased by 42.7% when manure dose of 36 tonnes/ha was applied. Furthermore, leaf carotenoid levels increased by 46.1% when 72 tonnes/ha of manure was applied.

Table 3. Crop growth rate, chlorophyll content, and carotenoid content of rice crops at various doses of CM and RHB

Treatments	Crop Growth Rate ($g/m^2/week$)	Chlorophyll Content mg/L)	Carotenoid Content (mg/L)
Cow Manure, CM (ton/ha)			
CM-0	12.32 b	0.021	7.77 a
CM-36	22.05 a	0.020	4.45 b
CM-72	15.63 b	0.015	6.50 a
Rice Husk Biochar, RHB (ton/ha)			
RHB-3	64.25 b	0.020	6.70
RHB-6	69.26 a	0.018	5.44
RHB-9	65.64 b	0.017	6.58

The combination treatment of CM doses and RHB doses had a significant effect on the dry weight of rice plants (Table 4). The treatment combination CM-0 + RBH-3 was not significantly different from CM-36 + RBH-6, CM-72 + RBH-6, CM-36 + RBH-6, CM-72 + RBH-9 and CM-72 + RBH -6.

The dry weight of rice plants in the CM-0 + RBH-3 treatment combination reached 105.68 g, an increase of 16.6% in the CM-36 + RBH-9 treatment. However, in the CM-72 + RBH9 treatment, the dry biomass of rice plants decreased by 23.4% compared to the CM-36 + RBH-9 treatment.

Table 4. Dry weight of rice plants at various doses of manure and rice husk biochar

Cow Manure (ton/ha)	Rice Husk Biochar (ton/ha)			Average
	RHB-3	RHB-6	RHB-9	
	----------g----------			
CM-0	105.68 abc	84.96 c	89.41 c	93.35
CM-36	106.95 abc	118.37 ab	123.26 a	116.20
CM-72	104.26 abc	109.17 abc	94.47 bc	102.63
Average	105.63	104.17	102.38	

The manure dose treatment had a significant effect on the number of productive tillers and rice yield, but had no significant effect on the weight of 1000 grains (Table 5). Productive tillers and rice yields had a similar trends, productive tillers in the 36 tons CM/ha (CM-36) treatment was significantly higher than the control but not significantly different from the 72 tons CM/ha (CM-72) treatment. In addition, productive tillers in the control were not significantly different from productive tillers in the 72 tons CM/ha (CM-72) treatment (53.98% vs 65.48%). The same trends occurred in rice yield parameters (4.39^{b} vs 6.65^{a} vs 5.44^{ab} tons/ha). When the manure dose was increased from control (CM-0) to 36 tons CM/ha (CM-36), the percentage of productive tillers increased by 47.6%. However, productive tillers decreased by 17.8% when manure dose was increased from the 36 tons CM/ha (CM-36) treatment to 72 tons CM/ha (CM-72). The high percentage of productive tillers in the treatment with a manure dose of 36 tons CM/ha (CM-36), was followed by a high rice crop yield of 6.65 tons/ha. The decrease in production of rice crop was 18.2% when the manure dose was increased from 36 tons/ha to 72 tons/ha. However, there was no significantly differences on the weight of 1000 rice grains in the treatments of 0, 36 and 72 ton/ha, consequtively. On the other hand, the treatment dose of RHB had no significant effect on the percentage of productive tillers, rice production yield, and weight of 1000 rice grains.

Table 5. Productive tillers, Yield and dan Weight of 1000 grains at various doses of CM and RHB

Treatments	Productive tillers (%)	Yield (ton/ha)	Weight of 1000 grains (g)
Cow Manure, CM (ton/ha)			
CM-0	53.98 b	4.39 b	16.76
CM-36	79.68 a	6.65 a	16.44
CM-72	65.48 ab	5.44 ab	18.01
Rice Husk Biochar, RHB (ton/ha)			
RHB-3	64.25	5.69	17.56
RHB-6	69.26	5.51	17.09
RHB-9	65.64	5.29	16.56

Conclusion

The results showed that the application of 36 tons of CM/ha and 9 tons of RHB/ha was a treatment combination that provides optimal results. However, the rice yield between the 36 ton CM/ha and 9 ton RHB/ha treatments was not significantly different to the rice yield in the 36 ton CM/ha and 3 ton RHB/ha treatment, therefore, the 36 ton CM/ha and 3 ton RHB/ha treatments can be recommended to be applied on organically rice cultivation, especially rice cv. Mentik Susu.

Recommendation

The research results should be recommended to be applied to rice cultivation that CM and RHB, respectively, up to 36 tons/ha and 3 tons/ha may be applied to the organic cultivation of rice plants, especially the local variety Mentik Susu.

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