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Growth and yield-related responses of hypoma 2 peanut to rice husk biochar rates under a controlled soil-water regime

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Attribution 4.0 International License**Abstract**

Low soil organic matter and limited water availability can constrain peanut productivity in former intensively cultivated paddy soils. This study evaluated the growth and yield-related responses of Hypoma 2 peanut to different rice husk biochar rates under a controlled soil-water regime. A greenhouse experiment was conducted from January to April 2026 in Tuban Regency, East Java, Indonesia, using a randomized block design with four biochar rates (0, 5, 10, and 15 t ha⁻¹) and four replications. Soil moisture was maintained at approximately 60% of field capacity across all treatments, and biochar was incorporated 10 days before planting. Plant height, leaf number, plant dry weight, and 100-seed weight were evaluated using analysis of variance followed by the least significant difference test at the 5% significance level. Biochar application significantly affected all measured variables. The highest numerical responses were recorded at 10 t ha⁻¹, with a plant height of 42.7 cm, 58.7 leaves plant⁻¹, plant dry weight of 21.6 g plant⁻¹, and 100-seed weight of 46.9 g. However, several responses were statistically comparable to those at 15 t ha⁻¹. These findings suggest that 10 t ha⁻¹ is the most promising biochar rate among those evaluated under the imposed soil-water conditions. Nevertheless, because only one moisture regime was tested, the results cannot establish biochar–water interactions or demonstrate drought-stress alleviation.

KEYWORDS

Dry cultivation; hypoma variety; limited water availability; rice husk biochar; soil amendment

1. INTRODUCTION

Peanut (*Arachis hypogaea* L.) is an important legume crop that contributes to food production, oilseed supply, and farm income, particularly in regions where smallholder agriculture depends on seasonal rainfall. Beyond its economic value, peanut supports diversified farming systems and contributes to soil fertility through biological

nitrogen fixation (Suyanto et al., 2025). Former paddy fields are generally maintained under flooded conditions during rice cultivation but are drained before being used for non-rice crops such as peanut. Following this transition, crop water supply depends on residual soil moisture and supplemental irrigation rather than standing water, and soil moisture may decline during the dry cultivation

phase. Peanut productivity is sensitive to such reductions in soil moisture, particularly when they restrict vegetative growth, biomass accumulation, pod filling, and seed development. Low soil organic matter can further intensify these constraints by reducing water retention, nutrient availability, and root-zone resilience (Murtaza et al., 2025). Rice husk biochar has therefore received increasing attention as a sustainable soil amendment because its porous structure and carbon-rich composition can improve soil physical properties, nutrient retention, and water-holding capacity.

Previous studies evaluated rice husk biochar or related biochar amendments in peanut and legume production, but their experimental conditions differed substantially from those of the present study. Fitria et al. (2024) tested rice husk biochar at 0, 0.6, 1.2, and 1.8 kg plot⁻¹ in combination with *Tithonia* liquid organic fertilizer in peanut and evaluated plant height, relative growth rate, flowering and harvest times, pod number, filled-pod percentage, dry pod and seed weights, and 100-seed weight. Water availability was not included as an experimental factor. Suyanto et al. (2025) evaluated rice husk-derived bioactive compost charcoal at 20–120 g polybag⁻¹ in alluvial soil and measured plant height, branch number, pod number, and wet and dry pod weights, but the amendment was a biochar–compost product and no controlled soil-water treatment was imposed. Zheng et al. (2021) applied biochar-based fertilizer at 0, 0.75, and 1.5 t ha⁻¹ under well-watered, moderate-water-stress, and severe-water-stress regimes and evaluated peanut morphophysiological traits, nutrient uptake, water use, and yield. However, that study used a formulated biochar-based fertilizer rather than rice husk biochar as a sole amendment. Research involving other crops also differed in soil and water conditions. Barus et al. (2023) tested rice husk biochar at 5, 10, and 20 t ha⁻¹ together with 5 t ha⁻¹ straw compost in a tropical upland rice–soybean system and evaluated soil chemical and physical properties, soil water content, and grain yield. Murtaza et al. (2025), by contrast, applied rice husk

biochar at 0, 2, and 4% (w/w) to paddy soil under continuously flooded conditions and assessed soil physical properties, rice growth, root development, and methane emissions.

These differences restrict the direct transfer of previous findings to peanut cultivation in former paddy soil because biochar responses depend on feedstock type, application rate, soil properties, nutrient status, water management, and crop genotype (Tadele et al., 2026). Hypoma 2 is an early-maturing peanut cultivar with an approximate maturity period of 90 days, a potential pod yield of 3.5 t ha⁻¹, and reported tolerance to drought during the generative stage (Sun et al., 2025). Field evaluation also identified Hypoma 2 as suitable for cultivation in highland rainfed paddy environments, supporting its relevance to non-flooded peanut production within paddy-based cropping systems (Fitria et al., 2024). Nevertheless, the available studies have not directly evaluated the responses of Hypoma 2 to graded field-equivalent rates of rice husk biochar applied as a sole amendment in low-organic-matter former paddy soil under a single controlled, non-flooded soil-water regime. Evidence is also limited regarding whether increasing rice husk biochar rates consistently enhances vegetative growth, dry matter accumulation, and seed weight or whether higher rates provide no additional agronomic benefit. Consequently, the present study evaluated rice husk biochar applied at 0, 5, 10, and 15 t ha⁻¹ and measured plant height, leaf number, plant dry weight, and 100-seed weight of Hypoma 2 peanut under these specific soil and water-management conditions.

This study hypothesized that Hypoma 2 peanut would respond differently to increasing rice husk biochar rates under a single controlled soil-water regime. The study aimed to evaluate the effects of rice husk biochar applied at 0, 5, 10, and 15 t ha⁻¹ on plant height, leaf number, plant dry weight, and 100-seed weight of Hypoma 2 peanut grown under greenhouse conditions with soil moisture maintained at approximately 60% of field capacity

(FC). These variables were selected as indicators of vegetative growth, dry matter accumulation, and yield-related performance. The findings were expected to provide a site-specific agronomic basis for using rice husk biochar as a soil amendment in former intensively cultivated paddy soil with low organic matter content. Because only one soil-water regime was applied, the study was designed to evaluate peanut responses to biochar rates under a defined soil-water condition rather than to assess interactions between biochar application and water availability. The use of locally available rice husk residues may support more sustainable soil amendment management, although further field validation under different soil-water regimes is required.

2. METHODS

2.1 Study Site and Experimental Conditions

The experiment was conducted from January to April 2026 in a greenhouse located at 6.914514° S and 112.137169° E (6°54'52.25" S, 112°08'13.81" E), Palang District, Tuban Regency, East Java, Indonesia, at an elevation of approximately 7 m above sea level. The experimental site was situated in a low-elevation area near the northern coast of East Java. Air temperature and relative humidity inside the greenhouse were not continuously recorded, which is acknowledged as a limitation of the study. Before treatment application, the initial physicochemical characteristics of the soil were determined using one composite soil sample prepared from 5 subsamples collected from different locations within the source field at a depth of 0–20 cm. The composite sample was air-dried, gently crushed, and passed through a 2-mm sieve before laboratory analysis. Soil particle-size distribution was determined using the hydrometer method, and the textural class was identified using the USDA textural triangle. Soil pH was measured potentiometrically in a 1:2.5 soil-to-water suspension. Soil organic carbon was determined using the Walkley–Black method, while soil organic matter was calculated by multiplying the

organic carbon value by 1.724. Total nitrogen was measured using the Kjeldahl method, available phosphorus using the Bray I method, and exchangeable potassium and cation exchange capacity using 1 M ammonium acetate extraction. Bulk density was determined using the core method, while field capacity was determined gravimetrically after 48 h of free drainage.

Before treatment application, the initial physicochemical characteristics of the soil were determined using one composite soil sample prepared from 5 subsamples collected from different locations within the source field at a depth of 0–20 cm

The soil had a clay-loam texture, consisting of 31.2% sand, 35.6% silt, and 33.2% clay. The initial soil pH was 6.18, while soil organic carbon and soil organic matter were 1.02% and 1.76%, respectively. Total nitrogen was 0.12%, available phosphorus was 12.8 mg kg⁻¹, exchangeable potassium was 0.28 cmol(+) kg⁻¹, and cation exchange capacity was 18.6 cmol(+) kg⁻¹. Bulk density was 1.29 g cm⁻³, and gravimetric field capacity was 31.4%. These results confirmed that the initial soil organic matter content was below 2%. The complete initial physicochemical characteristics and corresponding analytical methods are presented in [Table 1](#).

The initial soil pH was 6.18, while soil organic carbon and soil organic matter were 1.02% and 1.76%, respectively. Total nitrogen was 0.12%, available phosphorus was 12.8 mg kg⁻¹, exchangeable potassium was 0.28 cmol(+) kg⁻¹, and cation exchange capacity was 18.6 cmol(+) kg⁻¹

The remaining soil was air-dried, passed through a 20-mm sieve, thoroughly homogenized, and distributed uniformly among the experimental plots to reduce initial spatial variability. Each plot was prepared with a uniform soil depth of approximately 10 cm and a comparable soil volume.

Greenhouse cultivation excluded direct rainfall and minimized uncontrolled environmental variation among experimental units. Field capacity (FC) was determined before planting using the gravimetric method. Representative soil samples were saturated with water, allowed to drain freely for 48 h, weighed, oven-dried at 105°C to constant weight, and reweighed to determine the gravimetric water content at FC. The experimental soil-water condition was defined as a single controlled, non-flooded regime maintained at approximately 60% FC from 14 days after planting (DAP) until harvest. Soil moisture was monitored every two days, and irrigation water was added when required to restore

each plot to the designated moisture level. The same soil-water regime was applied uniformly across all rice husk biochar treatments. Experimental plots were prepared according to standard agronomic practices for peanut cultivation before treatment application.

Representative soil samples were saturated with water, allowed to drain freely for 48 h, weighed, oven-dried at 105°C to constant weight, and reweighed to determine the gravimetric water content at FC

Table 1. Example initial physicochemical characteristics of former paddy soil used for comparison

Soil property	Example value	Unit	Analytical method
Soil texture	Clay loam	—	Hydrometer method and USDA textural triangle
Sand	31.2	%	Hydrometer method
Silt	35.6	%	Hydrometer method
Clay	33.2	%	Hydrometer method
Soil pH (H ₂ O, 1:2.5)	6.18	—	Potentiometric method
Soil organic carbon	1.02	%	Walkley–Black method
Soil organic matter	1.76	%	Organic C × 1.724
Total nitrogen	0.12	%	Kjeldahl method
Available phosphorus	12.8	mg kg ⁻¹	Bray I method
Exchangeable potassium	0.28	cmol(+) kg ⁻¹	1 M NH ₄ OAc extraction
Cation exchange capacity	18.6	cmol(+) kg ⁻¹	1 M NH ₄ OAc extraction at pH 7
Bulk density	1.29	g cm ⁻³	Core method
Field capacity	31.4	% gravimetric	Gravimetric method after 48-h drainage

2.2 Experimental Design and Plant Material

Hypoma 2 peanut (*Arachis hypogaea* L.) was used as the plant material. Hypoma 2 is an upright-growing Indonesian peanut cultivar with an

approximate maturity period of 90 days, a yield potential of 3.5 t ha⁻¹, an average yield of 2.4 t ha⁻¹, and tolerance to drought during the generative stage (Oguz et al., 2022). Previous field evaluation in

rainfed paddy fields identified Hypoma 2 as suitable for cultivation in highland rainfed paddy environments, supporting its selection for the present experiment using former paddy soil under the imposed controlled soil-water regime (Budiyantri et al., 2025). Seeds were obtained from UPTD BP3MBTP, Gading Unit, Indonesia. The experiment followed a randomized block design (RBD) comprising four rice husk biochar treatments and four replications, resulting in 16 experimental units. Each experimental plot measured 12 m² and contained an equivalent amount of the prepared former paddy soil. Ten sample plants were randomly selected from the central area of each plot after excluding the outer rows and border plants to minimize edge effects. The selected plants were permanently labeled and used for all growth and yield-related measurements. Measurements from the ten plants were averaged to obtain one value for each plot, which served as the experimental unit for statistical analysis. The treatments comprised 0 t

ha⁻¹ without rice husk biochar application (b0), 5 t ha⁻¹ or 6 kg plot⁻¹ (b1), 10 t ha⁻¹ or 12 kg plot⁻¹ (b2), and 15 t ha⁻¹ or 18 kg plot⁻¹ (b3). The rates were selected with reference to previous studies evaluating rice husk biochar at 5–20 t ha⁻¹ under tropical cropping conditions (Barus et al., 2023), while the 5 t ha⁻¹ interval was used to provide a gradual assessment of crop responses within the selected range. Because the collected soil had been homogenized and distributed uniformly among the plots, blocking was primarily used to account for possible environmental gradients within the greenhouse, including differences in light exposure, temperature, and plot position. Treatments were randomly allocated within each block to reduce the influence of these residual environmental variations. The greenhouse setting, randomized block arrangement, biochar treatment structure, measured variables, and statistical workflow are summarized in Figure 1.

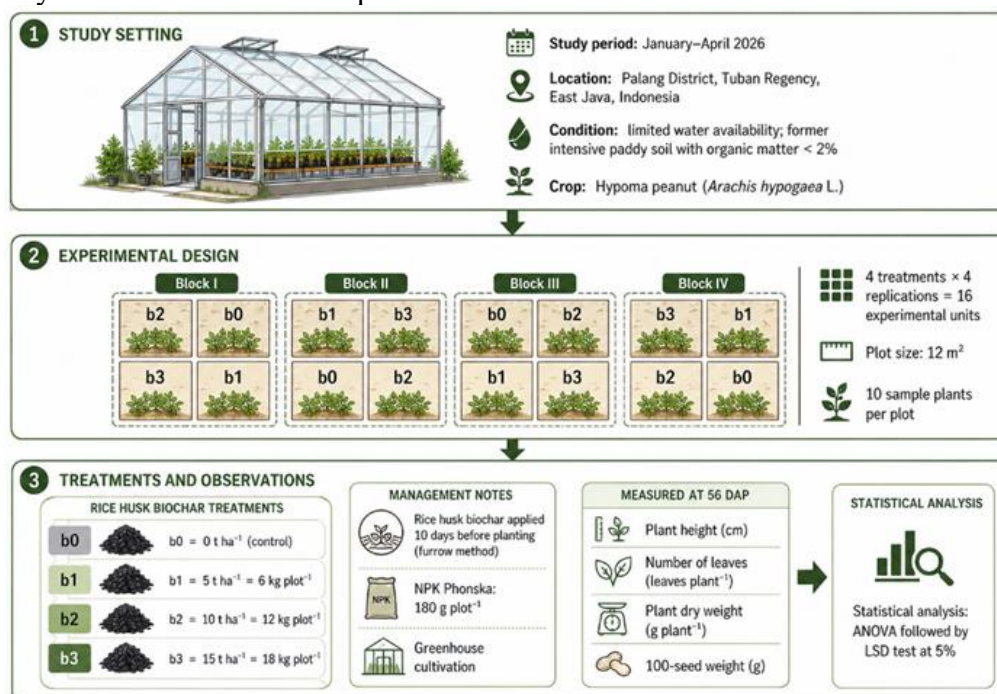


Figure 1. Schematic overview of the randomized block design used to evaluate the growth and yield-related responses of Hypoma 2 peanut to rice husk biochar applied at 0, 5, 10, and 15 t ha⁻¹ under a single controlled soil-water regime maintained at approximately 60% field capacity (FC). The experiment comprised four replications and 16 experimental units.

2.3 Rice Husk Biochar Production

Rice husk biochar used in this study was produced from locally available rice husk residues. Before pyrolysis, the rice husks were air-dried until reaching approximately 10% moisture content to improve combustion efficiency and promote more uniform carbonization. Biochar production was conducted using a gasification-based pyrolysis method for approximately 3 h. After completion of the carbonization process, the resulting biochar was immediately quenched with water to stop combustion and preserve the carbonized material. The exact pyrolysis temperature was not recorded during production and is recognized as a methodological limitation of the study.

2.4 Treatment Application and Crop Management

Rice husk biochar was applied once at the designated treatment rates and incorporated into the soil using the furrow application method 10 days before planting. The 10-day interval allowed initial interaction between the biochar and soil before crop establishment. Each experimental plot received the same basal application of NPK Phonska fertilizer at 180 g plot⁻¹ to maintain comparable nutrient inputs among treatments. Limited water availability was imposed from 14 days after planting (DAP) until harvest by maintaining soil moisture at approximately 60% of field capacity (FC). Soil moisture was monitored every two days at a depth of 0–20 cm using a calibrated soil-moisture meter. The instrument was calibrated against the gravimetric water-content values determined during the FC assessment. Irrigation was applied whenever soil moisture declined below the designated level and was discontinued once the target of approximately 60% FC was restored. The same soil-water regime was imposed uniformly across all rice husk biochar treatments, ensuring that water availability did not constitute an additional experimental factor. Peanut planting, weed control, pest management, and other crop-maintenance practices followed local agronomic

recommendations and were implemented uniformly across all experimental plots.

Peanut planting, weed control, pest management, and other crop-maintenance practices followed local agronomic recommendations and were implemented uniformly across all experimental plots

2.5 Growth and Yield Measurements

Plant observations were conducted at 56 days after planting (DAP). Growth variables included plant height (cm), number of leaves (leaves plant⁻¹), and plant dry weight (g plant⁻¹), while yield performance was evaluated using 100-seed weight (g). Plant height was measured from the soil surface to the highest growing point. Leaf number was determined by counting fully expanded leaves. Plant dry weight was obtained after drying plant samples to constant weight. Seed weight was measured using 100 randomly selected seeds from each experimental unit. All measurements were performed on the ten previously selected and labeled sample plants in each plot.

2.6 Statistical Analysis

All collected data were analyzed using analysis of variance (ANOVA) appropriate for a randomized block design to evaluate the effect of rice husk biochar application on peanut growth and yield variables. Before conducting ANOVA, the data were assessed for normality and homogeneity of variance assumptions. When treatment effects were significant at $p < 0.05$, mean separation was performed using the least significant difference (LSD) test at the 5% significance level. Statistical analyses were conducted using appropriate statistical software, and the results are presented as treatment means accompanied by their corresponding significance levels.

Before conducting ANOVA, the data were assessed for normality and homogeneity of variance assumptions

3. RESULT AND DISCUSSION

3.1 Effect on vegetative growth of hypoma peanut

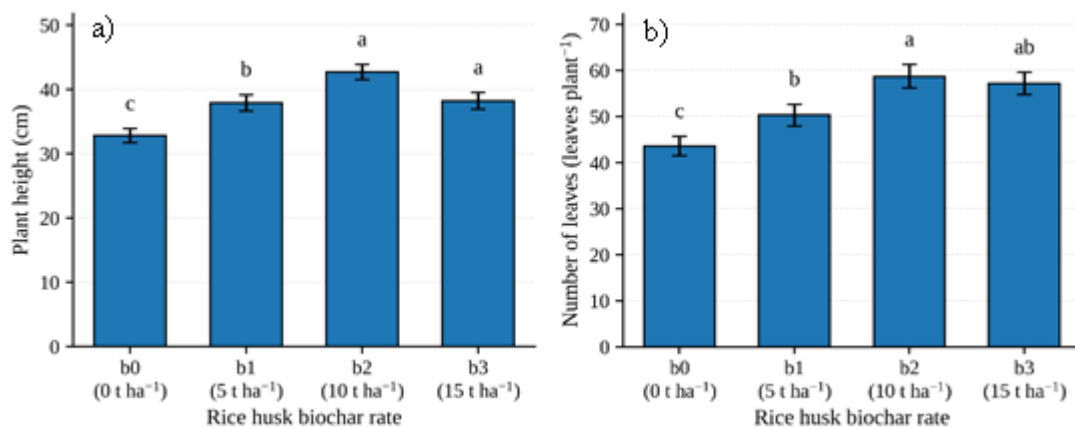


Figure 2. Vegetative growth responses of Hypoma 2 peanut to different rice husk biochar rates under a single controlled soil-water regime maintained at approximately 60% field capacity (FC) at 56 days after planting (DAP): (a) plant height and (b) leaf number. Treatments consisted of b0 = 0 t ha⁻¹, b1 = 5 t ha⁻¹, b2 = 10 t ha⁻¹, and b3 = 15 t ha⁻¹ rice husk biochar. Bars represent treatment means ± standard error (SE) based on four replications. Different lowercase letters indicate significant differences among treatments according to the least significant difference (LSD) test at $p < 0.05$

Vegetative growth provides an early indication of the response of Hypoma 2 peanut to rice husk biochar application under the imposed controlled soil-water regime. Plant height and leaf number at 56 days after planting (DAP) are presented in [Figure 2](#). Plant height increased from 32.8 ± 1.10 cm in the control treatment to 37.9 ± 1.25 cm at 5 t ha⁻¹, 42.7 ± 1.18 cm at 10 t ha⁻¹, and 38.2 ± 1.30 cm at 15 t ha⁻¹. The 10 t ha⁻¹ treatment produced the highest numerical value, representing a 30.2% increase compared with the control. However, the 10 and 15 t ha⁻¹ treatments shared the same significance letter, indicating that their plant height responses were statistically comparable according to the least significant difference (LSD) test at $p < 0.05$.

Greater plant height following rice husk biochar application may have been associated with changes in the physical, chemical, and biological conditions of the root zone. Evidence from peanut-specific studies supports this interpretation. Fitria et al. (2024) reported that rice husk biochar significantly affected peanut plant height and other

growth and production variables, although their experiment also included Tithonia liquid organic fertilizer. Rice husk-derived bioactive compost charcoal similarly affected plant height, branch formation, and yield-related traits of peanut grown in alluvial soil (Suyanto et al., 2025). A field study comparing biochars from several feedstocks further showed that rice husk biochar promoted peanut root development and biological nitrogen fixation and influenced soil aggregation and moisture retention, although its effects on kernel yield differed from those of other feedstocks (Liu et al., 2024). These studies provide crop-specific evidence that rice husk-derived biochar can modify conditions relevant to peanut vegetative development. Nevertheless, the present experiment did not measure root growth, biological nitrogen fixation, or biochar-induced changes in soil moisture; therefore, these mechanisms remain plausible explanations rather than directly demonstrated processes.

Leaf production showed a stronger response than plant height. Leaf number increased from 43.6

± 2.10 leaves plant⁻¹ in the control treatment to 50.3 ± 2.35 leaves plant⁻¹ at 5 t ha^{-1} , 58.7 ± 2.55 leaves plant⁻¹ at 10 t ha^{-1} , and 57.2 ± 2.40 leaves plant⁻¹ at 15 t ha^{-1} . The 10 t ha^{-1} treatment produced the highest leaf number, corresponding to a 34.6% increase compared with the control, whereas the 15 t ha^{-1} treatment produced a 31.2% increase. Statistical grouping showed that 10 t ha^{-1} resulted in a significantly greater leaf number than the control and 5 t ha^{-1} treatments. The 15 t ha^{-1} treatment produced an intermediate response because it shared significance letters with both the 5 and 10 t ha^{-1} treatments.

Improved canopy development at the moderate and higher biochar rates may have reflected greater nutrient retention and more favorable root-zone physical conditions. Evidence from another legume crop showed that rice husk biochar applied with straw compost at 10 and 20 t ha^{-1} increased soil porosity, soil water content, and soybean yield compared with the control (Barus et al., 2023). Although that study was conducted in a tropical upland system rather than former paddy soil, it provides legume-specific evidence that rice husk biochar can alter soil conditions associated with crop development. Peanut studies have likewise reported positive effects of rice husk biochar or rice husk-derived bioactive compost charcoal on vegetative and reproductive traits (Fitria et al., 2024; Suyanto et al., 2025). The contribution of soil-water modification could not be isolated in the present study because all treatments were maintained under the same controlled soil-water regime.

Plant height and leaf number did not increase proportionally with increasing rice husk biochar rates. Both variables reached their highest numerical values at 10 t ha^{-1} and declined slightly at 15 t ha^{-1} . Such a response indicates that increasing the application rate did not result in a continuous improvement in vegetative growth. Feedstock characteristics, application rate, soil texture, initial fertility, and pyrolysis conditions can influence biochar performance (Khan et al., 2024; Ndede et al., 2022). More specifically, rice husk biochar

applied to paddy soil was reported to reduce bulk density and increase total pore volume, saturated hydraulic conductivity, and available soil water content, demonstrating that this feedstock can modify the physical properties of paddy-derived soil (Pratiwi & Shinogi, 2016). However, that experiment involved flooded rice rather than a non-flooded legume crop, and its findings should not be transferred directly to peanut cultivation.

3.2 Effect on plant dry matter accumulation

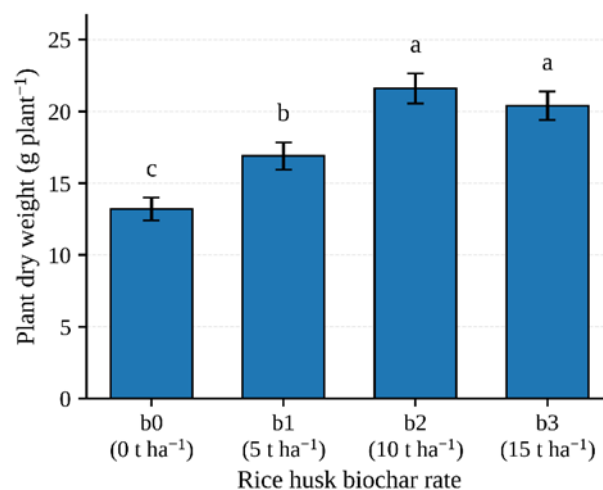


Figure 3. Plant dry weight of Hypoma 2 peanut as affected by different rice husk biochar rates under a single controlled soil-water regime maintained at approximately 60% field capacity (FC) at 56 days after planting (DAP). Treatments consisted of b0 = 0 t ha^{-1} , b1 = 5 t ha^{-1} , b2 = 10 t ha^{-1} , and b3 = 15 t ha^{-1} rice husk biochar. Bars represent treatment means $\pm$ standard error (SE) based on four replications. Different lowercase letters indicate significant differences among treatments according to the least significant difference (LSD) test at $p < 0.05$.

Plant dry weight reflects net dry matter accumulation and the capacity of peanut plants to convert acquired resources into structural biomass during growth. The response of plant dry weight to different rice husk biochar rates at 56 days after planting (DAP) is presented in Figure 3. Plant dry weight increased from $13.2 \pm 0.80 \text{ g plant}^{-1}$ in the control treatment to $16.9 \pm 0.95 \text{ g plant}^{-1}$ at 5 t ha^{-1} ,

21.6 ± 1.05 g plant⁻¹ at 10 t ha⁻¹, and 20.4 ± 1.00 g plant⁻¹ at 15 t ha⁻¹. The 10 t ha⁻¹ treatment produced the highest numerical mean, representing a 63.6% increase compared with the control, whereas the 15 t ha⁻¹ treatment resulted in a 54.5% increase. Nevertheless, the 10 and 15 t ha⁻¹ treatments produced statistically comparable plant dry weights, and both were significantly greater than the control and 5 t ha⁻¹ treatments according to the least significant difference (LSD) test at $p < 0.05$.

Greater plant dry weight following rice husk biochar application indicates enhanced biomass accumulation under the imposed controlled soil-water regime. The response may have resulted from combined changes in nutrient retention, root-zone physical conditions, and plant resource acquisition. The surface area, pore structure, and functional groups of biochar can facilitate cation exchange and nutrient adsorption, while its porous structure may also influence soil water retention (Kabir et al., 2023; Pandian et al., 2024; Razzaghi et al., 2020). More crop-specific evidence supports this interpretation. Rice husk biochar significantly affected relative growth rate, dry pod weight, and dry seed weight of peanut in a factorial experiment that also included Tithonia liquid organic fertilizer (Fitria et al., 2024). Rice husk-derived bioactive compost charcoal also significantly affected pod dry weight and other agronomic characteristics of peanut grown in alluvial soil (Suyanto et al., 2025). Although these studies did not measure whole-plant dry weight under conditions identical to those of the present experiment, they provide peanut-specific evidence that rice husk-derived amendments can support biomass production and assimilate allocation.

Evidence from legume and paddy-soil studies provides further context for the observed biomass response. Rice husk biochar applied at 10 and 20 t ha⁻¹ together with straw compost increased soil total carbon, porosity, soil water content, and soybean yield compared with the control, indicating that rice husk-derived amendments can improve soil conditions relevant to legume growth (Barus et al.,

2023). Rice husk biochar applied to paddy soil also reduced bulk density and increased total pore volume, saturated hydraulic conductivity, and available soil water content (Pratiwi & Shinogi, 2016). Another field study in nutrient-poor paddy soil reported increases in soil water-holding capacity, soil moisture, total carbon, nitrogen, phosphorus, microbial biomass, and paddy productivity following rice husk biochar application (Culas et al., 2025). These studies provide feedstock- and soil-specific evidence for possible mechanisms underlying biomass accumulation. However, flooded rice systems and tropical upland soybean cultivation differ from the non-flooded former paddy soil used in the present study; therefore, their findings cannot be transferred directly to Hypoma 2 peanut.

The non-linear response observed in the present study indicates that increasing the rice husk biochar rate beyond 10 t ha⁻¹ did not produce a proportional increase in plant dry weight. The slight numerical decline at 15 t ha⁻¹ suggests a plateau in biomass response rather than a continuous rate-dependent increase. Biochar performance can vary with feedstock characteristics, application rate, soil texture, soil-water conditions, and pyrolysis-related properties (Pandian et al., 2024; Razzaghi et al., 2020). Field evidence from a maize-peanut intercropping system showed that biochar increased soil water storage, mineral nitrogen availability at later growth stages, and total system yield (Luan et al., 2021). However, that study was conducted under a field-based intercropping system, whereas the present experiment evaluated greenhouse-grown Hypoma 2 peanut under monoculture. Therefore, its findings provide contextual support for the potential effects of biochar on soil water and nutrient conditions but are not directly comparable to the dry-matter response observed in the present study.

Field evidence from a maize-peanut intercropping system showed that biochar increased soil water storage, mineral

*nitrogen availability at later growth stages,
and total system yield*

3.3 Effect on yield-related performance of hypoma peanut

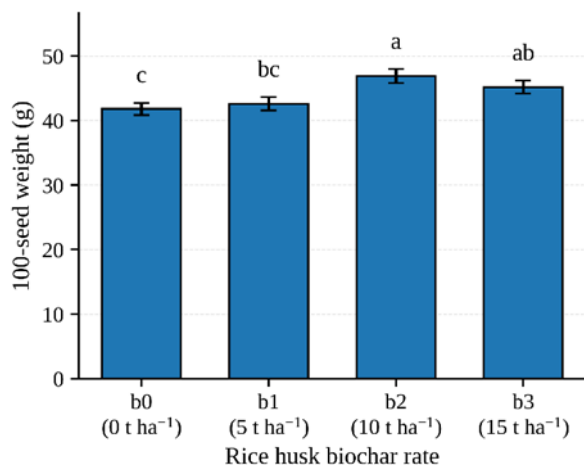


Figure 4. One hundred-seed weight of Hypoma 2 peanut as affected by different rice husk biochar rates under a single controlled soil-water regime maintained at approximately 60% field capacity (FC). Treatments consisted of b0 = 0 t ha⁻¹, b1 = 5 t ha⁻¹, b2 = 10 t ha⁻¹, and b3 = 15 t ha⁻¹ rice husk biochar. Bars represent treatment means ± standard error (SE) based on four replications. Different lowercase letters indicate significant differences among treatments according to the least significant difference (LSD) test at $p < 0.05$.

Seed weight is an important yield-related trait because it reflects assimilate allocation to developing seeds during the seed-filling period. The response of 100-seed weight to different rice husk biochar rates is presented in [Figure 4](#). The control treatment produced a 100-seed weight of 41.8 ± 0.95 g, whereas the values obtained at 5, 10, and 15 t ha⁻¹ were 42.6 ± 1.05 , 46.9 ± 1.10 , and 45.2 ± 1.00 g, respectively. The 10 t ha⁻¹ treatment produced the highest numerical mean, representing a 12.2% increase compared with the control. Nevertheless, the 10 and 15 t ha⁻¹ treatments shared the same significance grouping, indicating that their 100-seed weights were statistically comparable according to the least significant difference (LSD) test at $p < 0.05$.

The 5 t ha⁻¹ treatment produced only a small numerical increase and remained statistically comparable with the control. Therefore, the lower biochar rate did not produce a statistically detectable improvement in 100-seed weight under the experimental conditions.

Greater 100-seed weight at the moderate and higher rice husk biochar rates may reflect improved resource availability and assimilate allocation during seed filling. Peanut-specific evidence provides support for this interpretation. Fitria et al. (2024) reported that the main effect of rice husk biochar significantly influenced peanut production variables, including 100-seed weight, although their factorial experiment also included Tithonia liquid organic fertilizer. Rice husk-derived bioactive compost charcoal also affected the growth and yield-related characteristics of peanut cultivated in alluvial soil (Suyanto et al., 2025). These studies provide more direct evidence that rice husk-derived amendments can influence peanut seed development, although differences in amendment composition, soil conditions, and crop management limit direct comparison with the present experiment.

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Peanut responses to biochar may also differ between total yield and individual seed weight. Wang et al. (2021) reported that biochar applied at 10 t ha⁻¹ increased peanut yield and kernel yield by improving photosynthetic performance and plant nitrogen accumulation. However, biochar application did not significantly affect 100-kernel weight in that study, indicating that increased crop yield does not necessarily result from larger individual seeds. The greater 100-seed weight observed in the present study may therefore

represent a site- and treatment-specific response rather than a universal effect of biochar application. Nutrient availability, assimilate production, pod number, seed number, and competition among developing seeds may jointly influence final seed weight, but these processes were not measured in the present experiment.

Evidence from legume and paddy-soil studies provides additional context for possible soil-mediated responses. Barus et al. (2023) reported that rice husk biochar applied at 10 or 20 t ha⁻¹ together with straw compost increased soil porosity, soil water content, and soybean yield compared with the control. Rice husk biochar applied to paddy soil also decreased bulk density and increased total pore volume, saturated hydraulic conductivity, and available soil water content (Nguyen et al., 2024). These findings indicate that rice husk biochar can modify physical conditions relevant to nutrient and water supply in legume and paddy-soil systems. However, the soybean study included straw compost, while the paddy-soil study was conducted under continuously flooded rice cultivation. Their results therefore provide supporting mechanistic context rather than direct evidence for peanut cultivated under the non-flooded conditions of the present study.

The slight numerical decline in 100-seed weight at 15 t ha⁻¹ indicates that the response did not increase proportionally with the rice husk biochar rate. A similar rate-dependent pattern was reported by Wang et al. (2021), who found that peanut and kernel yields were highest at 10 t ha⁻¹ and declined at a higher application rate, although their biochar feedstock and growing conditions differed from those used in the present study. Biochar performance can vary with application rate, feedstock characteristics, pyrolysis conditions, initial soil fertility, and crop requirements. Soil moisture, nutrient availability, photosynthetic performance, and assimilate partitioning were not measured in the present experiment; consequently, the mechanisms responsible for the seed-weight response could not be directly identified.

4. CONCLUSION

This study evaluated the growth and yield-related responses of Hypoma 2 peanut to rice husk biochar rates under a single controlled soil-water regime maintained at approximately 60% FC. Rice husk biochar significantly affected plant height, leaf number, plant dry weight, and 100-seed weight. The 10 t ha⁻¹ treatment produced the highest numerical mean for each measured variable, while the 15 t ha⁻¹ treatment produced slightly lower values that were statistically comparable for several variables. Increasing the biochar rate from 10 to 15 t ha⁻¹ therefore provided no consistent additional agronomic benefit under the experimental conditions. These findings identify 10 t ha⁻¹ as the rate with the highest overall numerical responses among the rates evaluated, but do not establish it as an optimum or statistically superior rate. The experiment used only one soil-water regime; therefore, the results cannot demonstrate an interaction between rice husk biochar and water availability or confirm that biochar alleviates drought stress. Further factorial field experiments involving multiple soil-water regimes are required to evaluate biochar × water availability interactions. Future studies should also examine soil moisture dynamics, nutrient availability, pod and seed yield, long-term biochar effects, and economic feasibility across growing seasons.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Nofal Dwi Baskara conceived the research idea, developed the study design, conducted the literature review, coordinated the research activities, analyzed and interpreted the data, and took primary responsibility for writing, revising, and finalizing the manuscript from inception to completion. Rahemi, Syafitri Dewi and Agus Pahrevi contributed substantially to the implementation of the research by assisting in field activities, including plot preparation, fertilizer application, sample collection, field observations, and data recording. All authors participated in discussions of the

research findings and approved the final version of the manuscript.

ETHICS APPROVAL

No ethical approval was needed for this study.

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CONFLICT OF INTEREST

The author declares no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data available by request.

REFERENCES

- Barus, J., Ernawati, R. E. R., Wardani, N., Pujiharti, Y., Suretno, N. D., & Slameto, S. (2023). Improvement in soil properties and soil water content due to the application of rice husk biochar and straw compost in tropical upland. *International Journal of Recycling of Organic Waste in Agriculture*, 12(1). <https://doi.org/10.30486/IJROWA.2022.1942099.1355>
- Budiyanti, A. E., Hemon, A. F., & Farida, N. (2025). Komponen dan Daya Hasil Empat Varietas Kacang Tanah (*Arachis hypogaea* L.) yang diberi Plant Growth Promoting Rhizobacteria (PGPR). *Jurnal Ilmiah Mahasiswa Agrokomplek*, 4(1), 9-16. <https://doi.org/10.29303/jima.v4i1.6203>
- Culas, R. J., Anwar, M. R., & Maraseni, T. N. (2025). A framework for evaluating benefits of organic fertilizer use in agriculture. *Journal of Agriculture and Food Research*, 19, 101576. <https://doi.org/10.1016/j.jafr.2024.101576>
- Fitria, Y., Zahrah, S., & Sabli, T. E. (2024). Uji aplikasi biochar sekam padi dan POC tithonia untuk peningkatan pertumbuhan dan produksi tanaman kacang tanah (*Arachis hypogaea* L.). *Ekoagrotrop*, 2(1), 81-89. <https://doi.org/10.25299/ekoagrotrop.2024.22156>
- Kabir, E., Kim, K.-H., & Kwon, E. E. (2023). Biochar as a tool for the improvement of soil and environment [Review]. *Frontiers in Environmental Science*, Volume 11 - 2023. <https://doi.org/10.3389/fenvs.2023.1324533>
- Khan, S., Irshad, S., Mehmood, K., Hasnain, Z., Nawaz, M., Rais, A., Gul, S., Wahid, M. A., Hashem, A., & Abd Allah, E. F. (2024). Biochar production and characteristics, its impacts on soil health, crop production, and yield enhancement: A review. *Plants*, 13(2), 166. <https://doi.org/10.3390/plants13020166>
- Liu, C., Tian, J., Chen, L., He, Q., Liu, X., Bian, R., Zheng, J., Cheng, K., Xia, S., Zhang, X., Wu, J., Li, L., Joseph, S., & Pan, G. (2024). Biochar boosted high oleic peanut production with enhanced root development and biological N fixation by diazotrophs in a sand-loamy Primisol. *Science of The Total Environment*, 932, 173061. <https://doi.org/10.1016/j.scitotenv.2024.173061>
- Luan, C., He, W., Su, X., Wang, X., Bai, Y., & Wang, L. (2021). Effects of biochar on soil water and temperature, nutrients, and yield of maize/soybean and maize/peanut intercropping systems. *International Agrophysics*, 35(4), 365-373. <https://doi.org/10.31545/intagr/144133>
- Murtaza, G., Ahmed, Z., Iqbal, R., & Deng, G. (2025). Biochar from agricultural waste as a strategic resource for promotion of crop growth and nutrient cycling of soil under drought and salinity stress conditions: a comprehensive review with context of climate change. *Journal of*

- Plant Nutrition, 48(11), 1832-1883. <https://doi.org/10.1080/01904167.2025.2460769>
- Ndede, E. O., Kurebito, S., Idowu, O., Tokunari, T., & Jindo, K. (2022). The Potential of Biochar to Enhance the Water Retention Properties of Sandy Agricultural Soils. *Agronomy*, 12(2), 311. <https://doi.org/10.3390/agronomy12020311>
- Nguyen, C. N., Chau, H.-W., Kumar, A., Chakraborty, A., & Muttill, N. (2024). Biochar Amendment in Green Roof Substrate: A Comprehensive Review of the Benefits, Performance, and Challenges. *Applied Sciences*, 14(16), 7421.
- Oguz, M. C., Aycan, M., Oguz, E., Poyraz, I., & Yildiz, M. (2022). Drought Stress Tolerance in Plants: Interplay of Molecular, Biochemical and Physiological Responses in Important Development Stages. *Physiologia*, 2(4), 180-197. <https://doi.org/10.3390/physiologia2040015>
- Pandian, K., Vijayakumar, S., Mustaffa, M. R. A. F., Subramanian, P., & Chitraputhirapillai, S. (2024). Biochar – a sustainable soil conditioner for improving soil health, crop production and environment under changing climate: a review [Review]. *Frontiers in Soil Science*, Volume 4 - 2024. <https://doi.org/10.3389/fsoil.2024.1376159>
- Pratiwi, E. P. A., & Shinogi, Y. (2016). Rice husk biochar application to paddy soil and its effects on soil physical properties, plant growth, and methane emission. *Paddy and Water Environment*, 14(4), 521-532. [10.1007/s10333-015-0521-z](https://doi.org/10.1007/s10333-015-0521-z)
- Razzaghi, F., Obour, P. B., & Arthur, E. (2020). Does biochar improve soil water retention? A systematic review and meta-analysis. *Geoderma*, 361, 114055. <https://doi.org/10.1016/j.geoderma.2019.114055>
- Sun, M., Fan, S., & Zhang, N. (2025). Effects of biochar combined with the application of plant ash and effective microorganisms on the soil in the vegetable facility. *Scientific Reports*, 15(1), 15824. <https://doi.org/10.1038/s41598-025-98684-8>
- Suyanto, A., Indrawati, U. S. Y. V., Rosalina, S., & Kurniadi, E. (2025). Effect of Rice Husk Bioactive Compost Charcoal Application on the Agronomic Characteristics of Peanut (*Arachis hypogaea* L.) on Alluvial Soil. *Jurnal Teknik Pertanian Lampung (Journal of Agricultural Engineering)*, 14(2), 372-379. <https://doi.org/10.23960/jtep-l.v14i2.372-379>
- Tadele, H., Feyisa, T., Tsegaye, L., & Musie, S. (2026). Effects of biochar, vermicompost, and inorganic N-P nutrients on soil physical properties, maize growth, and yield, Northwest Ethiopia. *Arid Land Research and Management*, 40(3), 423-440. <https://doi.org/10.1080/15324982.2026.2650741>
- Wang, S., Zheng, J., Wang, Y., Yang, Q., Chen, T., Chen, Y., Chi, D., Xia, G., Siddique, K. H. M., & Wang, T. (2021). Photosynthesis, Chlorophyll Fluorescence, and Yield of Peanut in Response to Biochar Application [Original Research]. *Frontiers in Plant Science*, Volume 12 - 2021. <https://doi.org/10.3389/fpls.2021.650432>
- Zheng, J., Wang, S., Wang, R., Chen, Y., Siddique, K. H., Xia, G., & Chi, D. (2021). Ameliorative roles of biochar-based fertilizer on morpho-physiological traits, nutrient uptake and yield in peanut

(*Arachis hypogaea* L.) under water stress.
Agricultural Water Management, 257,
107129.
<https://doi.org/10.1016/j.agwat.2021.107129>