Effect of inorganic fertilizer and farmyard manure to available P, growth and rice yield in rainfed lowland Central Java

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Abstract. Application Farmyard manure in rainfed lowland can be a good alternative for sustainable agriculture. The objective of the study was to know the effect of organic and inorganic fertilizer on available P content, growth and rice yield. This study used a Randomized Block Design with six treatment and three replications. The treatments were the control, NPK, cow manure 10 t ha$^{-1}$, cow manure 10 t ha$^{-1}$+ NPK, cow manure 20 t ha$^{-1}$, cow manure 20 t ha$^{-1}$+ NPK. This study was conducted at Jakenan, Pati and has been carried out since 2015. Data on growth and yield were analyzed statistically using ANOVA. Available P data were analyzed descriptively. The results showed that the use of cow manure alone of 20 t ha$^{-1}$+ NPK for 4 years was able to increase the available P content from 6.62 ppm to 290.27 ppm. Application cow manure alone or combine with inorganic fertilizer (NPK) gave a significant effect on vegetative growth parameters than the control treatment. Long-term application (4 years) 10 t ha$^{-1}$ cow manure can increase Inpari 43 yield 135% and significantly different to control. The application of cow manure in the long-term can be considered for sustainable crop production in the rainfed lowland.

1. Introduction

Rice is the most important food crop commodity for Indonesia. The government, through the Ministry of Agriculture, continues to strive to improve through agricultural intensification programs and optimization of suboptimal land. Rainfed lowlands are considered less than optimal due to their low productivity. In Central Java, rainfed rice covers about 30% of 1 million ha of rice fields [1]. The average rice production in rainfed lowland only reaches 1.8 to 3.5 t ha$^{-1}$ [2]. The low yield of rainfed rice is caused by constraints on water availability, infertile soils (including shortages of N, P and K) and soil acidity [3,4]. Also, Pypers et al. [5] reported that tropical soils are characterized by low nutrient status including P deficiency where P deficiency is recognized as a limiting factor for crop production.

Poor nutrients in rainfed lowland require proper fertilizer management. Excessive application of inorganic fertilizers can cause physical, chemical and biological damage to the soil and reduce soil fertility [6]. Based on the results of a study by Hati et al. [7] the use of inorganic fertilizers in the long term can reduce yields due to a decrease in soil pH and an increase in exchangeable Al. For this reason, proper fertilizer management is required in rainfed rice fields to increase rice yields while maintaining soil health.
Long-term application of organic matter such as farmyard manure can gradually increase crop productivity while maintaining soil health [8]. According to Myint et al. [9], the use of organic matter is very important because it contains various types of nutrients needed by plants including micronutrients, can improve soil physical and chemical properties and increase microbial activity. Moreover, decomposed organic matter provides a source of inorganic P from mineralization or increases soil P availability by producing organic anions that reduce adsorbed P through competition or increase pH. Cow manure contains high levels of nutrients, namely C-Orgaic (28.42%), N (1.06%), P (0.74%), K (1.25%), Ca (1.44%) and Mg (0.44%) which can help increase nutrient content in the soil [10]. This study aims to determine the effect of using inorganic fertilizers and cow manure on available P, growth and rice yield of Inpari 43 in rainfed lowland.

2. Materials and methods

2.1. Material

The materials used in this study were cow manure, inorganic fertilizers (urea, SP-36, KCl), Inpari 43 rice seeds, organic pesticides, herbicides, NaHCO3, NaOH, distilled water. Cow manure used in this study was collected from cattle farms in Balingtan. Inpari 43 used in this study because it was able to produce a high yield in sub-optimal conditions and resistant to plant hopper pests.

2.2. Methods

This experiment was conducted in rainfed lowland at the Indonesian Agricultural Environment Research Institute, Pati, Central Java (6°46’43” LU, 111°11’51” BT) from November 2019 to March 2020. Each plot has a size of 5 m x 10 m. The study used a randomized block design with a single factor. The treatment consisted of six and each treatment was replicated three-time, namely P0 (control), P1 (NPK), P2 (cow manure 10 t ha⁻¹), P3 (Combination NPK+cow manure 10 t ha⁻¹), P4 (cow manure 20 t ha⁻¹) and P5 (Combination NPK +cow manure 20 t ha⁻¹). This inorganic and organic fertilizer treatment has been carried out since 2015.

Cow manure applied one week before planting by spread evenly into the land and mixed with a rotary. The planting system used was Jajar Legowo 2:1. The Planting was done by making a planting hole 3 cm deep and each hole was given 4 grains of rice seeds and then covered with cow manure. The amount of inorganic fertilizer (NPK) applied was calculated based on the Upland Soil Test Kit. The upland soil test kit is a tool for analyzing dryland soil nutrient content, which can be used in the field quickly, easily, cheaply and quite accurately. The upland soil test kit is used to measure levels of P, K, C-organic, pH and lime requirements in the soil. Fertilization was given in 3 phases there are at 10 to 15 days after planting (313 g urea, 250 g SP-36, 250 g KCl), at 35 to 40 days after planting (468.5 g urea) and at 65 to 70 days after planting (468.5 g urea). Irrigation was carried out based on conditions of water demand in the plantation. Weed sanitation was carried out chemically with pre-grown herbicides that sprayed 1 to 4 days after planting. Organic pesticides sprayed every 2 weeks with a dose 4 L ha⁻¹. Rice was harvested at 105 days after transplanting when 90% of the rice panicle was yellow.

Observations were recorded on available P content, plant height, total of tiller number, number of productive tiller and yield. At each site experimental area, composite topsoil (0 to 0.15 m) from 5 points was collected after harvest and analysis for available P (Olsen method) in the IAERI laboratory. Plant height (cm) was measured from the base of the stem to the highest leaf using a meter. The measurements were made every two weeks at the vegetative stage. A total number of tillers were obtained by counting all tillers at the primordial phase. Some productive tillers were measured by counting all productive tillers before harvest. Rice yield was measured by tilling on each experimental plot then converting it to productivity ha⁻¹. Data of plant height, total of tiller number, number of productive tillers and yield were analyzed statistically using analysis of variance (ANOVA) with the SPSS program and continued with Duncan Multiple Range Test (DMRT) if there was a significant difference at the level of 5%. Available P data were analyzed descriptively.
3. Results and discussion

3.1. Available P content in soil

The soil type in the research location is Inceptisols which is poor in nutrient content. The limiting factors for growth and yields of rice in Jakenan, Pati namely low content of organic C, nutrients N, P and K and soil CEC [11]. The analysis results of soil samples showed that the available P content of soil samples from control treatment was low, namely 6.62 ppm. The low content of available P is probably due to the absence of P nutrient input given and the nutrients in the soil have been used or absorbed by the plants within the 4 years of study.

The studies of various types of fertilization treatments showed that the P content in the soil increases with increasing doses of cow manure used (figure 1). The available P content in the use of cow manure at 10 t ha\(^{-1}\) and 20 t ha\(^{-1}\) is 190.6 ppm and 140.91 ppm respectively higher than the NPK fertilization treatment only, which is 66.07 ppm. This result is consistent with the results of a 5-year fertilization study conducted by [12] in rainfed lowland land, manure was able to increase available P by 25.94 kg ha\(^{-1}\), higher than control and inorganic fertilization. Meanwhile, if manure is combined with NPK, the available P content will be higher, namely 192.6 ppm and 290.27 ppm. This is because the soil gets additional P input from SP-36 fertilizer.

![Figure 1. Effect of inorganic fertilizer (NPK) and cow manure on available P content in soil](image)

The application of farmyard manure can increase the available P content in the soil because of the P content in cow manure itself. Cow manure is known to contain 79.64 ppm available P [13]. The decomposition of organic matter such as cow manure produces organic acids that can chelate free aluminum (Al) and iron (Fe), also dissolve P from its bonds with aluminum (Al-P) and iron (Fe-P) [14]. Moreover, according to Reddy et al. [15], the addition of manure is widely known to stimulate the build-up of microbial populations. Some of the soil inorganic P may have been taken up by these microbes to form organic P compounds that are present in the microbial detritus and thereby enrich the soil organic P fraction. The same statement by Zhong et al. [16] and Frossard et al. [17], improving soil conditions will increase the diversity of soil microbes and their activities in the soil increased the process of decomposing organic matter and will increase the availability of P and P uptake by plants.

The results of the study on the available P content of soil showed that the addition of manure alone or combined with NPK for 4 years was able to increase the availability of P in very high amounts. This means that for the next planting season, the soil does not need to be given P fertilizer anymore. According to Hooda et al. [18], The application of cow manure in the long term can supply the same amount of P as inorganic fertilizer (NPK) so that the need for P elements can be fulfilled from the residue.
3.2. Rice plant growth
Analysis of variance showed that the application of cow manure and inorganic fertilizers (NPK) either alone or in combination had a significant effect (P < 0.05) on the height of *Inpari* 43 plants in the rainfed lowlands (Table 1). The highest plant height was observed in the combination treatment of cow manure 20 t ha\(^{-1}\) and NPK (83.3 cm) and the lowest plant height was observed in the control treatment (52.6 cm) at 56 days after planting. Meanwhile, for the total number of tillers parameter, the mean number of tillers did not show a significant difference between treatments except for the control.

| Treatment                            | Plant Height (cm) | Total Number of Tillers |
|--------------------------------------|------------------|------------------------|
|                                      | 14 dap           | 28 dap                 | 42 dap | 56 dap | 14 dap | 28 dap | 42 dap | 56 dap |
| Control (without fertilizer)         | 13.1\(^{a}\)     | 24.5\(^{a}\)           | 30.5\(^{a}\) | 52.6\(^{a}\) | 3\(^{a}\) | 9\(^{a}\) | 10\(^{a}\) | 11\(^{a}\) |
| NPK                                  | 13.8\(^{a}\)     | 27.4\(^{a}\)           | 35.8\(^{b}\) | 64.7\(^{b}\) | 3\(^{a}\) | 10\(^{a}\) | 12\(^{a}\) | 15\(^{ab}\) |
| Cow manure 10 ton ha\(^{-1}\)        | 16.5\(^{b}\)     | 33.3\(^{b}\)           | 43.7\(^{c}\) | 73.3\(^{c}\) | 3\(^{a}\) | 11\(^{a}\) | 14\(^{a}\) | 20\(^{b}\) |
| Cow manure 10 ton ha\(^{-1}\) + NPK  | 15.7\(^{b}\)     | 33.1\(^{b}\)           | 44.6\(^{c}\) | 78.6\(^{cd}\) | 3\(^{a}\) | 10\(^{a}\) | 16\(^{a}\) | 19\(^{b}\) |
| Cow manure 20 ton ha\(^{-1}\)        | 16.1\(^{b}\)     | 32.4\(^{b}\)           | 46.7\(^{cd}\) | 77.2\(^{c}\) | 4\(^{a}\) | 10\(^{a}\) | 17\(^{a}\) | 21\(^{b}\) |
| Cow manure 20 ton ha\(^{-1}\) + NPK  | 16.9\(^{b}\)     | 35.3\(^{b}\)           | 51.5\(^{d}\) | 83.3\(^{d}\) | 3\(^{a}\) | 12\(^{b}\) | 15\(^{a}\) | 20\(^{b}\) |

Notes: DAP (day after planting)
Means followed by the same letter in each column are not significantly different (P < 0.05)

According to Miller [19], Organic sources derived from manure offer more balanced nutrition for plants, especially micro-nutrients that positively affect the height and the number of tillers in plants. The combination of organic and inorganic fertilizers provides several benefits including providing nutrients that can be used directly by plants, increasing organic matter, improving soil structure and increasing buffering capacity [20]. Also, the soil test results (figure 1) show that the addition of manure can increase the available P content in the soil to 290.27 ppm. Phosphorus is the second most important macronutrient after nitrogen which plays an important role in physiological and biochemical reactions such as photosynthesis and transfer characteristics [21]. Phosphorus fertilizer (SP-36) and cow manure in the soil increase the uptake of phosphorus by plants through the production of carbonic acid and acids increase the solubility of phosphate compounds [22]. If P is available in large quantities in the soil, it will allow a high absorption of P by plants [23] so that plants can grow more fertile. Moreover, the use of organic fertilizers alone or in combination with inorganic fertilizers can reduce the amount of Nitrogen lost [24]. Cow manure not only serves as a source of N and other nutrients but also increases the efficiency of applied N [25].

3.3. Yields
Analysis of variance showed that the application of cow manure and inorganic fertilizers (NPK) either alone or in combination had no significant effect (P < 0.05) on *Inpari* 43 rice yields but significantly different from the control (Table 2). The highest yield was observed in the cow manure application of 20 t ha\(^{-1}\) (9.6 t ha\(^{-1}\)) and the lowest was observed in control (4 t ha\(^{-1}\)). Application of cow manure in the long term (4 years) at a dose of 10 t ha\(^{-1}\) and 20 t ha\(^{-1}\) on rainfed lowland can increase the yield of *Inpari* 43 up to 135% and 140% respectively compared to control.

Inceptisols soil type in rainfed rice fields is one of the marginal land categories with low productivity [26,27]. The application of organic matter to the soil in drought-prone paddy fields affects grain yields, not only by increasing NPK supply but also by increasing groundwater holding capacity, cation exchange capacity and micronutrient supply [4]. The combination of these factors increases the yield of the cow manure treatment compared to control. The addition of manure for 4 years certainly increases the availability of nutrients such as available P (figure 1). The study conducted by Andriamananjara et al. [28] revealed that farmyard manure could increase the efficiency of P mineral use in rainfed lowlands and increase rice yields after continuous application for 3 years.
Table 2. Effects of the integrated application of inorganic fertilizer (NPK) and cow manure on yield component of *inpari* 43 in rainfed lowland

| Treatment                            | Number of Productive Tillers | Yield (t ha$^{-1}$) |
|--------------------------------------|------------------------------|---------------------|
| Control (without fertilizer)         | 10$^a$                       | 4.0$^a$             |
| NPK                                  | 11$^a$                       | 7.8$^b$             |
| Cow manure 10 ton ha$^{-1}$           | 12$^a$                       | 9.4$^b$             |
| Cow manure 10 ton ha$^{-1}$ + NPK     | 12$^a$                       | 8.7$^b$             |
| Cow manure 20 ton ha$^{-1}$           | 14$^b$                       | 9.6$^b$             |
| Cow manure 20 ton ha$^{-1}$ + NPK     | 15$^b$                       | 9.3$^b$             |

Note: Means followed by the same letter in each column are not significantly different (p <0.05)

Experiments of various types of fertilization carried out for 5 years on rice plants showed that in the first 3 years of fertilization, the highest rice yield was obtained in the inorganic fertilization treatment. However, in the last 2 years of the experiment, the results showed that fertilizing with cow manure showed higher rice yields compared to the use of inorganic fertilizers [13]. Cow manure releases nutrients slowly so the results will only be visible in the long term. The effect of using manure will only be seen after 3 to 5 years of application [9].

The use of organic matter in rice cultivation in rainfed land is a step that needs to be done as an effort to implement a sustainable agricultural system. Besides being able to increase production, maintain soil health, reduce pollution effects from the use of agrochemicals, but economically it is also quite promising. Market demand for organic agricultural products is increasing every year and export opportunities are wide open. The government also supports the trend of organic agriculture by issuing a government policy called Go Organic 2010. Several other policies are listed in the *Nawacita* program up to 2020. The Indonesian government has launched the establishment of 1,000 organic villages, consisting of 600 organic food villages, 250 organic villages, and 150 organic plantation villages [29].

How to make manure is relatively easy so that it can be done by farmers themselves, especially for farmers who raise livestock or in the surrounding environment there is a cattle farm. But in reality, the application of organic farming is still not widely applied by farmers because of several obstacles they face, namely: first, organic rice farming requires a large amount of compost (10 t ha$^{-1}$). If the supply of organic material is obtained by buying animal manure from farms, it will increase production costs; second, the nutrient composition in manure varies widely, so that the benefits for plants are not immediate and can only see in the long term; third, there is still a lack of understanding and limited information about organic fertilizers. Therefore, the socialization of the use of organic fertilizers to farmers needs to be carried out continuously and increase the provision of organic fertilizer subsidy quotas.

4. Conclusions

The combination of cow manure 20 t ha$^{-1}$ and NPK for 4 years increased the available P from 6.62 ppm to 290.27 ppm and the highest compare to other treatments. The combination of cow manure 20 t ha$^{-1}$ + NPK for 4 years has a positive effect on plant growth in the vegetative phase. The plant height was recorded 83.3 cm and significantly different for all treatments. The number of tillers was recorded 20 tillers but only significantly different from the control. The application of manure alone or in combination with NPK did not significantly different between treatments but significantly different to control. Application of cow manure 10 t ha$^{-1}$ and 20 t ha$^{-1}$ can increase rice yield up to 135% and 140%. Application of cow manure on rainfed lowlands in the long term can be used as an effective strategy that helps increase growth, rice yield and available P content in the soil so that P in the soil over time is maintained for production of sustainable crops.
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