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GROWTH AND YIELD OF SOYBEAN PLANTS (Glycine max (L.) Merrill) IN PODSOLIC SOIL WITH ARBUSCULAR MYCORRHIZAL FUNGI AND SYNTHETIC ZEOLITE FROM FLY ASH AS SOIL AMENDMENTS

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ABSTRACT

This research aims to understand the interaction between Arbuscular Mycorrhizal Fungi (AMF) and zeolite fly ash (FA) from coal and their impact on soybean productivity in Podzolic soil. The study was conducted in Aur Sakti Village, Tambang District, Kampar Regency, and the Soil Science Laboratory and Plant Ecophysiology Laboratory of the Faculty of Agriculture, University of Riau, over a four-month period from March to June 2022. The experiment employed a completely randomized design (CRD) with two factors: FA zeolite doses (Z0-Z3) and AMF doses (M0-M2). The results of the study indicate that the interaction of AMF Glomus sp or Gigaspora sp at 10 g per plant with FA zeolite at a dose of 1.5 g per plant enhances plant growth and soybean yield most optimally. FA zeolite at a dose of 1 g per plant also effectively improves soybean yield in terms of the weight of 100 seeds. Specifically, the application of FA zeolite at a dose of 1.5 g per plant yields the best results in terms of plant height, number of productive branches, flowering and harvesting age, number of seeds per plant, weight of seeds per plant, and weight of 100 seeds, compared to treatments without zeolite, with zeolite FA doses of 0.5 and 1 g per plant. The application of AMF Glomus sp and Gigaspora sp, each at 10 g per plant, also enhances the growth and yield of soybeans compared to treatments without AMF.

INTRODUCTION

Soybean (Glycine max (L.) Merrill), as a source of protein and functional food, holds strategic value in enhancing national food security. Soybeans, categorized as leguminous plants, are rich in protein, fats, and vitamins. Every 100 grams of soybeans contains an average of 330 calories, 35% protein, 18% fats, 35% carbohydrates, 10% water, and various minerals such as calcium, iron, vitamin A, and vitamin B1 (Pato and Yusmarini, 2002).

Data from the Ministry of Agriculture indicates that approximately 86.4% of the domestic soybean demand is met through imports. The Central Bureau of Statistics records soybean imports at 2.48 million tons, valued at US$1 billion (BPS, 2020). The national soybean productivity in 2019 was only 1.49 tons/ha (Center for Data and Agricultural Information Systems, 2020), whereas the potential productivity should reach 2.25 tons/ha. The low domestic soybean productivity is attributed to the conversion of agricultural land into residential areas (Malik, 2016). Marginal lands with low fertility potential, especially Podzolic soil, could be utilized for agriculture (Subagyo et al., 2004).

Podzolic soil is considered marginal due to various chemical constraints such as low pH, organic matter content, low macro and micro-nutrient availability, very low phosphorus availability, low molybdenum content, high aluminum saturation, and phosphorus fixation (Fitriatin et al., 2014). These factors hinder plant growth and reduce crop productivity, particularly for food crops with shallow and limited root systems. Podzolic soil, aside from chemical challenges, also exhibits undulating topography, making it susceptible to erosion. Therefore, there is a need for technological interventions to address Podzolic soil challenges.

Efforts to overcome these issues include the application of biofertilizers such as Arbuscular Mycorrhizal Fungi (AMF) and soil amendments like synthetic zeolite. The application of AMF is expected to address phosphorus deficiency issues by reducing phosphorus fixation from applied fertilizers. Meanwhile, synthetic zeolite application is anticipated to reduce aluminum solubility and saturation while retaining or absorbing essential nutrients from various sources, including synthetic, organic fertilizers, mineral weathering, and organic materials. Additionally, it enhances water absorption capacity, contributing to erosion control.

According to Prihantoro (2003), AMF can infect plant roots without damaging the host. AMF plays a crucial role in nutrient uptake, both macro and micro, and enhances plant protection against pathogens, enabling plants to thrive in extreme conditions. AMF application contributes to improved nutrient absorption and soybean productivity.

Numerous studies on AMF utilization have been conducted. Setiadi and Setiawan (2011) reported that AMF can enhance macro-nutrient uptake, especially phosphorus, and some micro-nutrients like copper and zinc, thus optimizing the use of synthetic fertilizers on marginal land. Yakim (2004) highlighted the specific role of AMF in leguminous plants, where nodules on the roots act as nitrogen fixers from the air if there is sufficient phosphorus in the plant's root system.

Zulhaida, (2021) found that a 12g AMF per plant treatment yielded better results than lower doses, indicating that higher doses of mycorrhiza tend to provide better outcomes for soybean plants. Other studies reported that the application of 7.5g of arbuscular mycorrhizal fungi per polybag enhanced the growth and production of soybean plants on saline soil, as evidenced by increased leaf area, root-shoot ratio, net assimilation rate, relative growth rate, infection rate, filled pod count, phosphorus and nitrogen uptake, sugar content, and 100-seed weight (Usnawiyah, 2012).

According to Hadianur et al., (2016), the application of AMF, specifically Glomus sp. and Gigaspora sp., or a combination of both, positively influences root colonization. This aligns with the findings of Junita, (2015), stating that mycorrhiza application can increase root infection percentage. Gigaspora sp. significantly affects fresh root weight in the vegetative phase, dry shoot weight in the vegetative phase, dry root weight in the vegetative phase, and root length in the vegetative phase, positively influencing tomato plant growth (Chalimah et al., 2007).

In addition to AMF utilization, synthetic zeolite also contributes to enhancing fertility in Podzolic soil, promoting soybean growth and production. Zeolite can be synthesized from industrial waste, such as fly ash from coal-fired power plants. Fly ash (FA) is classified as waste and poses an environmental pollution threat when disposed of improperly. The conversion of FA into synthetic zeolite aims not only to increase waste value but also to serve as a soil conditioner and a reservoir for water and essential nutrients.

Synthetic zeolite can be used as a soil conditioner and a fertilizer mixture, particularly with urea. It exhibits a long-lasting residual effect, absorbs ammonium, and significantly improves soil fertility and water availability due to its high cation exchange capacity (Suwardi, 2009). Synthetic zeolite with a cation exchange capacity (CEC) exceeding 250 cmol.kg-1 stores water and nutrients in ion form (both cations and anions). (Sudaryono et al., 2011) reported that applying 150 kg/ha of zeolite increased soybean yield by 28.6% compared to the control. However, increasing zeolite dosage to 600 kg/ha may decrease yields, possibly inhibiting the absorption of interacting cations such as K, Ca, Mg, and Na. According to Suwardi (2009), applying zeolite at a dosage of 200 kg/ha can increase agricultural crop yields more efficiently when combined with urea in a 1:1 ratio. Zeolite is also utilized as a soil conditioner for Podzolic soil and a mixture with urea and compost, proving its ability to enhance agricultural production on Podzolic soil (Sabilu, 2016). Abdurachman et al., (2016) stated that applying zeolite and dolomite to clay-textured soil can improve soil structure, soil air porosity, and water retention.

Saputra (2006) suggested that synthetic zeolite application can inhibit nutrient release or act as a slow-release fertilizer (SRF), ensuring that water and nutrient needs are met during the soybean's root development phase. Consequently, water and nutrient absorption during optimal growth phases promote physiological processes and plant metabolism, ultimately boosting soybean growth and yield. This research aims to study the interaction between AMF and fly ash zeolite (FA) from coal and their respective main effects on soybean productivity in Podzolic soil.

RESEARCH METHOD

This research was conducted in Aur Sakti Village, Tambang District, Kampar Regency, at the Soil Science Laboratory and Plant Ecophysiology Laboratory of the Faculty of Agriculture, University of Riau. The study spanned four months, starting from March to June 2022.

The materials used in this research included Anjasmoro soybean seeds, Podzolic soil, synthetic zeolite from coal fly ash, AMF (Arbuscular Mycorrhizal Fungi) of the genus Glomus sp and Gigaspora sp with a sand medium, Rhizobium, Urea fertilizer, Rock Phosphate (RP) fertilizer, KCl fertilizer, HCl, NaOH 1-3 M, Al(OH)3, distilled water (aquades), water, KOH 10%, H2O2 3%, 5% acetic acid ink solution, soybean seed samples, selenium, H3BO4 1%, Conway indicator, NaOH 40%, H2SO4, Dupont Lannete 40 SP, Dithane M-45 fungicide, and polybags measuring 35 cm x 40 cm.

The research tools included a hoe, sickle, machete, knife, analytical balance, oven, meter, hand sprayer, auger, shade net, ruler, wood, bucket, scoop, label, film bottle, measuring glass, pipette, stirring rod, scissors, microscope, mortar and pestle, Erlenmeyer flask, Kjeldahl apparatus, Kjeldahl flask, boiling flask, pilius, burette, stand, weighing bottle, beaker, distillation apparatus, destruction apparatus, desiccator, 20-mesh sieve, magnetic stirrer, autoclave, furnace, porcelain cup, Whatman paper, aluminum foil, writing and documentation tools.

The research was conducted through an experimental design using a completely randomized design (CRD) with two factors as follows:
Factor I, the dosage of coal Fly Ash (FA) Zeolite, consisting of four levels:
Z0 = Without FA Zeolite (control)
Z1 = FA Zeolite 100 kg/ha
Z2 = FA Zeolite 200 kg/ha
Z3 = FA Zeolite 300 kg/ha
Factor II, the dosage of AMF, consisting of three levels:
M0 = Without AMF (control)
M1 = (AMF Glomus sp 10 g/plant)
M2 = (AMF Gigaspora sp 10 g/plant)

The two factors were combined, resulting in 12 treatment combinations, each repeated three times, making a total of 36 units. Each experimental unit consisted of four polybags, making a total of 144 polybags.

RESULTS AND DISCUSSION

Plant Height and Number of Productive Branches

The analysis of variance results shows that the interaction of Mycorrhizal Fungi (FMA) and FA zeolite has a non-significant effect on the soybean plant height at 30 days after planting (DAP). However, it significantly influences the plant height at 45 DAP, 60 DAP, and the number of productive branches. Both the application of FA zeolite and FMA significantly affect the plant height and the number of productive branches. The Duncan's New Multiple Range Test (DNMRT) results at a 5% significance level for soybean plant height and the number of productive branches are presented in Table 1.

Table 1. Soybean plant height aged 30 HST, 45 HST, 60 HST and number of productive branches with FMA and FA zeolite application on podzolic soil

Age	Kinds of FMA	FA Zeolite Dosage (g per plant)				Average
		0	0.5	1	1.5	
		Tinggi Tanaman				
30 HST	Tanpa FMA	29.00 e	30.86 d	31.26 cd	31.86 bcd	30.75 b
	Glomus sp 10 g per tanaman	32.06 bc	32.73 b	32.63 b	34.90 a	33.08 a
	Gigaspora sp 10 g per tanaman	31.86 bcd	32.43 bc	32.26 bc	34.43 a	32.75 a
	Rata-rata	130.97 c	32.01 b	1 32.05 b	33.73 a	
45 HST	Tanpa FMA	55.33 e	57.33 d	58.00 cd	58.33 c	57.25 b
	Glomus sp 10 g per tanaman	58.13 cd	59.66 b	59.76 b	62.83 a	60.10 a
	Gigaspora sp 10 g per tanaman	57.67 cd	59.50 b	59.66 b	62.63 a	59.86 a
	Rata-rata	157.04 c	58.83 b	1 59.14 b	61.26 a	
60 HST	Tanpa FMA	56.33 e	58.33 d	59.03 cd	59.43 c	58.28 b
	Glomus sp 10 g per tanaman	59.00 cd	60.66 b	60.80 b	64.66 a	61.28 a
	Gigaspora sp 10 g per tanaman	58.73 cd	60.63 b	60.66 b	64.00 ab	61.00 a
	Rata-rata	158.02 c	59.87 b	1 60.16 b	62.70 a	
		Jumlah Cabang Produktif				
	Tanpa FMA	3.87 f	4.87 e	5.20 de	5.63 bcd	4.89 b
	Glomus sp 10 g per tanaman	44.30 f	5.50 bcd	6.07 b	7.87 a	5.93 a
	Gigaspora sp 10 g per tanaman	4.20 f	5.40 cde	5.97 bc	7.70 a	5.82 a

Rata-rata	14.12 d	5.26 c	1 5.74 b	7.07 a

Numbers followed by the same lowercase letters in the same column or row are not real according to DNMRT follow-up tests at the 5% level.

Table 1 shows that the interaction of FMA Glomus sp and Gigaspora sp each 10 g per plant with zeolite FA dose 1.5 g per plant increased soybean plant height aged 30 HST, 45 HST, 60 HST and the highest and noticeable number of productive branches compared to without FMA and zeolite FA and other treatment combinations, as well as the main effect of FMA administration of Glomus sp and Gigaspora sp each 10 g per plant increased plant height and number of productive branches of soybeans compared to without FMA and administration of zeolite FA doses of 0.5 and 1 g per plant respectively increased plant height and number of productive branches compared to without zeolite FA and at doses of zeolite FA 1.5 g per plant increased plant height and the number of productive branches was greater. This occurs due to an increase in root volume through external hyphae of both types of FMA and the provision of FA zeolite is able to increase water availability so that plants have the ability to absorb nutrients and water and improve plant physiological and metabolic processes.

Valentina et al. (2017) states that the external hyphae of FMA fungi can help the absorption of water and nutrients used in metabolic processes in the plant body to encourage plant vegetative growth. Derantika & Nihayati, (2019) stated that by increasing the absorption of water and nutrients by plants, it will increase the metabolism of carbohydrates, proteins and growth regulators to their hosts so that they can spur plant growth.

Steiner et al. (2003) states that microbial activity in soil can increase in zeolite-fed soils. This is because the addition of zeolite to the soil is able to improve the physical properties of the soil including improving soil aggregates (Santi & Goenadi, 2012) , porosity and consistency through changes in surface area (Troeh and Thompson, 2005) as well as the distribution of pore space, density and compression (Paul, 2007), so as to provide an appropriate environment for FMA activity and development. Plants given FMA experience an increase in their ability to absorb the nutrients needed, so that the metabolic process can run well and can increase plant growth (Rivana, 2016).

Suwardi (2007) also stated that the addition of zeolite increases the surface area of plant roots, which results in an increase in the amount of nutrients that can be absorbed by plants so as to improve the structure, texture, as well as soil aeration and drainage, so as to spur the development of important microorganisms in the soil and good for the development of plant roots and for the development of mycorrhizal spores.

The increase in soybean plant height is also thought to be caused by the influence of the number of root nodules. FMA administration can increase the number of effective root nodules compared to no FMA administration. Root nodules are a collection of Rhizobium bacteria that can fix nitrogen (N) from the air so that plants can use it. Lakitan, (2010) states that the function of element N for plants is as a constituent of protein and chlorophyll. The formation of chlorophyll is useful in the process of photosynthesis. Chlorophyll serves to capture sunlight which is useful for the formation of food in the process of photosynthesis. The results of photosynthesis will be used by plants for their growth process. The more root nodules formed, the more N that plants can use so that they can spur plant height growth. Hendrati & Nurrohmah, (2016) stated that increasing root nodules can increase the number of leaves, increase plant height and increase the diameter of *Calliandra calothyrsus legume plants*.

The application of FMA and FA zeolite can also increase P uptake and plant growth because FMA and FA zeolite are able to increase the P available in the soil, so that the application of FMA and FA zeolite into the soil can increase the availability of P that can be absorbed by plants. Increased P uptake in plants causes plant growth to increase including plant height, plant wet weight, plant dry weight and number of productive branches. Phosphorus is useful for forming pods and accelerating the ripening of pods. Soybean plants will photosynthesize well and produce sufficient assimilation for their growth, if the amount of nutrients that the plant can absorb is sufficient. This will encourage the formation of productive branches of plants. The increase in P uptake in plants is influenced by P availability, the higher P available, the higher P uptake (Yasir *et al.*, 2016).

Flowering age

The results of variety analysis showed that FMA and FA zeolite had a real effect, while the interaction had a non-real effect on the flowering age of soybean plants. The results of DNMRT follow-up tests at the level of 5% of the flowering age of soybean plants can be seen in Table 2.

Table 2. Flowering age of soybean plants (days) with FMA and FA zeolite on podzolic soils

Jenis FMA	Dosis Zeolit FA (g per tanaman)				Rata-rata
	0	0.5	1	1.5	
Tanpa FMA	38.33 d	37.33 cd	37.00 c	36.66 bc	37.33 b
Glomus sp 10 g per tanaman	37.33 cd	36.00 bc	36.00 bc	34.66 a	36.00 a
Gigaspora sp 10 g per tanaman	37.33 cd	36.33 bc	36.33 bc	35.33 ab	36.33 a
Rata-rata	37.66 c	36.55 b	36.44 b	35.55 a	

Numbers followed by the same lowercase letters in the same column or row are not real according to DNMRT follow-up tests at the 5% level.

Table 2 shows that the interaction of FMA Glomus sp 10 g per plant with zeolite FA dose 1.5 g per plant accelerated flowering age compared to without FMA and zeolite FA and other treatment combinations except by administering FMA Gigaspora sp 10 g per plant with zeolite FA dose 1.5 g per plant, as well as the main influence of FMA Glomus sp and Gigaspora sp each 10 g per plant accelerated flowering age compared to without FMA administration and administration of FA zeolite doses of 0.5 and 1 g per plant respectively accelerated flowering age compared to without FA zeolite and at 1.5 g FA zeolite dose per plant flowering age in soybean plants faster. This occurs due to the provision of FMA and FA zeolite is able to supply nutrients in greater quantities and is used by plants in increasing the rate of plant growth and development including in stimulating plant generative growth. In addition, the presence of FMA infects plant roots, which results in a better supply of nutrients to the upper part of the plant, thus accelerating the average age of flowering plants and impacting faster harvest age (Table 3).

Manan, (1976) suggested that plants infected with FMA would give a better growth response than plants not given FMA. This is because FMA can effectively increase the absorption of macronutrients (N, P, K, Ca and Mg) especially P and micronutrients (Cu, Zn and Mo). FA zeolite can also convert unavailable P into available P by reducing P fixation power against Fe and Al cations, resulting in increased nutrient uptake in plants. Shamsiyah *et al.* (2009) states zeolite can increase P uptake by changing the condition of P unavailable to P available. Zeolite has functions including restoring lost soil nutrients, storing and binding nutrients, loosening the soil, increasing soil aeration, saving fertilizer and absorbing heavy metals (Usman, 2009).

The flowering age of soybean plants is influenced by the availability and absorption of P nutrients because P nutrients function in flower formation. FMA administration can increase P uptake, so that the provision of FMA and synthetic zeolite can accelerate the flowering life of soybean plants. Goodwin & Mercer, (1983) stated that element P is able to stimulate the formation of flowers, fruits and seeds and is able to accelerate fruit ripening. Kurniawan et al., (2014) states that element P can accelerate the flowering life of soybean plants. The age speed of flowers is also influenced by the rate of assimilate translocation because assimilate is needed for the process of plant development. The rate of asmilate is influenced by the K content contained in plant tissues. Giving FMA and synthetic zeolite can increase the uptake of K nutrients in soybean plants so that the provision of FMA and synthetic zeolite can accelerate the flowering life of soybean plants.

Harvest age

The results of variety analysis showed that FMA and FA zeolite had a real effect, while the interaction had a non-real effect on the harvest age of soybean plants. The results of DNMRT follow-up tests at the level of 5% of the harvest age of soybean plants can be seen in Table 3.

Table 3. Harvest age (days) of soybean plants with FMA and FA zeolite on podzolic soils

Jenis FMA	Dosis Zeolit FA (g per tanaman)				Rata-rata
	0	0.5	1	1.5	
Tanpa FMA	97.66 f	96.33 de	96.00 de	94.00 b	96.00 b
Glomus sp 10 g per tanaman	96.33 de	94.66 bc	94.66 bc	90.66 a	94.08 a
Gigaspora sp 10 g per tanaman	97.00 ef	95.33 cd	94.33 bc	91.33 a	94.50 a
Rata-rata	97.00 c	95.44 b	95.00 b	92.00 a	

Numbers followed by the same lowercase letters in the same column or row are not real according to the DNMRT follow-up test at the level of 5%.

Table 3 shows that the interaction of FMA Glomus sp and Gigaspora sp each 10 g per plant with zeolite FA dose of 1.5 g per plant accelerates harvest life compared to without FMA and zeolite FA and other treatment combinations, as well as the main effect of FMA Glomus sp and Gigaspora sp each 10 g per plant accelerates harvest age compared to without FMA and administration of FA zeolite doses of 0.5 and 1 g per plant respectively accelerate harvest age compared to without FA zeolite and at 1.5 g FA zeolite dose per plant harvest age in soybean plants faster. This is due to the presence of FMA which helps plants absorb nutrients, especially P so that it is sufficient to accelerate the harvest life of soybean plants. In addition, this occurs due to the availability of macronutrients both P and K supplied by FMA. FMA can increase P uptake, so FMA can accelerate the harvest life of soybean plants. Goodwin & Mercer, (1983) stated that element P is able to stimulate the formation of flowers, fruits and seeds and is able to accelerate fruit ripening.

The provision of FA zeolite is also able to accelerate the harvest life of soybean plants. This is because the provision of FA zeolite can increase nutrients N, P and K. The speed of harvest age is also influenced by the rate of assimilate translocation because assimilate is needed for the process of plant development. The rate of asmilate is influenced by the K content contained in plant tissues. Giving zeolite can increase the absorption of nutrient K in soybean plants so that zeolite can accelerate the harvest life of soybean plants.

Persentase Polong Bernas

The results of variety analysis showed that FMA and FA zeolite had a real effect, while the interaction had a real effect on the percentage of pithy pods of soybean plants. The results of DNMRT follow-up tests at the level of 5% on the percentage of pithy pods of soybean plants can be seen in Table 4.

Table 4. Percentage of pithy pods (%) of soybean plants with FMA and FA zeolite on podzolic soils

Jenis FMA	Dosis Zeolit FA (g per tanaman)				Rata-rata
	0	0.5	1	1.5	
Tanpa FMA	70.40 f	72.27 e	74.00 cd	73.12 de	72.45 b
Glomus sp 10 g per tanaman	72.00 e	75.03 abc	74.87 abc	76.07 a	74.49 a
Gigaspora sp 10 g per tanaman	71.83 e	74.67 bc	74.33 cd	75.87 ab	74.17 a
Rata-rata	71.41 c	73.98 b	74.40 ab	75.02 a	

Numbers followed by the same lowercase letters in the same column or row are not real according to the DNMRT follow-up test at the level of 5%.

Table 4 shows that administration of FMA Glomus sp and Gigaspora sp 10 g per plant respectively increased the percentage of pithy pods compared to no FMA at zeolite FA doses of 0, 0.5 and 1.5 g per plant, but not significantly at 1 g per plant, as well as the main effect of FMA Glomus sp and Gigaspora sp each 10 g per plant increased the percentage of pithy pods compared to without FMA administration and administration of FA zeolite doses of 0.5 and 1 g per plant respectively increased the percentage of pithy pods compared to without FA zeolite and at 1.5 g FA zeolite dose per plant the percentage of pithy pods increased greater. This shows that to support the generative growth of plants, the availability of N, P and K elements is needed. The formation of pithy pods from soybean plants requires nutrients, especially P elements which are also contributed by FMA. Suhartini (2020), suggested that element P in plants functions in cell division, albumin formation, fruit formation and ripening, root development and disease resistance. With the provision of FMA, the availability of P nutrients will increase so that it will also increase the formation and ripening of fruits which has an impact on increasing the percentage of pithy pods.

Based on the research of Syamsiyah *et al.* (2009) states that zeolite administration can increase P uptake by 26.14%. The ability of P uptake by plants can be known by increasing the P content in plant tissues. The presence of zeolite will improve soil chemical properties, especially CEC (abdillah et al., 2011). Zeolite has the ability to increase P uptake (Arafat et al., 2016). Simanjuntak (2005) states that P nutrients are used by plants in the generative phase, namely in the formation of pods and seeds. In addition to P, element K is also a macronutrient needed for growth in pod formation and filling. Pakpahan, (2017) also stated that FMA can also increase the absorption of other nutrients such as N, K and microelements Zn and Cu. According to Munawar, (2018), element K is involved in transporting the results of photosynthesis from leaves through phloem to tissues of reproductive organs and storage including in pod formation.

The pods formed are the result of flowers that have undergone fertilization that continue to develop to form seeds. The more flowers that successfully undergo fertilization, the more chances of pods forming. Pods that have been formed will continue to develop in the seed formation phase, but not all pods can develop to form pithy pods.

Number of seeds per plant

The results of variety analysis showed that FMA and FA zeolite had a real effect, while the interaction had no real effect on the number of seeds per soybean plant. The results of DNMRT follow-up tests at the level of 5% on the number of seeds per soybean plant can be seen in Table 5.

Table 5. Number of seeds per soybean plant (grains) with FMA and FA zeolite on podzolic soils

Jenis FMA	Dosis Zeolit FA (g per tanaman)				Rata-rata
	0	0.5	1	1.5	
Tanpa FMA	29.66 d	53.78.c	56.56 c	80.33 b	55.08 b
Glomus sp 10 g per tanaman	54.33 c	81.55 c	81.56 b	103.89 a	80.33 a
Gigaspora sp 10 g per tanaman	53.89 c	80.11 b	81.11 b	102.44 a	79.38 a
Rata-rata	45.96 c	71.81 b	73.07 b	95.56 a	

Numbers followed by the same lowercase letters in the same column or row are not real according to the DNMRT follow-up test at the level of 5%.

Table 5 shows that the interaction of FMA Glomus sp and Gigaspora sp each 10 g per plant with zeolite FA dose 1.5 g per plant increased the number of seeds per plant compared to without FMA and zeolite FA and other treatment combinations, as well as the main effect of FMA Glomus sp and Gigaspora sp each 10 g per plant increased the number of seeds per plant compared to without FMA administration and administration of zeolite FA doses of 0.5 and 1 g per plant respectively increased the number of seeds per plant compared to without zeolite FA and at doses of zeolite FA 1.5 g per plant the increase in the number of seeds per plant was greater. This occurs due to the dose of FMA in soybean plants given can increase the ability to absorb nutrients, so that the metabolism of soybean plants becomes better. Herlina et al.,(2016) states that with FMA, the rate of nutrient absorption by the roots increases almost four times compared to normal roots and the area of root absorption can increase 80 times.

Giving FMA to plants can increase nutrient uptake, especially P. Musfal (2008) states that plants infected with FMA are able to absorb higher P elements than plants that are not infected. Taufiq & Sundari, (2012) stated that seed formation in plants really needs P nutrients.

Zeolite administration can affect water availability and can help the rate of nutrient absorption by improving soil properties. This is supported by the statement of Usman (2009) which states in general the function of zeolite is to maintain soil pH balance, increase soil CEC, restore lost soil nutrients, store and bind the elements needed both macro and micronutrients so that they remain available, loosen the soil, because zeolite has large pores so that oxygen circulation is good for plant roots, saves the use of fertilizer (not wasted), because it is bound by zeolite, absorbs heavy metals and elements that interfere with plant growth.

Zeolite is also able to increase P nutrient uptake in plants. Awliya, (2022) states that P nutrients play an important role in seed filling, fruit or grain ripening and increasing grain production. Munawar, (2018) stated that P plays a role in the process of photosynthesis and carbohydrate metabolism as well as the division of photosynthesis results from leaf organs to other organs including seed formation. If the higher the P nutrients absorbed by plants, it will increase the number of soybean seeds. Research results of Siregar *et al.* (2017) showed that increasing the provision of P elements can increase the number of soybean plant seeds.

Seed weight per plant

The results of variety analysis showed that FMA and FA zeolite had a real effect, while the interaction had no real effect on seed weight per soybean plant. The results of DNMRT follow-up tests at the level of 5% on seed weight per soybean plant can be seen in Table 6.

Table 6. Seed weight per plant (g) of soybeans with FMA and FA zeolite application to podzolic soils

Jenis FMA	Dosis Zeolit FA (g per tanaman)				Rata-rata
	0	0.5	1	1.5	
Tanpa FMA	3.72 d	6.98 c	7.33 c	10.71 b	7.18 b
Glomus sp 10 g per tanaman	6.89 c	10.33 b	10.87 b	14.55 a	10.66 a
Gigaspora sp 10 g per tanaman	6.83 c	10.15 b	10.82 b	14.43 a	10.56 a
Rata-rata	5.81 c	9.15 b	9.67 b	13.23 a	

Numbers followed by the same lowercase letters in the same column or row are not real according to the DNMRT follow-up test at the level of 5%.

Table 6 shows that the interaction of FMA Glomus sp and Gigaspora sp each 10 g per plant with zeolite FA dose 1.5 g per plant increased seed weight per plant the highest (290%) compared to without FMA and zeolite FA, while the main effect of FMA administration Glomus sp and Gigaspora sp each 10 g per plant increased seed weight per plant compared to without FMA administration and administration of zeolite FA doses 0.5 and 1 g per plant increased seed weight per plant compared to without zeolite FA, at a higher dose of zeolite FA at 1.5 g per plant there was an increase in seed weight per plant was greater. This occurs due to FMA administration to plants will help plants in absorbing (Santosa, n.d.) states that FMA can increase P uptake in plants. Element P plays a very important role in plant production and growth and in increasing the filling of soybean seeds. Research results of Siregar *et al.* (2017) showed that increasing the application of P elements can increase the dry weight of seeds per soybean plant. Increasing the dose of FMA provides an opportunity for FMA to symbiosis with plant roots so as to expand the absorption of roots to nutrients that are beneficial in the process of photosynthesis, thus the photosynthetes produced and distributed in seed filling also increase so as to increase the dry weight of seeds in soybean plants.

Zeolite administration can also increase P uptake and plant growth because zeolite is able to increase the P available in the soil, so that the application of zeolite into the soil can increase the availability of P that can be absorbed by plants (Yasir *et al.*, 2016). Awliya, (2022) states that P nutrients can stimulate the growth of flowers, fruits and seeds and can accelerate fruit ripening. If the higher the P absorbed by plants, it will further increase seed formation per plant. The more the number of seeds formed, the more the weight of the seeds.

Weight 100 Seeds

The results of variety analysis showed that FMA and FA zeolite had a real effect, while the interaction had no real effect on the weight of 100 soybean seeds. The results of DNMRT follow-up tests at the level of 5% against the weight of 100 soybean seeds can be seen in Table 7.

Table 7. Weight of 100 seeds (g) of soybean plants with FMA and FA zeolite on podzolic soil

Jenis FMA	Dosis Zeolit FA (g per tanaman)				Rata-rata
	0	0.5	1	1.5	
Tanpa FMA	11.24 c	12.99 b	12.97 b	13.33 ab	12.63 b
Glomus sp 10 g per tanaman	12.65 b	12.66 b	13.33 ab	14.00 a	13.16 a
Gigaspora sp 10 g per tanaman	12.66 b	12.67 b	13.32 ab	14.09 a	13.18 a
Rata-rata	12.18 c	12.77 b	13.20 b	13.80 a	

Numbers followed by the same lowercase letters in the same column or row are not real according to the DNMRT follow-up test at the level of 5%.

Table 7 shows that the interaction of FMA Glomus sp and Gigaspora sp each 10 g per plant increases the weight of 100 seeds compared to without FMA with no zeolite, but does not differ markedly in the administration of zeolite FA doses of 0.5, 1 and 1.5 g per plant, as well as the main effect of FMA Glomus sp and Gigaspora sp each 10 g per plant increased the weight of 100 seeds compared to without FMA and administration of FA zeolite doses of 0.5 and 1 g per plant each increased the weight of 100 seeds compared to without FA zeolite and at a dose of FA zeolite 1.5 g per plant the weight increase of 100 seeds was greater. This happens because giving FMA to plants will help plants in absorbing P elements. (2002), P nutrients play an important role in seed filling, fruit or grain ripening, and increasing grain production. According to Sukmawati (2013), mycorrhizal treatment provides heavier seed weight (9.3 g per plant) compared to treatment without mycorrhiza (7.2 g per plant).

Increased zeolite administration can increase P nutrient uptake in soybean plants. Phosphorus is necessary for cell division, root formation, strengthens stems, plays a role in carbohydrate metabolism , energy transfer, as well as the formation of flowers, fruits and seeds. Lack of P nutrients in plants will affect plant growth and development (Anjarsari et al., 2016)

CONCLUSION

The interaction of FMA Glomus sp or Gigaspora sp each 10 g per plant with zeolite FA dose of 1.5 g per plant increases plant growth (plant height, number of porductive branches, flowering age, harvest age) and soybean yields (number of seeds per plant, seed weight per plant) are highest compared to without treatment and other combinations, but at FA zeolite dose of 1 g per plant has been able to increase the yield of soybean plants at a weight of 100 seeds.

Giving zeolite FA dose of 1.5 g per plant increases the growth and yield of soybean plants best on parameters of plant height, number of productive branches, flowering age, harvest age, number of seeds per plant, weight of seeds per plant, weight of 100 seeds compared to without zeolite, zeolite FA dose of 0.5 and 1 g per plant. FMA Glomus sp and Gigaspora sp each 10 g per plant increased plant growth and soybean yields compared to no FMA.

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