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Research Article
Phosphate Fertilization Efficiency Improvement with the Use of Organic Fertilizer and its Effect on Soybean Plants in Dry Land

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Abstract

Background and Objective: Efforts to increase domestic soybean production have been widely carried out by farmers, including the management of soil fertility, such as the use of inorganic fertilizers. However, the development of soybean is generally on marginal dry land, the use of inorganic fertilizers is often inefficient (especially phosphate fertilizers), because phosphorus is fixed by Al or Fe. This study aimed to improve the efficiency of phosphate fertilization by the use of organic fertilizers from the wild plant *Calopogonium muconoides* and their effect on increasing yields of soybean crops on dry land. This research was conducted on the dry land of Takalar Regency, south Sulawesi, Indonesia. **Materials and Methods:** This research was carried out in the dry land of South Sulawesi, Indonesia. The experiments were arranged on the Split Plot Design. As the main plot was the dose of organic fertilizer from the wild plant *Calopogonium* consisting of three levels, namely 10, 15 and 20 t ha^{-1} as sub-plots were inorganic P fertilization consisting of three levels, namely 50, 100 and 150 kg SP36 ha^{-1}. Each treatment was repeated three times so there were 27 experimental units. **Results:** The results showed that the application of organic fertilizer with a dose of 20 t ha^{-1} increased growth and increased yields shown by higher plants and significantly more pods and higher production per ha (2.15 t ha^{-1}). **Conclusion:** Increasing the dosage of organic fertilizer and increasing the dose of inorganic P fertilizer increased the availability of nutrient phosphorus.

Key words: Soybean, fertilization, phosphate, efficiency, organic fertilizer, inorganic fertilizers, soil fertility

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Soybean is one of the foods with high protein content (39%) compared with other nuts[1] and have better marketing prospects so as to increase farmers' income. The increase in soybean production in this country has been endeavored, both intensification and area expansion. Increased production through area expansion is more difficult to do considering the increasingly high competition for land use, so that alternatives to increase production through intensification are relatively more appropriate[2]. Increasingly high competition for land use, so that alternatives to increase production through intensification are relatively more appropriate.

Efforts have been made to increase production through intensification by farmers, for example by using inorganic fertilizers, such as nitrogen, phosphorus and potassium fertilizers. However, on marginal dry land, the use of inorganic fertilizers is often inefficient, especially phosphorus fertilizers[3]. That phosphorus fertilizer given cannot be absorbed by plants. The mobility of P elements in the soil is very low and the P element from fast fertilizer is absorbed into the form of Al-P, Fe-P, Ca-P or occulted P and other forms[4] of P, so the availability for plants becomes very low. While the element P is very necessary for grain crops. Phosphorus is needed to improve soybean yield and quality[5].

Phosphorus uptake from soil by plants is usually a factor that limits the achievement of optimal crop yields[6]. Even when phosphorus is present in large quantities, availability for plants is still often problematic due to binding[7] of P by Al or Fe. Therefore, efforts are needed to improve the efficiency of the use of phosphate fertilizer used[8]. Increasing fertilizer efficiency can be done by applying the right type of fertilizer, application level and application method[9]. To improve the efficiency of P fertilization can be achieved by adding organic fertilizers, P-an-organic, microbial inoculation and biological fertilizers[10]. Organic fertilizer will increase soil organic matter content which will improve the movement of P and P content in the soil solution. Decomposition of organic matter produces organic acids including humid acid and fulfat acid. Humid acid and fulfat acids bind to many polyvalent cations such as Ca^{++}. Fe^{++} and Al^{+++} form Ca, Fe and Al, so that P is released into the soil solution and can eventually be absorbed by plants[11].

Organic matter greatly affects the physical and chemical properties of the soil. Soil organic matter is very important for increasing crop production, improving soil ecosystems and is vital for the supply and storage[12] of C and N. Micelles from organic matter contain negative charges from -COOH- and OH- groups which allow for cation exchange and increased water holding capacity. Organic matter also increases the ability of the soil to bind nutrients, thereby increasing the ability of the soil to provide nutrients for plants, reducing nutrient leaching, increase the ability of the soil to retain water, so that the availability of ground water increases[13]. Gilbert *et al.*[14] showed that increasing the organic matter in sandy soils can increase the CEC, nutrient cycles, the ability to hold water and reduce erosion.

Although it is known that the application of organic matter can increase fertilizer efficiency but because the organic material commonly used by farmers is manure, its availability in some regions in Indonesia is very limited, so for this reason, in this study the potential sources of organic material were used, such as from the wild plant *Calopogonium muconoides* which was used as organic fertilizer.

This research was conducted with the aim to improve the efficiency of phosphate fertilizer with organic fertilizer usage of *Calopogonium muconoides* wild plants and their effects on soybean yield improvement in dry land.

MATERIALS AND METHODS

Material and tools: This research was carried out in the form of experiments on dry land of south Sulawesi, Indonesia. Planting material consists of soybean seeds, organic fertilizer from the plants of *Calopogonium muconoides*, urea fertilizer and SP-36, while the tools used include: hoes, hand-tractors, shovels, scales, labels, meters, ovens and others.

Experimental design and procedures: This experiment was arranged in the form of Split Plot Design. As the main plot was the dose of organic matter which consisted of three levels, namely:

O1 : 10 t of organic fertilizer ha^{-1}
O2 : 15 t of organic fertilizer ha^{-1}
O3 : 20 t of organic fertilizer ha^{-1}

As a sub-plot was P-inorganic fertilization which consisted of three levels, namely:

P1 : 50 kg SP-36 ha^{-1}
P2 : 100 kg SP-36 ha^{-1}
P3 : 150 kg SP-36 ha^{-1}

Out of the two factors, 9 combinations of treatments were obtained and repeated three times to obtain 27 units of experimental units.

The land used in the experiment was divided into three blocks. Each block was divided into three main plots measuring 6×3 m, then the main plot is divided into 3 sub-plots with 2×3 m. The distance between the main plots is 1 m and the distance between blocks is 1 m. The tillage is done twice with an interval of 1 week. The application of organic fertilizer from calopogonium wild plants is given 2 weeks before planting with doses according to the provisions of the treatment.

Planting of soybean seeds is carried out in a manner with a distance between rows of 30 cm and distance in rows of 20 cm. Fertilization of SP-36 is given at the same time as planting with doses according to the conditions of treatment. Fertilization of KCl with a dose of 100 kg ha^{-1} given at the time of planting and fertilizing 100 kg of urea per hectare.

Variables measured: The variables observed in this study include plant height, number of pods, pod weight, dry seed weight per plant and dry seed weight per hectare and the content of soil available P.

Statistical analysis: All data were subjected to Analysis of Variance (ANOVA) using. When there was a significant treatment affect means were compared using LSD α 0.05.

RESULTS

Plant height: The results of data analysis showed that there were a number of weeks after planting (WAP). The results of the 0.05 LSD test presented in Table 1 showed that the application of 20 t ha^{-1} of organic material combined with phosphorus fertilizer 100-150 kg SP-36 ha^{-1} which was obtained by plants that were significantly higher was 73.33-74.78 cm and was significantly different from other interactions.

Number of pods: Parameters for the number of pods per plant indicated that phosphorus fertilization had a significant effect. Table 2 showed that the highest number of soybean pods was obtained by fertilizing phosphorus 100 kg SP-36 ha^{-1} with 75.47 pods per plant and significantly different from phosphorus 50 and 150 kg SP-36 ha^{-1}.

Pod weights per plant: Soybean pod weights per plant showed that phosphorus fertilization with a dose of 100 kg SP-36 ha^{-1}, obtained the heaviest weight of pods which was 26.41 g per plant and significantly different from phosphorus fertilization at a dose of 50 kg SP-36 ha^{-1} but not significantly different from the weight of pods obtained in 150 kg SP-36 ha^{-1} phosphorus fertilization per hectare (Table 3).

Seed weight per plant: The results of the analysis of seed weight data per plant showed that there was a significant effect of organic fertilizer and phosphorus fertilization on soybean seed weight per plant. In Table 4, the organic fertilizer 20 t ha^{-1} obtained soybean seed weight per plant was highest, 16.57 g and was significantly different from other treatments. In the phosphorus fertilizer with a dose of SP-36 100 kg ha^{-1} of soybean seeds obtained heaviest weight was 16.35 g plant^{-1} and significantly different from phosphorus fertilization doses of 50 and 100 kg SP-36 ha^{-1}.

Table 1: Effect of various doses of organic fertilizer and phosphorus fertilizer on plant height (cm) at the age of 8 weeks after planting soybeans

Organic fertilizers (t ha^{-1})	Phosphorus fertilization 50 kg SP-36 ha^{-1}	100 kg SP-36 ha^{-1}	150 kg SP-36 ha^{-1}
10	59.75^{b}_{y}	67.83^{a}_{y}	58.83^{b}_{z}
20	69.50^{b}_{x}	74.78^{a}_{x}	73.33^{a}_{x}
30	63.00^{a}_{y}	64.75^{a}_{y}	67.08^{a}_{y}

Number followed by the same letter in the same column (x, y, z) and the same line (a, b) are not significantly different based on the BNT test at the 5% level

Table 2: Amount of soybean pods per plant, with the application of organic fertilizer and phosphorus fertilization

Organic fertilizers (t ha^{-1})	Phosphorus fertilization 50 kg SP-36 ha^{-1}	100 kg SP-36 ha^{-1}	150 kg SP-36 ha^{-1}	Average
10	54.33	88.83	53.58	65.58
20	54.17	80.25	72.33	68.92
30	57.17	57.33	50.00	54.78
Average	55.17^{b}	75.47^{a}	58.64^{b}	

Number followed by the same letter on the same line are not significantly different by LSD at 5% level

Table 3: Soybean pod weight per plant (g) with organic fertilizer and phosphorus fertilization

Organic fertilizers (t ha^{-1})	Phosphorus fertilization 50 kg SP-36 ha^{-1}	100 kg SP-36 ha^{-1}	150 kg SP-36 ha^{-1}	Average
10	19.63	28.60	16.85	21.69
20	18.81	27.73	27.84	24.12
30	23.88	24.90	21.74	23.51
Average	20.77^{b}	26.41^{a}	22.14^{ab}	

Number followed by the same letter on the same line are not significantly different by LSD at 5% level

Table 4: Weight of soybean seeds per plant (g) with application of organic fertilizer and phosphorus fertilization

Organic fertilizer (t ha^{-1})	Phosphorus fertilization 50 kg SP-36 ha^{-1}	100 kg SP-36 ha^{-1}	150 kg SP-36 ha^{-1}	Average
10	11.79	15.53	10.47	12.60^{b}
20	14.87	18.26	16.57	16.57^{a}
30	13.67	15.25	13.92	14.28^{b}
Average	13.44^{b}	16.35^{a}	13.56^{b}	

Number followed by the same letter on the same line are not significantly different by LSD at 5% level

Table 5: Weight of soybean seeds per hectare (t) with organic fertilizer and fertilization phosphorus

Organic fertilizer (t ha^{-1})	Phosphorus fertilization 50 kg SP-36 ha^{-1}	100 kg SP-36 ha^{-1}	150 kg SP-36 ha^{-1}	Average
10	1.47	1.94	1.31	1.58^{b}
20	1.86	2.53	2.07	2.15^{a}
30	1.71	1.91	1.74	1.78^{b}
Average	1.68^{b}	2.13^{a}	1.71^{b}	

Number followed by the same letters in the same row and column are not significantly different by LSD at 5% level

Soybean seed weight per ha: Analysis of the data on the weight of soybean seeds per hectare showed that organic fertilizer and phosphorus fertilizer significantly affect soybean seed weight per hectare. Table 5 showed that 20 t ha^{-1} of organic fertilizer obtained the heaviest soybean weight per plant was 2.15 t ha^{-1} and is significantly different from other treatments. Phosphorus fertilization at a dose of 100 kg SP-36 ha^{-1} obtained the heaviest soybean weight of 2.13 t ha^{-1} and was significantly different from phosphorus fertilization at 50 and 100 kg SP-36 ha^{-1}.

Content of soil available P: The results of the analysis of the availability of soil P levels presented in Fig. 1 showed that the application of Calopogonium organic fertilizer with a dose of 20-30 t ha^{-1} showed an increase in the availability of soil P nutrients with increasing P dosage used. Increasing the dose of organic fertilizer and increasing doses of P-inorganic fertilizer increases the availability of P up to 6%.

DISCUSSION

The results showed that the application of organic fertilizer sourced from the wild plants Calopogonium with a dose of 20 t ha^{-1} improved growth and increased crop yields shown by higher plants and significantly more pods and higher production per hectare (2.15 t ha^{-1}). The ability of organic fertilizers to improve plant growth and yield is inseparable from the ability of organic fertilizers to improve nutrient availability, especially available P-soil nutrients which are increasing with increasing doses of organic fertilizer used (Fig. 1). This is in line with the results of the study by Subaedah *et al.*[15] showed that the use of organic fertilizers from crotalaria plants can increased P nutrient availability by up to 11% higher than without the use of organic fertilizers. Increasing nutrient availability P strongly supports growth and increases soybean yield, because element P is an indispensable element of soybean plants both for formation and activity of root nodules and plant needs[16]. Xue *et al.*[17] reported that soybean plants are very sensitive to the availability of phosphorus elements. The same thing was stated by Subaedah *et al.*[5], who reported that growth and yield and quality of soybean seeds (protein content) were influenced by the availability of P elements. At flowering, phosphorus needs to increase rapidly due to increasing energy demands and phosphorus are components of enzymes and ATP are useful in the process of energy transfer.

The results of the data analysis also showed a significant interaction between organic fertilizer and inorganic

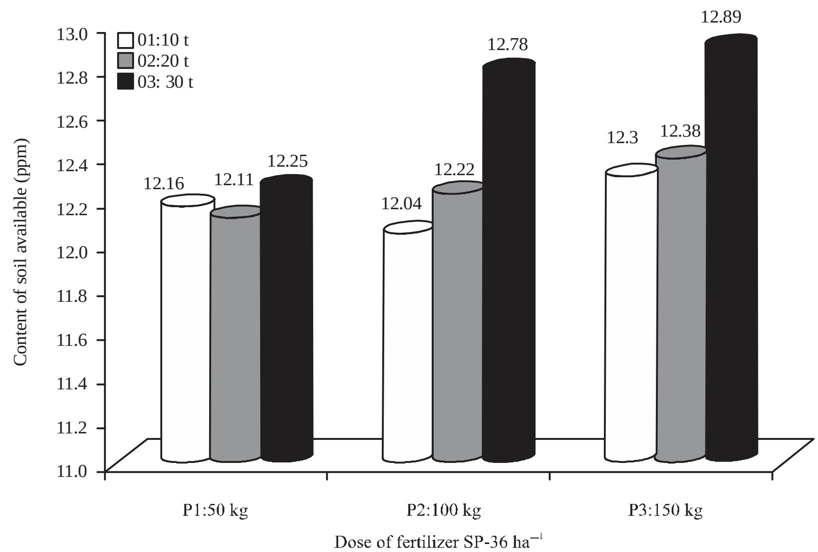

Fig. 1: Content of soil available P by application of organic fertilizer and phosphorus fertilizer

phosphorus fertilizer, where the application of organic fertilizer with a dose of 20 t ha^{-1} and 100 kg of phosphorus fertilization SP-36 ha^{-1} obtained the highest plant. The addition of organic matter has been reported to alter soil chemical properties, such as pH, increasing the acid content of humid acids in the soil fulfat acid[11]. Increasing soil pH will cause a decrease in the solubility of Al ions and reduce the concentration of Al can be exchanged because organic acids are able to correlate metal ions. As a result there will be a release of phosphorus ions into the solution which can then be absorbed by the plant and ultimately will improve the growth and yield of soybean. Moreover, the addition of P of inorganic fertilizers also increased the availability of P and increased solubility of nutrients in the soil (Fig. 1). This is in line with the results of research obtained by Ardinal and Gusmini[18], who reported that the application of manure and phosphorus fertilizer increased the availability of soil P, which ultimately increased the growth of peanuts. Likewise, research results of Sludge *et al.*[19], which concluded that the application of organic materials (40 t ha^{-1}) and the application of chemical fertilizers obtained maximum soybean crop. While the results of research of Awan *et al.*[20] suggested that the application of nitrogen fertilizers combined with the application of organic materials significantly increased rice yields.

CONCLUSION

- The application of 20 t of organic fertilizer sourced from the wild plants Calopogonium with a dose of 20 t ha^{-1} increases the availability of phosphorus nutrients and improves plant growth and yield of soybean plants by 2.15 t ha^{-1}
- Fertilizing 100 kg SP-36ha^{-1} produces more soybean plants with more cropping soybean pods and 2.13 t ha^{-1} of soybean production
- Increasing the dosage of organic fertilizer and increasing the dose of inorganic P fertilizer increase the availability of nutrient phosphorus

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