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Mycorrhizal Seed Coating Enhances Root Volume and Yield Components of Edamame Soybean

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Abstract

Elevated osmotic pressure in the root zone under saline conditions acts as primary constraint to crop production by disrupting essential physiological growth process. One effective strategy for soil saline management involves the use of mycorrhizal inoculants. Delivering these microbes via seed coating is a streamlined, economical, and accurate approach that optimizes plant performance under diverse stress condition. This study aimed to evaluate the effect of mycorrhizal seed coating on the growth and yield of edamame under saline conditions. This research was arranged in a randomized complete block design with two factors, consisting of mycorrhizal seed coating (0 and 12 g kg^{-1}) and planting media (soil, saline soil, soil + saline soil (1:1)). There were six treatment combinations, and each treatment was replicated four times, resulting in a total of 24 experimental units. The observed variables include plant height, root volume, number of pods per plant, weight of pod per fruit, number of seeds per plant, and weight of 100 seeds. The result showed that mycorrhizal seed coating had potential to improve edamame root development and optimize phosphorus uptake. While vegetative height remained unaffected, the treatment substantially improved yield components, including number of pods, seed weight, and overall seed weight. The efficacy of colonization is contingent upon soil pH and phosphorus availability, highlighting the importance of site-specific conditions. Consequently, mycorrhizal seed coating represents a practical and cost-effective strategy for improving edamame performance, offering a viable solution for enhancing crop resilience and yield in nutrient-deficient or saline environments.

INTRODUCTION

Edamame is vegetable soybean with large pods and seeds, which is generally consumed fresh, harvested when the pods are green. Edamame have complete protein content, folate acid, Mg, phosphorus, vitamin K, and anti-cholesterol (Sudiarti, 2017). Iswiyanto et al. (2022) explained that edamame has larger seeds with smooth texture and sweeter taste, and it is easier to digest. Edamame harvested for consumption at maturity level to 80% has a higher protein content (36%) than processed soybeans. Hakim (2013) stated that edamame contains antioxident and isoflavone, where isoflavones useful for preventing prostate cancer, breast cancer, and heart disease, lowering blood pressure, as well as reducing menopause disorders.

The significant health benefits of edamame make it highly sought after by consumers, thereby potentially increasing farmer's income. Rahman et al. (2019) mentioned that the average production of edamame (3.5 tons ha^{-1}) is higher than that of soybean (1.7 – 3.2 tons ha^{-1}). The highest demand in edamame export is from Japan, reaching 100.000

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tons year^{-1}. While Indonesia is only able to fill 3% of the Japanese market needs, China and Taiwan fill the other 97%. Based on data from BPS Jember (2014), total export of edamame in Jember District was 4.2 ton in 2013. and it drastically decreased to 600 kg in 2018 (BPS Jember, 2018). Meanwhile, there is no longer any data of edamame production and export from 2019 to 2023. The declining of edamame exports illustrates the low yield in edamame despite the high export demand.

Total edamame production in one of edamame producers (PT. Mitratani Dua Tujuh) in 2017 reached 9,000 tons, with a land area up to 1,500 ha. Total of 7,650 tons of edamame had been exported to Japan, Europe, Kuwait, Malaysia, Australia, and USA. One of the problems in edamame production is a phenomenon of yield loss, especially during harvest. The amount of harvest loss can reach 115.8 kg on 2.73 ha for a single harvest. High edamame yield losses are caused by pathogen infection, pickers negligence during harvest, weeds, inappropriate pesticide use, and low-quality seeds (Wibowo et al., 2020). Edamame seeds distributed among farmers and companies are the second generation of the original seeds. Most of the seeds used for cultivation do not have certificates or labels so that the quality is unknown (Hakim, 2013). Edamame genotypes produce high yield under suitable field condition, provided high-quality seeds are used. Using seeds of unknown quality for planting can decrease edamame yields due too poor physiological (Li et al., 2024) and physical seeds health (Wibowo et al., 2020).

Increasing edamame production can be achieved by expanding planting areas on marginal lands, such as saline soils. Indonesia has an estimated of 0.6 million hectares of saline land, which has expanded due to extreme climate change over the last two decades. This phenomenon cannot be controlled, making it necessary to change the cultivation technology. However, plant cultivation on saline soil is hindered by osmotic pressure in root area, disrupting plant growth (Masganti et al., 2022). Plant growth disruption in saline soil is caused by high level of soluble salts, including NaCl, Na_2CO_3, and Na_2SO_4. High level of soluble salts affects the physical properties of soil, causing blockages and crust formation, thus increasing soil density. High NaCl content also causes damage and leakage of cell membranes, thus damaging photosynthetic components and making them toxic to plants. High salinity in the soil also reduces the soil's osmotic potential, inhibiting nutrient absorption. Plant growth and yield are disrupted at soil salinity levels > 4 dS m^{-1}, while sensitive plants are already effected at salinity levels of 3 dS m^{-1} (Karolinoerita & Annisa, 2020).

Obstacles to cultivation technology in saline soil can be overcome through water management, land management by adding lime and sulfur, increasing farmer awareness, biological improvements using organic mulch (Karolinoerita & Annisa, 2020) and the addition of beneficial microbes such as mycorrhiza (Ishaq, 2023). Ardiansyah et al. (2014) reported that arbuscular mycorrhiza inoculation in Grobogan and Grobogan F4 soybean in saline soil (5-6 mmhos cm^{-1}) increased plant height, number of leaves, number of active branches, and plant production. The inoculation of arbuscular mycorrhiza can repair root areas in saline soil, thereby increasing nutrient and water absorption. Ishaq (2023) added that mycorrhiza plays an important role in increasing nutrient absorption and plant resistance at unfavorable conditions, including salinity, drought, or heavy metals. Mycorrhiza produces hyphae that can increase the absorption and availability of phosphorus (P) nutrients in soil.

Rocha et al. (2019a) explained that there are several methods that can be used in in the application of beneficial microbes to plants, such as direct inoculation in soil, inoculation on plants, and inoculation on seed. Microbial inoculation on seeds can be done by soaking seeds in a microbial solution, seed coating, film pelleting, and seed pelleting. Seed coating using beneficial microbes, such as arbuscular mycorrhiza and Trichoderma, has several advantages such as being very practical, fast, cheap, accurate, requiring only few inoculants, able to affect beneficial characteristics in seed, and able to increase the plant resistance to biotic and abiotic stress. Oliveira et al. (2017) described that chickpea seed inoculation using mycorrhiza Rhizopus irregularis BEG140 increased protein content in seed from 12.2 to 16% and weight of seeds per plant from 1.5 to 2 g. Manggung et al. (2014) reported that coating soybean var. Wilis seeds using Glomus sp. mycorrhiza and storing them approximately for three months resulted in a higher percentage of seed germination (80.6%), seed vigor index (75%), and seed growth simultaneity (79.6%) compared to control. Rocha et al. (2019b) added that chickpea seed coating with five types of mycorrhiza from Rhizophagus irregularis isolates resulted in the highest plant shoot weight (1.6 g) if compared to single coating seeds with Rhizophagus irregularis (1.3 g) and control (1.4 g). The weight of seeds per plant in mycorrhiza seed coated was higher (0.34 g) than that of control (0.29 g). Seed coating using mycorrhiza can be used as a solution to improve seed quality and overcome plant stress in saline soil, thereby increasing growth and production of edamame. This research aimed to determine the potential of mycorrhiza seed coating on growth and yield components of edamame under saline condition.

MATERIALS AND METHODS

Seed coating method

The seeds used were from a local edamame variety of Ryoko grade A (seed diameter 9.8 mm). Seed coating material used was Mycorrhiza "Zakti" containing > 1000 mycorrhizal propagules. Edamame seeds were coated using mycorrhiza "Zakti" at a dose of 12 g kg^{-1} of seed. The seeds were moistened with distilled water then powdered with mycorrhiza in a petri dish. Petri dish was shaken gently (moist edamame seed coat is easily damaged) for three minutes until all of the seeds were completely coated. Coated seeds were planted immediately within six hours of coating. Coated seeds were planted in February - April 2024.

Planting procedures

The planting media used were soil and saline soil. Saline soil was collected from the shore of Kepanjen Beach, Kepanjen Village, Gumukmas Sub-district, Jember District, East Java, Indonesia (pH 7). The experimental planting was conducted in the greenhouse of the Agronomy Department (95 meters above sea level), classified as lowland area. Analysis of the planting media, including total N (%), P_2O_5 (ppm), K_2O (me 100 g^{-1}), Na (me 100 g^{-1}), Ca (me 100 g^{-1}), and Mg (me 100 g^{-1}), was performed at the Soil Fertility Laboratory, Department of Soil Science, Faculty of Agriculture, University of Jember. The result of the planting media analysis can be seen in Table 1. Polybags (35 x 40 cm) were filled with planting media consisting of soil, saline soil, and a mixture of soil and saline soil with a ratio of 1:1 g. Four seeds were planted in each polybag. Soil pH was measured using digital soil pH meter. Basic fertilizer application was carried out based on Balitkabi (2013) recommendations for soybean in tidal fields, including urea 3.15 g polybag^{-1}, NPK 9.45 g polybag^{-1}, SP-36 3.15 g polybag^{-1}, and KCl 3.15 g polybag^{-1}, applied twice at 2 and 4 WAP (weeks after planting).

Crop management

Plants watering was performed twice in a day. Weed control was carried out manually by pulling out weeds around the polybag. Harvesting for consumption was conducted at 10 WAP when the pods were completely filled and the color of the pods was fresh-green. Harvesting was conducted carefully by removing the plants from the ground, then the pods on the stems were picked, counted, and weighed. Soil pH was measured using digital pH soil meter.

Experimental design

The research was arranged in a randomized complete block design, with two factors, namely mycorrhizal seed coating (0 and 12 g kg^{-1}) and planting media (soil, saline soil, soil + saline soil (1:1)). There were six treatment combinations, and each treatment was replicated four times, resulting in a total of 24 experimental units (polybags). The observed variables include plant height (cm), root vol-

Table 1. The results of planting media analysis

Variables	Soil	Criteria	Saline Soil	Criteria	Soil + Saline Soil	Criteria
Total N (%)	0.18	low	0.19	low	0.15	low
P_2O_5 olsen (ppm)	55.88	high	11.03	low	30.63	medium
K_2O (me 100 g^{-1})	0.64	extremely low	0.39	extremely low	0.65	extremely low
Na (me 100 g^{-1})	1.38	extremely high	0.08	extremely low	1.18	extremely high
Ca (me 100 g^{-1})	5.00	low	0.64	extremely low	2.12	low
Mg (me 100 g^{-1})	0.50	low	0.38	extremely low	0.41	low
pH	7.30	neutral	7.00	neutral	7.20	neutral

ume (ml), number of pods per plant (pods), weight of a single pod (g), number of seeds per plant (seeds), and weight of 100 seeds (g). The collected data were analyzed with F test (ANOVA) using SAS Software. The treatments showing significant effect were then tested using Duncan Multiple Range Test at α = 5%.

RESULTS AND DISCUSSION

Plant height (cm)

Although there was no significant difference in plant height, plant with mycorrhizal seed coating resulted in higher plant (22.3 cm) if compared with non-coated seeds (21.7 cm) (Figure 1). Environmental factors such as light availability are thought to be the cause of the insignificant effect of mycorrhizal seed coating on plant height. The research was conducted from February to April when rainy season has started, thereby reducing the intensity of sunlight. The decreasing of sunlight intensity inhibits photosynthesis process, thereby decreasing the energy used for root colonization. Ishaq (2023) explained that mycorrhiza is indirectly influenced by sunlight. The results of photosynthesis are energy transferred to roots for plant growth and food source for mycorrhiza. In shaded conditions, mycorrhiza's root colonization is reduced because photosynthesis process is inhibited. Wisnubroto et al. (2024) added that mycorrhiza is not actively sporulating in the rainy season, indicated by the low number of spores identified (0.29) in February.

The increase in plant height during 1-5 WAP (Figure 1) is due to the availability of nitrogen following the application of basic fertilizer. Nitrogen content in media is low (0.15-0.19%) (Table 1) so that the addition of urea and NPK fertilizers can be sufficient for vegetative plant growth. Pitaloka et al. (2023) reported that arbuscular mycorrhiza has no significant effect on soybean plant growth, which is due to the soil physical and chemical

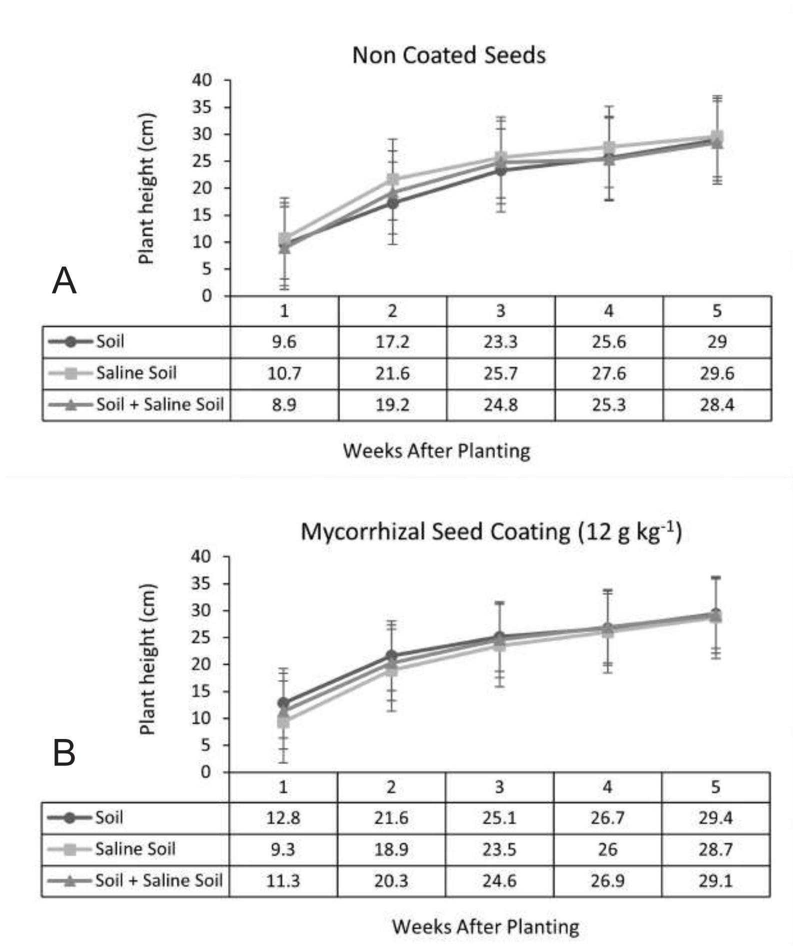

Figure 1. Plant height of non-coated (A) and mycorrhizal seed coated (B) edamame planted in various planting media at 1-5 W

properties, as well as the availability of nutrients. Yusdian et al., (2023) explained that edamame var. Ryoko-75 planted in slightly acid soil (pH 5.74) resulted in high yield with the addition of NPK doses. The NPK fertilizer dose of 350 kg ha^{-1} produced the highest number of pods per plant (17.3 pods), weight of pod per plant (49.4 g), and weight of pod per plot (2.5 kg). Edamame plants will grow well in slightly acid soil if the required nutrients are sufficient and balanced, and readily absorbed by the plants.

Based on Figure 1, edamame plants generally exhibited similar height at 1 WAP. Meanwhile at 2-5 WAP, non-coated seeds of Ryoko variety demonstrated better growth in saline soil (21.6-29.6 cm) than in soil (17.2-29 cm) and soil + saline soil (19.2-28.4 cm) (Figure 1A). This shows that edamame var. Ryoko has the potential to be cultivated as a saline-resistant type. Several studies on growth and yield response of edamame var. Ryoko had been conducted in highlands, lowlands (Hakim, 2013), and acidic soils (Mughniyarti et al., 2024; Yusdian et al., 2023). Hakim (2013) reported that plants grown from the seeds produced in highland are taller (21.6 cm) than plants from the seeds produced in lowlands (19.4 cm). Plants planted in highlands were heavier (9.96 g) than those planted in lowlands (7.26 g).

Number of pods per plant (pods)

The number of pods per plant varies across different planting media. Mycorrhizal seed coating led to a high number of pods per plant, reaching 40.1 pods in mixed media, but was not significantly different from coated seeds grown in soil (38.1 pods) (Figure 2). Soil analysis showed that the P level was high in soil media (55.8 ppm) and moderate in mixed soil + saline sand media (30.6 ppm) (Table 1). This shows that seed coating using mycorrhiza plays an important role in root colonization. Permanasari et al. (2016) explained that the higher the dose of mycorrhiza given, the higher the number of pods per plant, the number of seeds per plant, and the weight of dry seeds per plant. Mycorrhiza application to 60 g 6 kg^{-1} of soil resulted in a higher number of pods per plant (31.9 pods) compared to without mycorrhiza application (26.7 pods). Malik et al. (2017) added that arbuscular mycorrhiza (1000 spores of *Glomus* sp., *Gigasspora* sp., and *Entrophospora* sp.) applied in soybean var. Grobogan increased the number of pods per plant to 20.9 pods. Pradani et al. (2023) explained that the increase in pod productivity illustrates that mycorrhiza added to edamame seed successfully interact with the plant roots and create hyphae. These hyphae will penetrate in roots and infect the root zone so that the roots can absorb more nutrients. Nutrients that are usually absorbed in greater quantities are Nitrogen and Phosphorus.

Although coated seeds typically yield slightly fewer pods than non-coated seeds, the number of pods per plant in saline soil was comparable between non-coated (38 pods) and coated (36.7 pods) seeds (Figure 2). The results of the soil analysis on saline soil were low level of P (11 ppm), low N (0.19%), extremely low K_2O (0.39 me 100 g^{-1}), Na (0.08 me 100 g^{-1}), Ca (0.64 me 100 g^{-1}), Mg (0.38 me

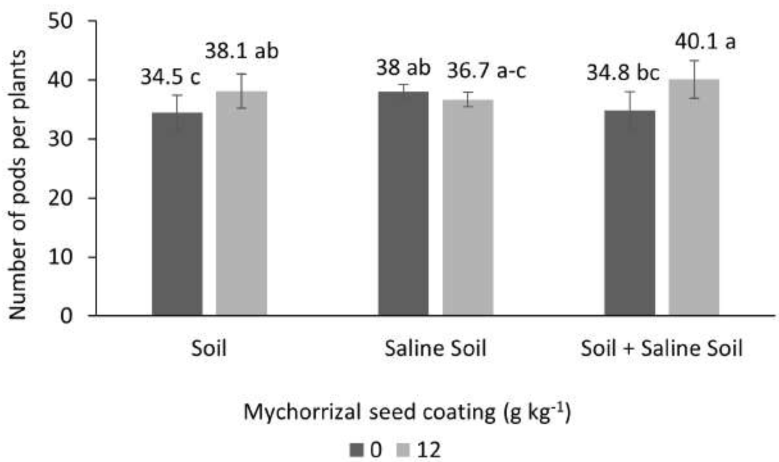

Figure 2. Effects of mycorrhizal seed coating and planting media on the number of pods per plant

100 g^{-1}), and pH 7 (Table 1). Tolib et al. (2017) stated that saline soil has a fairly high pH, which is between 7 – 8.5. Yusriadi et al. (2018) reported that total of mycorrhiza collected was higher (354 spores per 10 g soil) in lower pH soil to 5.8 in soybean roots than in pH 7.1 in paddy roots (87 spores per 10 g soil). The lower pH in soil, the higher total of mycorrhiza spores created. Mycorrhiza is "arcidophylis", which means that mycorrhiza prefers acidic environments. Wisnubroto et al. (2024) added that the relationship between soil pH and the number of spores described by a negative linear regression curve. The higher the pH value, the lower the number of spores.

Weight of a single pod (gram)

Mycorrhizal seed coating increased the weight of a single pod in mixed soil (2.46 g), but it was not significantly different from non-coated seeds grown in soil (2.4 g) (Figure 3). Mycorrhiza actively colonize the plant root that lacks of nutrients. Based on soil analysis, mixed soil + saline soil contains low nutrients if compared to soil media. Mixed media had lower total N (0.15%), P (30.6 ppm), and pH (7.2) compared to soil media (N total 0.18%, P 55.8 ppm, pH 7.3) (Table 1). Staton & Steinke (2021) explained that phosphorus requirements for soybean plants are 20 – 40 ppm. Based on the result, seed coating using mycorrhiza in mixed media plays an important role in maximizing the absorption of P so that it can be used by plants for seed filling. Malik et al. (2017) explained that weight of pods per plant in soybean var. Grobogan increased to 16.7 g after the application of 1000 spores of arbuscular mycorrhiza. Mycorrhiza is able to maximize the P uptake, which plays a role in seed filling, seed ripening, and increasing seed production. Pradani et al. (2023) added that edamame seed coating using mycorrhiza Glomus manihotis, Glomus intaradices, Glomus agregatum, Acaulospora sp., and Gigaspora sp. at a dose of 100 g 30 kg^{-1} seed resulted in weight of pods, reaching 2.5 ton ha^{-1}. The hyphae produced by mycorrhiza can initiate plants to absorb greater nutrients.

Non-coated seeds grown in soil media exhibited a higher average single pod weight (2.4 g) compared to those with mycorrhizal seed coating (2.15 g) (Figure 3). This result showed that mycorrhiza is less active in root colonization due to incompatibility with the growing environment. Soil media has the highest pH (7.3) if compared to saline soil (7) and mixed soil + saline soil (7.2) (Table 1). Yusriadi et al. (2018) explained that many arbuscular mycorrhizae exhibit inactive spores at pH levels unsuitable for its growth. Active mycorrhizae are found in soil with low pH because acidic environments contain low nutrients, where mycorrhizae prefer infertile soils.

High phosphorus level in soil media, reaching 55.8 ppm (Table 1), also inhibit root colonization activities by mycorrhiza. Yusriadi et al. (2018) explained that mycorrhiza is inactive in fertile land, especially in soil with high available of phosphorus. This condition will change the mutual relationship between plants roots with mycorrhiza. In fertile soil,

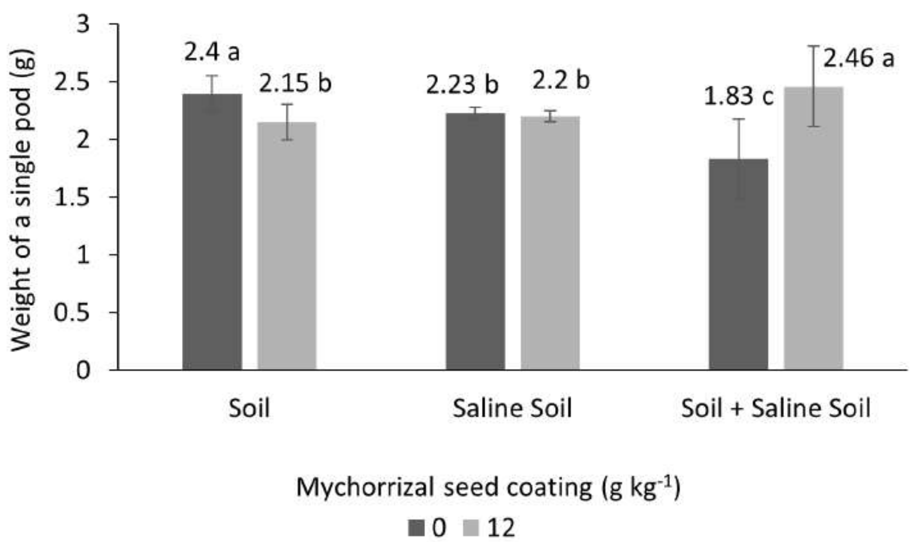

Figure 3. Effects of mycorrhizal seed coating and planting media on the weight of a single pod

plants do not require mycorrhizal support, preventing root colonization. Plant roots act as nutrient-absorbing organs, allowing plants to accumulate large amounts of phosphorus. Under these conditions, mycorrhizae still obtain nutrients from the host plant to survive but refuse to colonize the roots, impacting plant metabolism.

Number of seeds per plant (seeds) and Weight of 100 seeds (gram)

Most treatments showed no significant differences in the number of seeds per plant and weight of 100 seeds. Non-coated seeds planted in soil media produced the lowest number of seeds per plant (52.7 seeds) and weight of 100 seeds (36.2 g). The application of mycorrhiza to edamame seeds led to a higher number of seeds per plant (63.7 seeds) and a greater weight of 100 seeds (38.7 g) in soil media compared to non-coated seeds (Figure 4). High phosphorus content in soil media (55.8 ppm) (Table 1) can be converted into available form by mycorrhiza, making it more easily absorbed by plant roots. Ishaq (2023) explained that phosphorus is an immobile nutrient and limited for plants because it is easily fixated. Mycorrhiza plays a role in increasing P absorption through phosphatase enzyme and organic acids secretion that increase the solubility of P in soil. Hyphae created by mycorrhiza are also able to expand the P absorption area and reach small pores that cannot be reached by root hairs. Panataria et al. (2022) stated that phosphorus plays role in supplying and transferring energy in plant biochemical processes, especially in soybean pods filling.

No significant effects of seed coating were found on the number of seeds per plant and weight of 100 seeds, both in saline soil and mixed soil (Figure 4). This result is thought to be due to the low dose of mycorrhizae, which was 12 g kg^{-1} of seed, so that there was only a few active spores that could be infected the plant roots. Permanasari et al. (2016)

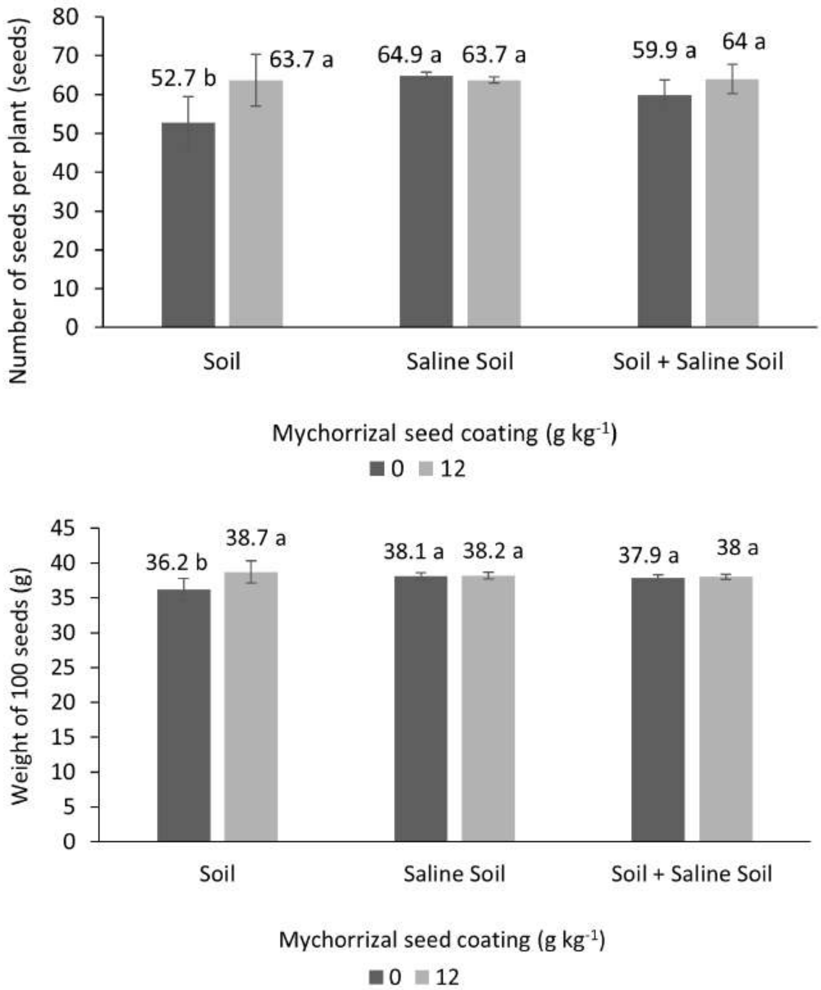

Figure 4. Effects of mycorrhizal seed coating and planting media on the number of seeds per plant and weight of 100 seeds

reported that application of mycorrhizae to black soybean variety Malika with a dose of 60 g 6 kg^{-1} soil resulted in a higher number of seeds per plant (61.1 seeds) and dry weight of seeds per plant (6.2 g) than mycorrhizae application at a dose of 40 g 6 kg^{-1} soil (57.4 seeds; 5.6 g) and 20 g 6 kg^{-1} soil (52.2 seeds; 5.1 g). Panataria et al. (2022) added that the higher doses of mycorrhizae application, the higher the production of seeds per sample. The application of mycorrhizae to soybean at a dose of 15 g $plant^{-1}$ resulted in a higher production of seeds per sample (23.3 g) than the application at doses of 10 g $plant^{-1}$ (20.9 g), 5 g $plant^{-1}$ (17.8 g), and 0 g $plant^{-1}$ (15.8 g). The same results were also seen in the production of seeds per plot and dry weight of 100 seeds. The higher the dose of mycorrhizae, the greater the chance of active spores infecting the roots.

The average weight of 100 seeds in edamame var. Ryoko was recorded at 37.8 g (Figure 4), where this experiment was conducted in the lowlands (95 m asl). Similar results were also reported by Hakim (2013), where edamame var. Ryoko planted in lowlands also resulted in a higher weight of 100 seeds (36.4 g). Based on the experimental results, edamame var. Ryoko has the potential to produce a higher weight of 100 seeds if not only single type of mycorrhiza is used. Rocha et al. (2019b) explained that hat the number of grains per plant, individual grain weight per plant, and yield per plant were also reported to show no significant results between Rcoat (chickpea seed coated using single Rhizophagus irregularis BEG140) and uncoated seeds. Seed coating using mixture of R. irregularis (BEG141, BEG236, DAOM 197198, KW and AS) resulted in a higher response to chickpea productivity if compared to non-coated seed and Rcoat. This is due to the mixture of AM being very effective and capable of producing higher amounts of grains with less shoot biomass.

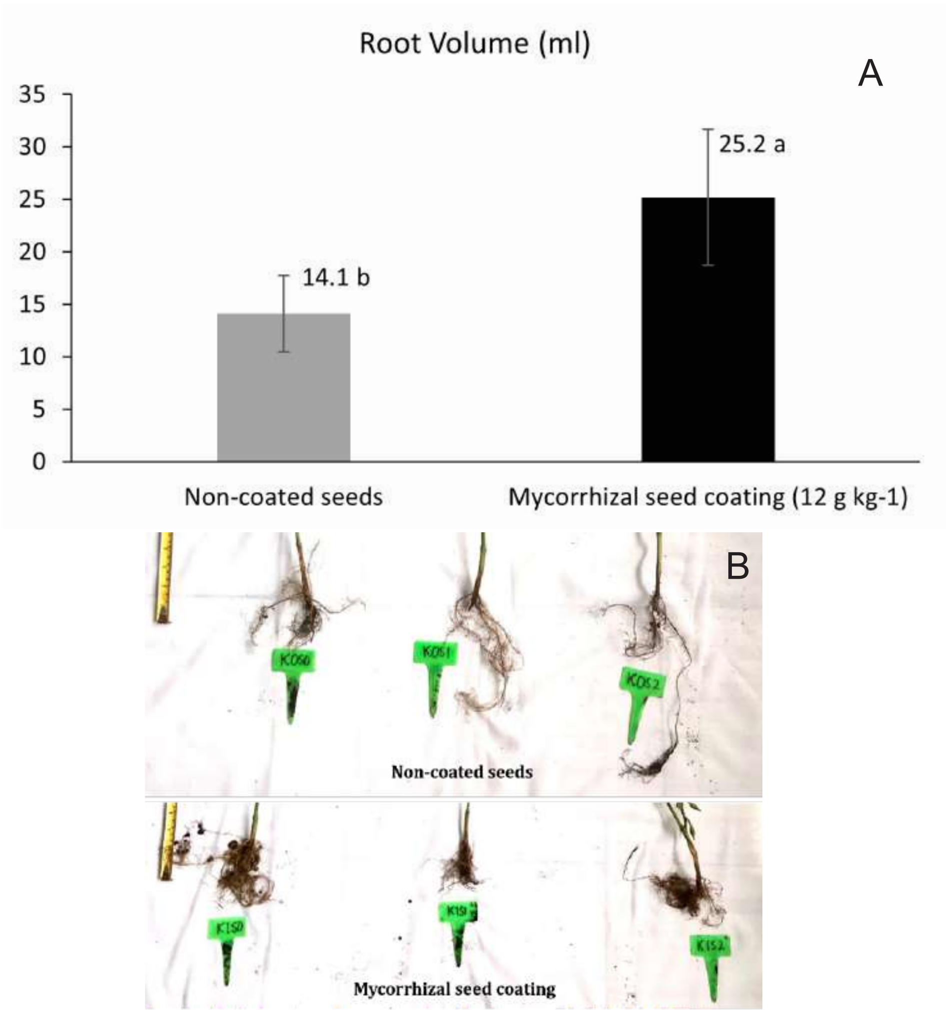

Figure 5. Root volume of edamame plants in response to mycorrhizal seed coating (A) and roots appearance due to mycorrhizal seed coating (B)

Root volume (ml)

Plants with mycorrhizal seed coating exhibited significantly larger root volumes, measuring 25.2 ml, compared to those with non-coated seeds, which had root volume of 14.1 ml (Figure 5A). Mycorrhizal inoculation through seeds effectively infected plant roots during growth, enabling the mycorrhizae to harness phosphorus nutrients from the media. This led to the production of hyphae, colonization of roots, and ultimately an increase in root weight (Figure 5B). Nath & Meena (2018) explained that arbuscular mycorrhizae had beneficial effects in increasing the absorption capacity of roots due to morphological and physiological changes in plant. There are increasing in absorption surface area, greater soil area explored, greater longevity in absorbing nutrients, better utilization of low-availability nutrients, and better retention of soluble nutrients. Permanasari et al. (2016) stated that root dry weight of soybean with 60 g of mycorrhizae per 6 kg^{-1} soil 40 days after planting was higher (3.2 g) than that with 40 g (3.1 g) and 20 g (2.8 g) of mycorrhizae per 6 kg^{-1} soil. Mycorrhizae produce external hyphae to 8 cm outside of root system. The diameter of hyphae is 20% smaller than root hair diameter, making it able to reach narrow areas to expand the nutrient uptake. Rocha et al. (2019b) reported that mixture of five Rhizophagus irregularis (MRcoat) showed higher rates of fungal colonization in chickpea roots to 69% if compared to control (54%) and single mycorrhizal seed treatments (42%). The combined use of multiple isolates and seed coating can be an effective tool for introducing mycorrhiza to improve yield of chickpea. Marwanto et al. (2024) reported that mycorrhizal inoculation through soil and seed coating (1.5 g of mycorrhiza containing 300 spores of Glomus mossae) had the same effect on root dry weight, which were 44.9 and 45.2 g per plant, respectively. This indicates that the application of AMF inoculum through seed coating was successful to induce P uptake in soil. Seed coating provides available AMF spores at seed-soil interface and accessibility to AMF spores at the initial stage of plant development. In the next plant growth AMF spores will colonize the roots and subsequently increased the root volumes.

CONCLUSIONS

Mycorrhizal seed coating increased edamame root volume to 25.2 ml. While not affecting plant height, it enhanced the number of pods per plant (40.1 pods) and weight of pods per plant (2.46 g) in mixed media. Mycorrhizal seed coating also led to a higher number of seeds per plant (63.7 seeds) and weight of 100 seeds (38.7 g) in soil media by improving phosphorus absorption. The effectiveness of mycorrhiza was influenced by soil pH and phosphorus level, suggesting optimal conditions for colonization. Mycorrhizal seed coating shows potential to improve edamame growth and yield, especially under low-fertility or high-salinity conditions.

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