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Optimizing Shade Level to Improve Vegetative Growth and Shoot Biomass of Patchouli (*Pogostemon cablin* Benth.) in Tomohon, North Sulawes.

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Abstract. Light availability is a key environmental factor controlling vegetative growth in patchouli, yet practical shade recommendations remain location specific. This study evaluated the effects of graded shading on patchouli (*Pogostemon cablin Benth*.) growth and shoot biomass under local conditions in Kakaskasen Dua, Tomohon City, North Sulawesi, Indonesia (March to October 2025). A randomized block design was applied with four shade levels (0%, 25%, 50%, and 75%) and five replications. Plant height and branch number were recorded at 30 and 60 days after planting, while shoot fresh weight and shoot dry weight were measured as aboveground biomass indicators. Shading significantly affected plant morphology and biomass accumulation. The 25% shade treatment produced the highest plant height (70.6 cm at 30 days and 88.0 cm at 60 days) and the greatest branch number (18.2 at 30 days and 33.2 at 60 days). Biomass responses were consistent with morphological outcomes, as 25% shade resulted in the highest shoot fresh weight (657.4 g) and shoot dry weight (214.4 g), followed by 50% shade, whereas open conditions and 75% shade produced lower biomass. Overall, moderate shading at approximately 25% provided the most favorable light environment for improving patchouli vegetative performance and shoot biomass in this study area.

Keywords: Branching, Light management, Patchouli, Shade level, Shoot biomass

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INTRODUCTION

Patchouli (*Pogostemon cablin Benth*) is a Lamiaceae species cultivated primarily for its essential oil, which is widely valued in perfumery, cosmetics, and related industries because of its distinctive aroma and strong fixative properties (Lal et al., 2023). Patchouli is indigenous to tropical Southeast Asia and is strongly associated with Indonesia as a major center of cultivation and supply (Irman et al., 2025). Despite its high economic value, patchouli production in Indonesia often faces practical constraints linked to suboptimal crop management and variable growing environments, which can limit biomass production and the quality attributes that determine market acceptance (Ernawati et al., 2021). Soil quality has been linked to patchouli yield across cropping systems in Aceh, Indonesia (Nisa et al., 2024).

Among environmental drivers, light availability is a central factor shaping plant growth and yield because it controls photosynthesis and also regulates plant development through photoreceptors and hormone mediated signaling networks (Yetgin et al., 2025). Changes in light intensity can alter biomass allocation, leaf structure, and the accumulation of secondary metabolites, including terpenoids that constitute essential oils in many Lamiaceae crops (Barbosa et al., 2021). In low light conditions, plants commonly express plastic morphological responses such as enhanced stem elongation and changes in branching patterns, responses that are closely linked to hormonal regulation under shaded environments (Ghorbel et al., 2023; Hashemifar et al., 2024).

For patchouli specifically, recent experimental evidence shows that shading can substantially modify both growth and essential oil related traits, but the direction and magnitude of responses depend on shade level and production context. In controlled shade net environments, patchouli grown under shading often produces greater leaf, stem, root, and total dry biomass than plants grown under full sun, and some shading treatments can also enhance essential oil yield even when the composition of key constituent's changes. Field oriented studies likewise indicate that partial shade can improve vegetative performance and may increase essential oil recovery and yield compared with fully open conditions, whereas deep shade can increase leaf expansion but does not necessarily translate into higher biomass and oil yield (Ribeiro et al., 2021). In Indonesian production settings, shade level is also linked to practical outcomes such as plant height, branching, biomass, and essential oil yield, with recent work in lowland conditions showing that higher shade levels can enhance vegetative growth and that optimal essential oil yield may depend on the interaction between shade and harvest age (Riti et al., 2025).

Although these studies confirm that light management is agronomically important, a clear research gap remains for location specific recommendations in many Indonesian growing areas. Farmers often cultivate patchouli under open fields or under partial shade without quantifying the proportion of light received by the crop, making it difficult to translate general guidance into practical on farm decisions. In addition, much of the recent literature emphasizes essential oil yield, quality, or anatomical traits under selected shade intensities, while fewer studies provide a focused assessment of easily observed morphological indicators (such as plant height, branching, and shoot biomass) under a simple graded shade series that can be implemented by smallholders (N.D et al., 2025; Ribeiro et al., 2021). This evidence gap is particularly relevant for highland vegetable and mixed farming landscapes where patchouli may be integrated into shaded or semi shaded niches and where microclimate differs from lowland production systems.

This study addresses the gap by evaluating patchouli morphological responses under four shade levels (0%, 25%, 50%, and 75%) under the local conditions of Kakaskasen Dua, Tomohon (North Sulawesi, Indonesia). The novelty of this work lies in applying a field-relevant shade gradient that reflects realistic farmer options and linking shade treatments to practical morphological performance indicators that can support cultivation decisions and serve as early proxies for biomass productivity. Therefore, this study aimed to quantify the effects of graded shading on plant height, branching, and shoot biomass of patchouli under highland conditions.

MATERIALS AND METHODS

Study area and study period

The experiment was conducted in Kakaskasen (Tomohon City, North Sulawesi, Indonesia), with laboratory support from the Plant Science Laboratory, Faculty of Agriculture, Universitas Sam Ratulangi. The study was carried out from March 2025 to October 2025.

Materials and experimental preparation

Patchouli (*Pogostemon cablin Benth*.) was established using stem cuttings with an approximate length of 15 cm. The planting medium was prepared by air-drying the soil, then crushing and sieving it prior to use. Polybags were filled with approximately 10 kg of air-dried soil per polybag. Basal fertilization was applied using chicken manure and compound NPK fertilizer before planting. Cuttings were planted into polybags and maintained under the assigned shade treatments. During early establishment, plants were covered with a temporary cover (sungkup), which was removed 15 days after planting.

Experimental design and shade treatments

The experiment used a randomized block design (*Rancangan Acak Kelompok*, RAK) (Wandari et al., 2025) with four shade levels: 0% (no shade), 25% shade, 50% shade, and 75% shade. Each treatment was replicated five times (five blocks), resulting in 20 experimental units. To make the treatment structure and observation schedule easy to follow, the shade treatments, replication, and measurement times are summarized in Table 1.

Table 1. Shade treatments, replication, and measurement schedule for patchouli (*Pogostemon cablin Benth*.)

Item	Description
Experimental design	Randomized block design (Rancangan Acak Kelompok)
Treatments (shade levels)	0% (no shade), 25%, 50%, 75%
Treatment codes	A (0%), B (25%), C (50%), D (75%)
Replication	5 blocks; 20 experimental units total
Growth variables	Plant height; number of branches
Biomass variables	Shoot fresh weight; shoot dry weight
Growth measurement times	30 and 60 days after planting
Biomass sampling time	At harvest or final sampling round [timing not reported in the docx]
Statistical analysis	ANOVA (F test) followed by LSD at 5% (BNT 5%)

Table 1 indicates that the study compared patchouli growth under a graded shade series using a replicated block layout, allowing the effects of shade level to be evaluated while accounting for field variability among blocks. The table also shows that plant height and branch number were assessed at 30 and 60 days after planting, and that shoot fresh and dry weights were used as aboveground biomass indicators.

Crop maintenance

Plant maintenance included irrigation, supplementary fertilization, and management of pests, diseases, and weeds during the experimental period(Manda et al., 2021).

Observed variables and data collection

The observed variables were plant height, number of branches, shoot fresh weight, and shoot dry weight (Chen et al., 2019). Plant height and branch number were recorded at 30 and 60 days after planting. Shoot fresh weight and shoot dry weight were determined to represent shoot biomass.

Statistical analysis

Data were analyzed using the F test (analysis of variance) (Jones et al., 2023; Kumar, 2024). When treatment effects were significant, mean separation was performed using the least significant difference test at the 5% level (BNT 5%).

RESULTS AND DISCUSSION

Effects of shading on plant height

Shading significantly affected patchouli plant height at both 30 and 60 days after planting, with the highest values consistently observed under 25% shade. To present the treatment responses clearly, mean plant height and the least significant difference (LSD, 5%) grouping are shown in Table 2.

Table 2. Effect of shading level on patchouli plant height (cm)

Shading treatment	30 days after planting	60 days after planting
0% (no shade)	41.80 (a)	52.20 (a)
25% shade	70.60 (c)	88.00 (d)
50% shade	51.40 (b)	74.60 (c)
75% shade	41.00 (a)	65.40 (b)
LSD 5%	6.65	8.94

Table 2 indicates that 25% shade increased plant height by about 69% relative to open conditions at both observation times, while 50% shade produced intermediate height and 75% shade improved height at 60 days compared with no shade but remained below 25% and 50%. These results support the idea that moderate shading can create a more favorable microenvironment for patchouli growth by reducing excessive radiation and associated heat load, while still maintaining sufficient light for carbon assimilation. Similar patterns have been reported for patchouli grown under shade nets, where shaded environments often increase vegetative biomass and total dry weight compared with full sun, although the optimal shade intensity can vary with shade material and growing conditions (Ribeiro et al., 2021).

Effects of shading on branching

Branch number showed a similar response pattern to plant height, with the highest branching observed under 25% shade at both 30 and 60 days after planting. The mean branch number and least significant difference (LSD, 5%) results are presented in Table 3.

Table 3 indicates that deeper shading reduced branching, with the 75% shade treatment producing the lowest branch number at both observation times.

This response is agronomically important because branching contributes to canopy development and potential leaf and stem biomass, which are directly linked to harvested herbage. Under shade, plants often adjust architecture and resource allocation, and excessive shade can limit assimilate supply for lateral growth even if stem extension remains possible. More broadly across Lamiaceae aromatic plants, shade treatments are frequently reported to alter biomass partitioning and secondary metabolite related traits, with outcomes depending on both shade intensity and local microclimate (Lalević et al., 2023).

The effects of shading on aboveground biomass are also summarized visually in Figure 1 and Table 4. The figure illustrates the response patterns of shoot fresh weight and shoot dry weight across the four shade levels, allowing a clear comparison of the magnitude and direction of biomass changes under increasing shade intensity.

Figure 1. Existing potato supply chain and marketing channels in Modoinding District

Shading treatment	30 days after planting	60 days after planting
0% (no shade)	16.20 (b)	23.80 (ab)
25% shade	18.20 (c)	33.20 (c)
50% shade	16.00 (b)	28.20 (bc)
75% shade	12.60 (a)	19.60 (a)
LSD 5%	2.78	6.17

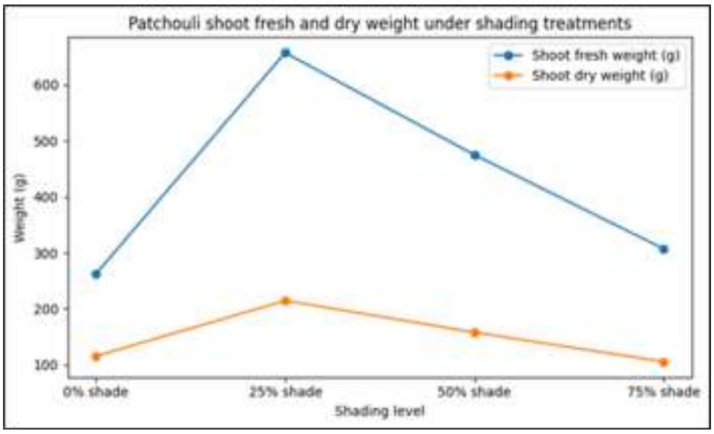

Figure 1. Effects of shading level on patchouli shoot fresh weight and shoot dry weight (g).

Figure 1 shows that both shoot fresh weight and shoot dry weight peaked at 25% shade and decreased as shading increased beyond this level. This pattern indicates that moderate shade improved biomass production, while heavier shade reduced dry matter accumulation. The trend is consistent with the numerical results presented in Table 4, where 25% shade produced the highest shoot fresh weight (657.4 g) and shoot dry weight (214.4 g), followed by 50% shade, whereas open conditions and 75% shade produced lower biomass.

Table 4. Shoot fresh weight and shoot dry weight of patchouli under different shading levels (g)

Shading treatment	Shoot fresh weight (g)	Shoot dry weight (g)
0% (no shade)	262.4	115.2
25% shade	657.4	214.4
50% shade	475	157.8
75% shade	307.2	105.4

From Table 4, 25% shade produced the highest shoot fresh weight and shoot dry weight, followed by 50% shade, while 75% shade resulted in lower dry matter accumulation than the moderate shading treatments. Relative to open conditions, 25% shade increased shoot fresh weight by about 151% and shoot dry weight by about 86%. This pattern suggests that moderate shading improved overall biomass production rather than only promoting stem elongation. These findings align with shade net studies on patchouli showing that shaded cultivation can increase dry biomass compared with full sun, although the reported optimum shade level differs among sites and shade materials, with some studies reporting stronger responses at around 50% shade (Ribeiro et al., 2021). Differences among studies are expected because shading modifies not only light quantity but also canopy temperature and humidity, and patchouli responses may depend on whether the production system is lowland or highland, as well as on the interaction between shade and management or harvest stage (Riti et al., 2025).

CONCLUSION

Under the local growing conditions of Kakaskasen Dua, Tomohon (North Sulawesi), shade level significantly influenced patchouli morphological performance. Across the measured traits, 25% shade consistently produced the best responses, including the greatest plant height and branch number at 30 and 60 days after planting, as well as the highest shoot fresh weight and shoot dry weight. Overall, these findings indicate that moderate shading (approximately 25%) is the most suitable light environment for improving vegetative growth and aboveground biomass of patchouli in this experimental setting. Because this study focused on morphological indicators, further work is recommended to quantify microclimate conditions under each shade level and to evaluate essential oil yield and composition so that agronomic recommendations can integrate both biomass production and oil quality targets.

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