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Effect of Biocon-NP Biofertilizer Combined with *Azolla microphylla* on the Growth of Green Mung Beans (*Vigna radiata*) in Saline Soil

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Abstract
Saline soil is one of the main obstacles in food crop cultivation because it reduces productivity. This study aims to analyze the effect of Biocon-NP biofertilizer and *Azolla microphylla* compost on mung bean (*Vigna radiata*) growth in saline soil. The study used a two-factor Randomized Group Design with 12 treatment combinations and 3 replications, total of 36 experimental units. The treatment factors included the dose of *Azolla microphylla* compost (0, 40, and 80 g) and the dose of Biocon-NP biofertilizer (0, 100, 125, and 150 ml). Parameters observed included plant height, number of leaves, number of primary branches, flowering age, plant biomass, root nodule biomass, and number of pods. Data were analyzed using two-way ANOVA and Duncan's further test. The results showed that the treatment interaction had a significant effect on all parameters except the number of primary branches and flowering age. The best treatment recommendation was the combination of Biocon-NP 150 ml and *Azolla microphylla* compost 80 g.

Keywords: marginal land; mung bean; nutrients; salinity; soil microbes; environment stress

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INTRODUCTION

The agricultural sector is important because it is directly related to the fulfillment of basic needs in the form of food for the community. However, conditions in the field show that the agricultural sector still has to face various challenges and obstacles that cause the productivity to be disrupted. Some of the challenges in agriculture include plant pests and viruses, climate change and land degradation (Lestari *et al.,* 2024; Ismaya & Saud, 2024). Agricultural land degradation is a condition where fertile agricultural land is decreasing due to land conversion due to increased population pressure (Salote *et al.*, 2022). Thus, efforts are needed to increase the productivity of food crops on marginal lands such as saline soils. Saline soils are soils with salinity conditions or high sodium content where sodium levels are above the critical threshold or tolerance threshold of plants (Masganti *et al.*, 2022). According to Sihotang (2021), salinity can affect the decrease in plant growth speed due to a decrease in the plant's ability to absorb water.

Research related to the use of saline soil as a planting medium was conducted by Diyanti *et al.* (2022), on the growth response of corn plants on various planting media, one of which is saline soil. On saline soil media, corn can grow, but it is considered less than optimal. Through research conducted by Taufiq *et al.* (2020), saline soil is proven to be used as a medium for growing soybeans, but the application of silica in the form of zeolite and liquid silica fertilizer is needed to increase plant growth and yield, and reduce the negative impact of high salinity on plant productivity. Research conducted by Maulana *et al.* (2020), also proved that saline soil can be used as a planting medium for various varieties of chili (*Capsicum annum*) but with the addition of mycorrhiza. Based on some of these studies, saline soil has the potential to be used as a planting medium for a plants, as it has been proven that plants can grow on saline soil media. However, optimization and proper plant selection are needed so that plants developed on saline soil media can produce good growth and productivity.

Plants that can be developed to optimize the use of saline soils mung beans (*Vigna radiata* L.). As in the research conducted by Sari *et al.* (2023), mung beans with Kenari and Vima 3 varieties showed their ability to witDAPand salinity stress. Azka (2021), in his research stated that the mung bean variety of Kenari is resistant to drought stress. According to research by Podder *et al.* (2020), mung bean plants can grow in salinity stressed environments. Based on this, mung bean plants can live under stress even though their growth is not optimal. Therefore, mung bean cultivation on saline land can be optimized with new methods and innovations to support the sustainability of production and productivity.

The method of improving the quality of saline soil can be developed by adding Biocon-NP biofertilizer, which is a microbial inoculum to increase plant growth by combining several bacteria such as *Azotobacter* sp., *Azospirillum* sp., and *Pseudomonas* sp. which play an important role in the soil. *Azotobacter* sp. is a bacterium that utilizes nitrogen from the atmosphere to form proteins in its cells which are then broken down in the soil so that plants obtain most of the nitrogen from the soil (Sumbul *et al.*, 2020), similar to *Azospirillum* sp. which is able to increase plant growth through atmospheric nitrogen binding and phytohorm one production (Cassán *et al.*, 2020). The results of research by Ni'mah & Yuliani (2022) showed that the application of *Azospirillum* sp. and corn cob biochar had an effect on soybean growth in saline soil. In addition, Biocon-NP also contains *Pseudomonas* sp. which can increase phosphorus absorption by plants through acidification, chelation, and exchange reaction mechanisms that convert mineral phosphorus into a form that is more easily absorbed (Barin *et al.*, 2022). Research by Novelia *et al.* (2022) showed that the addition of Biocon-NP in biofertilizers had a significant effect on the growth and yield of purple corn plants, including plant height, number, length, and width of leaves, flowering time, cob length, and cob fresh and dry weight. In line with that, Ekopranoto (2023) also reported that Biocon-NP increased corn production in the farmer group "Tani Makmur" in Kaliwungu Village, Kudus Regency. Research results by Trovicana *et al.* (2024) also showed that the combination of Biocon-NP and *Trichoderma harzianum* had an effect in increasing the number and weight of fresh fruit of San Marino chili varieties.

In addition to the application of biofertilizers, the addition of *Azolla microphylla* compost needs to be done to improve soil structure, considering that this aquatic plant has a high nitrogen and protein content and is easily composted (Rahman *et al.*, 2023; Azab & Soror, 2020). Research shows that the use of *Azolla microphylla* compost can increase plant dry weight and fertilizer efficiency (Laksitarani *et al.*, 2020), increase the number of onion bulbs (Mubarok *et al.*, 2022), and improve the growth of king grass (Qohar *et al.*, 2021). The combination of Biocon-NP biofertilizer, which plays a role in providing nitrogen and phosphate solubility, with *Azolla microphylla* compost, which improves soil structure, has the potential to increase the growth of mung bean plants on saline soils. Although the benefits of both have been widely studied separately in normal soils, no studies have explored the synergy between Biocon-NP and *Azolla microphylla* in saline soils and the specific mechanisms that affect plant tolerance to salinity stress. Thus, this study aimed to analyze the effect of Biocon-NP biofertilizer and *Azolla microphylla* compost on the growth of mung bean (*Vigna radiata*) in saline soil.

MATERIALS AND METHODS

This research was experimental research conducted from September 2024 to January 2025 at Green House Biology, Faculty of Mathematics and Natural Sciences, Surabaya State University. The study used a Randomized Group Design (RGD) with two treatment factors, namely the dose of *Azolla microphylla* compost (0 g, 40 g, and 80 g) based on the results of the compost nutrient content test in Soil and Water Laboratory of *UPT Pengembangan Agribisnis Tanaman Pangan dan Hortikultura* and the dose of Biocon-NP biofertilizer (0 mL, 100 mL, 125 mL, and 150 mL) which refers to research by Novelia *et al.* (2022). Thus, 12 treatment combinations with 3 replications each, totaling 36 experimental units.

The plants used were mung beans (*Vigna radiata* var. Vima 3) planted in saline soil media (5 kg regosol soil + 500 mL seawater Kenjeran Beach Surabaya with 3% salinity) in each polybag. *Azolla microphylla* compost was prepared by Takakura method and was applied one week before planting and routinely every week. Biocon-NP biofertilizer was fermented beforehand and poured weekly into the planting media. Seedlings were transplanted into polybags after 7 days of nursery, when they had grown 2-3 true leaves. Maintenance included regular watering (with saline and fresh water), weeding, and pest control.

Parameters observed included plant height, number of leaves, number of primary branches (observed on days 14, 21, 28, 35, and 45 after planting), flowering age (day of first flower appearance), plant biomass, root nodule biomass, and number of pods (on day 45 after planting). Data were analyzed using two-way ANOVA and were followed with Duncan's multiple range test to determine significant differences between treatments.

RESULTS

Measurement of planting media condition before treatment is presented in Table 1, while nutrient testing of *A. microphylla* compost is presented in Table 2. Statistical test of *A. microphylla* compost and Biocon-NP biofertilizer effect on various plant parameters recorded is presented in Table 3, as well in Figure 1 and 2.

Table 1. Measurement results of the condition of saline soil planting media before treatment with *Azolla microphylla* compost and Biocon-NP biofertilizer.

No	Parameters	Result
1	pH	7,5
2	Temperature (°C)	27,9
3	Soil Electrical Conductivity (dS m^{-1})	5

The measurement results of saline soil planting media showed a pH of 7.5, where according to Khamidov *et al.* (2022), the pH value of saline soil <8.5 is considered normal soil pH. Soil temperature of 27,9°C was within the normal range between 10°C - 28°C for plants, as classified by Conant *et al.* (2008). The soil electrical conductivity (EC) of 5 dS m^{-1} (5000 µS cm^{-1}) indicated high salinity since it falls within the electrical conductivity (EC) range of 3000 - 7500 µS cm^{-1} according to Ayers & Westcot (1985) (Table 1).

Table 2. Nutrient content of *Azolla microphylla* compost

No	Parameters	Nutrient Content	Criteria*)
1	Rasio C/N	8,18	Low
2	C-Organic (%)	17,43	Very High
3	N (%)	2,13	Very High
4	P_2O_5 (%)	2,32	Very High
5	K_2O (%)	2,31	Very High
6	Water Content	61,76	-

Note: *) Based on the criteria of Hardjowigeno (1987)

Table 3. Effect of *Azolla microphylla* compost and Biocon-NP biofertilizer on the parameters of green bean plant height 45 DAP

Parameter	Biocon-NP Biofertilizer (ml)	*Azolla microphylla* Compost (g)*			Average
		0	40	80	
Plant Height	0	55,37 ± 4,70[a]	81,30 ± 0,94[d]	92,07 ± 2,26[g]	76,24 ± 16,11[a]
	100	59,10 ± 3,65[a]	82,07 ± 4,27[de]	98,50 ± 4,97[h]	79,89 ± 17,12[b]
	125	65,50 ± 4,10[c]	86,00 ± 2,61[ef]	98,47 ± 3,03[h]	83,32 ± 14,33[c]
	150	76,50 ± 3,30[d]	88,98 ± 2,97[fg]	**104,88 ± 2,91[i]**	90,12 ± 12,29[d]
	Average	64,12 ± 8,99[a]	84,59 ± 4,19[b]	98,48 ± 5,63[c]	
Number of Leaf	0	13,17 ± 1,47[a]	19,83 ± 1,17[c]	28,83 ± 1,17[f]	20,61 ± 6,71[a]
	100	14,17 ± 1,47[a]	20,83 ± 1,17[cd]	30,83 ± 1,17[g]	21,94 ± 7,15[b]
	125	16,83 ± 1,17[b]	21,83 ± 1,17[d]	31,83 ± 1,17[g]	23,50 ± 6,51[c]
	150	19,83 ± 1,17[c]	23,83 ± 1,17[e]	**35,83 ± 1,17[h]**	26,50 ± 7,08[d]
	Average	16,00 ± 2,92[a]	21,58 ± 1,86[b]	31,83 ± 2,82[c]	
Plant Biomass	0	18,00 ± 4,47[a]	50,00 ± 3,03[d]	86,33 ± 4,50[h]	51,44 ± 28,98[a]
	100	21,50 ± 5,01[a]	56,83 ± 2,64[e]	104,17 ± 4,67[i]	60,83 ± 35,08[b]
	125	33,83 ± 4,49[b]	63,67 ± 4,32[f]	115,33 ± 3,78[j]	70,94 ± 34,87[c]
	150	43,67 ± 3,14[c]	76,17 ± 4,67[g]	**133,83 ± 4,67[k]**	84,56 ± 38,57[d]
	Average	29,25 ± 11,17[a]	61,67 ± 10,48[b]	109,92 ± 18,10[c]	
Root Nodule Biomass	0	0,43 ± 0,04[a]	1,40 ± 0,03[e]	1,97 ± 0,02[i]	1,26 ± 0,66[a]
	100	0,71 ± 0,04[b]	1,57 ± 0,04[f]	2,05 ± 0,04[j]	1,44 ± 0,57[b]
	125	0,86 ± 0,07[c]	1,77 ± 0,04[g]	2,27 ± 0,05[k]	1,63 ± 0,60[c]
	150	1,00 ± 0,03[d]	1,90 ± 0,02[h]	**2,46 ± 0,06[l]**	1,79 ± 0,62[d]
	Average	0,75 ± 0,22[a]	1,66 ± 0,20[b]	2,19 ± 0,20[c]	
Parameter	**Biocon-NP Biofertilizer Dosage (ml)**	***Azolla microphylla* Compost Dosage (g)**			**Average**
		0	**40**	**80**	
Number of Pods	0	4,33 ± 0,52[a]	10,33 ± 0,52[d]	15,83 ± 0,75[g]	10,17 ± 4,87[a]
	100	6,17 ± 1,17[b]	11,67 ± 1,03[e]	19,00 ± 1,41[h]	12,28 ± 5,53[b]
	125	8,83 ± 0,75[c]	14,17 ± 1,47[f]	22,50 ± 1,05[i]	15,17 ± 5,88[c]
	150	10,17 ± 0,75[d]	16,00 ± 0,89[g]	**26,50 ± 1,87[j]**	17,56 ± 7,06[d]
	Average	7,38 ± 2,45[a]	13,04 ± 2,44[b]	20,96 ± 4,25[c]	

Note: *) Duncan's multiple range test (DMRT) at 5% significance level was performed separately for each parameter. Different letters within the same parameter and the same column indicate significant differences, while the same letters indicate no significant difference.

Table 2 present the nutrient content of *Azolla microphylla* compost, showing a low C/N ratio of 8.18 and high organic carbon content (17.43%). The compost contained high levels of N (2.13%), P_2O_5 (2.32%), and K_2O (2.31%), which were classified as very high based on Hardjowigeno (1997). The moisture content of the compost was 61.76.

Based on Duncan's test at 0,05 level on plant height at 45 DAP, the treatment of 80 g *Azolla microphylla* compost resulted in significantly higher plant height compared to 40 g and 0 g. Likewise, Biocon-NP 150 ml biofertilizer treatment was significantly different from 125 ml, 100 ml, and 0 ml. In the combination treatment, 80 g compost + 150 ml Biocon-NP was significantly different from all other combinations. However, the treatment of 0 g compost + 0 ml Biocon-NP was not significantly different from 0 g compost + 100 ml Biocon-NP. Similarly, the treatment of 40 g compost + 0 ml Biocon-NP was not significantly different from 40 g compost + 100 ml Biocon-NP, and the treatment of 40 g compost + 100 ml Biocon-NP was not significantly different from 40 g compost + 125 ml Biocon-NP. The treatment of 40 g compost + 125 ml Biocon-NP was also not significantly different from 40 g compost + 150 ml Biocon-NP, while the treatment of 40 g compost + 150 ml Biocon-NP was not significantly different from 80 g compost + 0 ml Biocon-NP (Table 3.).

The Duncan test results in Table 3. for the parameter number of leaf show that the treatment of *Azolla microphylla* compost 80 g is significantly different from 40 g and 0 g. Biocon-NP 150 ml biofertilizer treatment was also significantly different compared to 125 ml, 100 ml, and 0 ml. In the combination treatment, 80 g compost + 150 ml Biocon-NP was significantly different from the other combinations. However, the 0 g + 0 ml treatment was not significantly different from 0 g + 100 ml, and the 40 g + 0 ml treatment was not significantly different from 40 g + 100 ml. In addition, the 40 g + 100 ml treatment was not significantly different from 40 g + 125 ml, and the 80 g + 100 ml treatment was not significantly different from 80 g + 125 ml.

Plant biomass accumulation showed a distinct pattern in response to both *Azolla microphylla* compost and Biocon-NP biofertilizer treatments, as indicated by the Duncan test results in Table 3. The application of 80 g *Azolla microphylla* compost resulted in significantly higher plant biomass compared to the 40 g and 0 g teratments, suggesting that increased compost dosage enhanced overall plant growth and biomass production. In addition, Biocon-NP biofertilizer at a dosage of 150 ml produce a significantly higher biomass compared to 125 ml, 100 ml, and 0 ml, indicating a strong response of biomass accumulation to higher biofertilizer input. When both factors were combined, the treatment combination of 80 g *Azolla microphylla* compost and 150 ml Biocon-NP showed the highest plant biomass and was significantly different from all other combinations. Nevertheless, the combination of 0 g *Azolla microphylla* compost with 0 ml Biocon-NP did not different significantly from 0 g *Azolla microphylla* compost with 100 ml Biocon-NP, indicating that biomass response remained similar at lower levels of biofertilizer application in the absence of compost.

The effect of treatment variations on root nodule biomass was also clearly demonstrated by the Duncan multiple range test results shown in Table 3. *Azolla microphylla* compost application significantly affected root nodule biomass, with the 80 g treatment showing significantly higher values compared to the 40 g and 0 g treatment. This result indicates that higher compost input supported better root nodule development. Futhermore, the application of Biocon-NP biofestilizer at 150 ml resulted in a significantly higher root nodule biomass compared to the 125 ml, 100 ml, and 0 ml treatments. In the interaction analysis, the combination of 80 g *Azolla microphylla* compost and 150 ml Biocon-NP showed a significantly higher root nodule biomass compared to all other treatment combinations. These results demonstrate a consistent trend in which higher levels of both compost and biofertilizer promoted improved root nodule biomass.

The Duncan test results in Table 3. for the parameter number of pods show that the treatment of Azolla microphylla compost 80 g is significantly different from 40 g compost and 0 g compost. Biocon-NP 150 ml biofertilizer treatment was also significantly different compared to 125 ml, 100 ml, and 0 ml. In the combination treatment, 80 g compost + Biocon-NP 150 ml was significantly different from the other combinations. However, the 0 g compost + Biocon-NP 150 ml treatment was not significantly different from 40 g compost + 0 ml Biocon-NP, and the 40 g compost + Biocon-NP 150 ml treatment was not significantly different from 80 g compost + Biocon-NP 0 ml.

Based on Figure 1, increasing doses of *Azolla microphylla* compost and Biocon-NP biofertilizer increased the number of primary branches. 80 g of compost produced the highest number of primary branches (10.29), while 0 g compost was the lowest (5.04). For Biocon-NP, the 150 ml dose was the highest (8.56), and 0 ml Biocon-NP the lowest (6.56). Duncan's test showed significant differences between 80 g of compost with 0 and 40 g, as well as between Biocon-NP 150 ml with 0 ml, 100 ml and

125 ml. The best dosage for compost is 80 g, while the recommended dosage of Biocon-NP is around 150 ml. Duncan's test was not conducted on the treatment combinations because the two-way ANOVA results did not show a significant effect.

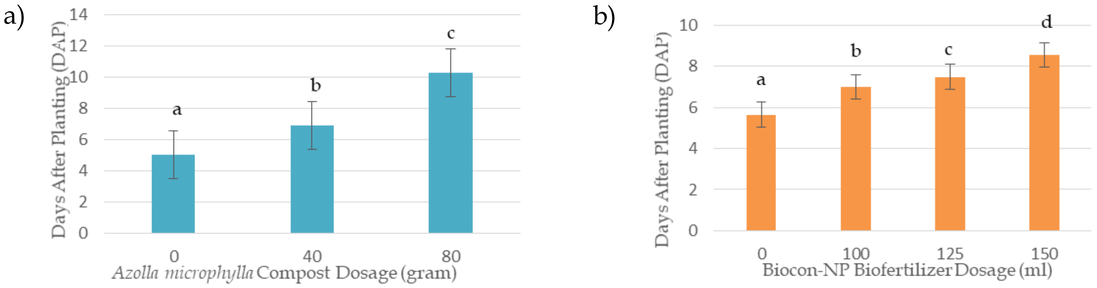

Figure 1. Number of primary branches of mung bean plants treated with (a) *Azolla microphylla* compost and (b) Biocon-NP biofertilizer treatment.

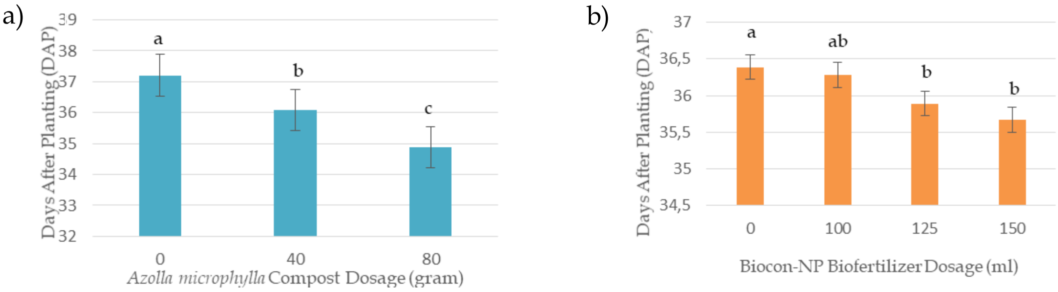

Figure 2. Flowering age of mung bean plants treated with (a) *Azolla microphylla* compost and (b) Biocon-NP biofertilizer treatment.

Based on Figure 2, Increasing the doses of *Azolla microphylla* compost and Biocon-NP biofertilizer tended to accelerate the flowering time. The 80 g compost treatment produced the fastest flowering age (34.88 DAP), while 0 g produced the longest flowering age (37.21 DAP). In the Biocon-NP treatment, the 150 ml dose gave the fastest results (35.67 DAP) and 0 ml the longest (36.39 DAP). Duncan's test showed significant differences between 80 g of compost with 0 and 40 g, as well as between 150 ml Biocon-NP with 0 ml, but not with 100 ml and 125 ml doses. The best dosage for compost is 80 g, while the recommended dosage of Biocon-NP ranges from 125-150 ml. Duncan's test was not conducted on the treatment combinations because the two-way ANOVA results did not show a significant effect. In general, the treatments showed a shift in flowering age towards an earlier generative phase, in response to increased nutrient availability from compost and biofertilizer.

DISCUSSION

Based on the research that was conducted, the application of various doses of Azolla microphylla compost and Biocon-NP biofertilizer significantly affected the growth of mung bean plants (*Vigna radiata*) in saline soil. Treatments with Azolla microphylla compost and Biocon-NP biofertilizer each had a significant effect on plant height, number of leaves, number of primary branches, flowering age, plant biomass, root nodule biomass, and number of pods. Furthermore, the interaction between Azolla microphylla compost and Biocon-NP biofertilizer also significantly influenced plant height, number of leaves, plant biomass, root nodule biomass, and number of pods. However, the interaction did not significantly affect the number of primary branches and flowering age. The best growth of mung bean plants was observed in the treatment with 80 g of Azolla microphylla compost combined with 150 ml of Biocon-NP biofertilizer.

In saline soil conditions, nutrient uptake by plants is often hindered by high osmotic pressure and the accumulation of ions such as Na^+ and Cl^-, which can lead to nutrient deficiencies. The application of *Azolla microphylla* compost helped overcome this problem by improving the availability of macro- and micro-nutrients as well as enhancing soil physical and chemical properties. This finding is supported by previous research conducted by Eko & Riancoon (2018), which reported that *Azolla microphylla* compost promoted growth in both vegetative and generative phases. It also aligns with

Novrimansyah (2020), who stated that *Azolla microphylla*-based fertilizer supported mung bean growth by increasing nutrient absorption efficiency.

In addition to increasing soil fertility because it contains essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), and organic carbon (C-organic) that play a significant role in plant growth, *Azolla microphylla* compost also has a beneficial impact on its improvement of soil properties (Marzouk *et al.*, 2023). Ram *et al.* (1994) stated that the addition of *Azolla microphylla* compost into the soil can significantly improve the soil's ability to water. The same thing was also expressed by Ripley *et al.* (2003), which showed that *Azolla microphylla* compost contributes to increasing water retention capacity (the ability of soil to hold and store water after infiltration or infiltration of water into the soil). This ability of the soil to retain water is very important in saline soils, as it helps reduce the impact of salinity stress by maintaining water availability for plants. In addition, increased water-holding capacity can improve soil structure, reduce leaching of excess salts, and create a more favorable environment for plant growth in highly saline growing media.

Biocon-NP biofertilizer contains the bacteria *Azotobacter* sp., *Azospirillum* sp., and *Pseudomonas* sp., which play a role in stimulating the availability of nutrients in the soil for plants. *Azotobacter* sp. and *Azospirillum* sp. are bacteria that have the ability to convert free nitrogen in the atmosphere into a form that can be utilized by plants. Nitrogen plays an important role in the formation of chlorophyll, which is a crucial pigment for the photosynthesis process (Soepriyanto *et al.*, 2021). Increasing nitrogen levels can support an increase in the rate of photosynthesis so that it can support the growth of height and number of plant leaves. According to Hanifa *et al.* (2022), nitrogen also helps cell division and enlargement. The more available sufficient nitrogen content, the cell division and enlargement will take place more smoothly so as to increase the growth of height, number of leaves, and number of plant branches. This is supported by the research of Reddy *et al.* (2018) where *Azotobacter* produces several substances similar to gibberellins and auxins. Gibberellin and auxin hormones play a role in the elongation activity of plant stem cells so as to support upward plant growth and affect plant height.

The role of *Azotobacter* sp. and *Azospirillum* sp. bacteria is supported by *Pseudomonas* sp. bacteria which also take an important part in the growth of mung bean plants. *Pseudomonas* sp. bacteria are phosphate solubilizing bacteria that play a role in increasing phosphorus availability by liberating organic phosphate or making soluble and insoluble inorganic phosphate compounds. This phosphorus plays an important role in supporting essential growth processes (Islam *et al.*, 2019). According to Di Benedetto *et al.* (2017), *Pseudomonas* sp. is a genus of Rhizobacteria that plays an important role as a biocontrol agent where its adaptability to environmental pressures makes this bacterium more effective in supporting plant growth and protecting against infection. These bacteria also produce various bioactive metabolites, such as antibiotics, siderophores, volatile compounds, and growth-promoting substances, which support plant health. In addition, *Pseudomonas* also produces toxic metabolites, including fenazine, pyrrolnitrin, 2,4-diacetylphloroglucinol (DAPG), pyoluteorin, and cyclic lipopeptides, which play a role in fighting pathogens (Haas & Keel, 2003). Because of this, mung bean plants grown in saline soils in this study can still grow and develop even under salinity stress.

The growth of plant height, number of leaves, and number of primary branches is the result of the contribution of *Azolla microphylla* compost. The nitrogen content supports chlorophyll formation and accelerates plant growth, thus contributing to the increase in plant height and number of leaves. Nitrogen is needed by plants, especially in the formation of chlorophyll which plays a role in the photosynthesis process. Photosynthesis produces photosynthate, which is then used in the process of cell division in meristematic tissues, thus contributing to the formation of plant organs such as primary branches (Hodiyah *et al.*, 2023; Andilau *et al.*, 2024). Primary branches in plants function as a place to grow leaves and fruit. The more primary branches that are formed, the more the number of leaves produced. This supports the optimal photosynthesis process, thus also increasing fruit or pod production (Dwiputra *et al.*, 2015).

Biocon-NP biofertilizer and *Azolla microphylla* compost made the soil looser and richer in organic matter. This condition creates a more ideal environment for root growth and colonization and activity of Rhizobium bacteria, which also has an impact on the formation of root nodules. The formation of root nodules occurs as a result of the interaction between Rhizobium bacteria and mung bean plants, where these bacteria play a role in nitrogen fixation from the air. The symbiotic relationship between the two is characterized by the appearance of nodules on the roots, which are formed due to Rhizobium infection or the entry of these bacteria into plant roots (Sari & Taryono, 2021). According to Benito *et al.* (2017), because they contain leghemoglobin, root nodules that are able to fix nitrogen effectively will be red or pink in color. Based on Table 6, it can be seen that the treatment with higher doses of Biocon-NP biofertilizer and *Azolla microphylla* compost resulted in increased root nodule biomass, where the best treatment was a combination dose of Biocon-NP biofertilizer 150 ml + *Azolla microphylla* compost 80 g. This shows that at this dose there is a balance of nutrients and good soil conditions for the growth of soil microbes, one of which is Rhizobium bacteria (nitrogen-fixing bacteria from the air). When compared to the control treatment (Biocon-NP biofertilizer 0 ml + *Azolla microphylla* compost 0 g) there was a significant difference in root nodule biomass. This is because in the control treatment the agent that plays a role in improving soil conditions is very lacking so that it does not support Rhizobium bacteria to move in the growing media environment.

In addition to root nodule biomass, the growth parameter of mung bean plants observed in this study was plant biomass (plant wet weight). Measurement of plant biomass is by weighing the weight of the entire plant body from roots, stems, branches, leaves, to pods. Based on this, there is a close relationship between root nodule biomass, plant stem height, number of branches, number of leaves, and number of pods which are the growth measurement parameters in this study to the accumulation of plant biomass. Amani *et al.* (2020) found that there was a positive correlation between the number of root nodules and plant biomass. This is because plants with more root nodules tend to have a healthier root system and higher nitrogen fixation capacity, which can increase the availability of nutrients in the soil for plant growth. This condition supports an increase in plant height, optimal development of branches and leaves, which in turn also supports the formation of more pods. The taller the plant and the greater the number of branches and leaves, the wider the photosynthetic area so that biomass production will be greater (Aryani *et al.*, 2022). The results of this study showed that the treatment with the highest biomass value was the Biocon-NP 150 ml biofertilizer + *Azolla microphylla* 80 g compost treatment (Table 3). This treatment showed significant differences with other treatments in the parameters of plant height, number of leaves, number of pods, and root nodule biomass, but not significantly different in the parameter of the number of primary branches. Under some conditions, especially under salinity stress, plants reduce the formation of primary branches and tend to prioritize leaf formation to maintain the photosynthesis process, while the growth of primary branches is limited. This is because the available energy and resources are more efficiently allocated to ensure plant survival in stressful conditions. According to Mi *et al.* (2024), salinity significantly affects the number of primary branches. The statement shows that salt stress can inhibit plant branching. This is also an adaptation strategy of plants to conserve energy and optimize the distribution of resources to more essential organs such as leaves.

Another parameter observed in this study was the flowering age of mung bean plants, where the results of the study in Figure 2 showed that the treatment of *Azolla microphylla* compost and Biocon-NP biofertilizer individually or separately had a significant effect on the flowering age parameter of mung bean plants. However, the combination of the two did not show a significant effect. This may occur because both treatments have similar mechanisms in increasing the availability of key nutrients such as nitrogen (N) and phosphorus (P), which play an important role in vegetative growth and transition to the generative phase. *Azolla microphylla* compost has a high content of N, P, K so that it can accelerate flowering by supporting early plant growth. The same thing is also played by Biocon-NP biofertilizer through the activity of its constituent bacteria, namely *Azotobacter* sp., *Azospirillum* sp., and *Pseudomonas* sp. which are able to increase the availability and uptake of nutrients so that they also support generative development such as flowering. However, when applied simultaneously or in combination, their effects do not synergize optimally due to unbalanced nutrient ratios. This condition is supported by the statement of Sipayung *et al.* (2017), where the faster flowering age of plants can extend the harvest period of plants, so that the production period will also be longer. But in his research, Brassica compost and a combination with more and more biofertilizers actually caused the vegetative period of plants to become longer. This indicates that an excess of certain nutrients such as nitrogen can prolong vegetative growth and delay the generative phase. Syarif (1986) stated that the application of nutrients in high doses can cause excess nutrients in plants, which can have a negative impact on their growth. Based on this, in its application to mung bean plants in saline soils, the use of only one treatment is sufficient to have a significant effect on the flowering age of plants so that fertilizer efficiency can be optimized.

In the generative phase of mung bean plants, the number of pods was also observed at 45 DAP in each treatment and the results were as shown in Table 3., where the treatment of Biocon-NP biofertilizer and *Azolla microphylla* compost either separately or individually or in combination had a significant effect on the number of pods of mung bean plants. This is related to the availability of essential nutrients such as phosphorus (P), nitrogen (N), and potassium (K) which play an important role in the generative development of plants. Phosphorus contributes to the formation, development and division of cells in the pods, thus supporting the increase in the number of pods formed. In addition, sufficient nitrogen and potassium help the process of chlorophyll formation, which plays a role in photosynthesis and produces sufficient energy supply for plants to be able to form more pods (Dwidjoseputro, 1994). Biocon-NP biofertilizer contains phosphate-solubilizing microbes, *Pseudomonas* sp. which increase the availability of phosphorus in the soil by dissolving bound phosphate into a form that is easier for plants to absorb. In addition, *Azolla microphylla* compost is also rich in phosphorus from the biomass tissue of *Azolla microphylla* which is released into the soil after decomposition. The interaction between these two phosphorus sources contributes to increasing the efficiency of phosphorus uptake by mung bean plants. In addition to the role of phosphorus, good vegetative growth also affects generative development in the form of an increase in the number of pods. Handayani & Hidayat (2012) stated that plant height affects the number of pods produced by a plant. This is in line with Kurniawati *et al.* (2017) who also stated that the growth of the number of productive branches contributes to the increase in pod yield.

The number of pods is also related to root nodule biomass (Amir & Dermawan, 2019). The role of root nodules is very important in the pod filling process because root nodule biomass indicates the level of nitrogen fixation activity by Rhizobium bacteria. These root nodules provide nitrogen during the pod formation to filling phase. Surtiningsih *et al.* (2009) revealed that the formation of effective root nodules can increase the ability of plants to fix nitrogen, which then plays a role in the synthesis of chlorophyll and enzymes. This increase in chlorophyll content and enzyme activity will encourage the rate of photosynthesis, which in turn has an impact on increasing vegetative and generative growth, including seed production which is the content of pods. Based on this, the results of this study indicate that both Biocon-NP biofertilizer and *Azolla microphylla* compost have an important role in increasing plant productivity in the form of pod number through the mechanism of increasing soil nutrient availability.

Based on the results of the study, it can be seen that individually, each treatment of *Azolla microphylla* compost and Biocon-NP biofertilizer showed significant results in all parameters tested. This is different from the interaction treatment between *Azolla microphylla* compost and Biocon-NP biofertilizer which showed significant results in the parameters of plant height, number of leaves, plant biomass, root nodule biomass, and number of pods, but had no significant effect on the parameters of the number of primary branches and flowering age. The number of primary branches in the combination treatment or interaction of *Azolla microphylla* compost and Biocon-NP biofertilizer was not significant because these two nutrient sources are complementary but do not specifically stimulate the formation of primary branches.

The activity of microorganisms is more focused on increasing the efficiency of nutrient uptake for generative organ growth, not branching. When plants are in a stressful environment and enter the generative phase, the distribution of energy and plant nutrients tends to prioritize reproduction such as the formation of flowers and pods rather than increasing branches. Meanwhile, the flowering age that was not significant between treatments was related to the compost combination treatment that actually accelerated the entry of plants into the generative phase. This acceleration occurs due to the increased supply of nutrients, especially nitrogen (N) and phosphorus (P) which play an important role in the preparation of ATP and nucleic acids. ATP is the main energy in metabolic processes, while nucleic acids (DNA and RNA) are needed in cell division and differentiation during the formation of generative organs such as flowers. According to Lingga (1995), phosphorus can accelerate the appearance of flowers because it triggers the photosynthetic activity of plants. Changes in photosynthetic products through respiration will produce assimilate, which is very important for the process of cell division. With an increase in photosynthetic yield and assimilate, the number and size of cells will increase, leading to flowering and pod formation. This response is a form of plant compensatory adaptation, accelerating the life cycle and reproduction under stressful conditions. The simultaneous appearance of flowers at 35 days after planting (DAP) as a result of this acceleration of the generative phase causes the variability of the data to be low so that differences between treatments are not statistically significant.

The results showed that the use of *Azolla microphylla* compost alone gave relatively good results and was economically sufficient compared to the use of Biocon-NP biofertilizer alone or in combination. This suggests that *Azolla microphylla* compost can be used as a single nutrient source which is more cost efficient. However, in terms of growth and production results, the combined treatment between *Azolla microphylla* compost and Biocon-NP biofertilizer gave more optimal results. Therefore, it is recommended to use *Azolla microphylla* compost alone in economically limited land conditions, but for maximum results the use of a combination of *Azolla microphylla* compost and Biocon-NP is more recommended. The optimal dose recommendation for the single treatment of *Azolla microphylla* compost is 80 g, the single treatment of Biocon-NP biofertilizer is 150 ml, and the combination treatment is *Azolla microphylla* compost 80 g + Biocon-NP biofertilizer 150 ml. This combination of doses was proven to provide the highest yield significantly, as well as supporting the acceleration of the generative phase of the plant.

CONCLUSION

This study concluded that the application of Biocon-NP biofertilizer and *Azolla microphylla* compost was able to increase the growth of mung bean plants (*Vigna radiata*) in saline soil. The best dose with individual application for Biocon-NP biofertilizer is 150 ml, while for *Azolla microphylla* compost is 80 g, both of which have a significant effect on plant height, number of leaves, number of primary branches, flowering age, plant biomass, root nodule biomass, and number of pods. The interaction between the two, with the best dose combination of 80 g of *Azolla microphylla* compost and 150 ml of Biocon-NP biofertilizer had a significant effect on plant growth in the parameters of plant height, number of leaves, plant biomass, root nodule biomass, and number of pods, but had no effect on the number of primary branches and flowering age.

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CONFLICT OF INTEREST

There is no conflict of interest.

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