

The Impact of Biofertilizers and NPK Fertilizers Application on Soil Phosphorus Availability and Yield of Upland Rice in Tropic Dry Land

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Abstract. Dry land in Indonesia is dominated by marginal soil which have low macro nutrient content, low organic matter content and low soil microbial activity. Improving soil quality it is necessary to increase nutrients availability such as biofertilizers application. Biofertilizers contains beneficial microbial inoculants to increase soil nutrient availability. The use of biofertilizers combined with NPK fertilizer will increase macro nutrients availability and optimize plant growth, thus will increase fertilizers efficiency. This experiment was carried out to study the impact of biofertilizers on available-P, plant P-uptake and yield of upland rice at Land Research of Agriculture Faculty, Universitas Padjadjaran. This experiment used a randomized block design consisting of ten treatments and three replications. The treatments consisted with two doses of biofertilizers (50 kg ha⁻¹ and 75 kg ha⁻¹) and three doses of N,P,K fertilizers (100%, 75%, and 50% from recommended doses). Biofertilizers contains N-fixing bacteria and phosphate solubilizing microbes. The result of experiment showed that application of biofertilizers 75 kg ha⁻¹ and biofertilizers 50 kg ha⁻¹ + N, P, K 50% increased soil phosphorus availability. The application of biofertilizers increased P-uptake up to 81%. Furthermore, biofertilizers 75 kg ha⁻¹ + N, P, K 75% increased the yield of upland rice by 164%.

1 Introduction

The problem of nutrient phosphorus is the high soil phosphorus content but it is not available for plants. There are several obstacles that make P in the soil unavailable to plants, especially on acid soils such as Inceptisols. This soil has physical, chemical and biological characteristics that do not support plant growth. Efforts to increase soil productivity can be done by utilizing beneficial soil microbes known as biofertilizers.

Biofertilizers are materials that contain beneficial microbes to increase the availability of soil nutrients and promote plant growth which is a prospect for sustainable agricultural

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development [1]. The microorganisms that are used as biofertilizers are N-fixing bacteria, P solubilizing microorganisms, mycorrhizae, and PGPR [2]. It has been widely researched the role of biofertilizers to increase soil nutrient content and crop production. The advantages of biofertilizers, such as reducing the use of chemical fertilizers and environmental pollution, increase nutrient availability and plant growth as well as improving the physical, chemical and biological properties of the soil [3].

One of the microbes that are used as biofertilizers is *Azotobacter chroococcum* as N-fixing bacteria and also supports plant growth through the synthesis of plant growth supporting substances or commonly called Plant Growth Promoting Rhizobacteria (PGPR) [4]. The other of N-fixing bacteria is *Azospirillum* [5]. One of the microbes that are often used in biofertilizers besides N-fixing bacteria is the phosphate solubilizing microbes (PSM). The efficiency of P in the soil can be increased by the use of PSM which is able to solubilizing phosphate that no available into available and can be absorbed by plants [6]. The increase in productivity that occurs is due to biological activity in the soil, where PSM releases phosphatase enzymes and organic acids that cause P to become available to plants [7, 8]. The application of PSM increased the soil phosphorus availability [9].

The use of biofertilizers in rice cultivation is expected to increase the availability of P in order to achieve the P needs of the plant so that it can optimize the growth and productivity of upland rice plants and reduce chemical residues caused by inorganic fertilization, especially in acid soils. Therefore, research is needed to study biofertilizers with N, P, K fertilizer applications to determine which one gives the best results in increasing P content in soil and plants, increasing rice yields and reducing the use of chemical fertilizers.

2 Material and Method

The experiment was carried out at the Experimental Field at the Faculty of Agriculture, Universitas Padjadjaran using Inceptisols. The materials used by consortium biofertilizer between N-fixing bacteria were *Azotobacter* sp., *Azospirillum* sp. with phosphate solubilizing microbes (*Pseudomonas mallei*, *Burkholderia* sp., *Aspergillus* sp. and *Penicillium* sp.) were superior isolates selected. N, P, K fertilizer used Urea, Super phosphate and potassium chloride. Upland rice seeds with Luhur 2 variety were obtained from the Indonesian Center for Rice Research.

2.1 Biofertilizer Preparation

Biofertilizer was made by culturing each bacteria on Nutrient Broth (NB) media and each fungi on Potato Dextrose Broth (PDB). After being grown on the media (48 hours), the population was calculated and put as much as 15% (37.5 ml/250 g carrier) into the carrier material for the mixture of peat and compost with a ratio of 1:1.

After incubating for one week, the population of microbes in biofertilizers were calculated. Based on population calculations, the density of each microbe were *Aspergillus* sp. 3.4×10^5 CFU g⁻¹, *Penicillium* 1.4×10^5 CFU g⁻¹, *Pseudomonas mallei* 9.6×10^7 CFU g⁻¹, *Pseudomonas cepaceae* 1.2×10^8 CFU g⁻¹, *Azotobacter* sp. 6.4×10^6 CFU g⁻¹, and *Azospirillum* sp. 1×10^7 CFU g⁻¹.

2.2 Treatment and data analysis

The experiment used a randomized block design consisting of ten treatments and three replications. The treatments consisted with two doses of biofertilizers (50 kg ha⁻¹ dan 75 kg ha⁻¹) and three doses of NPK fertilizers (100%, 75%, and 50% from recommended doses).

The recommended dosage of NPK fertilizers were 300 kg ha⁻¹ Urea, 100 kg ha⁻¹ SP-36 (super phosphate) and 100 kg ha⁻¹ KCl. Soil phosphorus availability was measured by Bray extract and P content of plant was analyzed by Kjeldahl method at the end of vegetative period. Yield of upland rice was measured at the end of generative period. Data were collected to analysis of variance (ANOVA) and treatment means were compared using Duncan test at p = 0.05.

3 Results and Discussion

3.1. Soil Characteristics

The Inceptisol soil used in this experiment had a pH of 5.58 (slightly acidic). Upland rice can grow optimally at soil pH between 5.5 to 8.0. Soil pH less than 5.5 or more than 8.0 will cause deficiency of P elements and too much Fe and Al elements will poison to the plants.

This soil contains C-Organic of 1.89% which includes low criteria, low Total N (0.19%), low C / N ratio (10), high potential P (44.35mg 100g⁻¹), but moderate soil P-available (13.13 ppm) and low potassium (20.02mg 100g⁻¹). The exchangeable cations such as Ca-dd 6.69 cmol kg⁻¹ were included in the moderate category, low of Mg-dd (0.93cmol kg⁻¹), low of K-dd (0.20 cmol kg⁻¹), moderate of Na-dd (0.67 cmol kg⁻¹) and a CEC of 14.98 cmol kg⁻¹ including the low category.

Based on the data from the analysis of the Inceptisol soil used for the study, the soil fertility level is quite low. This can be seen from the low N, P and K content in the soil and low soil organic carbon.

3.2. Soil phosphorus availability and P-uptakes

The results of statistical analysis showed that the combination of biofertilizers and N, P, K significantly affected the soil P availability. Table 1 showed that application of biofertilizers 75 kg ha⁻¹ and biofertilizers 50 kg ha⁻¹ + N, P, K 50% increased soil phosphorus availability significantly. The increase in the availability of P in the soil is the result of the addition of biofertilizers containing P-solubilizing microbes to produce organic acids which increase the availability of P [10]. The phosphate solubilizing microbes as potential biofertilizers and environment-friendly phosphorus biofertilizers to enhance fertilizers efficiency [11].

Table 1. Effect of biofertilizers and N, P, K on P available and P-uptake

Treatments	Available-P (ppm)	P-uptake (mg/plant)
control	29.9±1.25 a	62.7± 0.53 a
N, P, K 100%	31.1±0.76 ab	100.6± 1.52 ab
N, P, K 75%	31.6± 1.28 b	70.4± 0.70 ab
N, P, K 50%	30.4± 0.09 ab	52.1± 2.60 a
Biofertilizers 75 kg ha ⁻¹	31.8± 1.69 b	60.1± 1.94 a
Biofertilizers 50 kg ha ⁻¹	30.7± 0.23 ab	88.5± 1.90 ab
Biofertilizers 75 kg ha ⁻¹ + N, P, K 75%	30,5± 0.41 ab	46.2± 1.23 a
Biofertilizers 50 kg ha ⁻¹ + N, P, K 75%	31.2± 0.80 ab	81.5± 0.95 ab
Biofertilizers 75 kg ha ⁻¹ + N, P, K 50%	30.8± 0.86 ab	113.5± 0.90 b
Biofertilizers 50 kg ha ⁻¹ + N, P, K 50%	31.8± 0.86 b	72.8± 0.69 ab

Remarks: The average score followed by the same letter is not significantly different according to the Duncan Test at the 5% level

The results of statistical analysis showed that the combination of biofertilizers 75 kg ha⁻¹ + N, P, K 50% increased P-uptake significantly. Based on the data presented in Table 1, the P-uptake treated with biofertilizers 75 kg ha⁻¹ + N, P, K 50% was 113.5 mg/plant while the control treatment was 62.7 mg/plant. This difference indicated that the application of biofertilizers increased the P-uptake up to 81%. These results indicated that biofertilizers containing P-solubilizing microbes and N-fixing bacteria were able to increase the P content of plants. This is in line with [12] that application of biofertilizer containing N-fixer. P-solubilizer with green manure *C. juncea* increased N, P, and K uptakes and growth of sugarcane.

There are several treatments with P uptake in plants that are lower than the control treatment, this can be caused by dry land conditions so that the plants lack water, rainfall during planting is very low. Lack of water in these plants will inhibit mass flow in the soil and plant roots. The obstruction of this mass flow will disrupt the absorption of nutrients which can have a direct effect on root development, from soil to plants. According to [13] the absorption of P nutrients is influenced by the ability of plant roots and plants as a whole, because in some plants the root hair of plants plays an active role in the absorption of P.

3.3. Yield of upland rice

The results of experimental showed that the combination of biofertilizer treatment and N, P, K fertilizers significantly affected upland rice yield (dry grain weight). Table 2 showed that the best treatment to increase the yield was the treatment of biofertilizer 75 kg ha⁻¹ + N, P, K 75%, with yield of upland rice 406.77 g, whereas in the control only 153.99 g. The difference between these treatments indicated that the application of biofertilizers was able to increase the yield of upland rice by 164%. The increasing of upland rice yields was due to the availability of nutrients facilitated by P-solubilizing microbes. The application of phosphate solubilizing microbes combined with bio-organic phosphate increased soil P content and crop production [14].

Table 2. Effect of biofertilizers and N, P, K on yield of upland rice

Treatments	Yield (g)	Weights 1000 grains
control	153.99± 8.97 a	17.53± 0.53 a
N, P, K 100%	189.82±8.34 a	19.13± 1.52 a
N, P, K 75%	171.95± 6.81 a	19.30± 0.70 a
N, P, K 50%	163.66± 6.86 a	21.73± 5.60 a
Biofertilizers 75 kg ha ⁻¹	223.2± 8.68 ab	19.03± 1.94 a
Biofertilizers 50 kg ha ⁻¹	161.54± 9.93 a	18.90± 1.90 a
Biofertilizers 75 kg ha ⁻¹ + N, P, K 75%	406.77± 8.13 b	19.63± 1.23 a
Biofertilizers 50 kg ha ⁻¹ + N, P, K 75%	269.98± 7.57 ab	19.83± 0.95 a
Biofertilizers 75 kg ha ⁻¹ + N, P, K 50%	319.98± 9.66 ab	19.47± 0.90 a
Biofertilizers 50 kg ha ⁻¹ + N, P, K 50%	186.84± 6.90 a	19.20± 0.69 a

Remarks: The average score followed by the same letter is not significantly different according to the Duncan Test at the 5% level

Based on the results of statistical analysis, the combination of biofertilizer and N, P, K fertilizers did not significantly affect the weight of 1000 grains. The weight of 1000 grains in upland rice p treated with N, P, K 50% fertilizer was 21.73 g, this weight greater than the treatment of biofertilizers and N, P, K. The weight of 1000 grains from the treated by biofertilizer 50 kg ha⁻¹ + N, P, K 75% was 19.83 g, in case compared with the control treatment which produced a 1000 grain weight of 17.53 g, the treatment of biological fertilizers and N, P, K was still better. This difference indicates that the application of biological fertilizers to upland rice plants increases the weight of 1000 grains in plants by up to 13%, although this treatment did not affect significantly.

The weight of 1000 grains is influenced by several factors, both internal and external factors. Internal factors are the genetical conditions of the plant, while external factors include drought stress or water availability [15]. In this experiment, water availability was not very good because the rainfall on the experimental land was very low. Genetically, upland rice varieties Luhur 2 generally produce a weight of 1000 grains 24.6 g.

4 Conclusions

The application of biofertilizers containing P solubilizing microbes and N-fixing bacteria as well as N, P, K fertilizers increased available P, P uptake and yield of upland rice. The result of experiment showed that application of biofertilizers 75 kg ha⁻¹ and biofertilizers 50 kg ha⁻¹ + N, P, K 50% increased soil phosphorus availability. The application of biofertilizers 75 kg ha⁻¹ + N, P, K 75% increased the yield of upland rice by 164%. Biofertilizers application increased fertilizers efficiency up to 25% in dry land.

Acknowledgments. Part of this work was carried out within the financial support from the Directorate General of Higher Education Ministry of Research and Technology Indonesia. The authors would like to thank staff Laboratory of Soil Biology Faculty of Agriculture, Universitas Padjadjaran for their cooperation.

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