

Arabica Coffee Seedling Growth under Drought with Potassium, Boron, and Trichoderma spp.

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Abstract

Drought stress during the seedling stage can restrict vegetative growth and compromise the successful establishment of Arabica coffee (*Coffea arabica* L.) under field conditions. This study evaluated the individual and combined effects of potassium (K), boron (B), and *Trichoderma* spp. on the morphological growth responses of LS 795 Arabica coffee seedlings under drought stress and during subsequent recovery. The experiment was conducted at the Bale Tatanen Experimental Garden, Faculty of Agriculture, Universitas Padjadjaran, Jatinangor, Indonesia, from February to May 2026. A randomized complete block design (RCBD) was employed, comprising eight treatments with four replications. The treatments included an untreated control, potassium (1.38 g/L), boron (384 mg/L), *Trichoderma* spp. (20 g/plant), and their respective combinations. Plant height, leaf area, and leaf number were measured throughout an 18-day drought stress period and the subsequent recovery phase following rewatering. Analysis of variance (ANOVA) revealed no statistically significant treatment effects on plant height, leaf area, or leaf number during the drought stress period. However, significant differences in plant height emerged during the recovery phase, particularly at 15 days after rewatering, when seedlings treated with K + *Trichoderma* spp. and K + B + *Trichoderma* spp. exhibited the greatest plant heights, significantly exceeding those of the untreated control. In contrast, leaf area and leaf number did not differ significantly among treatments during recovery. These findings indicated that the tested treatments did not significantly alleviate drought-induced growth suppression during the stress period. Nevertheless, potassium application combined with *Trichoderma* spp., either with or without boron supplementation, was associated with improved plant height during post-drought recovery. The results suggest that these treatment combinations may support the recovery of vegetative growth in Arabica coffee seedlings following drought stress, although further investigation is required to determine their effects on physiological drought tolerance and long-term field establishment.

INTRODUCTION

Arabica coffee (*Coffea arabica* L.) is an economically important plantation crop in Indonesia, contributing significantly to employment opportunities, agricultural livelihoods, and the development of the national agroindustry (Rico et al., 2021). However, coffee production has become increasingly vulnerable to climatic variability and climate change-related environmental stresses, including rising temperatures, altered precipitation patterns, and prolonged dry periods (Boer et al., 2020; Sujatmiko, 2018). These climatic challenges can adversely affect coffee growth, productivity, and cultivation sustainability, particularly in production areas characterized by irregular rainfall distribution. Consequently, effective drought management strategies have become increasingly important for maintaining coffee production and strengthening the resilience of coffee cultivation systems under changing climatic conditions.

Drought stress represents a major environmental constraint affecting coffee growth and productivity. Previous studies have reported reductions in national coffee production associated with extreme climatic conditions, while prolonged dry periods have been identified as significant limitations to coffee cultivation in several production regions (Afifah et al., 2025; Muslihah & Karuniasa, 2020). At the physiological level, reduced soil water availability decreases cellular turgor pressure, restricts stomatal conductance, inhibits photosynthetic activity, and disrupts essential metabolic processes. These physiological disturbances can subsequently suppress vegetative growth, limit biomass accumulation, and reduce overall plant performance. The severity of these effects depends on drought intensity, stress duration, plant developmental stage, and the capacity of individual plants to maintain physiological functions under water-limited conditions.

The seedling stage is particularly susceptible to drought stress because young coffee plants possess relatively underdeveloped root systems and require adequate water availability to support vegetative growth and successful field establishment. Water deficits during this developmental stage can inhibit stem elongation, reduce leaf initiation and expansion, and impair root development, potentially increasing the risk of seedling mortality following transplantation (Abdoellah, 1997; Chekol et al., 2023, 2024; León-Rojas et al., 2023). These adverse effects may compromise seedling quality and subsequent establishment under field conditions. Therefore, the development of appropriate drought management strategies for LS 795 Arabica coffee seedlings is essential to support vegetative growth, enhance recovery following temporary water deficits, and improve their potential for successful transplantation.

Potassium (K) is an essential plant macronutrient that plays a fundamental role in regulating physiological processes associated with drought responses, including osmotic adjustment, maintenance of cellular turgor, stomatal regulation, water-use efficiency, and photosynthate translocation (Hasanuzzaman et al., 2018; Marschner, 2012). Adequate potassium availability contributes to the regulation of plant water balance and supports physiological functioning under conditions of limited soil moisture. Previous research has indicated that foliar potassium application can improve water-use efficiency and mitigate drought-induced reductions in aboveground biomass in Arabica coffee, suggesting its potential contribution to drought adaptation and vegetative growth maintenance (Ramírez-Builes, 2021). These findings provide a physiological basis for investigating potassium supplementation as a

potential strategy for supporting coffee seedling performance during drought stress and subsequent recovery.

Boron (B) is an essential plant micronutrient involved in cell wall structure and stability, meristematic growth, cell expansion, and the maintenance of normal plant development (Abreu-Junior et al., 2025). Adequate boron availability contributes to the structural integrity of plant tissues and supports processes associated with vegetative growth. Under water-limited conditions, appropriate boron nutrition may help maintain cellular and tissue functions that are important for plant growth and recovery. Previous studies have highlighted the importance of boron in supporting biomass accumulation, cell wall integrity, and vascular tissue development, which may indirectly influence water and nutrient transport during environmental stress (Ramírez-Builes et al., 2024; Rosolem & Leite, 2007). Nevertheless, because boron has a relatively narrow concentration range between deficiency and toxicity, its application requires careful consideration of dosage and plant nutritional requirements. These characteristics make boron an important factor to examine in relation to the morphological responses of Arabica coffee seedlings exposed to drought stress.

In addition to mineral nutrition, beneficial microorganisms have attracted considerable attention for their potential roles in improving plant growth and tolerance to environmental stresses. Fungi belonging to the genus *Trichoderma* can interact with plant roots and the rhizosphere, stimulate root system development, enhance nutrient acquisition, and produce growth-promoting metabolites, including indole-3-acetic acid (IAA) (Contreras-Cornejo et al., 2024; Sinaga et al., 2023; Woo et al., 2023). These biological interactions may contribute to improved root architecture, increased nutrient uptake efficiency, and enhanced plant adaptability under unfavorable environmental conditions. By promoting root development and modifying rhizosphere interactions, certain *Trichoderma* species and strains may support the ability of coffee seedlings to acquire water and nutrients under reduced soil moisture availability. However, the effectiveness of these biological responses may vary depending on fungal species, environmental conditions, plant genotype, and application methods.

Potassium, boron, and *Trichoderma* spp. influence plant growth and responses to environmental stress through distinct but potentially complementary physiological and biological mechanisms. Potassium primarily contributes to osmotic regulation, stomatal functioning, and maintenance of plant water status, whereas boron supports cell wall integrity, cellular development, and vascular tissue function. Meanwhile, *Trichoderma* spp. may promote root development, nutrient acquisition, and beneficial interactions within the rhizosphere. These complementary functions provide a theoretical basis for investigating whether combined applications offer greater benefits than individual treatments. In particular, integrating mineral nutrients with beneficial microorganisms may help support vegetative growth and facilitate recovery following temporary drought stress. However, potential interactions among these inputs require experimental verification because their combined effects may vary according to nutrient availability, microbial activity, and plant physiological conditions.

Previous studies have investigated the roles of mineral nutrients and beneficial microorganisms in supporting plant growth under environmental stress, including potassium supplementation during drought and *Trichoderma*-mediated stimulation of root development. Research on boron has also emphasized its importance in maintaining cell wall structure, vascular function, and normal plant development. Although these findings provide valuable

insights into the individual contributions of nutrient management and biological agents, evidence regarding their combined application remains limited, particularly for LS 795 Arabica coffee seedlings. Furthermore, relatively little attention has been devoted to evaluating the morphological responses of coffee seedlings receiving potassium, boron, and *Trichoderma* spp. treatments under a defined period of drought stress followed by rewatering. This limitation highlights the need for experimental investigations that compare individual and combined treatment effects across different phases of water availability.

The research gap addressed in this study concerns the limited understanding of how combined potassium, boron, and *Trichoderma* spp. applications influence the morphological growth of Arabica coffee seedlings during both drought exposure and subsequent recovery. Previous investigations have frequently emphasized plant responses during active stress, whereas post-stress recovery represents an additional dimension of plant performance. Treatments that do not significantly maintain vegetative growth during drought may still support renewed growth following the restoration of water availability. Therefore, examining both phases provides a more comprehensive assessment of seedling responses and enables researchers to distinguish growth maintenance during water limitation from growth recovery after rewatering. The novelty of this study lies in its integrated evaluation of three complementary agricultural inputs, applied individually and in combination, while examining plant height, leaf area, and leaf number across drought and recovery periods in LS 795 Arabica coffee seedlings.

Accordingly, this study aimed to evaluate the individual and combined effects of potassium (K), boron (B), and *Trichoderma* spp. on the morphological growth responses of LS 795 Arabica coffee seedlings under drought stress and during subsequent recovery. Specifically, the research examined differences in plant height, leaf area, and leaf number among treatment combinations to identify treatments associated with improved seedling growth performance during water limitation and following rewatering. The study was expected to contribute empirical evidence concerning the potential integration of mineral nutrition and beneficial microorganisms in coffee nursery management. From a practical perspective, the findings may provide an initial agronomic basis for developing nutrient and biological treatment strategies that support seedling growth recovery under increasingly variable water availability. Furthermore, the results may inform future research incorporating physiological indicators, root development measurements, and field establishment assessments to better understand the mechanisms and long-term effectiveness of combined potassium, boron, and *Trichoderma* spp. applications in Arabica coffee cultivation.

METHODS

This study was conducted over four months, from February to May 2026, in the shade house (screenhouse) of the Bale Tatanen Experimental Garden, Faculty of Agriculture, Universitas Padjadjaran, Jatinangor, Sumedang Regency, West Java, Indonesia, at an elevation of approximately 800 m above sea level.

The experimental materials consisted of six-month-old LS 795 Arabica coffee (*Coffea arabica* L.) seedlings obtained from the West Java Provincial Plantation Seed Development and Production Center. The seedlings were grown in 25 × 30 cm polyethylene planting bags

(polybags) filled with topsoil. Additional materials included urea as a basal fertilizer, potassium (K) fertilizer, boron (B) fertilizer, and a granular formulation containing *Trichoderma* spp. obtained from the West Java Provincial Plantation Protection Center. The equipment included a measuring tape, portable leaf area meter, hand sprayer, bucket, and measuring cylinder.

The experiment employed a single-factor randomized complete block design (RCBD) comprising eight treatments and four replications, resulting in 32 experimental units. Each experimental unit contained two seedlings, giving a total experimental population of 64 plants. The experimental units were randomly assigned within each block to minimize systematic variation. All treatments were subjected to 18 days of drought stress and consisted of the following: treatment A, untreated control without K, B, or *Trichoderma* spp.; treatment B, K fertilizer (1.38 g/L); treatment C, B fertilizer (384 mg/L); treatment D, *Trichoderma* spp. (20 g/plant); treatment E, K fertilizer (1.38 g/L) + B fertilizer (384 mg/L); treatment F, K fertilizer (1.38 g/L) + *Trichoderma* spp. (20 g/plant); treatment G, B fertilizer (384 mg/L) + *Trichoderma* spp. (20 g/plant); and treatment H, K fertilizer (1.38 g/L) + B fertilizer (384 mg/L) + *Trichoderma* spp. (20 g/plant).

The granular *Trichoderma* spp. formulation was applied directly to the planting medium at a rate of 20 g per plant and incorporated into the soil. Potassium (1.38 g/L) and boron (384 mg/L) fertilizers were applied as foliar sprays on five occasions at seven-day intervals. Applications were performed between 7:00 and 10:00 a.m. Western Indonesian Time (WIB), using a spray volume of 15 mL per plant. Drought stress was imposed by completely withholding irrigation for 18 consecutive days in all treatment groups, including the untreated control. Following the drought period, irrigation was resumed to evaluate post-stress recovery.

Growth observations were conducted at three-day intervals during the drought stress and recovery periods, with recovery measurements continuing until 15 days after rewatering. The observed parameters included plant height (cm), measured from the stem base at the soil surface to the highest growing point; leaf area (cm²), measured on fully expanded leaves using a portable leaf area meter; and leaf number, determined by counting fully expanded leaves on each plant.

The collected data were subjected to the Shapiro–Wilk test to assess normality, followed by analysis of variance (ANOVA) at a 5% significance level ($\alpha = 0.05$). When the ANOVA indicated statistically significant treatment effects, mean comparisons were performed using the least significant difference (LSD) test, known in Indonesian as *Beda Nyata Terkecil* (BNT), at the 5% significance level.

RESULTS AND DISCUSSION

Plant Height

Based on the results of the variety analysis in Table 1, the application of fertilizers K, B, *Trichoderma* spp., or their combinations did not have a significant effect on the height growth of Arabica coffee plants throughout the observation period during the drought stress period. Arabica coffee seedlings that experienced drought stress were shown to show a slow rate of plant height growth (Asmono et al., 2025; Chekol et al., 2023, 2024). Decreased water availability in the soil is thought to decrease the turgor potential of cells, thereby limiting the

process of mitosis and meristematic cell elongation in the plant crown (Chekol et al., 2024; Marthandan et al., 2020).

Apical meristem tissue is highly dependent on the adequacy of water to promote cell division that supports plant height gain (Ismaya et al., 2023). In addition, the very limited availability of water in the soil can trigger stomata closure and suppress the rate of carbon assimilation, which directly limits the metabolic processes and vegetative growth of plants (DaMatta et al., 2018; Ramírez-Builes et al., 2024).

Table 1. Plant Height (cm) of Arabica Coffee on Various Days After Drought Stress (HSC)

Treatment	0 HSC	3 HSC	6 HSC	9 HSC	12 HSC	15 HSC	18 HSC
A	41.23a	41.75a	41.93a	41.98a	42.23a	42.28a	42.55a
B	47.55a	47.73a	47.9a	48.13a	48.45a	48.45a	48.58a
C	45.13a	45.33a	45.35a	45.63a	46.0a	46.0a	46.25a
D	49.15a	49.48a	49.8a	50.25a	50.38a	50.68a	50.73a
E	42.0a	42.3a	42.4a	42.73a	42.88a	43.13a	43.13a
F	46.55a	46.83a	47.1a	47.55a	47.8a	47.83a	47.93a
G	47.85a	48.38a	48.55a	48.93a	49.28a	49.45a	49.6a
H	51.93a	52.08a	52.15a	52.25a	52.3a	52.3a	52.3a

Remarks: The numbers in the same column followed by the same letter did not differ significantly at the 5% test level (BNT test). A = control; B = K fertilizer; C = B fertilizer; D = *Trichoderma* spp.; E = K + B; F = K + *Trichoderma* spp.; G = B + *Trichoderma* spp.; H = K + B + *Trichoderma* spp.

Source: Experimental data processed by the authors, 2026.

Entering the recovery phase (Table 2), the height of the plants showed a very noticeable effect between treatments on the observation of 15 HSR. The combination of H and F treatments resulted in the highest average plant height. Both combinations resulted in significantly higher plant height than the controls.

The high recovery rate of the plant at the combination of F and H proves an effective synergistic interaction between nutrients and biological agents. The availability of K maintains the turgor pressure of meristematic cells, triggering cell division and elongation, thus supporting the high recovery of the plant after rewatering (Gardner et al., 1991; Xu et al., 2021). On the other hand, the sufficient availability of B supports the integrity and stability of xylem vascular tissue and prevents damage or death of apical shoots (*dieback*), thereby facilitating the distribution of water and nutrients from the roots to the crown (Ramírez-Builes et al., 2024; Rosolem & Leite, 2007).

Furthermore, inoculation of *Trichoderma* spp. biological agents in soil media during the stress phase helps maintain the plant's water and nutrient absorption capacity through the stimulation of root-stimulating phytohormone auxin secretion once groundwater availability is restored (Akbari et al., 2024; Contreras-Cornejo et al., 2009). Thus, the recovery response to fertilization treatments and biological agents has a better growth response compared to control treatments.

Table 2. Plant Height (cm) of Arabica Coffee on Various Days After Recovery (HSR)

Treatment	3 HSR	6 HSR	9 HSR	12 HSR	15 HSR
A	43.53a	43.88a	43.95a	44.90a	45.53b
B	48.93a	49.68a	49.90a	50.18a	51.48b
C	46.95a	47.60a	48.75a	48.88a	49.93b
D	50.75a	50.88a	51.13a	51.50a	51.78b
E	43.38a	43.85a	44.45a	44.60a	45.88b

Treatment	3 HSR	6 HSR	9 HSR	12 HSR	15 HSR
F	49.48a	50.73a	52.05a	52.43a	54.00a
G	50.18a	50.75a	50.80a	51.15a	51.75b
H	53.35a	53.73a	54.40a	55.00a	55.70a

Remarks: The numbers in the same column followed by the same letter did not differ significantly at the 5% test level (BNT test). A = control; B = K fertilizer; C = B fertilizer; D = *Trichoderma* spp.; E = K + B; F = K + *Trichoderma* spp.; G = B + *Trichoderma* spp.; H = K + B + *Trichoderma* spp.

Source: Experimental data processed by the authors, 2026.

Leaf Area

Based on the results of the variety analysis in Table 3 and Table 4, the application of K, B, and biological agents *Trichoderma* spp. fertilizers did not show a significant effect of treatment on the leaf area of Arabica coffee seedlings at all observation times during the drought stress period and recovery. Drought stress is known to reduce cell turgor pressure and inhibit cell division and enlargement, which under certain conditions leads to limited leaf development (Chekol et al., 2024; Marthandan et al., 2020). However, in this study, the difference in leaf area between treatments was not statistically significant during the stress period.

The unnoticeable growth response to these leaf area parameters continues until the end of the recovery phase. These findings are in line with the research of (Worku, 2010) which found that the growth rate of leaf area during the 15 days of recovery was recorded similar to the growth rate when the plant was in a tight condition. This suggests that leaf area recovery in coffee seedlings is slow (Worku, 2010). This slow recovery of leaf area is thought to be closely related to the possibility of not having recovered the leaf water potential and full stomata conductance after rewatering (Rodrigues et al., 2024).

Table 3. Leaf Area (cm²) of Arabica Coffee on Various Days After Drought Stress (HSC)

Treatment	0 HSC	3 HSC	6 HSC	9 HSC	12 HSC	15 HSC	18 HSC
A	28.03a	28.46a	28.16a	27.62a	26.62a	26.92a	28.06a
B	31.38a	29.13a	29.58a	29.09a	28.09a	28.39a	28.11a
C	27.8a	26.0a	24.23a	23.54a	22.54a	22.84a	22.14a
D	31.46a	29.27a	29.72a	32.34a	31.34a	31.64a	26.85a
E	31.16a	27.96a	26.5a	27.71a	26.71a	27.01a	26.75a
F	33.96a	31.11a	31.91a	30.98a	29.98a	30.28a	29.58a
G	27.87a	29.67a	27.19a	26.4a	25.4a	25.7a	25.0a
H	29.05a	25.44a	28.05a	27.42a	26.42a	26.72a	26.02a

Remarks: The numbers in the same column followed by the same letter did not differ significantly at the 5% test level (BNT test). A = control; B = K fertilizer; C = B fertilizer; D = *Trichoderma* spp.; E = K + B; F = K + *Trichoderma* spp.; G = B + *Trichoderma* spp.; H = K + B + *Trichoderma* spp.

Source: Experimental data processed by the authors, 2026.

Table 4. Leaf Area (cm²) of Arabica Coffee on Various Days After Recovery (HSR)

Treatment	3 HSR	6 HSR	9 HSR	12 HSR	15 HSR
A	29.46a	29.39a	28.43a	28.91a	27.93a
B	29.51a	25.72a	24.76a	25.24a	25.58a
C	23.54a	25.36a	24.40a	24.88a	25.31a
D	28.25a	31.87a	30.91a	31.39a	24.08a
E	28.15a	29.83a	28.87a	29.35a	24.82a
F	30.98a	32.27a	31.31a	31.79a	31.08a
G	26.40a	25.44a	24.48a	24.96a	23.55a
H	27.42a	25.87a	24.91a	25.39a	29.81a

Remarks: The numbers in the same column followed by the same letter did not differ significantly at the 5% test level (BNT test). A = control; B = K fertilizer; C = B fertilizer; D = *Trichoderma* spp.; E = K + B; F = K + *Trichoderma* spp.; G = B + *Trichoderma* spp.; H = K + B + *Trichoderma* spp.

Source: Experimental data processed by the authors, 2026.

Number of Leaves

Based on the results of the variety analysis in Table 5 and Table 6, the application of K, B, and biological agents *Trichoderma* spp. fertilizers did not show a real effect of treatment on the number of Arabica coffee seedling leaves at all observation times during the drought and recovery stress periods. The decrease in water availability in the soil medium significantly inhibits cell division and elongation, thereby directly suppressing the development and formation of new leaves in coffee plants (Worku & Astatkie, 2010). In addition to inhibiting the growth of new leaves, in some treatments there is also a tendency to decrease the average number of leaves as the drought day increases. The decrease in the number of leaves in Arabica coffee seedlings during drought-stress conditions is thought to be related to an adaptive mechanism in the form of leaf shedding to limit the rate of transpiration (DaMatta *et al.*, 2018; Hasanuzzaman *et al.*, 2018).

Table 5. Number of Arabica Coffee Leaves (Strands) on Various Days After Drought Stress (HSC)

Treatment	0 HSC	3 HSC	6 HSC	9 HSC	12 HSC	15 HSC	18 HSC
A	24.3a	25.0a	25.0a	24.3a	24.3a	23.8a	23.8a
B	26.5a	28.3a	29.3a	29.8a	34.8a	37.3a	37.3a
C	28.0a	29.3a	29.5a	29.8a	29.8a	30.0a	30.0a
D	26.8a	27.3a	27.5a	27.5a	27.5a	28.8a	28.8a
E	24.0a	24.5a	25.3a	25.5a	24.5a	24.5a	24.5a
F	24.8a	25.3a	27.3a	30.0a	30.0a	29.8a	29.8a
G	20.8a	22.0a	24.0a	24.0a	24.0a	23.5a	24.0a
H	30.0a	32.0a	33.8a	34.8a	41.3a	41.3a	41.3a

Remarks: The numbers in the same column followed by the same letter did not differ significantly at the 5% test level (BNT test). A = control; B = K fertilizer; C = B fertilizer; D = *Trichoderma* spp.; E = K + B; F = K + *Trichoderma* spp.; G = B + *Trichoderma* spp.; H = K + B + *Trichoderma* spp.

Source: Experimental data processed by the authors, 2026.

The growth response that has not differed significantly in the leaf count parameter continues after the plant is watered again until the end of the recovery phase. The increase in the number of leaves is a vegetative morphological parameter controlled by the activity of apical meristem cell division and cell enlargement which requires a relatively slow and gradual response time (Gardner *et al.*, 1991; Worku & Astatkie, 2010; Ismaya *et al.*, 2023). As a result, the application of K, B, and biological agents *Trichoderma* spp. in this study did not provide a significant difference in the number of leaves compared to the control in the observation of 15 HSRs.

Table 6. Number of Arabica Coffee Leaves (Strands) on Various Days After Recovery (HSR)

Treatment	3 HSR	6 HSR	9 HSR	12 HSR	15 HSR
A	24.3a	24.0a	24.5a	24.3a	25.3a
B	34.8a	34.0a	34.0a	33.8a	33.8a
C	29.5a	27.3a	27.5a	29.0a	32.8a
D	29.0a	29.0a	29.0a	29.0a	29.0a
E	24.3a	23.8a	23.5a	23.8a	24.8a
F	30.3a	25.0a	27.3a	27.8a	29.3a
G	24.0a	23.8a	23.8a	23.5a	23.5a
H	39.3a	38.3a	37.5a	38.0a	38.5a

Remarks: The numbers in the same column followed by the same letter did not differ significantly at the 5% test level (BNT test). A = control; B = K fertilizer; C = B fertilizer; D = *Trichoderma* spp.; E = K + B; F = K + *Trichoderma* spp.; G = B + *Trichoderma* spp.; H = K + B + *Trichoderma* spp.

Source: Experimental data processed by the authors, 2026.

CONCLUSION

The application of potassium (K), boron (B), and *Trichoderma* spp., either individually or in combination, did not significantly affect plant height, leaf area, or leaf number in LS 795 Arabica coffee (*Coffea arabica* L.) seedlings during the 18-day drought stress period compared with the untreated control. These findings indicated that the tested treatments did not significantly mitigate drought-induced reductions in vegetative growth under the experimental conditions.

Statistically significant treatment effects were observed only for plant height during the recovery phase, specifically at 15 days after rewatering. The combined applications of K + *Trichoderma* spp. and K + B + *Trichoderma* spp. resulted in significantly greater plant heights than those observed in the untreated control. However, leaf area and leaf number did not differ significantly among treatments throughout the recovery period. These findings suggest that potassium supplementation combined with *Trichoderma* spp., either with or without boron, may support post-drought recovery of seedling height, although no significant improvements were observed in leaf development under the conditions evaluated.

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest in the research, writing, or publication of this article.

AUTHOR'S CONTRIBUTION

All authors contributed to the preparation of this article. Author 1 (Selly Gunawan) played a role in the conceptualization of the research, played a role in data collection and analysis, played a role in the interpretation of the results and the preparation of the manuscript, while the other authors contributed to the review, editing, and final approval of the manuscript.

GENERATIVE ARTIFICIAL INTELLIGENCE USAGE STATEMENT

The author states that no generative artificial intelligence was used in the preparation of this article.

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