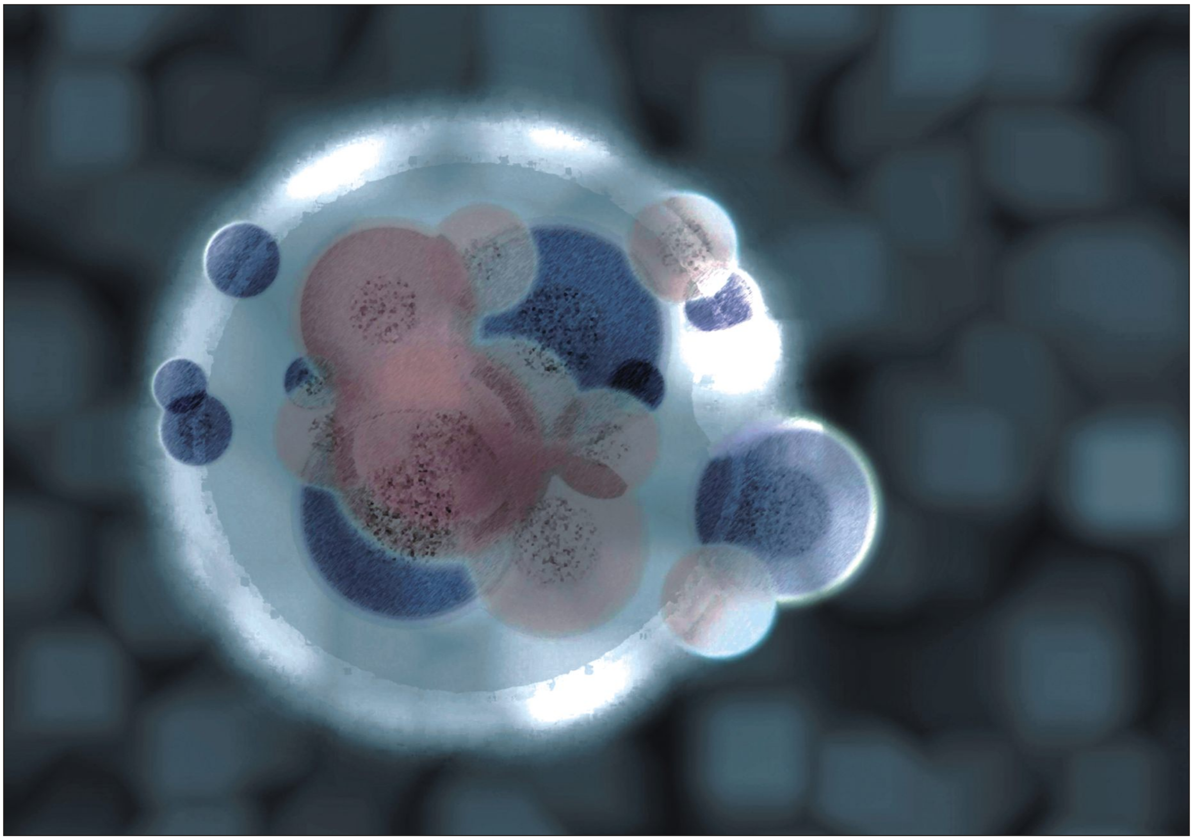

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Research Article
Growth and Yield of Two Soybean Varieties by Phosphate Fertilization and *Arbuscular mycorrhizal* Application

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Abstract

Background and Objective: Soybean is one of the main food commodities in Indonesia with high protein content. The need for soybeans is increasing in line with increasing public awareness of high protein foods, while soybean production in Indonesia is still very low. This study aims to analyze the growth and yield of two soybean varieties to increase the availability of phosphorus nutrients with the application of *Arbuscular mycorrhizae*. **Materials and Methods:** The experiment was designed in the form of a Split-Split Plot Design. As the main plot is the treatment of varieties consisting of two types, namely: Anjasmoro and Gema varieties. As a subplot is a mycorrhizal application consisting of two levels, namely without the application and mycorrhizal application. As sub-sub plots are phosphate fertilizers consisting of three levels, namely 50, 100 and 150 kg SP_{-36} ha^{-1}. Of the three factors obtained 12 treatment combinations. **Results:** The results showed that the growth of soybean plants was influenced by the variety used, and the interaction between phosphate fertilization and mycorrhizal application. In the pod weight parameters showed that the use of Anjasmoro varieties with mycorrhiza application and fertilization of 100 kg SP_{-36} ha^{-1} obtained pod weight. **Conclusion:** The results showed that the selection of soybean varieties determines the level of production obtained. The study also discovered that the effectiveness of mycorrhizae in increasing the availability of phosphorus nutrients was obtained in fertilizing low doses of phosphorus.

Key words: Fertilization, soybean, *Arbuscular mycorrhizae*, phosphorus, yield, gema variety, anjasmoro variety

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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

In Indonesia, soybean is a source of vegetable protein and is used as raw material for making tempeh and tofu, and is also used as animal feed[1]. Besides being rich in protein, soybean seeds also contain phosphorus, iron, calcium, vitamin B with complete amino acid composition, so that the potential for human body growth. Soybeans also contain unsaturated acids that can prevent arterial sclerosis, which is the hardening of the arteries[2].

The need for soybean is increasing from year to year in line with population growth and increasing public awareness of vegetable protein foods. While soybean production is still very low. This causes the high import of soybeans. In 2018, imports of soybean in Indonesia by 2.5 million tonnes[3].

Efforts to increase soybean production continue to be carried out, for example, the use of superior varieties. Variety selection plays an important role in crop cultivation because variety is the main key to increase production[4]. In addition to the selection of varieties, management of the growing environment must also be considered, because plant growth and production is greatly affected by environmental factors, both directly and indirectly[5]. Soybean development is generally carried out in dry land which is faced with many problems including low soil fertility. Therefore it is necessary to improve soil fertility by fertilizing.

Among the three primary macronutrients, phosphorus is one of the macronutrients that often limits crop production and its availability is often problematic[6,7]. Phosphate fertilization seeks to increase the availability of phosphate nutrients for plant growth and production. However, phosphate fertilization is not always directly proportional to the level of phosphate nutrient uptake by plants. In the soil, phosphorus is very easily fixed by other elements such as Al, Fe, Ca, and Mg, so that phosphorus is not available for plants[8-10]. To increase the efficiency of P fertilization, one way that can be done is to work on a combination of P fertilization with the application of biological fertilizer[11].

Mycorrhiza is a type of biological fertilizer and is a fungus that lives in the soil and can be associated with plants[12]. Mycorrhizal plants can absorb water and nutrients better because of hyphae threads from mycorrhiza so that access and wider reach in exploiting nutrients in an area[13;14]. External hyphae on mycorrhiza can absorb the phosphate element that is bound in the soil and become an element that is available to plants[15-16]. The use of arbuscular mycorrhizae also increases the resistance of drought plants[17].

Based on this description, a study was conducted to analyze the effect of varieties and increase the availability of P nutrients with the application of arbuscular mycorrhizae to an increase in soybean crop yields.

MATERIALS AND METHODS

Study area: This research was conducted in the dry land of Takalar Regency, South Sulawesi, Indonesia. The study lasted from April until September 2019. The planting material consists of Anjasmoro varieties, Gema, manure, mycorrhizae, urea, SP_{-36}, KCl and insecticide. While the tools used include: hoes, hand tractors, scales, labels, meters, ovens and others.

Experimental procedure: This experiment was designed with a Split-split Plot Design. As the main plot is the treatment of varieties consisting of two types, namely:

- V1: Anjasmoro Varieties
- V2: Gema Varieties

As a sub-plot is the administration of mycorrhizae consisting of two levels, namely:

- M1: Without mycorrhizae
- M2: mycorrhizal application (8 tons ha^{-1})

As sub-sub plot is the fertilization of phosphorus which consists 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}

Of the three factors, 12 treatment combinations were obtained and repeated three times to obtain 36 experimental unit units.

Implementation of the experiment: The land used in the experiment was divided into three blocks as replications. Each block is divided into 2 main plots measuring 10×3 m. The main plot was divided into two sub-plots measuring 4.5×3 m, then sub-plots were divided into three sub-plots measuring 1.5×3 m. The distance between the main plots is 1m and the distance between blocks is 1 m. Soybean seed planting is carried out with a distance of 40 cm between the rows and a distance of 20 cm in rows. SP_{-36} fertilization and mycorrhizae are given at the same time as planting with dosages in accordance with the provisions of the treatment, KCl fertilizing with a dose of 100 kg per hectare given at planting and fertilizing 100 kg per hectare of urea, given twice, namely at planting with 1/3 dose and 2/3 of the dose at the age of 30 days after planting.

Weeding is done manually at the age of 20 and 40 days after planting. Replanting crops and crop thinning are done if needed at the age of 2 weeks after planting.

The parameters observed in this study include: plant height, number of leaves, number of pods, pod weight per plant, weight of 100 seeds, weight of seeds per ha, and P-available in soil conducted at the end of the experiment.

RESULTS AND DISCUSSION

Plant height: The results of the analysis of plant height data at the age of 8 Weeks after Planting (WAP) showed that there was a significant interaction between the use of different varieties with application mycorrhizal. Likewise, the application of phosphorus fertilizer has a significant effect. The average height of the soybean crop in Table 1 indicated that the interaction between the use of varieties Gema with the use of mycorrhizal plants exhibits a high of 56.71 cm. In the treatment of phosphorus, fertilization shows that the more the dose of phosphorus fertilizer is given up to a dose of 150 kg ha^{-1} the higher the soybean plants produced.

Number of leaves: Observation of the number of leaves showed that there is a significant interaction effect between varieties and phosphorus fertilization. The average number of leaves in Table 2 showed that the Gema variety with 150 kg SP_{-36} ha^{-1} fertilization has a greater number of leaves, 26.7 strands, and is significantly different from the interaction between Anjasmoro varieties with the same dose.

Number of pods per plant: The number of pods per plant is presented in Fig. 1 and indicated that Anjasmoro varieties produce more pods compared with Gema varieties. This figure also shows that the application of mycorrhiza increased the number of pods in both Anjasmoro and Gema varieties.

Pod weight per plant: The results of the analysis of pod weight per plant showed that there were significant interactions between different varieties, mycorrhizal application and phosphorus fertilization. Table 3 showed that the interaction between Anjasmoro varieties with mycorrhiza application and fertilization phosphate of 100 kg SP_{-36} ha^{-1} (V1M1P2) obtained the heaviest pod weight of 41.70 g and was significantly different from other interactions except with interactions between Anjasmoro varieties with the use of mycorrhiza and fertilizing phosphorus 50 kg SP_{-36} ha^{-1} (V1M1P1).

Table 1: The average plant height (cm) of two soybean varieties at 8 WAP with mycorrhiza application and phosphate fertilizer

Varieties and Mycorrhizae	Phosphate Fertilization 50 kg (P1)	100 kg (P2)	150 kg (P3)	Average
V1M0	50.31	54.28	54.38	52.99^{ab}
V1M1	46.97	49.48	50.44	48.97^{b}
V2M0	50.58	53.69	54.34	52.87^{ab}
V2M1	57.71	56.61	55.83	56.71^{a}
Average	51.39^{b}	53.51^{a}	53.75^{a}	

The number followed by the same letters in the same row and column means are not significantly different according to LSD test α 0.05, WAP: Week after planting, V1: Anjasmoro variety, V2: Gema variety, M0 : No Mycorrhizae, M1: Mycorrhizae

Table 2: Effects of mycorrhizal application and phosphorus fertilization on the number of leaves of two soybean varieties

Varieties and Phosphate	Application mycorrhizae No Mycorrhizae	Mycorrhizae	Average
V1P1	22.1	23.3	22.7^{bc}
V1P2	25.0	22.5	23.7^{abc}
V1P3	22.6	23.2	22.9^{bc}
V2P1	20.8	20.2	20.5^{c}
V2P2	25.17	23.51	24.3^{ab}
V2P3	26.32	27.14	26.7^{a}
Average	23.7	23.3	

The number followed by the same letters are not significantly different according to LSD test α 0.05

Table 3: The average weight of pods per plant (g) of two varieties of soybean with mycorrhizae application and phosphorus fertilizer

Mycorrhizae and Phosphate	Varieties Anjasmoro (V1)	Gema (V2)
M0P1	26.38^{c}	11.93^{d}
M0P2	26.32^{c}	14.37^{d}
M0P3	31.67^{bc}	11.84^{d}
M1P1	36.16^{ab}	14.96^{d}
M1P2	41.70^{a}	14.04^{d}
M1P3	32.68^{bc}	13.87^{d}

The number followed by the same letters are not significantly different according to LSD test α 0.05

The weight of 100 seeds of soybean: Observation of the weight of 100 bji showed that different varieties significantly affect the weight of 100 seeds. The average weight of 100 seeds in Table 4 showed that the Anjasmoro variety has significantly heavier seeds (15.28 g) compared to the Gema variety (12.40 g).

Dry seed production per ha: The results of the analysis of the production of soybean dry seeds per ha indicated that differences in varieties and mycorrhizal applications have a

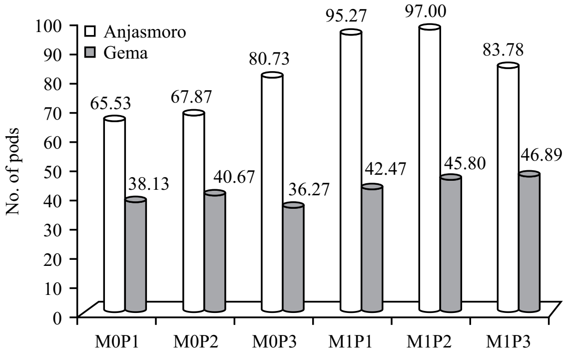

Fig. 1: Effect of application of mycorrhiza and phosphate fertilizer to the number of pods of two soybean varieties

Table 4: The weight of 100 seeds (g) two soybean varieties with application mycorrhizae and phosphorus fertilization

Mycorrhizae and Phosphate	Varieties Anjasmoro (V1)	Gema (V2)	Average
M0P1	15.81	12.47	14.14
M0P2	15.24	12.09	13.66
M0P3	14.79	12.19	13.49
M1P1	15.44	12.50	13.97
M1P2	15.87	12.68	14.27
M1P3	14.54	12.47	13.50
Average	15.28[a]	12.40[b]	

The number followed by different letters are significantly different according to LSD test α 0.05

Table 5: Production of dried seeds per ha (ton) two soybean varieties with mycorrhizal applications

Mycorrhizae	Varieties Anjasmoro	Gema	Average
No mycorrhizae	2.404	1.756	2.080[b]
Mycorrhizae	2.875	2.151	2.513[a]
Average	2.639[a]	1.937[b]	

Numbers followed by different letters in the same row and column mean different significantly based on the LSD Test 0.05

significant effect. Dry seed production per ha in Table 5 showed that the use of Anjasmoro varieties obtained higher production of 2.639 t ha^{-1} and significantly different from the production of Gema varieties which only produced 1.937 t ha^{-1}. In mycorrhizal application, treatment showed that mycorrhizal application increased soybean production 21% compared without mycorrhizal application (mycorrhizal application obtained a production of 2.513 t ha^{-1}, while without mycorrhiza only by 2.080 t ha^{-1})

P-available in soil: The results of the analysis of P-available in the soil indicated that mycorrhizal application increases P nutrient availability compared to phosphate fertilization

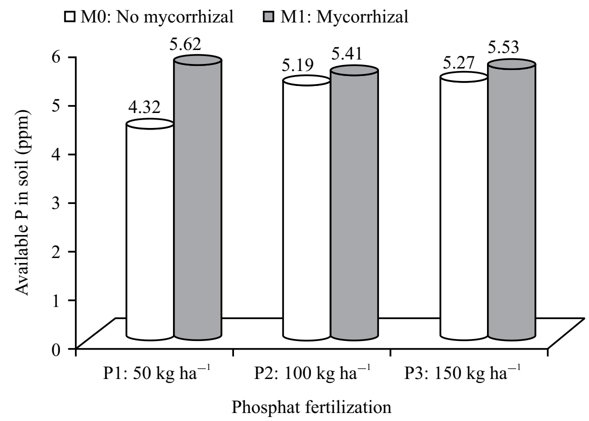

Fig. 2: Level of Availability of Nutrient P at various doses of phosphate fertilization with mycorrhizal application

without mycorrhiza (Fig. 2). The results of this analysis also showed that the availability of the highest phosphate nutrition is 30% with low dose phosphate fertilization (50 kg SP_{-36} ha^{-1}).

DISCUSSION

Different varieties, phosphate fertilization and mycorrhizal application affect the growth and production of soybean plants. Different varieties showed different plant growth and production. These results are in line with the findings of other studies[18,19], that plant growth and production is influenced by the variety used. In this study, it was also found that the Gema variety showed the highest plants and the number of leaves more than the use of the Anjasmoro variety. This is related to the growth form of the Gema variety which has vertical growth characteristics with narrower but thicker leaves, while Anjasmoro variety has wider growth with wider leaves. The parameter weights of 100 seeds indicated that the Anjasmoro variety has a weight of 100 seeds which is heavier than the Gema variety. Anjasmoro varieties are large/heavy seeded soybean varieties[20].

The mycorrhizal application showed a higher number of pods, as well as dry seed production per hectare which is markedly greater by 21% than without application mycorrhizal (Fig. 1 and Table 5). This is in line with the findings of a previous study[21] who suggested that mycorrhizal inoculation increased canopy biomass and increased grain yield by 40% compared without mycorrhizal inoculation.

Production component parameters (pod weight) showed that the Anjasmoro variety with 100 kg SP_{-36} fertilizer per ha accompanied by mycorrhizal application obtained the heaviest pod weight. Likewise, the dry seed production parameters showed that the Anjasmoro variety produces a significantly higher production of 2.639 tons. This is in line with the findings of another study[22] who suggested that crop production is positively correlated with the production component. Varieties play an important role in determining the growth and level of plant production achieved because the genetic potential of each variety is different.

Increased yield with the use of Anjasmoro varieties and mycorrhizal applications is supported by an increase in the availability of phosphorus. The highest increase in phosphorus availability was 30% in low dose P fertilization (Fig. 2). This is in line with the results of the previous study[23,24], that mycorrhizal activity in increasing the availability of phosphate nutrients was more effective in the use of low-dose P fertilizer. Furthermore, arbuscular mycorrhiza increases the activity of acid phosphatase in the soil, so that P-organic compounds in the soil can become available to plants after being hydrolyzed by the phosphatase enzyme[25,24].

Increased availability of P nutrients, allows absorption of P nutrients to run smoothly, and this is very beneficial for the development of soybean in the dry land, which is faced with the problem of low soil fertility, while phosphorus is needed by soybean plants, both for the formation and activity of root nodules and plant needs[26]. The results of other studies[27] showed that increasing the availability of P nutrients will increase soybean production. The face of a resource shortage crisis, the application of arbuscular mycorrhizae can play a key role in solving the problem of phosphate availability and increasing fertilizing efficiency, especially P fertilizer[28].

CONCLUSION

Mycorrhizal application increased the availability of phosphorus nutrients compared without mycorrhizal application. Increase the availability of phosphorus nutrients up to 30% by applying 50 kg SP_{-36} ha^{-1} phosphate fertilizer. The use of Anjasmoro varieties obtained higher production at 2.639 tons ha^{-1}. Mycorrhizal application obtained 21% higher production compared without mycorrhizal application.

SIGNIFICANCE STATEMENT

This study discovered that the yield of Anjasmoro varieties can be improved by increasing the availability of phosphorus nutrients with the application of mycorrhizae, that can be beneficial for improving soybean cultivation techniques. This study will help researchers to uncover critical areas of crop yield improvement through soil fertility management. Therefore, the development of this research is needed to be implemented to increase soybean crop production.

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