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RESEARCH ARTICLE

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Optimization of early growth of bululawang sugarcane seedlings through arbuscular mycorrhizal dose application under greenhouse condition

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Abstract
The early growth of Bululawang sugarcane bud-set seedlings requires seedling-production technology that can effectively and environmentally improve plant vigor. This study aimed to evaluate the early growth response of Bululawang sugarcane seedlings to different doses of arbuscular mycorrhizal fungi (AMF) under greenhouse conditions. The experiment was conducted from September 2023 to January 2024 using four AMF doses, namely 0 g, 5 g, 10 g, and 15 g per polybag, arranged in a Completely Randomized Design with five replications. The observed variables included shoot length, shoot diameter, number of leaves, root length, plant fresh weight, and plant dry weight. Data were analyzed using analysis of variance followed by Tukey's honestly significant difference test at the 5% significance level. The mean growth response index was calculated by normalizing all measured growth and biomass variables against the 0 g control. AMF application produced different responses in shoot growth, root development, and biomass accumulation. The 10 g dose produced the highest fresh weight of 293.20 g, whereas the 15 g dose produced the highest dry weight of 82.43 g and the highest mean growth response index of 142.83%. Therefore, 15 g was considered the agronomically optimum dose because it produced the strongest overall growth and dry matter accumulation, while 10 g was considered an efficient dose because it maximized fresh biomass at a lower AMF input. AMF application has potential as a biological technology for improving Bululawang sugarcane seedling quality during early growth.

KEYWORDS
bud-set seedlings; arbuscular mycorrhiza; early growth; sugarcane

1. INTRODUCTION

Sugarcane is an important estate crop that serves as the main raw material for the sugar industry. The success of sugarcane cultivation is not determined only by crop management in production fields, but also by seedling quality during the early growth stage. Sugarcane seedlings that grow rapidly, develop strong shoots, establish a good root system, and accumulate optimal early biomass are expected to adapt better after transplanting to the field (Meena et al., 2022). Therefore, improving early seedling growth is an important aspect of sugarcane seedling technology. One approach that can be developed is the use of arbuscular mycorrhiza as a biological agent that can potentially support nutrient uptake, improve root development, and increase plant growth efficiency in a more sustainable manner.

Several previous studies have shown that arbuscular mycorrhiza plays an important role in supporting the early growth of sugarcane, particularly by improving the root system and increasing nutrient uptake. Huang et al. (2026) reported that the application of arbuscular mycorrhizal fungi to sugarcane single-bud chip seedlings accelerated root colonization and increased root length, root surface area, shoot root number, and leaf phosphorus concentration in several sugarcane clones. Vesicular-arbuscular mycorrhiza application to SP 80-1816 and PS 882 sugarcane seedlings affected tiller number and root length, although not all growth variables, such as plant height, number of leaves, stem diameter, fresh weight, and dry weight, showed significant responses (Sales et al., 2022). In addition, combination of arbuscular mycorrhiza and compost affected root colonization, early growth, biomass production, and nutrient uptake in sugarcane seedlings. These findings indicate that the effectiveness of mycorrhiza in sugarcane is closely related to application dose, growing-medium conditions, growth stage, and the genetic characteristics or variety of the plant (Tripathi et al., 2025).

Information on the most suitable dose of arbuscular mycorrhiza for supporting early sugarcane seedling growth remains inconsistent. Although several studies have demonstrated that mycorrhiza can improve root growth, nutrient uptake, and plant biomass, plant responses may differ depending on sugarcane variety, planting material, growing-medium composition, inoculum dose, and experimental environment (Gomes Júnior et al., 2025; Ramadhan, Putri, Novanto, Istiqomah, & Azhar, 2025). In addition, studies on the application of arbuscular mycorrhiza to bud-set seedlings of the Bululawang variety are still relatively limited, especially during the early growth stage under greenhouse conditions (Muharram, Samago, & Garfansa, 2025). Bululawang is one of the widely cultivated sugarcane varieties and requires effective seedling technology to produce strong seedlings before field transplanting. Therefore, specific research is needed to evaluate the early growth response of Bululawang sugarcane seedlings to several levels of arbuscular mycorrhizal dose, so that more appropriate dose information can be obtained to support shoot growth, root development, and early biomass formation.

This study aimed to evaluate the early growth response of Bululawang sugarcane seedlings to the application of different doses of arbuscular mycorrhiza under greenhouse conditions. Specifically, this study examined the effects of arbuscular mycorrhiza application on shoot growth, number of leaves, shoot diameter, root length, plant fresh weight, and plant dry weight during the early seedling stage. This research is important for identifying a more suitable mycorrhizal dose to support early sugarcane seedling growth, particularly in the bud-set seedling system. The findings are expected to provide a scientific basis for developing sugarcane seedling technology that is more efficient, environmentally friendly, and supportive of biological-agent use in sustainable sugarcane cultivation systems.

2. METHODS

2.1 Material

The study was conducted from September 2023 to January 2024 in Jombang District, Jember Regency, under greenhouse conditions. The main biological material used in this study was Bululawang sugarcane bud-set seedlings. The arbuscular mycorrhizal fungi (AMF) inoculum used in this experiment was a dried commercial endomycorrhizal inoculum obtained from an agricultural biofertilizer supplier in Indonesia. The inoculum was formulated in a dry carrier substrate and contained viable AMF propagules, including spores, colonized root fragments, and extraradical hyphae. Based on the product description, the inoculum consisted of a mixed endomycorrhizal consortium commonly used for crop biofertilizer application and was dominated by Glomus spp. The exact number of spores or propagules per gram of inoculum was not independently quantified in this study. However, the inoculum was used before the expiration date stated on the product label and was stored in a dry, shaded condition before application to maintain propagule viability. This information was included because inoculum quality, propagule viability, and compatibility with the host plant can influence AMF colonization success and plant growth response.

The additional materials used in this study included topsoil, sand, and Dithane M45 fungicide containing 80% mancozeb as the active ingredient (Chinnathambi, Peeran, Srinivasan, Sankar, & George, 2024). The growing medium consisted of topsoil and sand mixed at a ratio of 2:1. The equipment used included 35 × 35 cm polybags, an analytical balance, a caliper, a ruler, and an oven. The analytical balance was used to measure plant fresh and dry weights, the caliper was used to measure shoot diameter, the ruler was used to measure shoot length and root length, and the oven was used to dry plant biomass at the end of the study.

2.2 Experimental procedure

The treatments consisted of four arbuscular mycorrhizal fungi (AMF) dose levels, namely A0 = 0 g, A1 = 5 g, A2 = 10 g, and A3 = 15 g per polybag. The dose range was selected to represent a stepwise application gradient, consisting of a non-inoculated control, a low dose, a medium dose, and a high dose under polybag seedling conditions. The 0 g treatment was used as the control to evaluate seedling growth without AMF inoculation, whereas the 5-15 g per polybag range was selected to assess whether increasing inoculum input could improve early shoot growth, root development, and biomass accumulation. This range was also adjusted to the practical application range of commercial AMF biofertilizer for nursery-scale seedling production and to the polybag volume used in the greenhouse experiment. Each treatment was replicated five times, resulting in 20 experimental units.

The growing medium was prepared by mixing topsoil and sand at a ratio of 2:1. AMF was added to the growing medium according to the assigned treatment level and then mixed evenly to improve contact between the inoculum and the developing root system (Amalyadi, Karni, Aminurrahman, Septian, & Al Gifari, 2025). The treated growing medium was placed into 35 × 35 cm polybags until approximately three-quarters of the polybag volume was filled. The single-bud sugarcane planting material was soaked in a Dithane M45 fungicide solution containing 80% mancozeb at a concentration of 2 g/L for 5 minutes as a pre-planting sanitation step to reduce pathogen contamination on the bud-set material. Because AMF is fungal in nature, the fungicide was applied only to the planting material and not directly to the AMF inoculum or treated growing medium, thereby minimizing direct exposure of AMF propagules to mancozeb. The same fungicide treatment was applied uniformly to all experimental units. However, because root colonization was not measured, any possible residual effect of fungicide treatment on AMF colonization could not be fully excluded. After soaking, the planting material was planted approximately 1 cm deep in the growing medium and lightly covered with soil. Plant maintenance included replanting within a maximum of 7 days after planting when seedlings failed to grow, watering every morning or afternoon according to plant needs, mechanical weed control, and pest and disease control when necessary.

2.3 Growth and biomass measurement

Each polybag contained one Bululawang sugarcane bud-set seedling, and each polybag was considered one experimental unit and one statistical replicate. Therefore, all growth and biomass measurements were taken from the single seedling grown in each polybag. Plant growth observations were conducted periodically during the seedling stage. The growth variables observed every two weeks included shoot diameter, number of leaves, and shoot length. Shoot diameter was measured using a caliper and expressed in centimeters. The number of leaves was counted manually based on fully expanded leaves. Shoot length was measured using a ruler from the stem base to the growing point and expressed in centimeters. Final sampling was conducted when the sugarcane seedlings were 3 months old. The variables observed at the end of the study included root length, plant fresh weight, and plant dry weight. Root length was measured using a ruler from the root base to the longest root tip. Plant fresh weight was measured using an analytical balance after all plant parts had been cleaned of soil and debris. Plant dry weight was measured after the plant biomass had been oven-dried at 70°C for 72 hours and then weighed using an analytical balance.

2.4 Data analysis

Data were analyzed using a one-factor Completely Randomized Design (CRD), with arbuscular mycorrhizal fungi (AMF) dose as the single treatment factor. The statistical model shown at equation (1) below:

$$\mathbf{Y}_{ij} = \boldsymbol{\mu} + \boldsymbol{\tau}_i + \boldsymbol{\varepsilon}_{ij} \quad (1)$$

where Y_{ij} is the observed value of the j-th replication under the i-th AMF dose, μ is the overall mean, τ_i is the effect of the i-th AMF dose, and ε_{ij} is the experimental error. The analyzed variables included shoot diameter, number of leaves, shoot length, root length, plant fresh weight, and plant dry weight. Prior to analysis of variance (ANOVA), the data were tested for normality using the Shapiro-Wilk test and for homogeneity of variance using Levene's test. Data that met the assumptions of normality and homogeneity were analyzed using one-way ANOVA to determine the effect of AMF dose on the early growth of Bululawang sugarcane seedlings. Significant treatment effects were further analyzed using Tukey's honestly significant difference (HSD) test at the 5% significance level. All statistical analyses were performed using IBM SPSS Statistics.

2.5 Growth response index calculation

The growth response index was calculated to integrate the responses of several growth and biomass variables into a single comparative value for each arbuscular mycorrhizal fungi (AMF) dose. This index was used because the optimum AMF dose could not be determined only from one variable, as fresh weight and dry weight showed different best-response points. The calculated variables included shoot length, shoot diameter, number of leaves, root length, plant fresh weight, and plant dry weight. The response index for each variable was calculated by comparing the mean value of each AMF treatment with the mean value of the non-inoculated control using the following equation (2) (Mahmood et al., 2022):

$$\text{Growth response index } (\%) = \frac{Xi}{X0} \times 100 \quad (2)$$

where X_i is the mean value of a given growth or biomass variable at each AMF dose, and X_0 is the mean value of the same variable in the 0 g control treatment. The 0 g treatment was set as 100%, and values above 100% indicated an increase in growth response relative to the control. After the response index was calculated for each variable, the mean growth response index was obtained by averaging the response index values of all measured variables within each AMF dose. This index provided a synthetic basis for comparing AMF dose effectiveness across shoot growth, root development, and biomass accumulation. Therefore, the dose with the highest mean growth response index was considered the agronomically optimum dose under greenhouse conditions, while individual variables such as plant fresh weight were also used to identify a more efficient dose for specific growth responses.

3. RESULT AND DISCUSSION

3.1 Shoot growth response of sugarcane seedlings

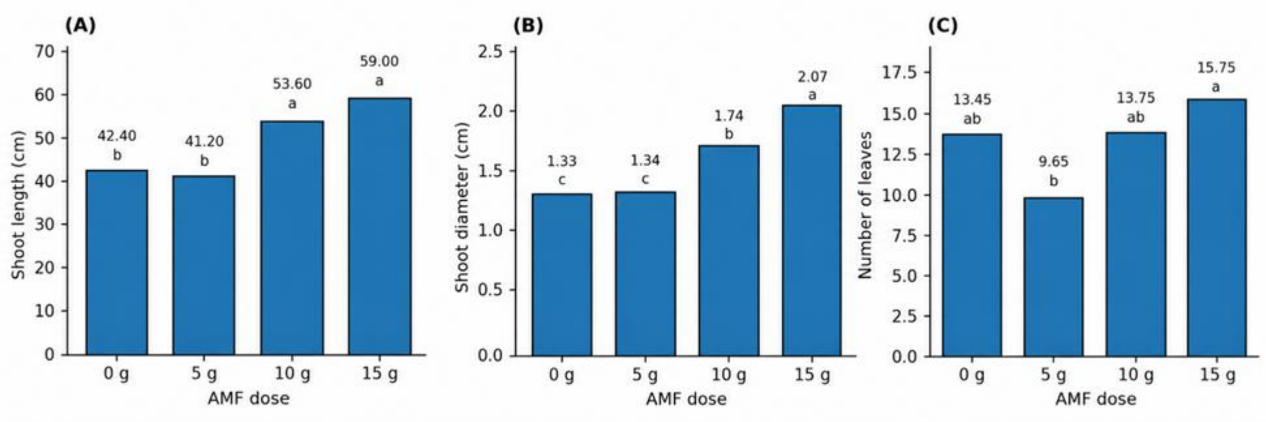

Figure 1. Effect of arbuscular mycorrhizal dose on shoot growth of Bululawang sugarcane seedlings. Different letters indicate significant differences based on Tukey's HSD test at $p < 0.05$

Shoot length is a key indicator for evaluating early seedling vigor because it reflects the ability of the seedling to develop aboveground vegetative growth. Figure 1A illustrates that shoot length of Bululawang sugarcane seedlings generally increased with increasing arbuscular mycorrhizal dose, although the 5 g dose produced a slightly lower value than the control. Shoot length was 42.40 cm in the 0 g treatment and slightly decreased to 41.20 cm at 5 g, before increasing to 53.60 cm at 10 g and reaching the highest value of 59.00 cm at 15 g. This pattern indicates that higher mycorrhizal doses, particularly 10-15 g, promoted better shoot elongation than the treatment without mycorrhiza. The increase in shoot length was presumably related to the ability of arbuscular mycorrhiza to extend the nutrient-absorbing area through external hyphae, thereby improving nutrient availability for cell division and elongation. Mycorrhiza applied during the early growth stage of sugarcane has been reported to increase nutrient uptake and stimulate root growth (Amalyadi & Widiastuti, 2025). Phosphorus also plays an important role during vegetative growth because it functions in energy storage and transfer in the form of ATP and ADP, which are required to support plant metabolism and growth. This finding is consistent with (Peroni et al., 2024), who reported that mycorrhizal application significantly affected plant length, and it is also in line with findings in sugarcane showing that mycorrhizal application significantly affected shoot length.

Shoot diameter showed a clearer response to increasing arbuscular mycorrhizal dose and can be used as an indicator of seedling robustness during the early growth stage. Figure 1B shows that shoot diameter was relatively similar in the 0 g and 5 g treatments, at 1.33 cm and 1.34 cm, respectively. It then increased to 1.74 cm at 10 g and reached the highest value of 2.07 cm at 15 g. This pattern indicates that increasing the mycorrhizal dose from 10 g to 15 g enlarged shoot diameter, whereas the 5 g dose was not sufficient to produce a stronger growth response than the control. Physiologically, shoot diameter may increase because plants with better nutrient acquisition are more capable of forming stem tissues and storing photosynthetic products. Sugarcane stores carbohydrate reserves in the stem; therefore, increased photosynthate accumulation can contribute to greater stem diameter and plant weight (Sun & Shahrajabian, 2023). This mechanism is also associated with the role of mycorrhiza in forming a mutualistic association with plant roots, because hyphal, vesicular, and arbuscular structures can expand the nutrient-absorbing area and improve nutrient uptake efficiency. These findings support previous studies indicating that mycorrhiza can significantly affect stem diameter and plant growth, and they are consistent with the base dataset showing that mycorrhizal dose had a highly significant effect on stem diameter.

Physiologically, shoot diameter may increase because plants with better nutrient acquisition are more capable of forming stem tissues and storing photosynthetic products.

The number of leaves reflects the early capacity of sugarcane seedlings to form photosynthetic organs that are important for assimilate production. Figure 1C shows a non-linear response pattern, with 13.45 leaves in the control, decreasing to 9.65 leaves at 5 g, increasing again to 13.75 leaves at 10 g, and reaching the highest value of 15.75 leaves at 15 g. The decrease at 5 g suggests that a low mycorrhizal dose did not necessarily stimulate better shoot growth, whereas the increase at 10 g and 15 g indicates that higher doses were more effective in supporting leaf formation. Biologically, a higher number of leaves can be associated with improved nutrient availability and metabolic energy, because leaves are the main photosynthetic organs that produce assimilates for subsequent plant tissue growth. Mycorrhiza can help plants acquire nutrients, especially phosphorus, which plays an important role in photosynthesis and plant energy formation (Chafai et al., 2023). Better nutrient support during the early seedling stage increases the opportunity for plants to form more leaves with active physiological function. This result is in accordance with Wahab et al. (2023), who described mycorrhiza as a beneficial symbiotic association between fungi in the rhizosphere and host plants, and with (del Rosario, Luis, Lino, Ricardo, & Jabín, 2022), who reported that sugarcane variety and mycorrhizal treatment affected the number of leaves and several other vegetative growth variables in sugarcane seedlings.

Mycorrhiza can help plants acquire nutrients, especially phosphorus, which plays an important role in photosynthesis and plant energy formation

3.3 Root system development of sugarcane seedlings

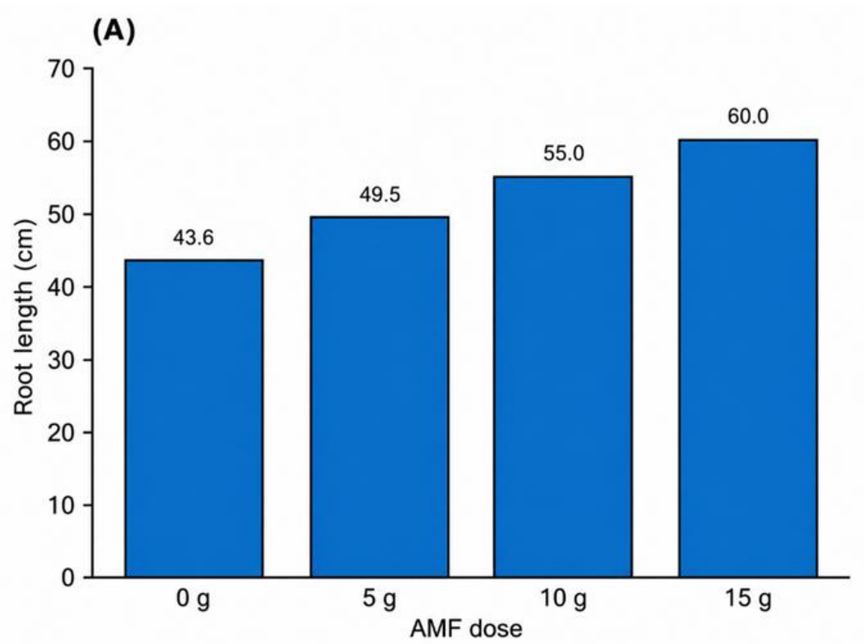

Figure 2. Effect of arbuscular mycorrhizal dose on root length of Bululawang sugarcane seedlings

Root length is an important variable for assessing the early ability of sugarcane seedlings to explore the growing medium and obtain water and nutrients. Figure 2 shows that root length tended to increase with increasing arbuscular mycorrhizal dose. The treatment without mycorrhiza produced a root length of 43.60 cm, which increased to 49.50 cm at 5 g, 55.00 cm at 10 g, and reached the highest value of 60.00 cm at 15 g. This pattern indicates that arbuscular mycorrhiza addition gradually promoted root elongation, although the analysis of variance in the parent study showed that the effect of mycorrhizal dose on root length was not statistically significant. The increasing trend in root length remains biologically relevant because longer roots can expand the exploration zone of plants within the growing medium. A more extensive root system can increase the opportunity for plants to acquire water and nutrients required during the early seedling stage (Asadi et al., 2022). Mycorrhiza is also known to associate with plant root systems and can help roots function more effectively in absorbing nutrients from the soil (Juntahum, Ekprasert, & Boonlue, 2022).

The increase in root length at higher mycorrhizal doses can be explained by the symbiotic relationship between arbuscular mycorrhiza and plant roots. Arbuscular mycorrhiza forms external hyphal structures that can reach areas of the growing medium beyond the direct absorption zone of the root (Chinnathambi et al., 2024). These hyphae expand the contact area between the root system and soil particles, thereby improving plant access to nutrients with low mobility, especially phosphorus. During the seedling stage, phosphorus is important for energy formation and plant metabolic activity, and its availability can support the formation of new root tissues. The increase in root length from 43.60 cm in the control to 60.00 cm at 15 g suggests that a higher amount of inoculum may strengthen the association between roots and mycorrhiza. However, because the differences were not statistically significant, this response is more appropriately interpreted as a physiological tendency rather than as a strong treatment effect.

The increase in root length at higher mycorrhizal doses can be explained by the symbiotic relationship between arbuscular mycorrhiza and plant roots

These results are consistent with several previous studies reporting that arbuscular mycorrhiza can support plant root development by increasing the nutrient-absorbing range. Gomes Júnior et al. (2025) explained that mycorrhizal addition during the early growth stage of sugarcane can stimulate root growth and increase nutrient uptake. Arbuscular mycorrhizal fungi supported the growth of sugarcane seedlings in media with limited nutrient conditions. Sun and Shahrajabian (2023) stated that arbuscular mycorrhiza has the potential to improve the growth and health of sugarcane seedlings because of its association with plant roots. Mycorrhizal application affected root length and several other plant growth components. Thus, although root length in this study did not differ significantly, the increasing pattern from 0 g to 15 g indicates that arbuscular mycorrhiza has potential to support root system formation in sugarcane seedlings during the early growth stage.

Mycorrhizal application affected root length and several other plant growth components. Thus, although root length in this study did not differ significantly, the increasing pattern from 0 g to 15 g indicates that arbuscular mycorrhiza has potential to support root system formation in sugarcane seedlings during the early growth stage

3.3 Biomass accumulation of sugarcane seedlings as an indicator of arbuscular mycorrhizal dose effectiveness

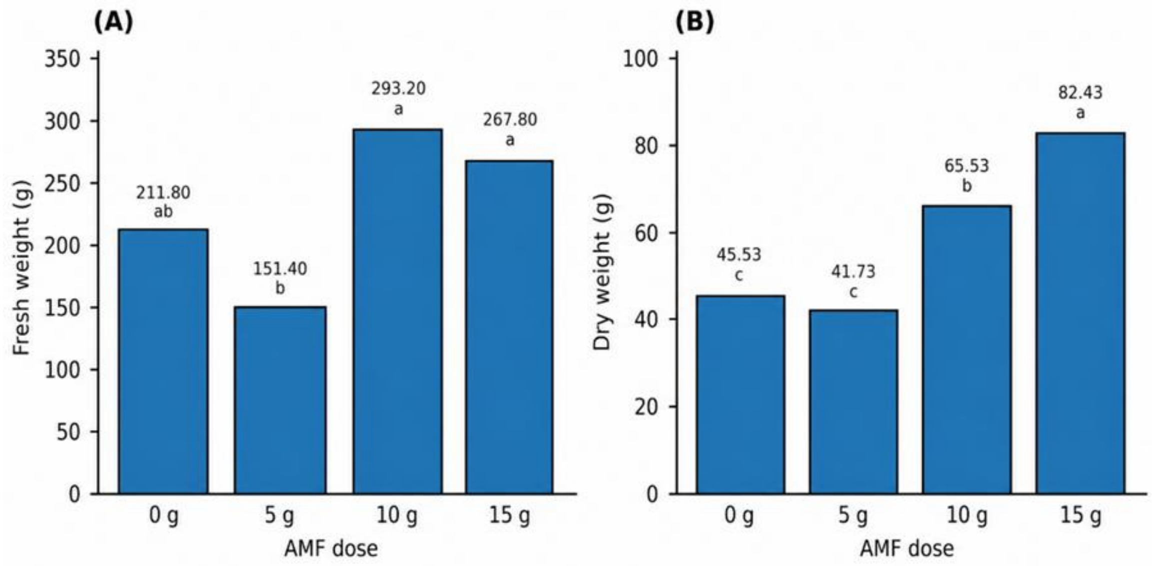

Figure 3. Effect of arbuscular mycorrhizal dose on biomass accumulation of Bululawang sugarcane seedlings. Different letters indicate significant differences based on Tukey's HSD test at $p < 0.05$

Plant fresh weight is an indicator of early biomass accumulation that reflects the combined contribution of plant tissue growth, water content, and metabolic products stored in plant organs. The fresh weight response of Bululawang sugarcane seedlings followed a non-linear pattern with increasing AMF dose, as presented in Figure 3A. The treatment without AMF produced a fresh weight of 211.80 g, which decreased to 151.40 g at 5 g, increased sharply to 293.20 g at 10 g, and then slightly decreased to 267.80 g at 15 g. This pattern indicates that the 10 g dose produced the highest fresh weight in Bululawang sugarcane seedlings, whereas the 15 g dose remained high but did not exceed the 10 g treatment. The response suggests that AMF effectiveness did not always increase linearly with increasing dose, because successful AMF association can be influenced by the balance between inoculum amount, growing-medium conditions, and host-plant response (Huang et al., 2026). The decline in fresh weight at 5 g may have occurred because the inoculum amount was not yet sufficient to establish a strong functional association with the developing root system, whereas the 10 g dose was presumably more suitable for supporting fresh biomass formation during the early seedling stage. Plants associated with AMF can have a wider nutrient-absorbing range through the formation of hyphae, vesicles, and arbuscules, allowing nutrient uptake to occur more effectively.

Plant dry weight is a more stable indicator for evaluating dry matter accumulation because it represents the net result of biomass formation after water content has been removed. The dry weight response of Bululawang sugarcane seedlings increased more clearly at higher AMF doses, as presented in Figure 3B. Plant dry weight was 45.53 g in the 0 g treatment, slightly decreased to 41.73 g at 5 g, increased to 65.53 g at 10 g, and reached the highest value of 82.43 g at 15 g. This pattern indicates that the 15 g dose was more effective in supporting dry matter accumulation, whereas the 10 g dose already produced a substantial increase in dry weight compared with the control. The increase in dry weight can be linked to improved nutrient uptake efficiency in mycorrhizal plants, especially phosphorus, because AMF hyphae can assist phosphate absorption from the growing medium and transfer it to the host plant (Safahani, Mancinelli, Mohseni, & Radicetti, 2026). Phosphorus plays a role in energy storage and transfer through ATP and ADP, making its availability important for metabolic activity and biomass formation. The final products of photosynthesis and plant metabolism can be manifested as increased plant dry weight, so the higher dry weight at 15 g indicates greater accumulation of plant organic matter. Furthermore, the relevance of (Peroni et al., 2024), who explained that mycorrhiza as a symbiotic association in the rhizosphere can provide a mutually beneficial relationship for the host plant.

Fresh weight and dry weight responses indicate that AMF application contributed to biomass accumulation in Bululawang sugarcane seedlings, although both variables showed different best-response points. The highest fresh weight was obtained at 10 g, whereas the highest dry weight was obtained at 15 g. This difference suggests that the 10 g dose was more prominent in supporting fresh biomass formation, while the 15 g dose was stronger in increasing dry matter accumulation. Such a response may occur because fresh weight is more influenced by water content and tissue hydration, whereas dry weight more directly reflects organic matter accumulation derived from plant metabolism. Sugarcane stores photosynthetic products as reserves in the stem; therefore, increased photosynthate formation and storage can contribute to higher plant biomass (Tripathi et al., 2025). Therefore, the 10–15 g range can be considered effective for supporting biomass accumulation in Bululawang sugarcane seedlings, with 10 g being more potential for increasing fresh weight and 15 g being more potential for increasing dry weight.

3.4 Determination of the optimum arbuscular mycorrhizal dose based on the growth response index

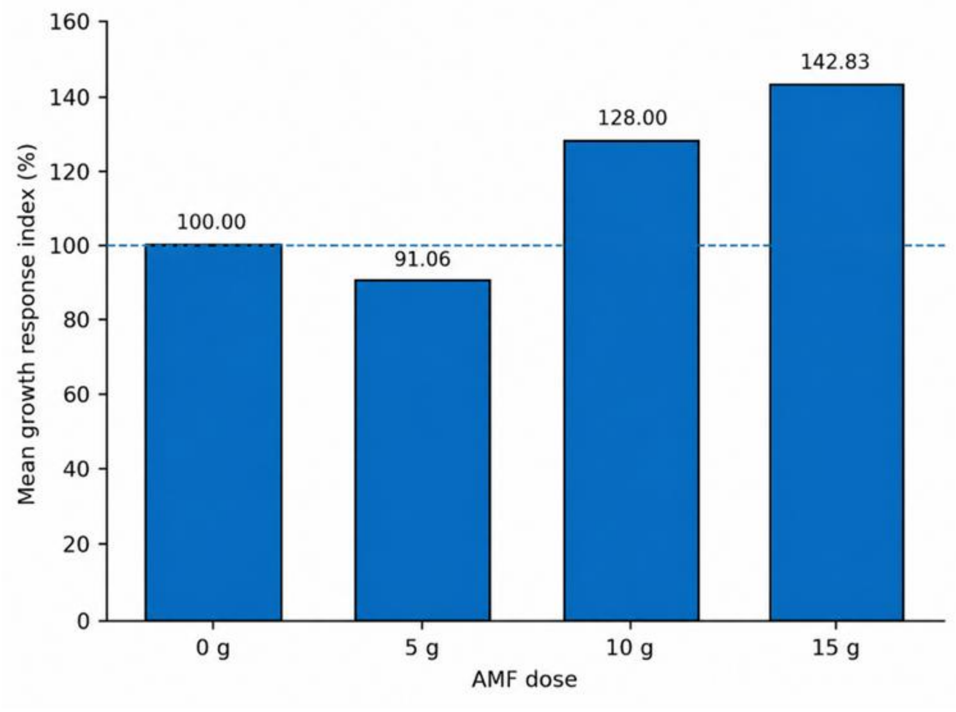

Figure 4. Mean growth response index of Bululawang sugarcane seedlings under different arbuscular mycorrhizal fungi (AMF) doses. The index was calculated from shoot length, shoot diameter, number of leaves, root length, plant fresh weight, and plant dry weight by normalizing each treatment value against the 0 g control. Values above 100% indicate a higher response than the non-inoculated control.

The growth response index is a synthetic approach for evaluating the effectiveness of arbuscular mycorrhizal dose based on several growth and biomass variables. Figure 4 shows that the mean growth response index in the 0 g control was set at 100.00%, then decreased to 91.06% at 5 g, increased to 128.00% at 10 g, and reached the highest value of 142.83% at 15 g. This pattern indicates that the 5 g dose did not improve the growth response compared with the control, whereas the 10 g and 15 g doses produced stronger growth responses. The higher index at 15 g indicates that this dose provided the most consistent overall growth response in Bululawang sugarcane seedlings. The increase in response index may be explained by the role of arbuscular mycorrhiza as a root symbiont that helps plants acquire nutrients by expanding the absorption area, especially for nutrients with limited mobility in the growing medium such as phosphorus (Safahani et al., 2026). Phosphorus is important for energy transfer, ATP and ADP formation, and plant metabolic activity; therefore, its availability can strengthen vegetative growth and biomass formation (Juntahum et al., 2022). The parent study also showed that mycorrhizal dose had significant or highly significant effects on several important growth variables, including number of leaves, shoot length, stem diameter, fresh weight, and dry weight.

Based on the growth response index, the 15 g dose can be positioned as the agronomically optimum dose because it produced the highest mean response value among the treatments. The 10 g dose also remained important because it produced a response index of 128.00%, representing a 28.00% increase over the control. Thus, the 10 g dose can be considered an efficient dose, while the 15 g dose can be considered the dose that produced the maximum growth response under greenhouse conditions. The difference between the responses to 10 g and 15 g indicates that AMF effectiveness is determined not only by inoculum presence, but also by the adequacy of inoculum quantity in forming a functional association with plant roots. AMF can support sugarcane seedling growth in growing media by improving nutrient acquisition and strengthening root-related growth processes (Chen et al., 2023). Mycorrhizal association during the early growth stage of sugarcane also contributes to nutrient uptake and root growth stimulation (Wahab et al., 2023). Therefore, the response-index analysis supports the 10–15 g range as a potential AMF dose range for Bululawang sugarcane bud-set seedling production under greenhouse conditions.

4. CONCLUSION

This study evaluated the early growth response of Bululawang sugarcane seedlings to different arbuscular mycorrhizal fungi (AMF) doses under greenhouse conditions. AMF application produced different responses in shoot growth, root development, and biomass accumulation. The 10 g and 15 g doses showed better growth responses than the control, whereas the 5 g dose did not consistently improve seedling growth. The highest fresh weight was obtained at 10 g, at 293.20 g, while the highest dry weight was obtained at 15 g, at 82.43 g. Based on the mean growth response index, the 15 g dose produced the highest value, at 142.83%, and can therefore be positioned as the agronomically optimum dose for Bululawang sugarcane seedlings under greenhouse conditions. The 10 g dose can be considered an efficient dose for supporting fresh biomass formation because it produced the highest fresh weight at a lower AMF input. These findings indicate that AMF application has potential as a biological technology for improving the quality of Bululawang sugarcane seedlings during the early growth stage. Further research is recommended to test the effectiveness of 10-15 g AMF under field conditions and to evaluate root colonization levels and plant nutrient uptake efficiency.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Dwija Putripertiwi: Funding acquisition, Conceptualization. Muzna Ardin Abdul Gafur: Conceptualization, Funding acquisition, Writing –

original draft, Supervision. Wa Ode Dian Purnamasari: Writing – original draft, Writing – review & editing.

ETHICS APPROVAL
No ethical approval was needed for this study.

FUNDING
This research received no external funding.

CONFLICT OF INTEREST
The authors declares no conflicts of interest.

DATA AVAILABILITY STATEMENT
Data available by request.

REFERENCES
Amalyadi, R., Karni, I., Aminurrahman, A., Septian, I. G. N., & Al Gifari, Z. (2025). Exploring the nutritional and functional potential of forage-based diets in poultry feeding systems: a systematic review toward sustainable avian nutrition. *Environmental and Agriculture Management, 2*(2), 87-103. doi:https://doi.org/10.31102/eam.2.2.87-103

Amalyadi, R., & Widiastuti, L. K. (2025). Gas-to-feed revolution: a novel review of the microbial conversion of industrial emissions into sustainable livestock feed. *Environmental and Agriculture Management, 2*(2), 104-121. doi:https://doi.org/10.31102/eam.2.2.104-121

Asadi, M., Rasouli, F., Amini, T., Hassanpouraghdam, M. B., Souri, S., Skrovankova, S., . . . Ercisli, S. (2022). Improvement of Photosynthetic Pigment Characteristics, Mineral Content, and Antioxidant Activity of Lettuce (Lactuca sativa L.) by Arbuscular Mycorrhizal Fungus and Seaweed Extract Foliar Application. *Agronomy, 12*(8), 1943. doi:https://doi.org/10.3390/agronomy12081943

Chafai, W., Haddioui, K., Serghini-Caid, H., Labazi, H., AlZain, M. N., Noman, O., . . . Khalid, A. (2023). Impact of Arbuscular mycorrhizal Fungal Strains Isolated from Soil on the Growth, Yield, and Fruit Quality of Tomato Plants under Different Fertilization Regimens. *Horticulturae, 9*(9), 973. doi:https://doi.org/10.3390/horticulturae9090973

Chen, D., Saeed, M., Ali, M. N., Raheel, M., Ashraf, W., Hassan, Z., . . . Negm, S. (2023). Plant Growth Promoting Rhizobacteria (PGPR) and Arbuscular Mycorrhizal Fungi Combined Application Reveals Enhanced Soil Fertility and Rice Production. *Agronomy, 13*(2), 550. doi:https://doi.org/10.3390/agronomy13020550

Chinnathambi, S., Peeran, M. F., Srinivasan, V., Sankar, S. M., & George, P. (2024). Optimizing mycorrhizal fungi application for improved nutrient uptake, growth, and disease resistance in cardamom seedlings (Elettaria cardamomum (L.). *Heliyon, 10*(20). doi:https://doi.org/10.1016/j.heliyon.2024.e39227

del Rosario, M.-H. M., Luis, S.-C. J., Lino, S.-S., Ricardo, S.-P., & Jabín, B.-B. J. (2022). Arbuscular Mycorrhizal Fungi: Inoculum Dose Affects Plant Development and Performance of Sugarcane (Saccharum spp.) Plantlets During Acclimatization Stage. *Journal of Soil Science and Plant Nutrition, 22*(4), 4847-4856. doi:10.1007/s42729-022-00964-z

Gomes Júnior, C. C., de Souza, R. P. B., Menezes, K. M. S., de Souza, A. H., Tomazeli-Silva, A., Valadares, S. V., . . . DaMatta, F. M. (2025). Boosting coffee seedling performance through arbuscular mycorrhizal association. *Mycorrhiza, 35*(6), 69. doi:https://doi.org/10.1007/s00572-025-01245-0

Huang, Q.-Q., Wang, S., Nong, Y.-J., Zhong, K.-M., Su, Y.-C., Qin, X.-J., . . . Li, Y.-R. (2026). Analysis of Arbuscular Mycorrhizal Fungal Community in Soil of Sugarcane at Different Tillage Depths. *Sugar Tech*. doi:https://doi.org/10.1007/s12355-026-01729-z

Juntahum, S., Ekprasert, J., & Boonlue, S. (2022). Efficiency of Arbuscular Mycorrhizal Fungi for the Growth Promotion of Sugarcane Under Pot Conditions. *Sugar Tech, 24*(6), 1738-1747. doi:10.1007/s12355-022-01129-z

Mahmood, T., Iqbal, M. S., Li, H., Nazir, M. F., Khalid, S., Sarfraz, Z., . . . Du, X. (2022). Differential seedling growth and tolerance indices reflect drought tolerance in cotton. *BMC Plant Biology, 22*(1), 331. doi:10.1186/s12870-022-03724-4

Meena, M. R., Appunu, C., Arun Kumar, R., Manimekalai, R., Vasantha, S., Krishnappa, G., . . . Hemaprabha, G. (2022). Recent Advances in Sugarcane Genomics, Physiology, and Phenomics for Superior Agronomic Traits. *Frontiers in Genetics, Volume 13 - 2022*. doi:https://doi.org/10.3389/fgene.2022.854936

Muharram, M., Samago, T. Y., & Garfansa, M. P. (2025). Improving soil acidity on peat soil through rice husk ash and rabbit urine biofertilizer application. *Environmental and Agriculture Management, 2*(2), 72-86. doi:https://doi.org/10.31102/eam.2.2.72-86

Peroni, P., Liu, Q., Lizarazu, W. Z., Xue, S., Yi, Z., Von Cossel, M., . . . Iqbal, Y. (2024). Biostimulant and Arbuscular Mycorrhizae Application on Four Major Biomass Crops as the Base of Phytomanagement Strategies in Metal-Contaminated Soils. *Plants, 13*(13), 1866. doi:https://doi.org/10.3390/plants13131866

Ramadhan, S. A., Putri, L. I., Novanto, P. R., Istiqomah, F. N., & Azhar, A. (2025). Effects of NPK Fertilizer and Arbuscular Mycorrhizal Fungi (AMF) on the Growth of Oil Palm (Elaeis guineensis Jacq.) Seedlings. *PLANTA TROPIKA, 13*(2), 208-218. doi:https://doi.org/10.18196/pt.v13i2.26091

Safahani, A., Mancinelli, R., Mohseni, B., & Radicetti, E. (2026). Synergistic Application of Biochar, Arbuscular Mycorrhizal Fungi, and Optimized Fertilization for Sustainable Sunflower Production in Semi-Arid Environments. *Journal of Soil Science and Plant Nutrition, 26*(1), 2219-2236. doi:10.1007/s42729-025-02992-x

Sales, L. R., Silva, A. O., Sales, F. R., Rodrigues, T. L., Barbosa, M. V., Santos, J. V. d., . . . Carneiro, M. A. C. (2022). On farm inoculation of native arbuscular mycorrhizal fungi improves efficiency in increasing sugarcane productivity in the field. *Rhizosphere, 22*, 100539. doi:https://doi.org/10.1016/j.rhisph.2022.100539

Sun, W., & Shahrajabian, M. H. (2023). The Application of Arbuscular Mycorrhizal Fungi as Microbial Biostimulant, Sustainable Approaches in Modern Agriculture. *Plants, 12*(17), 3101. doi:https://doi.org/10.3390/plants12173101

Tripathi, M. K., Shukla, S. K., Jaiswal, V. P., Sharma, L., Nagargade, M., Pathak, A. D., . . . Ranka, A. (2025). Integration of Mycorrhizae, Azotobacter and Pseudomonas spp (PSB) with NPK and their Effects on Sugarcane Crop and Soil Health in Uttar Pradesh, India. *Sugar Tech, 27*(2), 340-356. doi:10.1007/s12355-024-01513-x

Wahab, A., Muhammad, M., Munir, A., Abdi, G., Zaman, W., Ayaz, A., . . . Reddy, S. P. (2023). Role of Arbuscular Mycorrhizal Fungi in Regulating Growth, Enhancing Productivity, and Potentially Influencing Ecosystems under Abiotic and Biotic Stresses. *Plants, 12*(17), 3102. doi:https://doi.org/10.3390/plants12173102