Preliminary Evaluation of the Morphophysiological Performance of Three Indonesian Garlic Varieties under Urban Lowland Conditions

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Abstract. Urban agriculture has emerged as a pragmatic and effective solution to address land scarcity while supporting sustainable food production in modern cities. The rapid process of urbanization has created an urgent need for the development of efficient urban agriculture solutions to ensure food security. This study aims to address these challenges by evaluating the growth of garlic (*Allium sativum* L.) with the incorporation of yard-long beans (*Vigna unguiculata*) as a living shade crop to facilitate adaptive environmental conditions. The experiment was conducted at the Greenhouse of the Department of Crop Science, Sriwijaya University, from July to November 2025, employing a completely randomized design (CRD). The treatments consisted of local Indonesian garlic varieties—Lumbu Sembalun (LS), Lumbu Kuning (LK), and Lumbu Hijau (LH)—grown under the living shade of yard-long bean foliage. The results demonstrated that the LH and LK garlic varieties exhibited superior growth characteristics in comparison to LS, as evidenced by higher germination percentages and more vigorous early vegetative growth. Conversely, LS exhibited suboptimal growth patterns but displayed earlier bulb initiation. Four weeks after planting (WAP), the results demonstrated that the LH treatment exhibited significantly superior shoot length (54.70 cm), number of leaves (8.25 leaves), and relative chlorophyll content (53.83 SPAD) compared to the LK and LS treatments. These findings were accompanied by a significantly larger bulb diameter and higher total fresh biomass in the LH treatment. Furthermore, the formation of aerial bulbs was observed in all 4-month-old hardneck garlic genotypes, suggesting a robust reproductive adaptation to lowland environmental conditions. The intercropping of yard-long beans also yielded dual-crop benefits; in addition to being harvestable, they promoted optimal garlic growth. However, further analysis is necessary to elucidate the relationship between the two as part of an intercropping system.

1 Introduction

The rapid process of urbanization has led to a substantial reduction in the availability of arable land, thereby creating significant challenges for sustainable food production and ensuring urban food security [1]. Consequently, urban agriculture has emerged as a pivotal strategy to enhance household food availability by leveraging limited spaces, such as residential gardens and yards, while promoting land-use efficiency and environmental sustainability [2].

Garlic (*Allium sativum* L.) is considered to be one of the world's most economically valuable vegetable crops, primarily due to its culinary, nutritional, and medicinal properties. However, commercial garlic production is predominantly concentrated in highland areas due to the fact that optimal bulb formation requires relatively low temperatures [4]. In numerous tropical countries, including Indonesia, the expansion of garlic cultivation into lowland areas has emerged as a pivotal strategy to mitigate reliance on imports. However, elevated temperatures, excessive solar radiation, and fluctuating microclimatic conditions in lowland environments often result in reduced plant growth, physiological performance, and bulb development [5].

A pragmatic strategy for modulating the microclimate in small-scale urban farming is the implementation of living shade created by climbing vegetable crops. In comparison with artificial shading materials, the implementation of living shade has been shown to enhance land-use efficiency, contribute to augmented crop yield, and promote ecological sustainability [6]. The yard-long bean (*Vigna unguiculata*) is particularly well-suited for this purpose due to its climbing growth habit and rapid canopy development. It has been demonstrated through previous studies that biological shading has the capacity to moderate solar radiation and improve the microenvironment of the crop [7]. However, it should be noted that plant responses are largely dependent on genotype and environmental adaptation.

Garlic cultivars exhibit significant variation in their capacity to withstand environmental stresses, such as elevated temperatures and intense light conditions.

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These genotypic differences have been demonstrated to influence physiological processes, vegetative growth, and subsequent bulb formation under suboptimal growing conditions [8]. Despite the growing interest in lowland garlic cultivation, there is a paucity of information regarding the adaptability of Indonesian garlic cultivars when cultivated under a living shade system. Therefore, cultivar-specific responses must be understood to ensure the selection of suitable planting materials for household-scale urban farming in tropical lowland environments.

This study was a preliminary investigation that generally aimed to compare the growth, physiological characteristics, and early bulb development of three Indonesian garlic varieties grown under a shade system using long beans as a cover crop in lowland conditions. These findings are expected to provide scientific evidence for the selection of garlic varieties with superior adaptability to sustainable urban agricultural systems.

2 Materials and methods

2.1 Research procedure

The experiment was conducted in the Net House of the Department of Agricultural Cultivation, Faculty of Agriculture, Universitas Sriwijaya, Indralaya, South Sumatra, Indonesia, from July to November 2025. During the experimental period, the mean air temperature inside the net house ranged from 28 to 32°C, and the mean relative humidity ranged from 70 to 85%.

The planting materials consisted of three Indonesian local garlic cultivars: The three villages under discussion are Lumbu Sembalun (LS), Lumbu Kuning (LK), and Lumbu Hijau (LH). The seeds used in this study were obtained from local farmers in West Nusa Tenggara who are certified by the local government. Garlic (Allium sativum) bulbs are selected for planting based on their uniform size and health. The bulbs are categorized into three size classes: large (weighing 1.5–3.0 g and with a diameter of 1.2–1.6 cm); medium (weighing 1.0–1.5 g and with a diameter of 0.9–1.2 cm); and small (weighing 0.5–0.7 g and with a diameter of <0.9 cm) (Figure 1). The bulbs are free from visible signs of pests or disease and without physical damage.

The experimental setup employed a completely randomized design (CRD), with three distinct local Indonesian garlic cultivars—Lumbu Sembalun (LS), Lumbu Kuning (LK), and Lumbu Hijau (LH)—serving as the primary treatments. Each treatment was replicated four times which each experimental unit consisted of 12 garlic plants, giving a total experimental population of 144 plants. Observations were conducted on four sample plants selected from each experimental unit. Experimental units were randomly assigned using a completely randomized procedure to minimize positional effects within the net house.

Prior to the implementation of garlic planting, the establishment of yard-long bean plants was initiated to develop a living shade system. The planting of beans was executed a week prior to the planting of garlic, thereby allowing sufficient time for the development of adequate canopy formation. The bean plants were trained vertically using three trellises measuring 2 m in height and 6 m in width, positioned on the left, middle, and right sides. The spacing of plants for yard-long bean was 35 cm in the row, resulting in a canopy coverage of approximately 70% during the growth phase of garlic. Garlic cloves were subsequently planted in pots beneath the bean canopy at a spacing of 15 by 20 cm and at a planting depth of approximately 1 cm.

Uniform crop management practices were applied to all experimental units. The soil moisture was maintained through regular irrigation, administered as needed. The planting medium (soil) was enriched with organic fertilizer, comprising well-decomposed chicken manure, in a 1:3 ratio (v/v). The weeds were manually extirpated on a biweekly basis. The application of pesticides was a component of the experimental design, and the incidence of pests and diseases was monitored on a weekly basis. Infected plant tissues were meticulously removed by hand when the need for such intervention arose.

2.2 Data collection

Growth and yield observations were conducted periodically from planting until harvest using representative sample plants selected from each experimental unit. The plant height (in centimetres) was measured from the soil surface to the tip of the longest fully expanded leaf using a measuring tape, while the number of leaves was determined by counting all fully expanded green leaves on each sample plant. The length of the leaves (in centimetres) was measured using a ruler from the base of the leaf to its apex. The chlorophyll index was determined using a SPAD chlorophyll meter (Model SPAD-502Plus) by taking measurements on the middle portion of the youngest fully expanded leaf.

At harvest, yield-related variables were recorded. The diameter of the bulbs was measured in millimetres using a digital calliper, while the weight of the fresh bulbs was determined immediately after harvest using an analytical balance. The formation of aerial bulbils was evaluated by recording the number of bulbils per plant, followed by measurements of bulbil diameter (mm) using a digital calliper and fresh bulbil weight (g) using an analytical balance.

All observations were conducted on four plants from each experimental unit. These plants were selected to be representative of the entire experimental unit. Standardized measurement procedures were used to ensure consistency throughout the experiment.

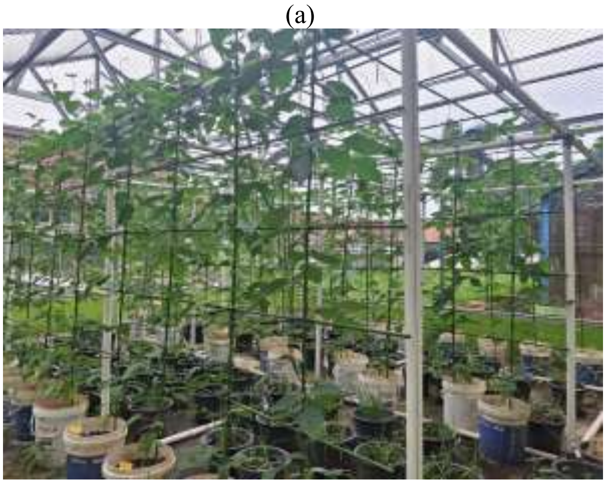
2.3 Experimental design and data analysis

All parameters' data will be subjected to an Analysis of Variance (ANOVA) to determine the significance of the main effects and their interactions. In instances where substantial disparities are identified ($p < 0.05$), a post-hoc Tukey's Honest Significant Difference (HSD) test will be implemented for the purpose of conducting mean comparisons.

3 Results and discussion

The performance of garlic and yard-long bean under the net house intercropping system at 4 Weeks After Planting (WAP) and 8 WAP was showed in Figure 1.

(a)



(b)

Fig. 1. Garlic plants intercropped with yardlong bean at 4 WAP (a) and 8 WAP (b).

At 4 WAP, the yard-long bean plants successfully established their vegetative structure along the vertical trellises, providing an initial living shade canopy over the young garlic plants beneath them (Figure 1a). By 8 WAP, the biological canopy of the yard-long beans had expanded significantly, increasing spatial coverage and creating a denser vertical shade structure (Figure 1b). The initial agronomic adaptability of the lowland garlic was showed through garlic sprouting at 4 WAP (Figure 3) dan germination percentage (Figure 4).

The visual observations of the early vegetative stage of the three-yard-long bean varieties at one week after planting (WAP) are presented in Figure 2. The observed morphology indicates that all three varieties—White (W), Red (R), and Green (G)—successfully initiated initial seedling growth, as evidenced by the emergence of healthy green cotyledonary leaves and erect hypocotyls.

The phenotypic evaluation revealed that the germination pattern among the three-yard-long bean types exhibited a high degree of uniformity.

Fig. 2. Growth of 1-WAP YardLong Bean Plants. W = White YardLong Bean; R = Red YardLong Bean; G = Green YardLong Bean. Germination of the three long bean types tended to be uniform from 1 WAP to 12 WAP.

The initial agronomic adaptability of the lowland garlic was showed through garlic sprouting at 4 WAP (Figure 3) dan germination percentage (Figure 4). The experimental data demonstrated that the Lumbu Hijau (LH) and Lumbu Kuning (LK) varieties exhibited significantly superior sprouting performance compared to the Lumbu Sembalun (LS) variety. As demonstrated in Figure 3, under the White yardlong bean shade (P), LK attained a cumulative sprouting percentage of 96.7% (86.7% at 4 WAP + 10.0% at 8 WAP), and LH achieved 96.7% (60.0% at 4 WAP + 36.7% at 8 WAP). LK demonstrated 73.3% cumulative sprouting, while LH exhibited a consistent high output of 80.0%. In contrast, the LS variety exhibited a conspicuously diminished sprouting capacity, with its most modest cumulative performance recorded under the Red yardlong bean shade (M), reaching a mere 30.0% (26.7% at 4 WAP + 3.3% at 8 WAP).

Fig. 3. Growth of garlic plants at 4 WAP.

The vegetative growth performance of the three garlic varieties at 4 weeks after planting (WAP) exhibited significantly varied responses across the evaluated parameters (Table 1). A statistical analysis was conducted, and the results indicated that the genetics of the varieties significantly influenced shoot length, number of leaves, and SPAD values. However, this treatment did not result in any substantial variation in root length.

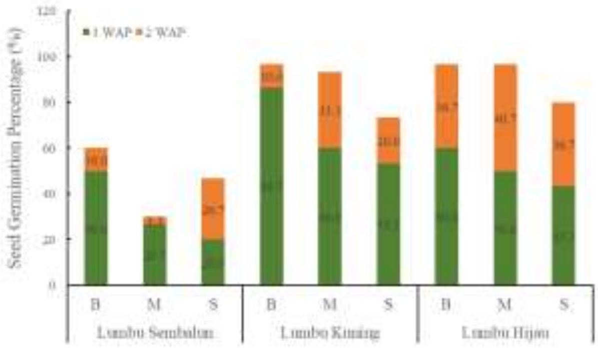


Fig. 4. Germination Performance of Three Garlic Landraces Across Bulb Size Categories (B, M, and S) at 1 and 2 WAP. B= large; M= medium; and S= small.

The absence of a statistically significant outcome in the measurement of root length suggests that at the conclusion of the growth stage (4 WAP), the three garlic varieties exhibited comparable rates of below-ground root development. This finding suggests that root elongation during this phase may be more influenced by uniform environmental conditions, such as soil media and moisture, rather than by genetic variance. In contrast, the variables of shoot length and leaf number exhibited a substantial response to variety. Lumbu Hijau (LH) demonstrated superior growth, exhibiting greater shoot length and leaf number compared to the other two varieties. In contrast, the statistical results for Lumbu Kuning (LK) and Lumbu Sembalun (LS) exhibited congruence in terms of leaf number, suggesting that the rate of leaf development for both was statistically equivalent at this stage (Table 1).

Table 1. Root length, shoot length, number of leaves, and SPAD value of three garlic varieties at 4 weeks after planting (WAP).

Varieties	Root Length (cm)	Shoot Length (cm)	Number of Leaves	SPAD
LS	10.20	38.35 b	4.75 b	49.98 b
LK	10.93	44.43 ab	5.25 b	41.13 b
LH	12.15	54.70 a	8.25 a	53.83 a
P< 0.05	ns	**	**	*

Note: Means followed by the same letter in each column are not significantly different (Tukey's test, $P < 0.05$). LS= Lumbu Sembalun; LK= Lumbu Kuning; LH= Lumbu Hijau.

A similar dominant trend was observed in the relative chlorophyll content (SPAD value) (Table 1). Lumbu Hijau (LH) exhibited the highest chlorophyll content, which differed significantly from Lumbu Sembalun (LS) and Lumbu Kuning (LK). This high SPAD value in LH suggests an augmented light-harvesting capacity and elevated photosynthetic potential. The combination of taller shoot length, a greater number of leaves, and superior chlorophyll content provides LH with a stronger physiological foundation, which is crucial for supporting better bulb development in the later growth stages compared to LS and LK.

The post-harvest quality and characteristics of garlic are strongly influenced by the genetics of the variety, as reflected in the parameters of bulb diameter and total fresh weight at 4 weeks after planting (WAP) (Figure 5). A subsequent statistical analysis revealed a significant impact of the garlic varieties evaluated on both bulb diameter and overall biomass accumulation. For the bulb diameter parameter (Figure 5a), Lumbu Hijau (LH) demonstrated the most optimal growth performance, which was significantly larger than that of Lumbu Kuning (LK). However, the bulb diameter of LH did not significantly differ from Lumbu Sembalun (LS). Conversely, LK produced the smallest bulb diameter among the three varieties. This variation suggests that the LH variety possesses a genetic advantage in terms of lateral bulb expansion or swelling during this growth phase compared to LK.

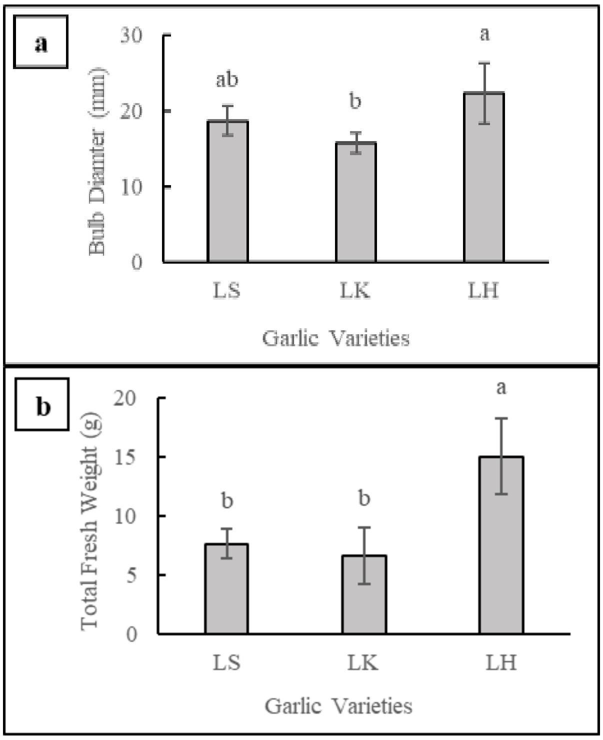


Fig. 5. Bulb Diameter and Total Fresh Weight of Three Garlic Varieties at 4 weeks after planting (WAP). LS= Lumbu Sembalun; LK= Lumbu Kuning; LH= Lumbu Hijau. Means within the same bar followed by the same letter are not significantly different according to Tukey's test ($P < 0.05$).

A more distinct trend was observed in the total fresh weight parameter (Figure 5b). Lumbu Hijau (LH) accumulated a significantly higher total fresh biomass compared to both Lumbu Sembalun (LS) and Lumbu Kuning (LK). The identical notation between LS and LK indicates that their biomass allocation was statistically similar at this stage. The superior performance of LH in both bulb diameter and total fresh weight indicates a strong physiological correlation with its vegetative vigor observed in earlier growth stages.

Fig. 6. Bulbils (Mini Bulbs) of 4-Month-Old Garlic Plants. A bulbil is a small bulb that develops inside the garlic flower head (spathe), particularly in hard neck garlic varieties.

It has been previously documented that garlic varieties demonstrating enhanced vegetative growth, leaf development, and photosynthetic activity tend to exhibit larger bulb diameters and higher biomass accumulation. This phenomenon can be attributed to the increased assimilate production and enhanced translocation of these assimilates toward storage organs. The vigorous vegetative growth exhibited by the plants is characterized by increased leaf number, leaf length, leaf width, and plant height. This contributes to higher photosynthetic capacity and assimilate production, which are subsequently partitioned to bulb development. This results in greater bulb size, bulb weight, and total biomass accumulation [9].

The enhanced shoot length, augmented leaf number, and elevated chlorophyll content documented in LH are likely to have contributed to an augmented photosynthetic rate, thereby promoting superior photoassimilate translocation to the sink organs (bulbs) and culminating in elevated overall moisture and biomass retention [10]. Consequently, Lumbu Hijau demonstrated the greatest capacity to yield superior bulbs in lowland conditions in comparison to Lumbu Sembalun and Lumbu Kuning.

The morphological development of garlic plants at 4 months old revealed the distinct formation of aerial mini bulbs, which are botanically classified as bulbils (Figure 6). Visual observations confirmed that the development of the bulbils occurred within the spathe, which functions as the protective sheath surrounding the garlic inflorescence. This reproductive characteristic has been predominantly linked to hardneck garlic types, which have the capacity to produce flowering stalks (scapes) and aerial propagules under conducive environmental conditions [11].

The appearance of bulbils at this particular stage of development signifies a transition toward reproductive or secondary storage structures. Morphologically, the bulbils manifested a clearly delineated bulb-like morphology, situated within the lower portion of the scape or emerging from a divided spathe. The coloration of the subjects ranged from creamy white to light reddish-purple, reflecting normal tissue maturation and anthocyanin accumulation during development. A similar set of morphological characteristics of garlic bulbils has been reported during inflorescence differentiation and maturation in bolting garlic cultivars [12].

From a physiological perspective, the formation of these 4-month-old bulbils functions as an alternative vegetative propagation strategy for the plant. In contrast, true seeds are seldom viable in commercial garlic, and these aerial bulbils accumulate essential photo assimilates diverted from the main pseudo stem. Consequently, they function as viable, disease-free planting materials (clones). The successful and uniform formation of bulbils observed in the present study indicates strong reproductive vigor and adaptation of the hard neck garlic genotype to the experimental environment [14] [15].

Conclusion

Cultivating garlic in lowland areas with long beans used as a living shade crop under net house conditions has great potential for development. These findings suggest that a living shade intercropping system can support the cultivation of lowland garlic varieties. However, further research is needed on the effects of the living shade system on microclimate modification, stress reduction, and increased final yield. Among the tested varieties, Lumbu Hijau (LH) and Lumbu Kuning (LK) demonstrated superior adaptability in terms of germination, early vegetative vigor, and chlorophyll content compared to Lumbu Sembalun (LS). The superior vegetative performance exhibited by LH is directly correlated with optimal postharvest quality, as evidenced by larger bulb diameter and higher total fresh biomass accumulation at 4 weeks after planting. This indicates higher yield potential compared to the other two varieties under lowland conditions. This innovative intercropping system has the potential to serve as a simple, sustainable, and productive solution for urban lowland agriculture. It is designed to maximize vertical space, and its practicality in strengthening household food security and environmental resilience in resource-constrained areas is a notable benefit.

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