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Performance of paddy crop in swampland under organic pellet fertilization from *Azolla* and vermicompost

Keragaan tanaman padi di lahan rawa dengan pemupukan pelet organik dari *Azolla* dan vermikompos

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ABSTRACT

This study aimed to examine the effect of applying organic pellet fertilizers from vermicompost and *Azolla* using coal fly ash as an adhesive on paddy crop response in swampland. The research was performed in a pot experiment using a completely randomized factorial design with two treatment factors. The organic pellet fertilizer doses were: 0 ton ha^{-1} (a control); 10 ton ha^{-1}; 20 ton ha^{-1}; and 30 ton ha^{-1} as the first factor. In the second factor, the different NPK fertilizer dose was applied: the absence of NPK fertilizer as a control; 0.5 and 1 time of the recommended dose. The results showed that the application of organic pellet fertilizer significantly improved soil pH but not significant on soil organic C and N levels. There was tendency of increased on soil pH, C-organic, and N-total with the increased doses of organic pellet fertilizers applied. The NPK fertilizer application significantly improved plant height, tiller number and plant biomass as the dose were rised up. The organic pellet fertilizer application significantly improved plant height, number of tillers, and plant biomass. Applying organic pellet fertilizer at a dose of 10 tons ha^{-1} should be sufficient as no further improvement with the increasing doses.

INTRODUCTION

Amid limited land, swampland is a potential land for paddy cultivation in the next future. Swamplands generally have low soil fertility, partly due to high soil acidity and low availability of plant nutrients, so crop production on these lands is generally low (Subagyo, 2006; Haryono et al., 2013). Soil quality improvement in increasing the productivity of lowland swamps aims to raise and maintain crops' nutrient availability. It can be achieved with balanced fertilization using organic and inorganic fertilizers (Djafar, 2013; Rois et al., 2017).

The application of organic fertilizers is known to increase crop production (Angelova et al., 2013). On the other hand, inorganic fertilizers in the cultivation of food crops are still very much needed, especially fertilizers containing N, P, and K elements readily available to plants, mostly paddy crops. Fertilization at a dose of 300 kg urea ha^{-1}, 50 kg SP-36 ha^{-1}, and 150 kg KCl ha^{-1} significantly increased the growh and yield of paddy crops grown on swampland (Djafar, 2013; Rois *et al.*, 2017).

Organic fertilizers can be physically divided into bulk and pellets or granules. Bulk organic fertilizers are commonly used to have several drawbacks, including that they can generate dust and are relatively more complicated in their application and transportation. Also, bulk organic fertilizers applied to the soil tend to decompose faster and are easily lost through leaching (Utari et al., 2015). Solid organic fertilizers in pellets form are a way to overcome the shortage of bulk organic fertilizers. Pellet fertilizer has several advantages, i.e., more straightforward in application, packaging, and transportation. Making organic pellet fertilizer is relatively easy (Isroi, 2009; Wahyono et al., 2011).

Pellet fertilizer can be made using a mixture of vermicompost - *Azolla* biomass and coal fly ash as an adhesive. Vermicompost is an organic

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fertilizer rich in nutrients, including C-organic, N-total, P, K, Ca, and Mg (Yadav and Gupta, 2017; Dominguez et al., 2019). Besides, during the vermicompost formation processes, it is known that it involves various microbial consortia that can positively affect soil and plants (Dominguez et al., 2019). Therefore, providing vermicompost will increase the availability of soil nutrients and nutrient absorption by plants. Furthermore, *Azolla* is an aquatic plant that can be a source of an organic fertilizer rich in N nutrients, and its biomass growth is relatively fast (Sudadi et al., 2014; Muradov et al., 2014). The symbiosis of *Azolla* with *Anabaena azollae* is known to fix air nitrogen around 30-60 kg N ha^{-1} (Kollah et al., 2015; Roy et al., 2016). A low C/N ratio of *Azolla* biomass (between 9-10) indicates that this organic material can immediately be mineralized to produce nutrients available to plants (Bhuvaneshwari and Kumar, 2013; Roy et al., 2016).

Table 1. Soil and organic pellet properties

Parameters	Soil	Organic pellet fertilizer
pH (H_2O)	4.36	7.22
C-organic (%)	4.34	16.64
N-total (%)	0.20	1.27
P-available (mg Kg^{-1})	7.7	26.10
K-exchangeable ($cmol_{(+)}$ kg^{-1})	0.32	25.58
C/N	21.7	13.10

The combination of vermicompost and *Azolla* biomass can be expected to improve the organic pellet fertilizer's nutrient quality. A material that functions as an adhesive is needed in the process of making organic pellet fertilizer. In this study, the adhesive used is coal fly ash. Coal fly ash can be used as a mixture of organic fertilizers (Hermawan et al., 2018). Coal fly ash is dominated by fine-sized particles (0.01 - 100 µm) and silicate compounds and has pozzolanic properties (such as cement), so it can act as an adhesive (Yao et al., 2015; Srinavas et al., 2017).

The application of pellet fertilizers made from vermicompost and azole biomass as a raw material to improve the fertility of lowland swamps and its effect on rice plant growth has not been widely used. Therefore the research was carried out to examines paddy crop performance in swamplands due to organic pellet fertilizer made from vermicompost and *Azolla* biomass as raw material.

MATERIALS AND METHODS

Making Pellet Fertilizer

Organic pellet fertilizer was prepared in the laboratory. *Azolla* biomass and vermicompost were provided by facilities in the university. Meanwhile, coal fly ash was obtained from the power plant in Muara Enim District, South Sumatra. Organic pellet fertilizer was mixed by *Azolla* biomass and vermicompost and coal fly ash adhesive with a ratio of 4: 4: 2 (dry weight, w/w). Before mixing, the *Azolla* biomass and vermicompost were mashed and filtered using a sieve of 2.0 mm. Coal fly ash was also pulverized and filtered ground to pass through a 0.05 mm sieve. Then, mixed each weight proportion evenly and added deionized water to form a paste (± 40% moisture content). Next, the mixture was put into a grinding tool (screw extruder) to form pellets. The resulting pellets were then dried using an oven at 50° C for 24 hours (± 10-15% moisture content). The properties of the resulting organic pellet fertilizer showed in Table 1.

Experimental design

This research was carried out in the greenhouse. Swampland was obtained from the swamp of the experimental garden, Faculty of Agriculture, Sriwijaya University. The indicator crop used was swampland paddy variety, i.e., Inpara. Soil and plant analysis were performed at the laboratory. The soil used for the experiment was 10 kg $pot^{-1,}$ with the properties can be shown in Table 1.

The treatments were arranged according to a completely randomized factorial design, with three replicates and two factors. The first factor was the dose of organic pellet fertilizer, including control treatment, 10 tons ha^{-1}, 20 tons ha^{-1}, and 30 tons ha^{-1}. The second factor, i.e., the dosage of N, P, and K fertilizers, includes control treatment, 50%, and 100% recommended dose (300 kg urea ha^{-1} + 50 kg SP-36 ha^{-1} + 150 kg KCl ha^{-1}).

Data Collection and Analysis

The variables observed were soil pH using a pH meter, soil C-organic using the Walkey and Black method, soil N-total using the Khjedahl method, plant height, maximum number of tillers, and dry weight plant stover in the primordium stage. The data were analyzed statistically using an analysis of variance (ANOVA) to determine the influence of treatment on the parameters tested and the least significant difference (LSD) test to determine the difference between the treatments tested.

Table 2. The influence of doses of organic pellets fertilizers and NPK fertilizers on soil pH, organic C content (%) and total N at 10 weeks after planting

NPK Fertilizer	Organik Pellets Ferlilizers (ton ha^{-1})				Effect of NPK
	0	10	20	30	
	---------- pH H_2O ----------				
0	4.55 a	5.13 cd	5.28 d	4.96 bc	4.98
0.5 x Recommended Dose	4.63 a	4.81 ab	5.04 bcd	4.96 bc	4.85
1.0 x Recommended Dose	4.83 abc	4.84 abc	4.78 ab	4.98 bcd	4.85
Effect of Pellets	4.67 a	4.92 b	5.03 b	4.97 b	-
ANOVA	NPK = ns ; Pellets = * ; Interactions = *				
$LSD_{0.05}$	Pellets = 0.17 ; Interactions = 0.30				
	---------- Organic C (%) ----------				
0	4.10	4.92	4.77	4.18	4.49
0.5 x Recommended Dose	4.28	4.70	4.54	4.67	4.54
1.0 x Recommended Dose	4.90	4.93	4.75	4.75	4.83
Effect of Pellets	4.43	4.85	4.68	4.53	
ANOVA	NPK = ns ; Pellets = ns ; Interactions = ns				
	---------- Total N (%) ----------				
0	0.025 b	0.024 b	0.020 ab	0.019 ab	0.022
0.5 x Recommended Dose	0.015 a	0.019 ab	0.020 ab	0.015 a	0.017
1.0 x Recommended Dose	0.022 ab	0.022 ab	0.015 a	0.045 c	0.025
Effect of Pellets	0.020	0.020	0.018	0.026	
ANOVA	NPK = ns ; Pellets = * ; Interactions = *				
$LSD_{0.05}$	Interactions = 0.017				

RESULTS AND DISCUSSIONS

The influence of treatment on soil pH

Based on the analysis of variance, it was known that the application of NPK fertilizer has no significant effect on soil pH, while the application of organic pellets fertilizers and the interaction between NPK and organic pellet fertilizers has significant effect on soil pH. The organic pellets fertilizers can significantly increase soil pH. Meanwhile, increasing the dosage of organic pellet fertilizers up to 30 ton ha^{-1} did not significantly differ in soil pH, even though the soil's pH value tended to increase with increasing doses of organic pellet fertilizers (Table 2). Organic fertilizers in the soil will further decompose, among others, to produce humic acids. Humic acid is known to reduce the solubility of Al in the soil; as a result, the hydrolysis of Al and the solubility of H^+ ions in the soil solution also decreases so that the soil pH will increase. The results of the decomposition of organic fertilizers will also release cations that cause the increasing of OH^- concentration so that the soil pH will be raised (Havlin et al., 2005; Angelova et al., 2013).

The soil pH value tended to decrease with increasing doses of the NPK fertilizer (Table 2). The NPK fertilizer can reduce the pH value because urea applied to the soil will release H^+ ions. Havlin et al. (2005) suggested that nitrogen from fertilizers in the soil can be converted into nitrate ions through the nitrification process. The hydrogen ions generated through the nitrification processes will have the potential to increase soil acidity. Changes in soil pH value occurred in combining NPK fertilizer dosage treatment and organic pellet fertilizers. In the NPK fertilizer treatment of 0.5 times the recommended dose and without NPK fertilizer (control) combined with organic pellet fertilizer up to a dose of 20 tons ha^{-1} could significantly increase soil pH. Meanwhile, the soil pH value in combining NPK fertilizer one time the recommended dose and organic pellet fertilizer up to 30 ton ha^{-1} tended to increase the soil pH value (Table 2). The decomposition of organic fertilizers will increase the content of organic compounds in the soil and bind H and Al ions as a source of soil acidity, as well as increase soil CEC and soil pH (Angelova et al., 2013).

The influence of treatment on soil organic C

The results of the analysis of variance showed that the treatment of NPK and organic pellet fertilizers and the interaction between NPK and pellet organic fertilizers did not have a significant

effect. The C content of swamplands used in this study was classified as very high (4.34%) (Table 1), hence the addition of organic pellets and NPK did not significantly affect increasing the soil organic C content. The C-organic level in the soil classified as dynamic and changes depending on the organic matter decomposition process in soils (Angelova et al., 2013).

Table 3. The influence of doses of organic pellets fertilizers and NPK fertilizers on plant height and number of tillers of swampland paddy in the primordium phase

NPK Fertilizer	Organik Pellets Ferlilizers (ton ha^{-1})				Effect of NPK
	0	10	20	30	
	---------- Plant Height (cm) ----------				
0	97.33	124.00	123.33	123.00	116.91 a
0.5 x Recommended Dose	112.67	126.00	134.33	133.67	126.66 b
1.0 x Recommended Dose	124.00	140.00	122.67	142.33	132.25 b
Effect of Pellets	111.33 a	130.00 b	126.77 b	133.00 b	
ANOVA	NPK = ** ; Pellets = ** ; Interactions = ns				
$LSD_{0.05}$	Pellets = 7.70 ; NPK = 6.67				
	---------- Number of Tillers ----------				
0	2.00	12.67	13.67	16.67	11.25 a
0.5 x Recommended Dose	4.33	17.67	18.67	19.33	15.00 b
1.0 x Recommended Dose	8.00	24.00	23.33	22.67	19.50 c
Effect of Pellets	4.77 a	18.11 b	18.55 b	19.55 b	
ANOVA	NPK = ** ; Pellets = ** ; Interactions = ns				
$LSD_{0.05}$	Pellets = 2.91 ; NPK = 2.52				

*Remarks: ns = no significant effect; ** = very significant effect*
Numbers followed by the same letter are no significant difference (P<0.05)

The analysis of soil organic C content (Table 2) showed that the rise of NPK fertilizer and the organic pellet fertilizer increased soil organic C content. In this study, the combination of organic pellet and NPK fertilizers tended to raise the soil organic C content, although relatively low. The organic pellet fertilizers can increase the C-organic soil of the siring with increasing doses. Organic fertilizers and inorganic fertilizers can increase the soil organic C content related to increased activity and microbial population in the soil (Havlin et al., 2005; Angelova et al., 2013).

The influence of treatment on total N in soil

The analysis of variance on total N showed that the NPK fertilizer treatment and the pellet organic fertilizer treatment had no significant effect. However, the interaction between the NPK and organic pellet fertilizer significantly affected soil N availability in the plant's primordium phase. The initial N-soil analysis before being treated was in a low category (0.2%) and decreased to be in the deficient category <0.1 during the primordium stage (Table 1). It was assumed that most of the N in the soil had been absorbed by plants during the primordial stage. Paddy needed excess nitrogen during the primordium stage. The requirement of Nitrogen higher in plant rather than other nutrients, which is often being a limitation factor for plant productivity (Havlin et al., 2005; Utama, 2015).

The LSD test results (Table 2) showed that the total N-soil content in the combination treatment of organic pellet fertilizer 30 ton ha^{-1} and NPK fertilizer one time recommended dose had soil N content significantly higher than in other treatment combinations. The increase in soil N-total content was partly due to the addition of organic pellet fertilizers. Organic pellet fertilizer made from vermicompost and *Azola* used in this study has a relatively high N content (1.27%) and was believed to increase the soil's N content.

Table 2 showed that increasing the organic pellet fertilizer dose increased the total N-content in the soil. Organic matter is a source of plant nutrients. The decomposition of organic matter will produce several proteins and amino acids, which will be mineralized to ammonium (NH_4^+) and, through the nitrification process, will form nitrate ions (NO_3^-). Thus, organic matter is the largest contributor to soil nitrogen (Havlin et al., 2005; Sposito, 2008). NPK fertilizer can increase the value of N-soil availability because inorganic fertilizers can provide high and quickly available nutrients for plants. Increased NPK fertilizer dose raised the total N content in the soil (Table 2). Nitrogen fertilizers will increase the total soil

nitrogen content and plant nitrogen uptake (Havlin et al., 2005)

The influence of treatment on plant height and number of tillers

Based on the analysis of variance on the growth components of swampland paddy data's, it was known that the NPK fertilizer and the pellet organic fertilizer treatments had a very significant effect. However, the interaction between the fertilizer treatment had no significant effect on plant height in the primordium phase and the maximum tiller number of swampland paddy. The application of pellets organic fertilizer significantly improved plant height and tiller number, but 10 tons ha^{-1} should be sufficient as no further improvement with the increasing doses. The treatment of NPK fertilizer significantly Improved plant height and tiller number as the dose were rised up (Table 3).

Plant height at one time recommended dose of NPK fertilizer was significantly higher than that control but was no significant difference from NPK fertilizer at a dose of 0.5 x recommended (Table 3). Table 3 also shows that increasing the dose of NPK fertilizer tended to increase swampland paddy height. Following the previous study, the addition of inorganic fertilizers will raise plant nutrients' availability and, in turn, increase plant growth (Rois et al., 2017). Plant height in the treatment of organic pellet fertilizer at a dose of 30 tons ha^{-1} was no significant difference when compared to the plant height in the treatment at a dose of 10 tons ha^{-1} and a dose of 20 tons ha^{-1}, but all three were significantly higher than the control treatment (Table 3). It shows that the application of pellets organic fertilizer at a dose of 10 tons ha^{-1} had increased swampland paddy growth. The increase in the dosage of organic pellet fertilizers did not show a significant difference in plant height. Optimal plant growth can be achieved if the nutrients needed for plant growth and yield are available in optimum and proportional quantities. The availability of nutrients and balanced amounts will affect plants' metabolic processes to grow and develop (Havlin et al., 2005; Sposito, 2008).

Table 4. The influence of doses of organic pellets fertilizers and NPK fertilizers on plant dry weight of swampland paddy in the primordium phase

NPK Fertilizer	Organik Pellets Ferlilizers (ton ha^{-1})				Effect of NPK
	0	10	20	30	
	---------- Dry Weight of the Stover (g pot^{-1}) ----------				
0	4.24	42.50	58.04	146.75	62.88 a
0.5 x Recommended Dose	13.59	80.24	128.84	154.61	94.32 a
1.0 x Recommended dose	26.59	158.48	203.79	258.45	161.83b
Effect of Pellets	14.81 a	93.74 b	130.22 c	186.60 d	
ANOVA	NPK = ** ; Pellets = ** ; Interactions = ns				
$LSD_{0.05}$	Pellets = 28.77 ; NPK = 33.21				
	---------- Dry Weight of the Root (g pot^{-1}) ----------				
0	4.12	39.16	74.31	125.80	60.85 a
0.5 x Recommended Dose	23.58	87.12	138.17	250.07	124.74 b
1.0 x Recommended dose	30.85	235.55	189.13	280.60	184.03 c
Effect of Pellets	19.52 a	120.61 b	133.87 b	218.82 c	
ANOVA	NPK = ** ; Pellets = ** ; Interactions = ns				
$LSD_{0.05}$	Pellets = 43.45 ; NPK = 50.18				

Remarks: ns = no significant effect; ** = very significant effect
Numbers followed by the same letter are no significant difference (P<0.05)

The maximum number of plant tillers at the NPK fertilizer treatment dose one time the recommended dose had an average maximum number of tillers, significantly more than the control treatment and 0.5 times the recommended dose (Table 2). The application of inorganic fertilizers to the soil can increase the availability of nutrients immediately available to plants (Havlin et al., 2005). Paddy crops that are given sufficient inorganic fertilizers will be able to produce a more significant number of tillers. Nutrients N, P, and K can increase plant height and the number of tillers of paddy crops (Rois et al., 2017).

In the treatment of organic pellet fertilizer, the maximum number of tillers at the treatment dose of 30 tons ha^{-1} was no significant difference from the number of tillers in the treatment dose

of 10 tons ha^{-1} and a dose of 20 tons ha^{-1}, but the number of tillers in all three was significant, more than the control treatment (Table 3). This data proves that the application of organic pellet fertilizers can increase the number of swampland paddy tillers. The high N content (Table 2) in the soil due to the N supply from *Azolla* and vermicompost (Table 1) as raw material for making organic pellets was assumed to be the cause of the increase in the number of tillers swampland paddy. The results showed that organic pellet fertilizers positively affected the number of tillers and grain production (Utama, 2015; Rois et al., 2017). Organic fertilizers that contain various plant nutrients can raise plant nutrients' availability and improve the soil's physical, chemical, and biological conditions to encourage plant growth and development (Angelova et al., 2017).

The influence of treatment on plant dry weight

The analysis of variance on the dry weight data of swampland paddy in the primordium phase showed that the NPK fertilizer and the organic pellet fertilizer had a significant effect. However, the interaction between the two factors had no significant effect on the swampland paddy's plant stover and root dry weight. Table 4 shows that the escalated dose of NPK fertilizer of organic pellet fertilizer raises the plant's dry weight, both dry weight of the stover and root dry weight of swampland paddy. The plant's dry weight, both stover and root, also tended to increase with the escalating dose of organic pellet fertilizer at each NPK fertilizer dose. These data indicated a positive interaction between NPK fertilizer dosage treatment and pellet fertilizer dosage on swampland paddy biomass production.

The application of organic pellet fertilizer tends to improved plant biomass as the dose were increased and NPK fertilizers treatment significantly Improved plant biomass as the dose were increased (Tabel 4). The application of organic matter to the soil will cause the nutrient cycle to be balanced to contribute nutrients to support plant growth. The use of organic fertilizers also plays a vital role in improving the soil's physical, chemical, and biological characteristics, so that the nutrients from the inorganic fertilizers can be absorbed by plants optimally (Havlin et al., 2005; Angelova et al., 2017).

The LSD test (Table 4) showed that the plant's dry weight on the NPK fertilizer treatment one time the recommended dose was significantly higher than the NPK fertilizer treatment with a lower dose. Likewise, in treating organic pellet fertilizer doses, plants' dry weight in the organic pellet fertilizer application with a 30 tons ha^{-1} was significantly higher than the lower dose. The difference in the plants' dry weight, among others, is thought to be due to an increase in soil pH value and N availability (Table 2) and other nutrients due to the treatment application. Availability of nutrients in the soil, among others, is relying on soil pH and nutrient input from outside and the decomposition of organic matter (Havlin et al., 2005; Sposito, 2008).

CONCLUSIONS

The application of organic pellet fertilizer significantly improved soil pH but not significant on soil organic C and N levels. There was tendency of increased on soil pH, C-organic, and N-total with the increased doses of organic pellet fertilizers applied. The NPK fertilizer application significantly improved plant height, tiller number and plant biomass as the dose were rised up. The organic pellet fertilizer application significantly improved plant height, number of tillers, and plant biomass. Applying organic pellet fertilizer at a dose of 10 tons ha^{-1} should be sufficient as no further improvement with the increasing doses.

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