Effect of indigenous organic fertilizer on the growth and yield of paddy

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Abstract. The utilization of organic fertilizer (OF) is one of the solutions to reduce the negative impact of inorganic fertilizer (IF). OF can maintain soil fertility and quality that also increases farm yield. This research aimed to analyze the effects of various fertilizer, including IF and OF from indigenous source, on the growth and yield of paddy. The experimental method used Randomized Block Design Pattern with five treatments, consisted of: 1) no fertilizer (control); 2) IF; 3) cow manure compost (CMC), 4) indigenous organic fertilizer (IOF); and 5) commercial fertilizer (CoF). All treatments were replicated four times. The data were analyzed statistically by the F test, followed by the Duncan Multiple Range Test at the level of 95%. The results showed that various fertilizer treatments did not resulting significant difference on plant height, 1000 seed weight, and grain yield but resulting significant difference for tillers number at day 14, 21, 28, 35, 44, 50, 57, 64, 70, and 80 and panicles number at day 86, 93, and 99. The grain yield with IOF is 1.8% higher than control and 4.9% higher than IF. Our results highlight the benefit of OF utilization from indigenous sources that available around us.

1. Introduction
The majority of paddy field management goal in Indonesia is to achieve high production of rice. In order to achieve that goal, farmers have utilize synthetic fertilizers continuously in their farm. Intensive usage of synthetic fertilizers on agricultural land in a long time can damage the soil structure, decline soil organic matter, and cause environmental pollution [1]. Synthetic fertilizer is mainly used to increase the production, however, the utilization often ignore the negative impact to the environment [2].

The management of fertilizer utilization (i.e. amount and type) is one of the main factors that affecting better income in rice farming [3]. However, there is a limited choices of available fertilizer, especially considering the economic factor [4]. So, it is important to change the fertilizer into a better compound that not only increase yield but also maintain environment quality, such as (organic fertilizer) OF, in an organic farming management system.
Organic agriculture becomes popular because of people are more aware about health and environmental issue that direct them to buy organic food [5,6]. As a result, organic agriculture can support sustainable rural development and reduce poverty [7]. However, plant cultivation can reduce soil fertility, how to maintain soil fertility and how continuously cultivate the land without decrease the soil quality are the major problems in agriculture [8].

One of the important crops in Indonesia is rice which is not only as Indonesian’s staple food but also as livelihood of almost one billion people that works on rice production and postharvest activities in rural regions [9]. Rice is also considered as one of the most important food worldwide and it is widely planted in Asian tropical countries [10]. In the production activity, the addition of a sufficient amount of biofertilizer can increase a 5-30% crop yield [11]. Furthermore, the application of organic farming system in the paddy field can increase the productivity of dry unhulled rice around 6% higher than the conventional farming system [12]. In addition, the application of organic farming system by rice farmers in the Philippines was able to reduce the production costs up to 49% and increase their income [13].

An environmental friendly approach has been widely implemented by introducing beneficial microorganisms to increase nutrients, plant growth, and the ability of plant tolerance from abiotic and biotic stresses [14]. Microbial fertilizers become famous throughout the world as it does not negatively affect the environment like IF and it is beneficial for nutrient uptake from the contact between microorganisms and plant [15]. Fertilizer from biological agents consist of living microorganism cells or latent (hidden) and their metabolites which are inoculated into seeds, soil, or in seed root that can help plant growth and increase yield namely biological fertilizer (biofertilizer). Biofertilizer is a part of organic agriculture as it is replacing the use of chemical IFs and enhancing the use of OFs. It is a better alternative effort to reduce the use of chemical fertilizer (CF), so that it can support the sustainable agriculture with less environmental damage [16,17].

Local Microorganism (MOL) can be used as an elementary part of fertilizer. Microbial technology utilization is not only necessary to plants but also useful to decompose organic matters, unused agricultural materials, disposal household materials, and industrial waste [18]. Moreover, MOL can replace IFs and other commercial fertilizers roles but its production is not difficult with lower cost as the basic materials is from sufficient unused matter [19]. For instance, banana hump can be used to produce MOL, it contains microbial decomposing organic matter. Decomposing microbes are found in the outer and inner side of the banana hump. The kind of microbes that have been identified inside banana hump MOL are Bacillus sp., Aeromonas sp. and Aspergillus nigger, these microbes are commonly used to decompose organic matter. Banana hump contains starch 45.4% and protein 4.35%, the nutrient contents in it can help plant growth and prevent disease [20–22].

PGPR is a mechanism of rhizosphere bacteria exploitation to gain the benefits in plant health defense and plant growth-promoting [23]. PGPR is also can be said as a biological agent that has been proven as an alternative way to decrease disease attacks effectively [14]. One of the examples is bamboo roots, it can be utilized for PGPR material that very essential because the microorganisms in the bamboo root are beneficial for soil fertility and plant health.

Livestock waste is a potential resource that can be used as OF through further processing which transform it into composted manure. It is another effort to utilize a lot of disposal materials that can be useful for the farmer. Manure compost addition can be helpful to keep or develop soil chemical levels, improve soil pH, nitrogen concentration, and several cations. Moreover, manure had a better impact on enhancing C and N levels of soil organic than mineral fertilizers and also safer NO3- leaching like other OF usage [24–27].

Currently, studies related to OFs from indigenous resources on paddy growth and yield is still lacking. The main goal of this study was to analyze effect of the various fertilizers on growth and yield of paddy, especially OFs from indigenous resources that were available around, easy to get, and easy to use. We utilized the materials, such as banana hump, bamboo root, and cow manure to produce OFs and these materials are often used by the farmers in Klaten, Indonesia.
2. Materials and methods

2.1. Study area
This research was conducted in Klaten Regency, Central Java Province, Indonesia. Klaten Regency is located at 110°26'14"-110°47'51" S and 7°32'19"-7°48'33" E covering 65,556 ha in which approximately 39,647 ha is agricultural land [28]. Approximately 3.72% of the land is positioned between 0-100 meters above the sea level, 83.52% is positioned between 100-500 meters above the sea level, and 12.76% is positioned between 500-2,500 meters above the sea level. In 2016, some of the paddy fields were changed into buildings for housing, it was affected on the reduction of rice production in Klaten. However, it is important to develop the agricultural land in Klaten Regency as rice producer to meet rice requirement. In 2017, Klaten Regency produced around 380,268 tons rice [28].

2.2. Procedures
Randomized Block Design Pattern with four replications was used as a field experimental planned method and there were 5 treatments in each plot. Thus, the total numbers of the unit plot were 20. The experimental treatments were: 1) No fertilizer/ NF(control); 2) Inorganic fertilizer/ IF (100 kg ha$^{-1}$ urea + 100 kg ha$^{-1}$ NPK at 15 days after transplanting (day) and 150 kg ha$^{-1}$ urea + 150 kg ha$^{-1}$ NPK at 30 day); 3) cow manure compost/ CMC (5 t ha$^{-1}$ at 1 day); 4) indigenous organic fertilizer/ IOF (12.5 t ha$^{-1}$ banana hump MOL + 12.5 t ha$^{-1}$ bamboo root PGPR + 2.5 t ha$^{-1}$ CMC at 1 day and 12.5 t ha$^{-1}$ banana hump MOL + 12.5 t ha$^{-1}$ bamboo root PGPR at 20 day); and 5) commercial fertilizer/ CoF (4 l ha$^{-1}$ commercial biofertilizer + 500 kg ha$^{-1}$ commercial organic fertilizer).

Banana hump MOL was made by soaking 1 kg of banana hump cut in 1 l coconut water and 1 kg molasses in 10 l rice washing water and then this mixture was kept in a drum for 14 days fermentation process. The procedure of bamboo root PGPR preparation consisted of two steps processes, the first step was soaking 1 kg bamboo root in 3 l cold boiled water and kept it for 3 days. The second step was began after 4 days of the first step by mixing 0.25 kg bran, 1 tablespoon of shrimp paste, 1 teaspoon of lime betel, and 4 tablespoons of sugar into 10 l water and then the mixture was boiled and kept in a drum and until it was cold. Then, all the liquid were mixed and kept for 4 days.

The land was plowed before processed into muddy plots for each treatment with a size of 2 × 5 m$^2$ [29]. Furthermore, a 30 cm width channels were made between each treatment with to avoid fertilizers contamination between treatments plot [30]. The rice planting system used was tile system with a 23 cm × 23 cm square space. This study used rice (Oryza sativa L.) of a famous variety in Klaten Regency namely Mentik Wangi. Crop maintenance was divided into several activities, such as weeding, growing, watering, and controlling pests and diseases. Weeding maintenance was done twice at the age of 15 day using harrow and at the age of 30 day by hand (manually). Died plants were replaced at day 7. To anticipate the rat attacked, we made a shelter for owls which were the natural predators for rat and installed a 60 cm high plastic fence around the experimental area, so that the rats could not enter. We also used sulfur fumes inside the rat's den. Harvesting was done when the rice seed had shown a 90% yellow color. In this experiment, harvesting was done at day 105 and leaves had mostly turned yellow.

2.3. Data analysis
MOL and PGPR that were used in this research were analyzed in Sebelas Maret University laboratory to determine the content of microbes. Whereas the variables of this experiment were 1) plant height; 2) the number of tillers; 3) the number of panicles; 4) 1,000 seed weight; 5) grain yield. The data were analyzed using the F test at 5% level to find out whether there were any real differences between treatments. If there is a significant difference between or part of the treatment, the analysis followed by Duncan's multiple range test at a 95% confidence level.
3. Results and discussion

3.1. Plant height

Table 1 shows that various fertilizer treatments indicated no significant difference on the plant height at day 14, 21, 28, 35, 44, 50, 57, 64, 70 and 80. IF had the highest result of the plant height at day 14, 21, 28, 35, 44, 50, 57, 64, and 70. Nevertheless, at day 80, CMC had the highest result of the plant height. The application of IOF increased plant height with averagely 7.2%, 15.3%, 4.9%, 3.6%, 0.9%, 4.9%, 1.5%, 9.9%, 12.8%, and 15.1% higher than control at day 14, 21, 28, 35, 44, 50, 57, 64, 70, and 80. This is due to the capability of the IOF application to provide the nutrient need of paddy for better growth.

Table 1. Effect of fertilizer treatments on plant height at day 14, 21, 28, 35, 44, 50, 57, 64, 70, and 80

| Treatment | Plant Height (cm) |
|-----------|-------------------|
|           | day 14 | day 21 | day 28 | day 35 | day 44 | day 50 | day 57 | day 64 | day 70 | day 80 |
| No fertilizer | 18abc | 22.2abc | 32.9abc | 38.8abc | 43.8abc | 49.3abc | 53.8abc | 57.3abc | 63.1abc | 79.5abc |
| IF         | 19.9b  | 25.8c  | 37b    | 50.6b  | 53.9b  | 64.3b  | 70b    | 72.9b  | 78b    | 87.9b  |
| CMC        | 20b    | 24.7bc | 36.5b  | 40.8ab | 45.3b  | 52.3b  | 55.4b  | 62.7b  | 72.2b  | 94.5c  |
| IOF        | 19.3ab | 25.6c  | 34.5ab | 40.2ab | 44.2a  | 51.7a  | 54.6a  | 63b    | 71.2b  | 91.5bc |
| CoF        | 18.4abc| 24.0b  | 35.2abc| 41.7b  | 46.8a  | 53a    | 56.3a  | 61.7b  | 68.8b  | 87.9b  |

Means in the same column followed by the same letter were not significantly different (P>0.05)

Plant height is influenced by the nutrients N, P, and P$_2$O$_5$ which are needed for the synthesis of amino acid and protein, especially at the point of plant growth to accelerate the process of plant growth, such as cell division and extension [31]. The main role of N element for plants is to stimulate overall growth, especially stems, leaves, and sprouts so that the use of fertilizer can stimulate the growth of paddy stems. Therefore the addition of N nutrients can increase the vegetative growth of plants. [32,33].

Figure 1. Comparison of the number of fungi and bacteria content among several kind of biofertilizers, CFU=Colony Forming Unit

Figure 1 illustrates the comparison of microbial content in this experiment biofertilizers (MOL and PGPR) with other researches including PGPR, a liquid inoculum of diazotrophic bacteria Klebsiella planticola, and PGPR2, a combination of liquid inoculum from Azotobacter, Derxia, and Bacillus genera [34]. Other compared biofertilizer are Beejamrutha, the mixture of local cow dung and lime, and jeevamrutha, a mixture of local cow dung, cow urine, local jaggery, pulse flour, and garden soil [35]. MOL has the highest number of total fungi and f P-solubilizers, whereas PGPR has the highest number of bacteria and Azotobacter. A high amount of microorganisms showed that soil fertility was positively
correlated with paddy height. Fertile soil had 10-100 million microorganisms [36], so that the addition of banana hump MOL and bamboo root PGPR was affected paddy growth.

3.2. Number of tillers
Table 2 shows that various fertilizer treatments indicated a highly significant difference on the number of tillers at day 14, 21, 28, 35, 57, 64, 70, and 80. IF had the highest result of the number of tillers at day 14, 21, 28, 35, 57, 64, 70, and 80. The application of IOF increased number of tillers 14.3%, 41.7%, 16.7%, 20%, 28.6%, 31.6%, 23.5%, 20%, and 16.7% higher than control at day 21, 28, 35, 44, 50, 57, 64, 70, and 80. This is due to the capability of the IOF application to create better soil conditions and to fulfill the nutrient need for paddy growth. According to [37], the use of IOF had lower effects on plant height and the number of tillers than IF because of 3 reasons which are the low diffusion of IOF, insufficient of the nutrients contained in IOF, and less amount of IOF application. Providing IFs into the soil can increase the availability of nutrients rapidly to the plant, so it can accelerate the growth and development of the plant. N will accelerate plant growth, i.e. plant height and the number of tillers [38,39].

Table 2. Effect of fertilizer treatments on number of tillers at day 14, 21, 28, 35, 50, 57, 64, 70, and 80

| Treatment | day 14 | day 21 | day 28 | day 35 | day 44 | day 50 | day 57 | day 64 | day 70 | day 80 |
|-----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| No fertilizer | 3.5a | 7.0a | 12.0a | 18.3b | 25.3a | 21.5a | 19.3a | 17.3a | 15.0a | 11.8a |
| IF | 5.8a | 13.3a | 19.3a | 25.3a | 47.0b | 38.0b | 33.5b | 28.3b | 25.3b | 20.3b |
| CMC | 5.3bc | 9.3b | 15.0bc | 21.8bc | 29.8a | 27.0a | 24.0a | 20.5a | 16.3b | 14.5a |
| IOF | 3.3a | 8.5b | 16.8ab | 21.0bc | 29.8a | 27.5a | 25.0a | 21.0a | 18.0b | 14.3a |
| CoF | 4.3b | 7.0a | 12.8ab | 17.0a | 25.8a | 23.4a | 21.8a | 19.3b | 17.0b | 13.5a |

Means in the same column followed by the same letter were very significantly different (P<0.01)

3.3. Number of panicles
Table 3 shows that various fertilizer treatments indicated significantly different on the number of panicles at day 86, 93 and 99. IOF had the highest result of the number of panicles at day 86 and 93, whereas IF had the highest result of the number of panicles at day 99. The application of IOF increased the number of tillers 41.8%, 58.5%, and 32.3% higher than control at day 86, 93, and 99. This is due to the capability of IOF treatment to improve better paddy growth by providing nutrient sufficient availability. Raising the activity of microorganisms causes the decomposition process of organic compounds running optimally. The activities of microorganisms are higher in banana hump MOL and it contains an adequate supply of oxygen that increases the number N nutrient, both nitrate and total N [40].

Table 3. Effect of fertilizer treatments on the number of panicles at day 86, 93, and 99

| Treatment | day 86 | day 93 | day 99 |
|-----------|--------|--------|--------|
| No fertilizer | 5.5ab | 6.5a | 9.3a |
| IF | 3.8a | 9.3bc | 14.0b |
| CMC | 6.0ab | 7.5ab | 9.8a |
| IOF | 7.8b | 10.3c | 12.3b |
| CoF | 4.3a | 7.0a | 9.5a |

Means in the same column followed by the same letter were significantly different (P<0.05)

3.4. 1000 seed weight and grain yield
Table 4 shows that various fertilizer treatments indicated no significantly different on 1000 seed weight and grain yield. IOF had the highest result of 1000 seed weight and CMC had the highest result of the grain yield. The application of IOF increased 1000 seed weight 5.3% and grain yield 1.8% higher than
control. The high level of phenolic acid in banana hump MOL provides some elements, such as Al, Ca and Fe which useful in the flowering and seed formation processes [22].

Intensive application of IF caused the decline of rice productivity because the quantity and quality of soil organic matter were lessened and affected the slow supply of N, P and K as available form that caused accumulation of toxins for plant and decrease of nutrient availability in the soil [41]. OF raised rice yield significantly as well as enhanced soil productivity and net profit without accumulative of chemical N input [42].

**Table 4. Effect of fertilizer treatments on 1000 seed weight and grain yield**

| Treatment | 1000 Seed Weight (g) | Grain Yield (ton ha⁻¹) |
|-----------|----------------------|------------------------|
| No fertilizer | 29.08a               | 4.00a                  |
| IF        | 28.37a               | 3.88a                  |
| CMC       | 29.97a               | 4.30a                  |
| IOF       | 30.63a               | 4.07a                  |
| CoF       | 30.26a               | 4.22a                  |

Means in the same column followed by the same letter were not significantly different (P>0.05)

4. Conclusion
The results of this research show that various fertilizer treatments were not significantly different on the plant height, very significantly different on the number of tillers at day 14, 21, 28, 35, 44, 50, 57, 64, 70 and 80 after transplanting, and significantly different on the number of panicles at day 86, 93 and 99 but not significantly different on 1000 seed weight and grain yield. The grain yield with IOF higher 1.8% than no fertilizer (control) and higher 4.9% than IF. This research shows that the application of the organic agriculture system can be used as a better choice to replace the conventional system by using OF made from indigenous sources that available. Thus, the utilization of OF can reduce the strong dependence of IF and increase profit income by lessening production cost and increasing yield. Further research is required to understand the dosage of OF that can produce a maximum yield of paddy field in the properly various mixture OFs trial.

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