








# MORPHOLOGICAL CHARACTERISTICS, GROWTH BEHAVIOR, AND POTENTIAL OF YARD-LONG BEAN (*VIGNA UNGUICULATA* SSP. *SESQUIPEDALIS* (L.) VERDC.) AS A VEGETABLE FOR CULTIVATION IN TROPICAL URBAN AREAS

## Short communication

Benyamin LAKITAN<sup>1,2</sup>, Strayker A. MUDA<sup>1\*</sup>, Purwanto PURWANTO<sup>3,4</sup>,  
Dora F. NURSHANTI<sup>5</sup>, Tili KARENINA<sup>6</sup>, Rofiqoh P. RIA<sup>1</sup>, Fitra GUSTIAR<sup>1</sup>,  
Niluh P.S. RATMINI<sup>3,7</sup>, Fitri RAMADHANI<sup>1</sup>, Sanggam D. VIRYANANDA<sup>1</sup>

<sup>1</sup>College of Agriculture, Universitas Sriwijaya, Indonesia

<sup>2</sup>Research Center for Sub-optimal Lands, Universitas Sriwijaya, Indonesia

<sup>3</sup>Postgraduate of Environmental Science, Universitas Sriwijaya, Indonesia

<sup>4</sup>Research Center for Ecology and Ethnobiology, National Research and Innovation Agency, Indonesia

<sup>5</sup>College of Agriculture, Universitas Baturaja, Indonesia

<sup>6</sup>Regional Research and Development Agency, South Sumatra Province, Indonesia

<sup>7</sup>Research Center for Food Crops, National Research and Innovation Agency, Indonesia

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## ABSTRACT

This study covers the morphological characteristics, growth behavior, and cultivation of yard-long beans (green and red surface fruits) as vegetable for urban communities. This study shows many similarities in the morphological traits (leaf shape and color, as well as the number of leaflets) and growth behavior (climbing growth, flowering time, fruiting, and harvesting) between the two cultivars. The green-fruited cultivar had smaller leaves and fewer leaves, lesser leaf weight, thinner petioles, and lower SPAD value compared to the red-fruited one. In both cultivars, the leaves slightly wilt at midday, but this did not have a negative effect on fruit growth and average fruit size in the long term. The fruits can be harvested 8–10 days after the petals and stamens have fallen. The earliest matured pods also become the longest and heaviest. After harvesting the initial pod, it will flower and bear fruit again on the same bunch. However, in the same bunch and at the same time only 1 or 2 pods will grow to marketable size. The green cultivar produced a larger fruit yield than the red, but their quality was comparable. Both yard-long bean cultivars responded to the solar tracking phenomenon, the upper surface of the leaf being dominantly oriented to the east.

**Key words:** fruiting vegetable, harvest period, leaf solar tracking, temporary wilting, urban farming

## INTRODUCTION

The area of agricultural land is decreasing due to conversion of its use to various other interests that are more profitable (Fang et al. 2024; Ivanka et al. 2024). This condition is also in conflict with the increasing demand for food in line with the population growth (Putra et al. 2020; Rozi et al. 2023). The reduction of land area for food crops in rural areas has triggered the emergence of the use of urban land for the cultivation of horticultural crops, especially vegetables (Degefu & Kifle 2024; Tuffour et al. 2024).

Initially, cowpea was domesticated from wild genotypes in Africa, and later in Asia, some cowpeas evolved into yard-long beans (Kongjaimun et al. 2012). Yard-long bean (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdc.) is a fruiting vegetable that is a source of vitamins, minerals, and dietary fiber (Choi et al. 2024). This plant produces fruits with a harvest cycle of 45–60 days. It is suitable for vertical cultivation in narrow lands in urban areas. Yard-long beans are now popularly cultivated in Indonesia and the Southeast Asian region (Quamruzzaman et al.

2022), because they grow quickly, the first fruits can be harvested within 2 months of seed are planting, the productivity is relatively high, and they are liked by consumers. Although breeding efforts have not been extensive (Suma et al. 2021), there are several yard-long bean cultivars in Southeast Asia, including those with dominant green fruit, red or purple fruit that are beginning to attract consumer attention, and pale green fruit that are less attractive (Ahmed et al. 2024). This study focused more on the first two cultivars.

Yard-long beans are typically cultivated by farmers on relatively large land, in monoculture, and for commercial purposes, but this plant can also be planted in the backyards of houses to meet the needs of families in urban areas. Yard-long bean is a tall, climbing herbaceous annual plant with long, stringless pods and a nutritious source of vitamins, minerals, and dietary fibers. Cultivation is carried out vertically using climbing fences to save on limited available space.

This study was conducted to provide an in-depth understanding of the morphology, growth behavior, and potential of green and red yard-long beans when cultivated in urban areas with limited availability of open space in tropical climate zones.

## MATERIALS AND METHODS

This research was carried out during the dry season in June–August 2024 in the tropical lowlands, at an altitude of less than 10 meters above sea level but rarely submerged in water because it is located near drainage channels in the urban area of Palembang, Indonesia. The research location was Jakabaring Research Facility (104°46'44"E, 3°01'35"S), Palembang, Indonesia. The study was conducted at the beginning of the dry season, as indicated by the decrease in rainfall. The monthly rainfall in June, July, and August gradually decreased to 219.00 mm, 63.50 mm, and 27.20 mm, respectively, while the average relative humidity also decreased slightly to 83.27%, 79.88%, and 76.33%. The experiment included two commercial, locally selected cultivars of yard-long beans: one with green fruit (more commonly cultivated) and one with dark red fruit (which we want to introduce for cultivation on a larger scale).

Perfect seeds (uniform size, color, no spots and rotteness) were soaked in tap water for 2 hours and immediately planted in pots 30 cm high, 30 cm in

diameter, and 10 liter in volume. The pots were first filled with topsoil mixed with humus and dead leaves that had completely decomposed. The pots were filled with growing substrate to a thickness of 25 cm and, in addition to the four holes on the bottom surface of the pot, which serve for drainage, four holes were also added on the side walls of the pot at a height of 25 cm, parallel to the soil surface in the pot.

Six pots were placed in a line next to a climbing fence. There were five sets of climbing fences with 30 pots. Three plants were planted in each pot. Therefore, the total number of plants was 90. The plants were trained to grow vertically.

The stems elongate rapidly after 3 weeks from planting. After 5 weeks, the length of the main stem reaches about 2 meters. The reproductive phase begins after 5–6 weeks. Flowers bloom on compound stems, starting from the base of the flower raceme. At the moment of petal fall, the potential fruit becomes easily visible, elongated, round in shape about 1 mm in diameter and about 1–2 cm long. The elongated fruit can reach over 60 cm in a little less than 10 days. The proper criterion for harvesting is when the fruit is still young and the protruding seeds from the inside of the fruit are not too visible. Fertilization was done three times with Mutiara NPK fertilizer (16:16:16), in the early vegetative phase, in the generative phase, and at the end of the productive phase. The dose at each time of fertilization was 6, 9, and 5 g per pot. Watering was carried out regularly in the afternoon when there was no rain. Meanwhile, weed, pest, and disease control was done mechanically and did not include pesticides.

### Data collection and analysis

Midrib length data were measured at 6.00 am and 6.00 pm on selected terminal leaflets. The criterion used was to start measurements when the midrib length was approximately 1 cm until the terminal leaflet stopped elongating, which took less than 12 days. The collected data were used to visualize the midrib elongation curve and its elongation behavior during the day and night.

Yard-long bean leaves are classified as trifoliolate with three leaflets. The lateral leaves are the same shape and size. The area of the middle leaflet was measured using the Easy Leaf Area application, a digital image scanner developed by Easlon and Bloom (2014). The measurement procedure was performed by capturing each leaf, and then the leaf area was automatically recorded in the application.

SPAD values were measured to compare the leaf greenness or chlorophyll content between green and red fruiting yard-long beans. Measurements were taken using a Konica-Minolta SPAD-502 Plus chlorophyll meter.

Leaf fresh and dry weight, leaf water content, specific leaf weight, and total mature leaf area were measured in the morning (6.00–7.00 am) and at noon (12.00–1.00 pm). These data were used to detect temporary leaf wilt under midday conditions. Leaf area, petiole length, diameter, volume, and rachis length were used for morphological comparison of green and red yard-long beans. Pod length was measured every day for 10 days to check the fruit elongation rate, which was used as a reference for determining the fruit harvest time.

Data were processed according to the purpose of their collection. Regression analysis was used to understand the trend and patterns related to leaf expansion, fruit enlargement, and plant growth, while pairwise comparison using paired t-test analysis was used to compare morphological components of plants between cultivars. Statistical analysis was performed using RStudio, developed by Posit PBC.

## RESULTS AND DISCUSSION

The length of the terminal leaflets was measured after the leaf bud had expanded, averaging 1.7 cm for

green and 2.7 cm for red yard-long beans. The terminal leaflet midrib stopped elongating within 10–12 hours, as did the leaflet blade. The average midrib length at maturity was significantly longer in red (19.3 cm) than in green (16.6 cm) yard-long beans (Fig. 1). The rate of relative midrib elongation during the day and night showed that the midrib elongation process occurs faster at night than during the day in both green and red yard-long beans (Fig. 1).

The midrib elongation curve in the first half follows the shape of an exponential curve and forms an asymptotic curve at the end of the curve. The combination of exponential-asymptotic curves forms a sigmoidal curve, which was initially slow, then increased rapidly, then became slow, and then flattened out, as an indication that the midrib elongating process had stopped. Unfortunately, the slowest midrib elongation process (<1 mm per 12 h) at the earlier stage of leaf development could not be captured because the three leaflets are still unfolded and overlapped. This research proves that the leaf midribs stop elongating or the leaf stops enlarging in less than 10 days. In comparison, the relative leaf elongation rate decreased after 15 days for red, pink, and yellow Swiss chard (Lakitan et al. 2023).

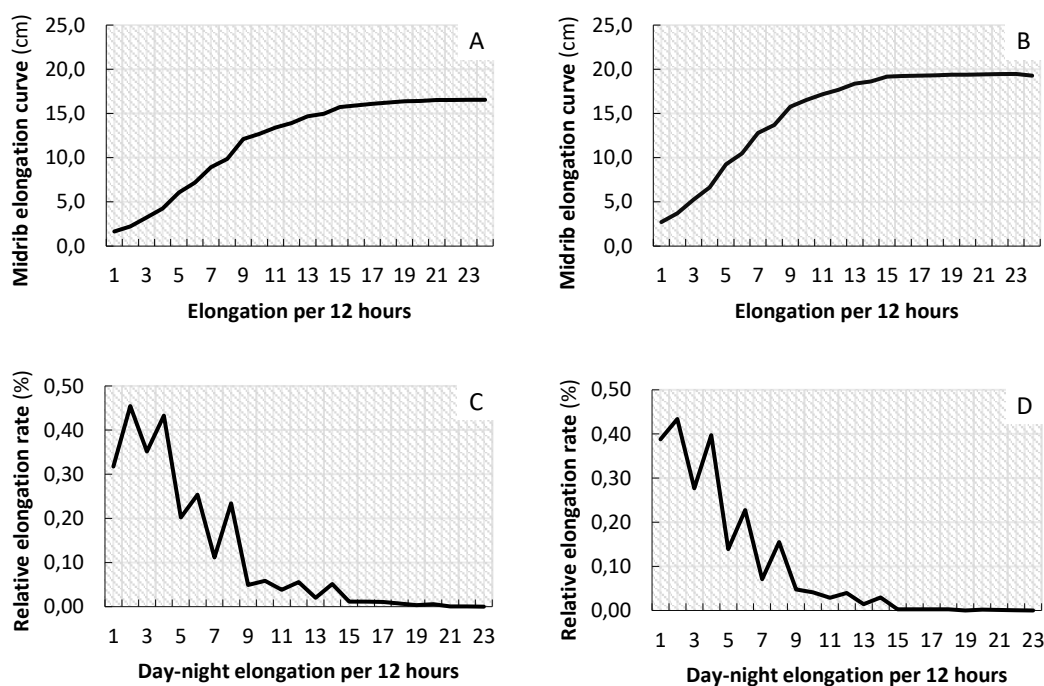


Figure 1. Midrib elongation pattern (A, B) and day–night relative elongation rates (C, D) of the green (A, C) and red (B, D). The odd numbers represent measurement at day and even numbers for night

The relative leaf expansion rate (RLER) in this study was varied between day and night, alternating every 12 hours, to determine the process of faster leaf expansion during the day or at night. The results of this study consistently proved that the RLER was higher at night compared to day for both green and red yard-long bean cultivars. Widuri et al. (2017) also reported that the dynamic changes in the RLER were mainly caused by the day-night cycle rather than long-term gradual drought stress. Plants grow and transpire at night. Nocturnal leaf growth provides more efficient use of the absorbed water compared with diurnal growth. Nocturnal transpiration and expansive leaf growth should be considered as a potential acclimation mechanism (Fricke 2020). In contrast, Shi et al. (2021) reported that daytime atmospheric carbon dioxide improved plant growth and leaf quality of mulberry (*Morus alba* L.) seedlings.

Leaf morphogenesis involves cell division, expansion, and differentiation in the developing leaf, which occur at different rates and in different positions along the mediolateral and proximodistal axes

of the leaf. The cluster of green-fruited yard-long beans is different from that of red-fruited beans. However, there is a slight overlap between the two clusters. The leaves of red-fruited yard-long beans are larger than the leaves of green-fruited beans.

Broad, thin leaves often cause temporary wilting at noon in the tropics. Temporarily leaf wilting is thought to be caused by an increase in transpiration rates. They become disproportionate to the rate of water absorption by the root system in the soil or growing substrates. Midday measurements have been proven to significantly reduce leaf water content of green and red yard-long beans, but this decrease was temporary (Fig. 2).

The decrease in leaf water content is then followed by a decrease in the water content in the upper above-ground organs. However, the temporary wilting at noon did not significantly inhibit growth and yield in the long term, as long as the plants were watered in the evening. Leaf dry weight, leaf specific weight, and mature leaf blade area were not significantly affected by the temporary decrease in water status. The decrease in leaf moisture content did not reach the point of permanent wilting.

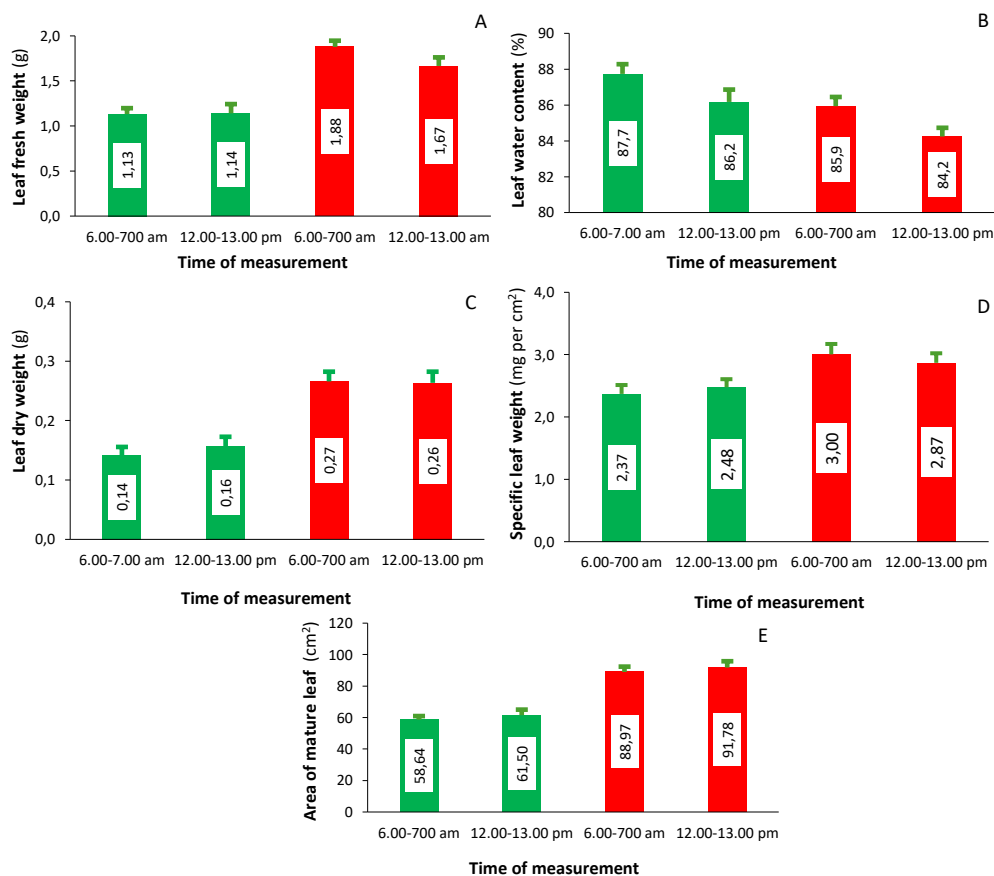


Figure 2. There are means from some water related traits measured at early morning compared to at around midday on the green and red yard-long bean

The differences in morphological traits between green and red cultivars are shown in Table 1. Some traits were comparable, such as petiole length, rachis length, petiole dry weight, rachis to petiole ratio, and water content to leaf area ratio. However, red yard-long beans are larger in many other respects, including leaf area, fresh, and dry weight, and petiole diameter, fresh weight, and volume (Table 1). In short, the red yard-long beans have larger leaves and petioles than green ones. The fruit should be harvested immediately after 8–10 days of petal and stamen withering and falling. As a fruiting vegetable, the yard-long bean is ideally harvested when the fruit has elongated to near maximum length, the cross-section of the fruit is oval, but the seeds are not excessively inflated and visible from the outside of the fruit. Although the leaves size are smaller on average, the green yard-long beans produce fruit that is slightly longer and wider than the red beans.

Green and red yard-long bean plants were cultivated under the same agroclimatological conditions. Therefore, there are differences in the leaf size, fruits, and other morphological traits because they come from different genetic sources. Southeast Asia is the center of yard-long bean diversity. However, not many breeding efforts have been carried out so far. Suma et al. (2021) encouraged breeding efforts focused on increasing fruit yield.

Productivity is enhanced by increasing the number of pods per plant, earlier harvesting, inhibition of stem elongation, resistance and tolerance to biotic stress, and adaptation to different agroclimatic conditions.

The number of leaves on the main stem, total fresh and dry leaf weigh, fresh and dry stem weight, and stem diameter of red-fruited yard-long beans were significantly different from those of green-fruited beans. However, other morphological traits, including main stem length, number of branches, total stem fresh and dry weight, root length, and total branch dry weight, were not significantly different. SPAD value has been widely used as a rapid, reliable, and real-time approach to determining chlorophyll and nitrogen content in leaves. Red yard-long beans have red skin color, but the leaves remain green. Comparison of the two cultivars showed that the leaves of the red-fruited cultivar were richer in chlorophyll than those of the green-fruited cultivar (Table 2).

This research was conducted using a climbing frame facing two different directions, a climbing frame oriented perpendicular to the east–west sunlight trajectory and a climbing frame with the north–south side parallel to the sunlight trajectory. The growth of the stems and leaves of yard-long beans is predominantly oriented to the east or toward sunrise. The upper surface of the leaf blade is predominantly oriented to the east (Fig. 3).

Table 1. Morphological comparison of green and red yard-long beans

Traits	Green	Red	p
Leaf area (cm <sup>2</sup> )	57.11	84.49	**
Leaf fresh weight (g)	1.14	1.74	**
Leaf dry weight (g)	0.16	0.26	**
Petiole length (cm)	10.43	10.37	ns
Rachis length (cm)	3.73	3.93	ns
Petiole diameter (mm)	28.79	33.85	**
Petiole fresh weight (g)	0.82	1.13	**
Petiole dry weight (g)	0.09	0.16	*
Rachis to petiole ratio (cm per cm)	0.37	0.38	ns
Water content to leaf area (% per cm <sup>2</sup> )	1.72	1.75	ns
Petiole volume (cm <sup>3</sup> )	6.96	9.45	*

\* Significant difference based on paired t-test at  $p < 0.05$ ; \*\* Significant difference based on paired t-test at  $p < .01$ ; ns – nonsignificant difference based on paired t-test at  $p < 0.05$

Table 2. Differences in plant components of green and red yard-long beans after all marketable fruit has been harvested

Number of leaves on the main stem	11.00	14.32	*
Leaf fresh weight (g)	42.22	56.77	*
Leaf dry weight (g)	9.62	11.42	*
SPAD value	44.80	52.29	**
Stem diameter (mm)	6.32	8.04	**
Stem fresh weight (g)	31.25	44.74	**
Stem dry weight (g)	6.27	7.50	*
Main stem length (m)	2.07	2.20	ns
Number of branches	9.27	9.30	ns
Branch fresh weight (g)	10.28	11.82	ns
Branch dry weight (g)	2.07	2.15	ns
Root length (cm)	62.04	49.78	ns
Root fresh weight (g)	18.15	25.52	*
Root dry weight (g)	2.26	2.82	ns

Note: see Table 1

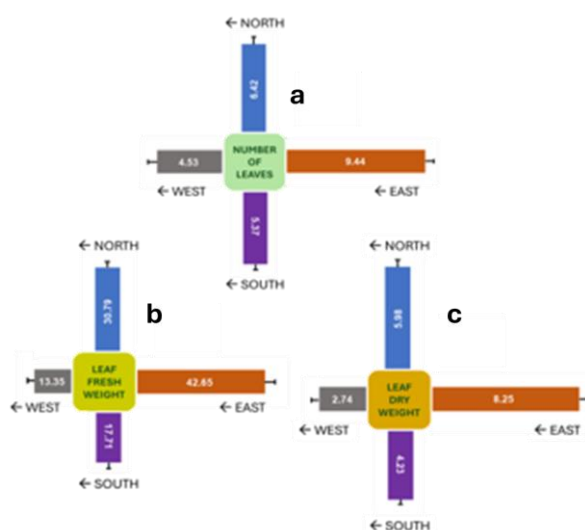


Figure 3. Solar tracking phenomenon in yard-long bean plants on the upper surface of leaf blades, which tend to face east as evidenced by the greater number of leaves (a), fresh leaf weight (b), and dry leaf weight (c)

This phenomenon is commonly referred to as solar tracking. It has been known for more over half a century that leaves of many species can move diurnal, either perpendicularly or parallel to the rays of the sun. Leaves positioned perpendicularly for tracking purposes appear to have high rates of photosynthesis during the day, whereas leaves positioned parallel have reduced leaf temperatures and transpiration water losses (Ehleringer & Forseth 1980). However, only elongating vegetative shoots perform phototropic solar tracking on the upper surface of leaf blades (Kutschera & Briggs 2016).

The largest fruit length, diameter, fresh weight, and seed number were found in the earliest harvested pods. The size and quality of the harvested

fruits gradually decreased with time (Fig. 4). Rarely, it is seen that the flower and fruit have flower bunches that produce multiple fruits but not at the same time. At the same time, the bunches produce only one or two fruits. Nevertheless, after fruit harvest, one or two more fruits will reappear on the same bunches (Fig. 5A). The morphological characteristics of yard-long bean, which produces green and red fruits, do not differ much except for the color of the outer surface of the fruit. The numerous similarities between the cultivated cultivars are that the breeding of this plant is still not intensive. There is a large diversity of germplasm in this crop, but the main commercial cultivars were developed through pure line selection (Pidigam et al. 2021).

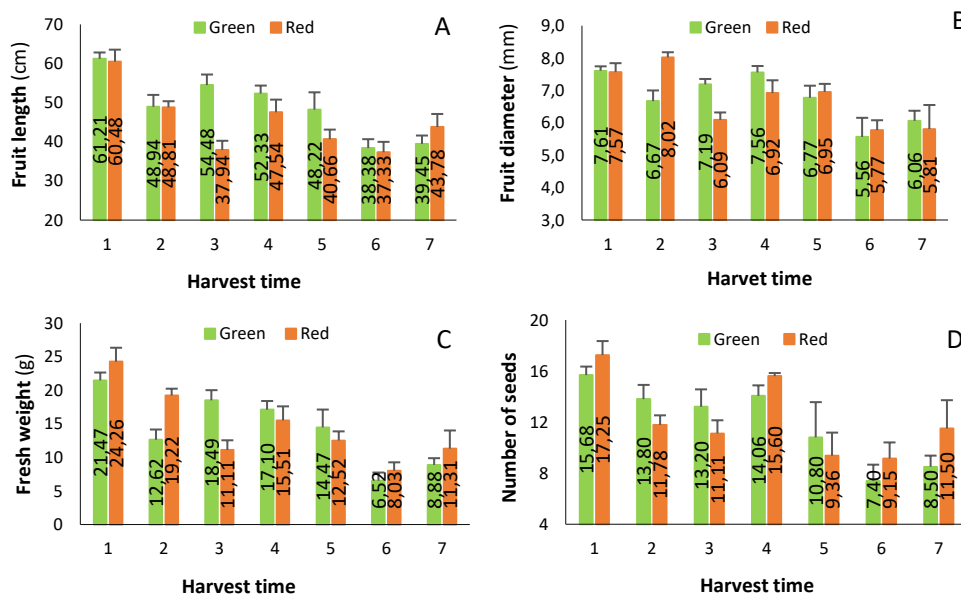


Figure 4. Some morphological traits indicating that the best yard-long bean fruits are obtained in the earliest harvests and then their number gradually decreases in subsequent harvests



Figure 5. Compound fruit bunches of yard-long bean (A), whole plant *Vigna unguiculata* ssp. *sesquipedalis* (B)

## CONCLUSION

Yard-long beans grow quickly and can be harvested in less than two months. The pod is ready for harvest 8–10 days after the petals and stamens have fallen. After the first fruit is harvested, it will flower and bear fruit again on the same bunch. However, on the same bunch and at a time, only 1 or 2 fruits will grow to marketable size. The earliest fruits harvested also become the longest and heaviest.

Leaf blades reach their maximum size in less than 10 days after leaf bud development. Leaves grow faster at night than during the day. Green-fruited cultivars have smaller leaves, less leaf number and weight, and thinner petioles, but are similar

in other morphological traits to red-fruited cultivars. The total fruit yield of the green cultivar is significantly higher than that of the red cultivar, but fruit quality is equally excellent. The solar tracking phenomenon is noticeable, the petiole is tilted, and the upper surface of the leaf is dominantly oriented to the east or toward sunrise.

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## REFERENCES

- Ahmed S., Das M., Sojib M.R., Talukder S.K., Sultana S., Datta P. et al. 2024. Evaluation of local and exotic hybrid genotypes of yardlong bean (*Vigna unguiculata*) in saline prone area of Bangladesh. *Sarhad Journal of Agriculture* 40(2): 347–353. DOI: 10.17582/journal.sja/2024/40.2.347.353.
- Choi Y.M., Shin M.J., Yoon H., Lee S., Yi J., Wang X., Desta K.T. 2024. Nutritional qualities, metabolite contents, and antioxidant capacities of yardlong beans (*Vigna unguiculata* subsp. *sesquipedalis*) of different pod and seed colors. *Antioxidants* 13(9): 1134; 15 p. DOI: 10.3390/antiox13091134.
- Degefu M.A., Kifle F. 2024. Impacts of climate variability on the vegetable production of urban farmers in the Addis Ababa metropolitan area: Nexus of climate-smart agricultural technologies. *Climate Services* 33; 100430; 10 p. DOI: 10.1016/j.cliser.2023.100430.
- Easlon H.M., Bloom A.J. 2014. Easy Leaf Area: Automated digital image analysis for rapid and accurate measurement of leaf area. *Applications in Plant Sciences* 2(7); 1400033; 4 p. DOI: 10.3732/apps.1400033.
- Ehleringer J., Forseth I. 1980. Solar tracking by plants. *Science* 210(4474): 1094–1098. DOI: 10.1126/science.210.4474.1094.
- Fang X., Ghazali S., Azadi H., Skominas R., Scheffran J. 2024. Agricultural land conversion and ecosystem services loss: a meta-analysis. *Environment, Development and Sustainability* 26(9): 23215–23243. DOI: 10.1007/s10668-023-03597-z.
- Fricke W. 2020. Energy costs of salinity tolerance in crop plants: night-time transpiration and growth. *New Phytologist* 225(3): 1152–1165. DOI: 10.1111/nph.15773.
- Ivanka R., Muhammad F.A., Dita L.A., Simarmata T. 2024. Assessing the current state and future trends of land use conversion: implications for food security in Indonesia. *International Journal of Life Science and Agriculture Research* 3(4): 284–290. DOI: 10.55677/ijlsar/v03i4y2024-10.
- Kongjaimun A., Kaga A., Tomooka N., Somta P., Vaughan D.A., Srinives P. 2012. The genetics of domestication of yardlong bean, *Vigna unguiculata* (L.) Walp. ssp. *unguiculata* cv.-gr. *sesquipedalis*. *Annals of Botany* 109(6): 1185–1200. DOI: 10.1093/aob/mcs048.
- Kutschera U., Briggs W.R. 2016. Phototropic solar tracking in sunflower plants: an integrative perspective. *Annals of Botany* 117(1): 1–8. DOI: 10.1093/aob/mcv141.
- Lakitan B., Susilawati S., Wijaya A., Ria R.P., Muda S.A. 2023. Leaf blade growth and development in red, pink, and yellow petiole cultivars of the Swiss chards grown in floating culture system. *Jordan Journal of Biological Sciences* 16(1): 157–164. DOI: 10.54319/jjbs/160119.
- Pidigam S., Thuraga V., Pandravada S.R., Natarajan S., Adimulam S., Amarapalli G. et al. 2021. Genetic improvement of yardlong bean (*Vigna unguiculata* (L.) Walp. ssp. *sesquipedalis* (L.) Verdc.). *Advances in Plant Breeding Strategies: Vegetable Crops* 10: 379–420. DOI: 10.1007/978-3-030-66969-0\_10.
- Putra A.S., Tong G., Pribadi D.O. 2020. Food security challenges in rapidly urbanizing developing countries: insight from Indonesia. *Sustainability* 12(22); 9550; 20 p. DOI: 10.3390/su12229550.
- Quamruzzaman A.K.M., Islam F., Akter L., Khatun A., Mallick S.R., Gaber A. et al. 2022. Evaluation of the quality of yard-long bean (*Vigna unguiculata* subsp. *sesquipedalis* L.) cultivars to meet the nutritional security of increasing population. *Agronomy* 12(9); 2195; 12 p. DOI: 10.3390/agronomy12092195.
- Rozi F., Santoso A.B., Mahendri I.G.A.P., Hutapea R.T.P., Wamaer D., Siagian V. et al. 2023. Indonesian market demand patterns for food commodity sources of carbohydrates in facing the global food crisis. *Heliyon* 9(6); e16809; 12 p. DOI: 10.1016/j.heliyon.2023.e16809.
- Shi S., Qiu Y., Wen M., Xu X., Dong X., Xu C., He X. 2021. Daytime, not nighttime, elevated atmospheric carbon dioxide exposure improves plant growth and leaf quality of mulberry (*Morus alba* L.) seedlings. *Frontiers Plant Science* 11; 609031; 12 p. DOI: 10.3389/fpls.2020.609031.
- Suma A., Latha M., John J.K., Aswathi P.V., Pandey C.D., Ajinkya A. 2021. Yard-long bean. In: Pratap A., Gupta S. (Eds.), *The Beans and the Peas*. Woodhead Publishing, pp. 153–172. DOI: 10.1016/b978-0-12-821450-3.00010-x.
- Tuffour M., Owusu G., Sarpong D.B. 2024. Urbanization effects on urban vegetable farmers adaptation: Evidence from Ghana. *Urban Agriculture and Regional Food Systems* 9(1); e20052; 14 p. DOI: 10.1002/uar.2.20052.
- Widuri L.I., Lakitan B., Hasmeda M., Sodikin E., Wijaya A., Meihana M. et al. 2017. Relative leaf expansion rate and other leaf-related indicators for detection of drought stress in chili pepper (*Capsicum annuum* L.). *Australian Journal of Crop Science* 11(12): 1617–1625. DOI: 10.21475/ajcs.17.11.12.pne800.