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Effect of Mycorrhiza and Lamtoro Leaf Compost on the Growth of Mung Beans (*Vigna radiata*) in Saline Soil

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Abstract
Saline soil is one of the alternatives in marginal lands for mung bean cultivation. However, high NaCl and other limiting factors need to be overcome. This study aims to describe the effect of mycorrhiza application and the addition of lamtoro leaf compost on mung bean growth in saline soil. This study used a Randomized Group Design with two treatment factors. The first factor was the concentration of mycorrhiza (0 g, 40 g, and 60 g) and the second factor was the concentration of lamtoro leaf compost (0 g, 50 g, 100 g, and 150 g). Plant growth was examined based on parameter number of leaves, plant height, root length, and biomass of active root nodules, age of first flower, number of flowers, and pod biomass. Data were analyzed using two-way ANOVA followed by Duncan test ($p < 0.05$). The results showed that the treatment of mycorrhiza 40 g + lamtoro leaf compost 100 g gave the highest results in various parameters recorded. This study also showed that the application of mycorrhiza and lamtoro leaf compost was able to accelerate the generative phase at the age of 45 Days After Planting (DAP).

Keywords: NaCl; nitrogen; plant growth; phosphorus; soil quality
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INTRODUCTION

Mung beans are one of the most important food commodities from the legume group, ranking third in importance after soybeans and followed by peanuts. Every year there is a surge in production. Mung bean production in Indonesia in 2022 reached 29,255 tons, produced from a harvest area of 197,508 hectares, with productivity reaching 1.188 tons per hectare (BPS, 2022). In addition to meeting domestic needs, national mung bean production also has a great opportunity to become a supplier in some mung bean markets at the world level so that it can increase foreign exchange (Barus *et al.,* 2014).

This study focuses on mung beans as the research target because needs to make efforts to increase the productivity of mung beans based on their economic and agronomic properties, namely that they are easy to grow due to their short harvest period of 55 - 60 days, are disease-resistant, and have a relatively stable selling price with complete nutritional content and composition. Mung bean growth can be influenced by several factors including soil fertility, climatic conditions, and water availability. If the water in the soil decreases, it can cause water stress (Rini and Efriyani, 2016). On the other hand, the condition of agricultural land in Indonesia is diverse and over time is decreasing due to the country's infrastructure development, so one alternative is to utilize marginal land as a planting medium in agriculture. One of these marginal lands is the soil around coastal areas in Indonesia.

Saline soil contains a lot of dissolved salt, namely Na, which will have an impact on reducing the content of nutrients Ca, Mg, and K, so that it will affect the growth stages in plants including the germination phase, seed growth phase, vegetative phase and generative phase. Increased salinity can increase osmotic pressure in water, decrease the relative water content of the leaves, and decrease the chlorophyll content of the leaves (Wahyuningsih *et al.,* 2017).

The critical salinity limit for mung beans of the canary variety decreased by 10% at various concentrations, namely at 1.0 dS/m, 1.8 dS/m, 2.65 dS/m, 1.5-3.3 dS/m. If it exceeds the salinity limit, it is difficult for mung bean plants to grow. This salinity greatly affects the indirect immobilization of nutrients in the soil such as Mg, Fe, P, N, and Zn so that these elements are difficult to absorb by plant roots and cause inhibition of plant growth. Phosphorus in saline soil is difficult to dissolve, resulting in low phosphorus content in it (Penn and Camberato, 2019). Likewise, the nitrogen element contained is very minimal. This is due to the limited nitrogen metabolism absorbed by the soil due to water and salt stress in it (Jat and Gerard, 2014).

The utilization of saline soil as a growing medium in Indonesia has not been maximized because more efforts are needed for nutrients to improve the chemical, biological, and physical properties of saline soil. One alternative that continues to be developed is the use of mycorrhiza. Mycorrhizal fungi, especially on marginal lands with few nutrients, can increase the absorption of macronutrients, especially phosphate (P) and micro nutrients through their external hyphae (Palasta and Rini, 2017). Phosphorus acts as nucleic acids, phospholipids, bioenzymes, proteins, metabolite compounds and also part of Adenosine Triphosphate (ATP) which plays a role in energy transfer during the respiration process and can increase plant resistance to pests and diseases (Gulo *et al.,* 2023).

In the growth of mung beans on saline soils in addition to the alternative use of mycorrhiza, another way that can be applied is the addition of lamtoro leaf compost which plays an important role in plant nutrients, namely N, P, and Ca (Calcium). In several studies, it has been proven that lamtoro plants can be used to maintain and increase soil productivity. This is because lamtoro leaf compost used in planting media can increase the P (phosphorus) element and optimize the N (nitrogen) element in the soil where the higher the organic matter content in the soil, the higher the nitrogen content in the soil (Bachtiar, 2017). The content of lamtoro leaf compost after testing is 2.10% N, 1.9%, P and 1.57% K. Based on these results, lamtoro leaf compost has the potential as an organic material to optimize plant growth in saline soil. Related research also proved that the application of lamtoro leaf compost fertilizer with various concentrations had a positive effect on the growth of red spinach (Ningsih *et al.,* 2013).

The interaction that occurs between mycorrhiza and organic matter when applied in the soil can improve the physical and chemical properties of the soil. Mycorrhiza will form external hyphae that bind soil particles so that aggregate stability and soil pores become better and also fulfill the availability of elements such as P, Mg, K, Fe, and Mn while organic matter can increase the capacity to hold water (Ramadhan *et al.,* 2015). Lamtoro leaf compost in this case will help in maintaining and increasing soil productivity by optimizing the absorption of N elements in the soil so that it can help the growth of mung bean plants more optimally. The aim of this study was to examine the application of mycorrhiza and lamtoro leaf compost to accelerate the generative phase of *V. radiata* at 45 DAP in saline soil.

MATERIALS AND METHODS

The tools used in this research were polybags, containers, cameras, picks, rulers, Ohaus balances, pH meters, thermometers, refractometers, stationery. The preparation process began by preparing 4 kg of lamtoro leaves and 3 kg of organic compost in a container, then watered with EM4 solution until 50% humidity. After that, laboratory testing was carried out to determine the levels of N, P, K, C/N ratio, and moisture content. Meanwhile, the preparation of planting media was carried out by mixing regosol soil and sand (2:1) which was watered with 1000 ml seawater solution at the first watering and 500 ml at the next watering, then dried for 5 days and sterilized using 2% formaldehyde as much as 200 ml. After being sterilized, the soil was dried under plastic cover for two days and open for three days and then measured soil conductivity with an EC meter (Electrical Conductivity). The planting process began with soaking mung bean seeds in warm water for 1 hour and then sowing the seeds for 1 week before transplanting. Each polybag contained planting media according to the treatment (mycorrhiza at 0 g, 40 g, 60 g, lamtoro leaf compost at 0 g, 50 g, 100 g, and 150 g). Pearl NPK fertilizer 16: 16 : 16 was given at the age of 7 Days After Planting (DAP) and 28 DAP (Pratiwi *et al,* 2022). Observations were made on the parameters of the number of leaves and plant height at 15, 30, and 45 DAP while on the parameters of plant wet weight, root length, active root nodule biomass, age of first flowering, number of flowers, and pod biomass were carried out at 45 DAP.

Data collected from observations of mung bean growth, including fresh weight, height, number of leaves, root length, active root nodule biomass, age of first flower, number of flowers, and pod biomass on each plant were analyzed using a normality test to determine the distribution of data and homogeneity test to determine whether the data collected in the study was homogeneous. Furthermore, two-way ANOVA test was used to determine the effect of mycorrhiza application and the compost on the growth of mung bean plants. Data with significant difference from ANOVA result was further analyzed with Duncan post-hoc test at significance level of 5% to compare differences between treatments.

RESULTS

Before the application of mycorrhiza and lamtoro leaf compost, saline soil was measured for environmental parameters such as pH, moisture, and soil conductivity (EC). Based on Table 1. the results shows that pH of 7.5 and humidity of 70%. The electrical conductivity (EC) value contained is 5dS m-1. EC is an electrical conductivity used to measure salinity parameters by estimating the amount of salt dissolved in the soil tested with extra water-saturated paste ECe (electrical conductivity of the extract) at 25˚C which is based on USDA (U.S. Department of Agriculture) salinity laboratory standards (Carillo *et al.,* 2011). The measurement of soil conditions and content showed that the soil was salinity-stressed soil.

Table 1. Measurement of salinized soil environmental parameters before treatment

Treatments	Measurement Results	Quality Standard for Saline Soil	Quality Standard for Planting Media***
pH	7,5	7 - 8,5*	> 5,5
Moisture	70%	-	≥ 30 – 50%
Electrical Conductivity (EC)	5 dS m^{-1}	≥ 4 dS m^{-1}**	≤ 1 – 3 dS m^{-1}

Notes: *) Based on Tolib *et al.* (2017); **) Based on USDA (U.S. Department of Agriculture); ***) Based on EN 13037 - 13041:2011 (European Standard, 2011)

Table 2 shows that the available carbon nutrient content in the compost at 16.81% (very high), available nitrogen of 2.10% (very high), total C/N ratio of 8.00% (medium), organic matter of 28.91, total phosphate of 1.59% (very high), total potassium of 1.57% (very high), and moisture content of 47.70.

Table 2. Measurement results of nutrient content in the compost

Treatments	Measurement Results	Quality Standard for Compost*
%C	16,81	> 5,00 (very high)
%N	2,10	> 0,75 (very high)
C/N	8,00	8,0 – 12,0 (medium)
%Organic Material	28,91	-
%P_2O_5 Total	1,59	> 0,1 (very high)
%K_2O Total	1,57	> 0,20 (very high)
Water Content	47,70	-

Notes: *) Based on SNI 19-7030-2004 (Badan Standardisasi Nasional, 2004)

Growth parameters observed of mung bean plants can be seen in Table 3, Figure 1, and Figure 2. The results of the study showed that the interaction between mycorrhiza concentration and lamtoro leaf compost had a significant effect on the parameters of plant height, root length, plant wet weight, and active root nodule biomass but had no significant effect on the number of leaves (Figure 1 and Table 3). All parameters showed that the best treatment was mycorrhiza 40 g and lamtoro leaf compost at 100 g. This combination treatment provided the best results for mung bean growth in saline soil. However, in the active root nodule biomass parameter, there was no significant effect on the interaction treatment of mycorrhiza concentration of 60 g with lamtoro leaf compost concentration of 0 g (Figure 1).

Table 3. Growth of number of mung bean leaves

Mycorrhiza (g)	Lamtoro Leaf Compost (g)*				Average ± SD
	0 g	50 g	100 g	150 g	
0 g	19,50 ± 1,73	23,33 ± 2,36	21,17 ± 1,26	20,00 ± 1,04	21,00 ± 1,60 a
40 g	19,83 ± 1,26	20,50 ± 3,77	23,67 ± 2,52	22,00 ± 3,77	21,50 ± 2,83 a
60 g	23,17 ± 2,60	22,67 ± 1,04	22,89 ± 4,58	21,00 ± 1,80	22,09 ± 2,51 b
Average ± SD	20,83 ± 1,86	22,17 ± 2,39	22,58 ± 2,79	21,00 ± 2,20	21,52 ± 2,55

Note: *)Different letters on the table indicate a significant effect based on Duncan's test at the 0.05 level.

The vegetative period required by mung bean plants is 45 DAP, but in the ongoing observations there were flowers that appeared before the vegetative period ended so the observations were continued with the parameters of the age of first flower, number of flowers, and pod biomass. The results showed that the application of mycorrhiza concentration, lamtoro leaf compost concentration and the interaction between mycorrhiza concentration and lamtoro leaf compost concentration showed a significant effect on the three parameters (Figure 2).

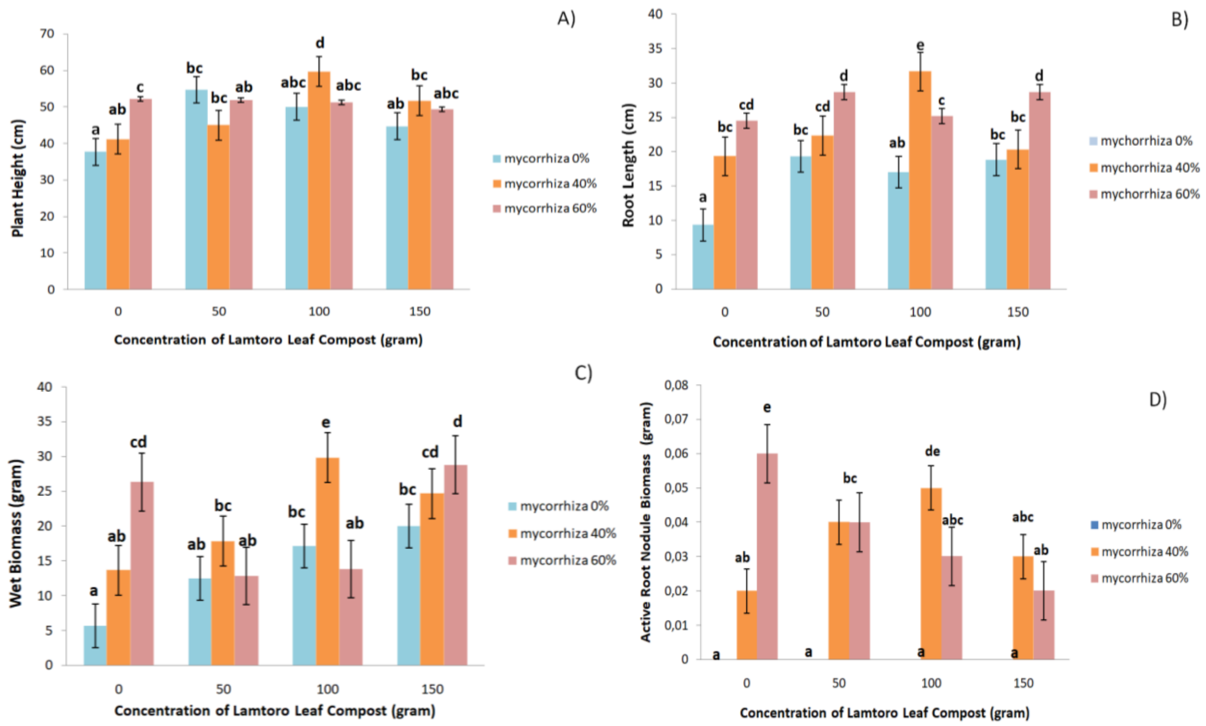

Figure 1. The effect of the combination of mycorrhiza and lamtoro leaf compost on (a) plant height, (b) root length, (c) weight biomass, (d) active root nodule biomass (Different letters on the graph indicate a significant effect based on Duncan's test at 0.05).

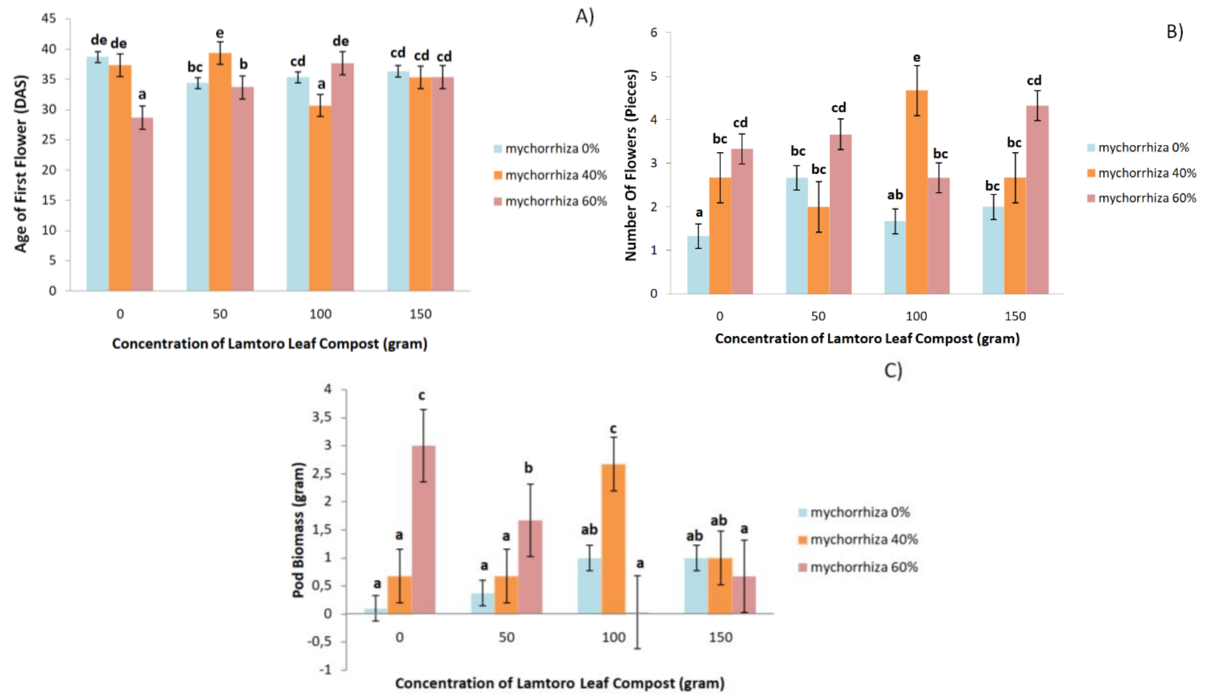

Figure 2. The effect of the combination of mycorrhiza and lamtoro leaf compost on a) age of first flower, b) number of flowers, c) pod biomass (Different letters on the graph indicate a significant effect based on Duncan's test at 0.05).

DISCUSSION

Saline soils have two types, namely soils around the coast with salinity stress from seawater intrusion and soils in arid and semi-arid areas which are soils with salinity due to groundwater evaporation or water on the surface (Rahman *et al.*, 2020). The problems caused when saline soils are used for cultivation are low C-organic, N, P, and K content, high pH, high Na^+ content and high osmotic pressure (Masganti *et al.*, 2022).

Soil salinity can be measured by its conductivity, namely electrical conductivity (EC), which is a salinity parameter by estimating the amount of dissolved salt in the soil with units of mS cm^{-1} or dS m^{-1} (Ismayilov *et al.,* 2021). A high conductivity value indicates that more salt is dissolved in the liquid. If the results show that the dissolved salt in the soil exceeds the critical limit for plants, the absorption of water and nutrients will be inhibited due to high osmotic pressure (Fahrudin and Sugriwan, 2020).

Soil solutions with high salt content in the plant root area cause the osmotic pressure in it to increase so that plant roots are difficult to absorb water which results in physiological drought of a plant (Riono, 2023). This condition will trigger water in plant cells to move out so that the protoplasmic wall will be damaged or commonly referred to as plasmolysis so that plants must overcome this by providing mycorrhiza and lamtoro leaf compost. High levels of NaCl in the soil can occur due to the influx of salt water or due to the level of evaporation that exceeds precipitation (Karolinoerita and Annisa, 2020).

Table 2 shows the results that lamtoro leaf compost has a very high N content of 2.10% which is in accordance with the quality standards of organic fertilizer by Hardjowigeno (2007) so that lamtoro leaf compost plays a major role in contributing high N nutrients for plant growth. Lamtoro leaf compost used in yellow cempaka seedlings showed significant results in the parameters of plant height, number of leaves, and plant sturdiness with a ratio of 1: ½ (soil + lamtoro leaf compost). These results indicate that lamtoro leaf compost can increase the availability of nitrogen in the soil by adding organic matter in it. Compost is an alternative that can be used to increase the yield of mung bean plants and does not cause adverse effects on the environment and the plants themselves because it is made from natural ingredients so that it can be easily absorbed optimally by plants (Sulham, 2019).

Based on the results of the research obtained in the vegetative phase (Figure 1 and Table 3), it shows that there is a significant effect both on the provision of mycorrhizal concentrations, lamtoro leaf compost and their interactions with the best combination at 0 grams of mycorrhizal concentration with 100 grams of lamtoro leaf compost concentration on plant height parameters of 59.67 cm, root length of 31.67 cm, plant wet weight of 29.83 grams, and active root nodule biomass of 0.006 grams. The application of mycorrhiza concentration and lamtoro leaf compost did not have a significant effect on the number of leaves parameter, but the interaction between mycorrhiza concentration and lamtoro leaf compost gave a significant effect of 24 leaves.

Figure 2. shows data on the generative phase of mung bean plants by giving the concentration of mycorrhiza, lamtoro leaf compost, and their interactions which have a significant effect on the parameters of the age of first flower, number of flowers, and pod biomass. The best combination was produced by giving 0 grams of mycorrhiza concentration with 100 grams of lamtoro leaf compost concentration on the parameters of the age of the first flower, namely 29 DAP, the number of flowers as many as 5 flowers, and pod biomass of 3.00 grams.

This can occur because the use of lamtoro leaf compost in this study serves to loosen saline soil that is sandy to clay texture so that it can be used for more optimal mung bean growth. Loose soil can make it easier for plants to absorb nutrients in the soil that will be used by plants for the process of forming new cells in certain parts of the plant. This can be one of the factors in increasing the height of mung bean plants which is a result of the elongation of the internodes of mung bean plants as the plant ages (Zuhrufah *et al.,* 2015). In addition, the large nitrogen content in lamtoro leaf compost plays an important role in the preparation of enzymes and chlorophyll molecules (Nainggolan *et al.,* 2020).

Saline-stressed plants will show a defense strategy by increasing nitrogen absorption in the form of NH_4^+ to support N assimilation in the roots (Dubey *et al.,* 2021). High N metabolism in the roots indicates the plant's response in increasing growth and biomass in stressed conditions (Susanto and Rahayu, 2023). In research on corn plants added with nitrogen in the form of NH_4^+ was able to reduce the impact of losses from NaCl compared to NO_3 (Yongha Boh *et al.,* 2013). Cation absorption competition between Na^+ and NH_4^+ can be said to be the initial mechanism of inhibition in the root zone so as to reduce cell osmotic potential and increase leaf water potential to maintain the balance of cell turgidity (Noor *et al.,* 2024).

Meanwhile, the use of mycorrhiza contributes to help in expanding the absorption area of P nutrients so that there are changes in plant physiology and the production of microbial secretions in the soil (Nasution *et al.,* 2014). The increased absorption of P elements is also caused by the ability to secrete enzymes that will be absorbed by plants, where mycorrhiza will infect the roots and then will secrete phosphatase enzymes and organic acids so that P elements will be available in the soil for plants (Raja *et al.,* 2021).

In saline soils, mycorrhizal symbiosis can be explained by changes in photosynthesis and antioxidant enzyme activity of plants. Mycorrhiza with increased Mg^{2+} can support higher chlorophyll concentrations. This suggests that salt interferes less with chlorophyll synthesis in plants with mycorrhizae than in non-mycorrhizal plants. Effective Mg^{2+} uptake helps by increasing chlorophyll concentration and hence improving photosynthetic efficiency and plant growth (Li *et al.,* 2019).

Nutrient uptake can occur with the application of arbuscular mycorrhiza which can reduce the uptake of Cl^- ions. Cl^- ions will enter the boxes of the vacuole membrane so that it will prevent disrupting metabolic pathways in the plant (Balliu *et al.,* 2015). In addition, mycorrhizal colonization of plants with mycorrhiza can reverse the effects of salinity on K^+ and Na^+ nutrients. Mycorrhizal colonization can increase K^+ uptake under saline conditions. The Na^+/H^+ antiporter catalyzes the transfer of Na^+ from the cytoplasm into the vacuole or apoplast. A higher K^+ : a higher Na^+ ratio helps prevent disruption of various K-mediated enzymatic processes and inhibition of protein synthesis (Okon *et al.,* 2020). A high K^+ : Na^+ ratio is also beneficial in influencing the cytoplasmic ion balance or excretion of Na^+ from the plant (Hussain *et al.,* 2021).

In some studies revealed that inorganic N taken up by mycorrhizal fungi is incorporated into amino acids and N transport is from extraradical mycelium to intraradical mycelium and then to the plant, which will be a great boost to the nutrient composition and growth of the host plant (Makarov, 2019). Mycorrhizal colonization increases the activity of nitrate reductase and glutamine synthetase involved in N assimilation involved in N assimilation from the host plant (Ulzen *et al.,* 2020).

Changing the vegetative phase to the generative phase of the plant can accelerate a plant to produce fruit. In this study, it can be characterized by the appearance of the first flower on mung bean plants. In general, mung bean plants will appear flowers at the age of 34 DAP. The results show that the role of mycorrhiza and lamtoro leaf compost can accelerate flower formation because mycorrhiza can fulfill the needs of P and N elements in mung bean plants more optimally with certain doses.

At present, it has been widely reported that mycorrhizal symbiosis is positively related to the reproductive fitness of host plants and the mechanism of how mycorrhizal symbiosis affects plant fitness is relatively well understood. Mycorrhizal symbiosis can help host plants to successfully achieve reproductive fitness by providing nutrients, regulating hormone balance, and production of other secondary products (Bennett and Meek, 2020).

The formation and development of flowers is largely determined by the level of P content in plants, especially in saline conditions that can withstand P elements to be absorbed by plants. If the P element can be fulfilled properly in a plant, the ability of the plant to flower can be faster and develop better (Lambers *et al.,* 2015). Increased phosphorus content has a positive effect on flower bud formation and development, flower number, pollen size, and seed production (Pangestu *et al.,* 2023). Element P can increase flower formation as a biocontrol and produce phosphatase enzymes to hydrolyze organic P and inorganic P and plays an important role in enzyme reactions, proteins and metabolic regulation in the cytosol and chloroplast (Salsabella and Rahayu, 2025).

The effect of mycorrhizal symbiosis on pollen production and performance is mainly due to the improvement of plant phosphorus acquisition, and that mycorrhizal inoculation and high soil phosphorus conditions have the same beneficial effect on male function (Bolly and Wahyuni, 2021). Mycorrhiza can transport phosphorus from soil to plant roots through extraradical hyphae, especially during flowering, abundant phosphorus supply can promote pollen production and survival. This can be considered as an important way for mycorrhizal symbiosis to affect the male flower function of the host plant (Pereyra *et al.,* 2019).

Compost can directly affect plants through hormonal mechanisms and indirectly affect soil microorganisms, leading to improved nutrient uptake dynamics and improved soil properties, which in turn increase plant growth and productivity (Rahayu and Tamtomo, 2016). The nutrient-rich environment created by appropriate concentrations of compost in the media results in improved plant performance compared to controls and higher concentrations (Sánchez *et al.,* 2017). Soil treated with compost, the soil will become fertile so that it can stimulate fruit formation in plants. Research by Ceri dan Anggorowati (2023) on effect of type and dose of compost on growth and yield of tomato plants in alluvial soil showed that the addition of compost in the soil can significantly increase fruit formation and fruit weight.

CONCLUSION

It can be concluded that the application of mycorrhiza concentration and lamtoro leaf compost has a significant effect on the vegetative and generative growth of mung beans in saline soil on the parameters of plant height, plant wet weight, root length, active root nodule biomass, age of first flower, number of flowers, and pod biomass but has no significant effect on the number of leaves. The treatment combination that gives the best treatment for mung bean growth is the provision of 40 grams mycorrhiza with 100 grams lamtoro leaf compost.

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CONFLICT OF INTEREST

There is no conflict of interest

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