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UTILIZATION OF AGRICULTURAL WASTE AND BIOLOGICAL AGENTS TO INCREASE RICE YIELD

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ABSTRACT - Agricultural waste can be fermented into liquid organic fertilizer to provide nutrition and phytohormon for plants. The application of this liquid organic fertilizer will improve nutrient availability, root morphology, growth and yield of plants. The objective of this research was to examine the effect of nitrogen, phosphorus, and potassium (NPK) synthetic fertilizers and different types of Liquid Organic Fertilizer (LOF) on plant growth and rice yield. The experiment was conducted at Bener Village, Ngrampal sub-district, Sragen district, Indonesia, from March to November 2011. The experiment was developed according to Randomized Completely Block Design with five replicates. The treatments were: LOF "Double", LOF "Plus", LOF "Bacteria", LOF "Bacteria+Plus", and NPK fertilizers (Control without LOF). Plant growth was measured weekly on five plant samples while plant yield was assessed at harvest time. The data were subjected to analysis of variance followed by Duncan's Multiple Range Test. The results showed that plants treated with synthetic fertilizer (NPK, Control) have the lowest plant growth and rice yield compared to those treated with LOF. The types of fertilizer applied did not affect the number of tillers. Plants treated with LOF "Bacteria+Plus" or LOF "Plus" displayed more leaves and better plant height of than those treated with LOF "Double" or synthetic fertilizer. Plants treated with LOF "Bacteria+Plus" or LOF "Plus" had a significantly higher number of seed/panicles, grain weight per hill, per plot and per hectare than those treated with LOF "Double" or synthetic fertilizer.

KEY WORDS: Biological agents, agricultural waste, liquid organic fertilizer, rice

INTRODUCTION

Indonesia is the third largest rice producer in the world with a production of 57,049,000 tons, in 2008, after India and China with production of 141,134,000 tons and 185,490,000 tons, respectively (IRRI World Rice Statistics, 2010). One of the main concerns in Indonesian agricultural development is on boosting rice production (Sukristiyonubowo, *et al.,* 2011). The Indonesian government policy during 1967-1997 was directed at gaining high yields using inorganic fertilizers and synthetic pesticides while neglecting the use of organic fertilizers and bio pesticides (Adiningsih, 2006; Khudori, 2008). However, the high yield of rice production only lasted for a short period. This policy resulted in decreasing soil fertility that has caused inefficient utilization of soil nutrition (Padmini *et al*, 2007). Farmers found that plants did not respond to fertilization even when the fertilizer dose was increased. Improved plant productivity did not significantly correlate with the increased dose of fertilizer (Deore *et al.*, 2010; Padmini, 2009). Furthermore, intensive use of chemical pesticides leaves residue that contaminates soil, and causes the demise of some soil decomposer organisms, resulting in disturbed biological soil equilibrium , pest and disease outbreak, and disrupted plant growth (BPTP, 2011). In addition, chemical residue disturbs the balance of nutrients in soil, reduces soil biodiversity, decreases soil fauna biomass, increases fluctuation of dominant soil fauna population groups and hampers decomposition processes of organic matters (Las *et al*., 2006; Tim sintesis Kebijakan, 2008; Hossaen *et al*, 2011).

With the growing concern for evironmental protection and sustainable development, agricultural experts propose a system that limits the application of inorganic fertilizer and pesticides and uses more local and natural resources to manage soil fertility, water, pests and other agronomic needs. Soil fertility is managed through the application of organic matter to enhace soil biological activity, nutrient recycle and nitrogen fixation. This approach is known as Low External Input and Sustainable Agriculture (LEISA) (Pender, 2008). Recently, the LEISA approach has become increasingly popular among farmers and consumers, as they want healthier crop production with minimal detrimental impacts on the environment.

There are different types of soil biota within soil, including microbes (bacteria, fungi, actinomycetes, microflora, and protozoa) and soil fauna. Each of the soil biota has a specific function. Microbes are very instrumental in helping the growth of plants by providing nutrients (e.g. N-fixing microbes, P-solubilizing microbes), helping the absorption of nutrients (e.g. mycorrhizal arbuscular fungi), stimulating plant growth (e.g. hormone-producing microbes), and controlling pests and diseases (e.g. antibiotic-producing microbes, antipathogen) (Kosit, 2011). Diversity of soil biota can be used as biological indicators of environmental and soil quality.

Developing sustainable agriculture technology through environmentally sound approaches to enhance growth and yield of rice is needed. Utilization of waste products for further agricultural processes is a form of sustainability. Agricultural waste can be processed into organic fertilizer. Organic fertilizer includes solid organic fertilizer (compost) and liquid organic fertilizer (LOF). In the decomposition process of agricultural waste, the presence of fungi will keep the temperature low. When the temperature is over 65° C, there will be no fungi present. The bacteria decompose large molecules of agricultural waste into small molecules in liquid organic fertilizers (Kosit, 2011). Organic fertilizer contains a considerable amount of nitrogen, phosphorus, and potassium (N, P, K) and various micronutrients, and plant hormones (Simbarashe *et al.,* 2011).

In general, the development of LEISA in Indonesia has not been encouraging. Farmer's dependence on inorganic fertilizer is still high in rice production and government support for LEISA is negligible. Therefore, it is necessary to study the utilization of LOF from agricultural waste and biological agent for increased rice yield. The biological agent is formulated into bacteria fertilizer that contains 1) major microbes as providers of N, P, K elements through biosynthetic, bio enzymatic and fixation so they are available to plants; 2) secondary microbes that produce a food source for the proliferation of all microbes in the biotic associations; 3) and creates ideal soil conditions for development of all microbes. The objective of this research was to examine the effect of inorganic fertilizer (NPK) and various types of LOF on plant growth and rice yield.

MATERIALS AND METHODS

Field experiments were conducted in Bener village, Ngrampal Sragen, Central Java, Indonesia from June until October in 2011. Materials used in the study included: rice seed variety IR-64, compost, organic liquid fertilizer (LOF), NPK compound fertilizer (N:P:K = 15:15:15). The experiments were arranged in Randomized Completely Block Design with four replicates. Each plot size was 50 m x 6 m. The field for LOF treatments was prepared for LEISA systems using 1.5 tons of manure/ha and 200kg of NPK fertilizer/ha applied prior to planting. The treatments used were LOF "Bacteria" (15 mL/L water); LOF "Double" (15 mL/L water); LOF"Plus" (15 mL/L water); mixture of LOF "Bacteria" (7.5mL/L water) + LOF "Plus" (7.5 mL/L water); Control (without LOF, NPK compound fertilizer 450 kg/ha). The foliar application of LOF was applied four times in 10 day intervals with the first application at two weeks after transplanting.

The LOF was prepared in the field using agricultural waste (rotting/over ripened fruits and vegetables) enriched with rice sprout, with (LOF "Plus")/without neem leaves extract (LOF "Double"). The nutrient contents of LOF were analyzed at the Integrated Research and Testing Laboratory (LPPT), Universitas Gadjah Mada, Yogyakarta, Indonesia. The laboratory analysis showed that the content of macronutrients were 0.07% nitrogen, 0.023% phosphorus and 0.138 % potassium; the micronutrients were 1.51 ppm Zn, 2,10 ppm Mn, 26,87 ppm Fe, 157,59 ppm Mg, and plant hormones IAA 0,07 ppm. LOF "Bacteria" contained *Lactobacillus* sp 1.75 x 10^7, Photosynthetic Bacteria 1.01 x 10^7, Actinomycetes 1,5 x 10^7, P-solubilizing microbes 2,7 x 10^7 (Succofindo analysis No.: A/ 277/LM/Anls/12/2010, Merdeka fertilizer leaflet).

Plant growth (plant height and number of leaves) was measured every ten days and plant yields (number of tillers, panicle numbers and lengths, number of seeds per panicle and unproductive tillers) were assessed at harvest time in five plant samples. The data was subjected to an analysis of variance followed by Duncan's Multiple Range Test (DMRT; α: 5%) using SAS® software.

RESULTS

Plant Growth

The application of LOF significantly improved plant height at 20 days after transplanting in comparison to rice that was not treated with LOF (Table 1). The plant height of rice treated with the mixture of LOF "Bacteria" and LOF "Plus" was significantly higher than those without LOF but not significantly different from plants treated with other types of LOF at 20, 40 and 50 days after transplanting (Table 1). The plant height of rice treated with LOF "Double" was not significantly different from rice that was not treated with LOF at 30, 40, 50 and 60 days after transplanting (Table 1).

The number of leaves of rice treated with LOF was not significantly different from that of plants without LOF at 20 days after transplanting. The number of leaves of rice treated with the mixture of LOF "Bacteria" and LOF "Plus" was significantly higher than those without LOF but not significantly different from plants treated with other types of LOF at 30, 40 and 50 days after transplanting (Table 2).

Yield Components

The effect of LOF application on various yield components including the number of tillers, panicle numbers and length, number of seeds per panicle and unproductive tillers were significant. The results of the application of LOF "Bacteria + Plus" were not significantly different from those of LOF "Plus" and both produced significantly higher number of tillers and panicle lengths than those without LOF. The effect of LOF "Bacteria" and LOF "Double" applications on the number of tillers, the number of panicles and the length of panicles was not significantly different from those without LOF, but their application also produced yield components with the same results as other types of LOF. The advantage of using LOF "Bacteria" and LOF "Bacteria + Plus" was that most tillers were able to form panicles. They produced significantly less unproductive tillers with more numbers of grain/panicles (Table 3).

The use of various LOF indicated that the weight of 1000 grains did not significantly differ in all treatments. The weight of grains per hill or per plot or per hectare of rice treated with a mixture of LOF "Bacteria + Plus" was not significantly different from those treated with LOF "Plus" or LOF "Bacteria" but was significantly higher than those treated with LOF "Double" or without LOF (Table 4).

Table 1. The effect of LOF applications on plant height at ages 20 to 60 days after transplanting

TREATMENT		Plant height (cm)				
		20 days	30 days	40 days	50 days	60 days
LOF	"Double"	37,67 a	37,33 b	60,33 ab	79,67 ab	93,67 b
	"Plus"	37,00 a	40,33 a	61,33 ab	81,33 ab	95,00 a
	"Bacteria"	36,33 a	40,33 a	60,67 ab	80,33 ab	94,00 a
	"Bacteria+Plus"	37,00 a	41,33 a	62,67 a	82,33 a	95,67 a
	Without LOF	31,67 b	35,33 b	59,00 b	78,00 b	92,67 b

Note: Means followed by the same letter within a column are not significantly different from one another at P≤ 0.05 (DMRT)

Table 2. The effect of LOF applications on number of leaves at ages 20 to 60 days after transplanting

TREATMENT		Number of leaves				
		20 days	30 days	40 days	50 days	60 days
POC	"Double"	41,61 a	60,67 ab	122,67 ab	127.67 ab	110,00 b
	"Plus"	40,33 a	61.33 ab	122,33 ab	128,00 ab	112,67 a
	"Bacteria"	30,33 a	60,67 ab	120,67 b	124.00 b	110,33 b
	"Bacteria+Plus"	40,33 a	62,67 a	124.00 a	132,33 a	113,00 a

Table 3. The effect of LOF applications on yield components

TREATMENT		Yield components				
		Number of tillers	Number of panicles	Length of panicles (cm)	Number of grain/ panicles	Un-productive Tillers (%)
POC	"Double"	23,33 ab	17,83 ab	25,67 ab	103,67 b	5,50 a
	"Plus"	25,33 a	18,17 ab	26,00 a	137,67 a	5,83 a
	"Bacteria"	21,67 b	17,83 ab	25,17 ab	134,00 a	2,50 b
	"Bacteria+Plus"	26,50 a	19,83 a	26,17 a	127,00 a	2,17 b
	Without LOF	20,33 b	15,83 b	24,33 b	107,67 b	6.00 a

Note: Note: Means followed by the same letter within a column are not significantly different from one another at P≤ 0.05 (DMRT)

Table4. The effect of LOF applications on yield components

TREATMENT		Yield components			
		Weight of 1000 grain (g)	Weight of grains per hill (g)	Weight of grains per plot (g)	Weight of grains/ha (ton)
POC	”Double”	25,67 a	35,70 b	1402,80 bc	7,07 bc
	”Plus”	24,67 a	38,75 ab	1436,20 ab	7,18 ab
	”Bacteria”	25,67 a	43,63 a	1436,20 ab	7,18 ab
	”Bacteria+Plus”	26,00 a	43,92 a	1536,40 a	7,68 a
	Without LOF	25,33 a	34,00 b	1302,60 c	6,52 c

Note: Means followed by the same letter within a column are not significantly different from one another at $P \leq 0.05$ (DMRT)

DISCUSSION

This study showed that application of various types of LOF improved the growth and yield of rice. Similar results were obtained by the study of Deore *et al*. (2010), which indicated that the growth and yield of Chili increased significantly in plants treated with LOF. However, using LOF does not replace soil fertilization, because supplying plant's major nutrient needs (NPK) is most effective and economical via soil application. The LOF application has proven to be an excellent method of supplying plant requirements for secondary nutrients (calcium, magnesium, sulfur) and micronutrients (zinc, manganese, iron, copper, boron, and molybdenum), while supplementing N-P-K needs for short and/or critical growth stage periods (Simbarashe *et al.,* 2011).

The weight of 1000 grains was not significantly affected by the types of fertilizer applied. This means that the size of the grain is more or less the same and is strongly predetermined by the genetic property of the rice variety. Shomura *et al*. (2008) reported that when a gene associated with grain size is deleted, sink size that is responsible for cell numbers in the outer glume of the rice flower will increase and this will further improve rice yields.

Use of LOF “Bacteria” or a mixture of LOF “Bacteria” + “Plus” can improve growth and yield of the rice, although the results were not significantly different from other LOF usage. LOF “Bacteria” functions to provide N, P and K essential nutrients to crops and also increases plant resistance to pests and diseases as well as maintains the ecological balance in the soil. The role of bacteria in LOF is to decompose large molecules of organic matters into small molecules. During the decomposition *Bacillus* sp. produces the enzyme protease; Lactic acid bacteria decompose sugars to become lactic acid, format acid, ethanol, and CO2; yeast helps to change sugars into ethyl alcohol and CO2. Yeast is used for the fermentation process (Kosit, 2011). Fungi may increase the uptake and efficiency of micronutrients like Zn, Cu, Fe and Mg (Suresh *et al*., 2011).

Besides providing nutrients for plants, LOF “Plus” also supplies a natural hormone that is needed for plant growth. Decomposed fruit and vegetables are known to produce hormones and vitamins (Kosit, 2011). As a result, plants are strong and hardy producing the highest rice yield. LOF "Plus" also contains a biopesticide i.e. neem leaves extract. Neem is a plant that can be used as a botanical pesticide. Neem contains the active ingredient Azadirachtin that is toxic and works as an antifeedant and repellent against insects. Udomporn *et al.* (2009) reported that fermented LOF from herbs such as derris, neem, turmeric, citronelle grass, tobacco, and wood vinegar can substitute chemical insecticides. The lower growth and yield of rice treated with POC "Double" was because the plants were less resistant to pests and diseases. The number of tillers was quite high, but they did not form maximum panicles.

The application of LOF "Bacteria" or the mixture of LOF "Bacteria + Plus" resulted in a high percentage of panicles. This was indicated by the presence of a small number of unproductive tillers. Panicle numbers and lengths were not significantly different from those without the LOF, but the number of seeds produced per panicle and grain weight per hill was higher and more tillers were capable of forming panicles. This indicates that the grains in the panicle were denser and did not fall out easily. Organic fertilizer with optimum inorganic N combinations might have prolonged the availability of N and thereby senescence was delayed contributing to more photosynthesis during the seed filling stage (Raikar *et al*., 2009).

CONCLUSION

The use of LOF "Bacteria" or a mixture of LOF "Bacteria + Plus" can improve growth and yield most effectively. An additional application of LOF "Bacteria" and a mixture of "Bacteria + Plus" to NPK fertilizer significantly reduced the numbers of unproductive tillers.

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STATEMENT OF AUTHORSHIP

Both authors worked together in designing and conducting the experiment. The first author analyzed the data and wrote the first draft of the manuscript. The second author revised the manuscript to meet the standards of international publication.

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