Growth response of guava (*Psidium guajava* L.) varieties in containers for urban horticulture

Abstract

Guava (*Psidium guajava* L.), valued for its taste and nutritional benefits, thrives in tropical and subtropical regions, with optimal growth in areas with distinct winters. It tolerates a wide temperature range but is heat-sensitive. Container farming offers a sustainable urban solution by optimizing space and reducing costs, making it ideal for addressing food security and environmental challenges in rapidly urbanizing areas by 2050. This study was conducted at the Department of Fruit Science, College of Agriculture, Vellayani to assess the growth response of guava (*Psidium guajava* L.) varieties under container cultivation. The experiment evaluated five air-layered guava varieties grown in 80 litre air- pots: T_1 (Allahabad Safeda), T_2 (Lucknow 49), T_3 (Arka Kiran), T_4 (Arka Rashmi), and T_5 (Arka Mridula). In terms of vegetative parameters like plant height (72.33cm) and primary and secondary stem girth (2.55cm and 1.93cm respectively), Arka Mridula outperformed the other varieties. The physiological and biochemical parameters (total chlorophyll (0.98 mg $100g^{-1}$, total reducing sugar (1.84%) and carotenoid (0.70 mg $100g^{-1}$) contents in leaf) were the highest in Arka Mridula. However, earliest flowering (101 days after pruning), the highest number of flowers (12.33) and the best canopy spread (74.67 (EW)) X 63.33cm (NS)) were registered in Arka Rashmi. Thus, the present study unveils the suitability of Arka Rashmi for container growing of guava.

Key words: Guava, *Psidium guajava*, varietal evaluation, container growing, urban horticulture

Introduction

Guava (*Psidium guajava* L.), belonging to the Myrtaceae family is a well-known fruit tree cultivated across tropical and subtropical regions, Guava is highly valued in the market due to its appealing taste, aroma, sweet flavour, and a well-balanced combination of acidity, sugar, and pectin (Mitra *et al*., 2007). The fruit is particularly rich in vitamin C and also contains significant amounts of vitamins A and B (Rai *et al*., 2010). Additionally, guava is a good source of pectin, calcium, and phosphorus. The pink color in the flesh of pink guava varieties is due to the carotenoid lycopene (Mercadante *et al*.,1999).

The guava tree is highly adaptable and can thrive in a wide range of climatic conditions, making it suitable for cultivation in many tropical and subtropical regions. It is also a low-maintenance crop with high productivity, offering considerable economic returns (Kadam *et al*., 2012). In regions where winter temperatures drop to 7°C, guava growth halts, leaves turn purple, and commercial production can become challenging.

India is the leading producer of guava with around 4,107 metric tonnes of annual production, covering an area of 2,70,000 hectares, with an average yield of 15.61 metric tonnes per hectare (National Horticulture Board, 2019). Uttar Pradesh, Madhya Pradesh, Bihar, Andhra Pradesh and Haryana are the major states cultivating guava.

Kerala, a state with geographical and spatial limitations has enormous potential to address the urban food supply chain, through urban home gardening, particularly on roof tops and balconies and container growing is one of its key components. Container farming is a micro-scale farming model where individual households can grow fruits and vegetables in containers.

As the global urban population is projected to double in the next 30 years, particularly in developing countries, cities would be facing increased challenges in food security, environmental degradation, poverty, and malnutrition. By 2050, over 60 per cent of the world's population will be residing in urban areas, intensifying competition for the small percentage of land (only 18%) that is cultivable. This land is further threatened by urban expansion, industrial development, and environmental disasters. Urban horticulture offers a viable solution by utilizing small urban spaces to grow food and greenery, thus improving food production, generating employment, and reducing environmental pollution (Solankey *et al*., 2020). Fruit crops like guava, citrus, ber, and pomegranate can be successfully cultivated in urban and semi urban areas in containers (Srivastava *et al.*, 2019).

Cultivation of guava in Kerala is limited to homesteads mostly occupied by local varieties. Guava responds well to canopy modification by pruning and training and is one of the most suitable crops for high density planting, as it bears fruits on current season's growth (Singh, 2007). A large number of guava varieties have been released for commercial cultivation by various institutions, such as CCS Haryana Agricultural University (Hisar Safeda, Hisar Surkha), CISH, Lucknow (Lalit, Shweta), IIHR, Bengaluru (Arka Amulya, Arka Kiran, Arka Mridula, Arka Rashmi), GBPUA&T (Pant Parbhat), and AAI, Allahabad (Allahabad Surkha). However, their adaptability to urban horticulture through container growing has not been thoroughly studied. The existing germplasm and varieties show significant heterozygosity, resulting in considerable variation in vegetative and floral parameters. (Praveen, 2019)

Guava cultivation in many regions is largely limited to homesteads, where local varieties are predominant. While crop improvement efforts in India have led to the development of promising selections and hybrids suited to different agro-climatic conditions (Dinesh and Vasugi, 2010), there is limited information on their performance in container growing. In Kerala Agricultural University studies were conducted to evaluate the effects of various container types, sizes, and planting materials on performance of guava in containers (Tharene, 2024). In this study two types (plastic container and air-pots) and three sizes (40L,60L and 80L) of containers and three planting materials (rooted cuttings, air layers and grafts) were evaluated for container growing of guava and the best results for the growth and yield response was obtained for air layers grown in 80L air-pots. However, efforts for a comprehensive varietal evaluation in container systems remain insufficient.

In this context, this study was proposed to explore the growth response of guava (*Psidium guajava* L.) varieties raised in containers for urban horticulture.

Materials and methods

Planting materials and experimental site: The experiment was carried out from November 2023 – October 2024 at the Department of Fruit Science, College of Agriculture, Vellayani. The area is situated at 8º 43' North Latitude and 76º 54' East Longitude at an altitude of 29 m above mean sea level. The experiment involved a comparison of performance among different varieties of guava (three months old air layers). Healthy air layers of variety Arka Kiran and Lucknow 49 were purchased from Agricultural Research Station (ARS), Mannuthy, Thrissur, Kerala Agricultural University, while varieties like Arka Mridula, Arka Rashmi and Allahabad Safeda were purchased from College of Agriculture, Vellanikkara. Thrissur. The potting mixture was composed of soil, FYM, and sand in 1:1:1 ratio. One fifth of the recommended dose of fertilizers as per the KAU Package of Practices (KAU, 2016) will be applied to the plants in pots.

Design of experiment and treatment details: The experiment was laid out in a completely randomized design (CRD) with five treatments and three replications. Treatments include five varieties (T_1- Allahabad Safeda, T_2- Lucknow 49, T_3 – Arka Kiran, T_4- Arka Rashmi, T_5- Arka Mridula) of guava.

Measurement of growth parameters

Growth characters viz., plant height, plant spread, stem girth, primary branch girth and secondary branch girth were recorded from the observational plants at trimonthly intervals from each treatment and the mean values were worked out. Pruning of the layers was carried out at a height of 20 cm above the ground level six months after planting.

Plant height

The height of the plant was measured from the base of the stem at soil level to the growing tip in the vertical position and expressed in centimeters (cm).

Plant spread

The spread of the plant was recorded by measuring the maximum spread in North-South and East-West directions with the help of measuring scale and expressed in centimeters

Stem girth

Stem girth was measured as the circumference of the main stem at 10 to 15 cm from the base of the stem using a twin and measured with a scale and expressed in centimeters (cm).

Primary branch girth

Circumference of the primary branch was observed and expressed in centimeters (cm).

Secondary branch girth

Circumference of the secondary branch was observed and expressed in centimeters (cm).

Measurement of floral parameters

Days to flowering

The number of days taken from the last pruning to the first blooming was measured and recorded in days.

Number of flowers

The number of flowers in each plant observed during the experimental period was counted from the last pruning.

Physiological parameters

The total chlorophyll content in the leaves was measured using the method outlined by Hiscox and Israelstam (1980). The total reducing sugars in the leaves were quantified using the Dinitrosalicylic acid (DNS) method as described by Somogyi (1952). The total soluble protein in the leaves was determined using Lowry's method (1951). The total carotenoid content in the leaves was estimated according to the procedure described by Sadasivam and Manikam (1976).

Statistical analysis: The observations were subjected to statistical analysis adopting standard procedures (ANOVA) by using KAU GRAPES Software (Gopinath *et al.,* 2021).

Results and Discussion

Vegetative parameters

Plant height

The different guava varieties varied significantly from each other in plant height (Table 3). Plant height was assessed at three-month intervals from 3 months after planting (MAP) to 9MAP. At 3 MAP, T_2 (39.00 cm) was the tallest, followed by T_4 (32.00 cm), while the shortest was T_3 (27.83 cm) and it was on par with T1 (28.00 cm) and T_5 (28.67 cm). At 6 MAP, T_2 maintained the greatest height (63.67 cm), followed by T_1 and T_5; T_3 had the lowest height (53.33 cm). By 9 MAP, which was 3 months after pruning of main stem, T_5 exhibited the highest plant height (72.33 cm), which was on par with T_1 (71.33 cm), while T_4 had the lowest recorded height (56.67 cm). The present study revealed that at 9MAP the guava variety Arka Mridula exhibited the maximum height (72.33 cm)in container growing, which was on par with

Allahabad Safeda (71.33 cm). This finding aligns with Sahoo (2017), in which Allahabad Safeda demonstrated superior height over other guava varieties, indicating its inherent potential for robust vertical growth.

Girth of main stem (stem girth)

Girth of main stem showed significant difference throughout the observation period among different varieties of guava (Table 2). Stem girth was assessed at three-months interval from 3 MAP to 9 MAP. At 3 MAP, T_2 exhibited the largest stem girth (3.83 cm), followed by T_3 (3.30 cm), which was on par with T_1 (3.17 cm). The smallest stem girth was observed in T_4 and T_5 (2.80 cm each). At both 6 MAP and 9 MAP, T_2 continued to have the highest stem girth measurements (5.31 cm and 6.08 cm, respectively), while the lowest stem girth was recorded in T_3 (4.28 cm at 6 MAP and 5.08 cm at 9 MAP).

Plant spread (E-W)

Plant spread in the east-west (E-W) direction showed significant differences throughout the period among different varieties of guava (Table 3). During the initial stages 3 MAP, T_4 (37.33 cm) had the greatest plant spread which was on par with T_3 (36.33cm) and the lowest spread in T_1(28.67cm). At 6 and 9 MAP, the highest plant spread was recorded in T_4 (54.33 cm and 74.67 cm, respectively). The lowest spread at 9 MAP was in T_1 (41.33 cm). Plant spread reflects the growth habit and is closely linked to flowering and fruiting ability. The findings of Singh *et al*. (2016) in guava cultivar Allahabad Safeda support this, as they reported a significant connection between plant spread, flowering, and fruit yield attributes.

Plant spread (N-S)

The plant spread in the north-south (N-S) direction showed significant differences throughout the period among different varieties of guava (Table 4). At 3 MAP, T_3 (40.33 cm) had the greatest plant spread, followed by T_2 (38.67 cm), which was on par with T_4 (37.67 cm). The lowest spread was recorded in T_1 (34.67 cm). At 6 and 9 MAP, the highest plant spread was recorded in T_4 (55.67 cm and 63.33 cm, respectively). The lowest spread at 6 MAP and 9 MAP was in T_1 (42.33 cm) and (46.33 cm). Arka Rashmi excelled in plant spread (both N-S and E-W spread), whereas, Arka Mridula exhibited the least spread. The variation in growth characteristics among different guava cultivars has been documented by Patel *et al.* (2007). These differences in plant growth are largely attributed to the genetic traits of each cultivar, with each genotype being developed in distinct ecological zones, leading to potentially varied responses in different agro-climatic conditions. These results align with the findings of Dolkar *et al*. (2014) on guava growth patterns, emphasizing the influence of cultivar-specific traits on plant spread.

Girth of primary branches

Girth of primary branches was significant across the measurement period among different varieties of guava, with assessments conducted at three-month intervals from 3 MAP to 9

MAP (Table 5). At 3 MAP, T_2 exhibited the thickest primary stem girth (2.65 cm), while T_4 had the thinnest primary stem girth (1.90 cm). At 6 MAP and 9 MAP, T_5 recorded the highest primary stem girth measurements (3.20 cm and 2.55 cm, respectively). By 9 MAP, the lowest primary stem girth was observed in T_2 (1.86 cm).

Girth of secondary branches

The girth of secondary branches showed significant difference between the treatments across the observation period (Table 6). At 3 MAP, T_1 exhibited the highest secondary stem girth (1.72 cm), which was on par with T_2 (1.62 cm), while T_5 had the smallest secondary stem girth (1.21 cm). At 6 MAP, T_1 recorded the highest secondary stem girth (2.32 cm), and at 9 MAP, T_5 had the highest secondary stem girth (1.93 cm). The lowest secondary stem girth at both 6 and 9 MAP was recorded in T_3 (1.86 cm and 1.55 cm, respectively). Primary and secondary stem girth are the crucial indicators of a plant's vigour and sustained growth. In this study, Arka Mridula demonstrated the highest girth in both primary and secondary stems, aligning with the findings of Marak and Mukunda (2007) in Apple Colour guava, where they investigated the relationship between increased stem girth and overall plant vigour and growth. Their research indicated that thicker stems contribute significantly to enhanced vegetative development and robustness in guava plants.

Flowering parameters

Days to flowering

Days to flowering was recorded after pruning the main stem (Table 7). T_4 had the fewest days to flowering (101 days), while T_5 had the highest number of days to flowering (132.33 days). The study revealed a notable varietal influence on floral parameters of container grown guava layers particularly regarding the days to flowering and the number of flowers produced. Arka Rashmi presented earliest flowering, followed by Arka Kiran. This observation is in consonance with that of Singh (2003), who found that red-fleshed guava varieties exhibited earlier flowering, fruit set, and fruit ripening compared to other guava varieties.

Number of flowers

The number of flowers was noted after pruning the main stem (Table 7). The highest number of flowers was observed in T_4 (12.33), followed by T_3 (10.33), and the lowest was noted in T_5 (5.33) which was on par with T_1 (5.67). The observed variation in flowering may be attributed to cultivar-specific traits and environmental conditions. Understanding the flowering and fruiting behaviours of fruit trees is crucial for both fruit growers and breeders. A similar pattern in flowering percentage was observed, supporting the findings of Dubey *et al*. (2004), who studied different varieties of guava focusing on flowering and fruit characteristics; Sharma *et al*. (2017) on the time and duration of guava flowering; and Sarkar *et al*. (2016) and Dolkar *et al*. (2014) on the growth and yield attributes of guava.

PHYSIOLOGICAL AND BIOCHEMICAL PARAMETERS

Chlorophyll Content

Chlorophyll A, chlorophyll B, and total chlorophyll content in guava leaves showed significant variation among different varieties of guava (table 8). The highest chlorophyll A content was observed in T_1 (0.85mg 100g $^{-1}$), followed by T_5 (0.82 mg 100g $^{-1}$), while the lowest was noted in T4 (0.77 mg 100g $^{-1}$). The highest Chlorophyll B content was observed in T_5 and T_1 (0.84 mg 100g $^{-1}$each), while the lowest was noted in T_4 and T_2 (0.81 mg 100g $^{-1}$). The highest total chlorophyll content was observed in T_5 (0.98 mg 100g $^{-1}$), followed by T_1 (0.91 mg 100g $^{-1}$), while the lowest was noted in T_4 (0.79 mg 100g $^{-1}$). Arka Mridula had the highest chlorophyll content compared to all other varieties of guava. Higher chlorophyll levels indicate more efficient photosynthesis (Zhu *et al*., 2010), which might have lead to better vegetative growth in Arka Mridula.

Total reducing sugar

Total reducing sugar content of guava leaves varied significantly among the different varieties (table 9). Reducing sugar was the highest in T_5 (1.84 %) and the least was noted in T_2 (1.53 %). Also, the reducing sugar content (1.84%) of leaves was the highest among all the varieties under study. This variety also exhibited the highest plant height and stem girth but flowering was delayed compared to other varieties. Elevated sugar levels in leaves, without triggering flowering, suggests that sugars have been primarily used for vegetative growth. This might have resulted from a limited sucrose transport system that prevents sugars from reaching flower-inducing areas. As a result, sugars accumulate in the leaves, boosting growth in height and stem girth instead of promoting flowering (Slewinski *et al*., 2009).

Total soluble proteins

Total soluble protein content showed significant variation among the different varieties of guava (Table 9). The highest soluble protein content was recorded in T_1 (0.52 %) least was noted in T_3 (0.39 %). On soluble protein analysis, Allahabad Safeda exhibited the highest soluble protein content (0.52%) followed by Arka Mridula. Arka Mridula outperformed the other varieties with respect to plant height and it was on par with Allahabad Safeda. This result aligns with findings by Jing *et al*. (2023), which demonstrated that higher soluble protein levels, particularly in alfalfa leaves, are significantly associated with increased plant height. The research suggests that soluble proteins enhance photosynthetic capacity, thereby supporting better growth and taller plants.

Total Carotenoids

Carotenoid content in guava leaves showed significant difference among the different varieties (Table 9). Carotenoid content was the highest in T_5 (0.70 mg 100g $^{-1}$) and the least in T_4 (0.61 mg 100g $^{-1}$).

Conclusion

In conclusion, vegetative parameters including plant height and primary and secondary stem girth were the highest in Arka Mridula which was reflected in physiological and biochemical parameters like chlorophyll (0.98 mg 100 g^{-1}), reducing sugar (1.84%) and carotenoid (0.70 mg100 g^{-1}) contents that gave the highest values. However, in canopy spread and flowering parameters like days to flowering and number of flowers the highest values were in Arka Rashmi. Plants with a compact canopy and good reproductive parameters are ideal for container growing. Thus, the present study unveils the suitability of Arka Rashmi for container growing of guava.

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Table 1. Variation in plant height (cm) among different varieties of guava

Treatment	3 MAP	6 MAP	9 MAP
T_1	28.00^{c}	57.67^{b}	71.33^{a}
T_2	39.00^{a}	63.67^{a}	63.33^{b}
T_3	27.83^{c}	53.33^{d}	61.33^{c}
T_4	32.00^{b}	54.67^{c}	56.67^{d}
T_5	28.67^{c}	57.67^{b}	72.33^{a}
SEm±	0.68	0.33	0.49
CD(0.05)	2.14	1.05	1.56

Table 2. Variation in girth of the main stem (cm) among different varieties of guava

Treatment	3 MAP	6 MAP	9 MAP
T_1	3.17^{b}	4.71^{d}	5.43^{d}
T_2	3.83^{a}	5.31^{a}	6.08^{a}
T_3	3.30^{b}	4.28^{e}	5.08^{e}
T_4	2.80^{c}	4.85^{c}	5.61^{c}
T_5	2.80^{c}	4.90^{b}	5.67^{b}
SEm±	0.06	0.01	0.02
CD(0.05)	0.19	0.01	0.05

Table 3. Variation in plant spread – East West direction (cm) among different varieties of guava

Treatment	3 MAP	6 MAP	9 MAP
T_1	28.67^{d}	39.67^{d}	41.33^{d}
T_2	31.00^{c}	38.67^{e}	50.67^{c}
T_3	36.33^{a}	44.33^{c}	63.67^{b}
T_4	37.33^{a}	54.33^{a}	74.67^{a}
T_5	34.67^{b}	47.00^{b}	64.33^{b}
SEm±	0.39	0.30	0.49
CD(0.05)	1.24	0.94	1.56

Table 4. Variation in plant spread – North South direction (cm) among different varieties of guava

Treatment	3 MAP	6 MAP	9 MAP
T_1	31.67^{d}	42.33^{e}	46.33^{d}
T_2	38.67^{b}	44.67^{d}	47.67^{c}
T_3	40.33^{a}	50.67^{c}	57.67^{b}
T_4	37.67^{b}	55.67^{a}	63.33^{a}
T_5	35.67^{c}	52.33^{b}	58.67^{b}
SEm±	0.33	0.42	0.33
CD(0.05)	1.05	1.33	1.05

Table 5. Variation in girth of primary branches (cm) among different varieties of guava

Treatment	3 MAP	6 MAP	9 MAP
T_1	2.13^{b}	2.90^{c}	2.25^{c}
T_2	2.65^{a}	2.97^{b}	1.86^{e}
T_3	2.02^{bc}	2.82^{d}	2.16^{d}
T_4	1.90^{c}	2.70^{e}	2.31^{b}
T_5	2.10^{b}	3.20^{a}	2.55^{a}
SEm±	0.06	0.02	0.01
CD(0.05)	0.19	0.05	0.01

Table 6. Variation in girth of secondary branches (cm) among different varieties of guava

Treatment	3 MAP	6 MAP	9 MAP
T_1	1.72^{a}	2.32^{a}	1.75^{c}
T_2	1.62^{a}	2.21^{b}	1.66^{d}
T_3	1.27^{bc}	1.86^{e}	1.55^{e}
T_4	1.43^{b}	2.00^{d}	1.78^{b}
T_5	1.21^{c}	2.15^{c}	1.93^{a}
SEm±	0.06	0.01	0.01
CD(0.05)	0.17	0.01	0.01

Table 7. Variation in days to flowering and number of flowers among different varieties of guava

Treatment	**Days to flowering (days)**	**Number of flowers (days)**
T_1	117.67[d]	5.67[d]
T_2	102.67[b]	8.33[c]
T_3	106.33[c]	10.33[b]
T_4	101[a]	12.33[a]
T_5	132.33[e]	5.33[d]
SEm±	0.39	0.33
CD(0.05)	1.24	1.05

Table 8. Variation in physiological and biochemical parameters among different varieties of guava

Treatment	Chlorophyll A (mg 100g $^{-1}$)	Chlorophyll B (mg 100g $^{-1}$)	Total Chlorophyll (mg 100g $^{-1}$)
T_1	0.85[a]	0.84[a]	0.91[b]
T_2	0.79[c]	0.81[c]	0.82[c]
T_3	0.78[d]	0.82[b]	0.81[c]
T_4	0.77[e]	0.81[c]	0.79[d]
T_5	0.82[b]	0.84[a]	0.98[a]
SEm±	0.003	0.003	0.003
CD(0.05)	0.011	0.011	0.011

Table 9. Variation in physiological and biochemical parameters among different varieties of guava

Treatment	Total reducing sugars (%)	Total soluble proteins (%)	Total carotenoids (mg 100g $^{-1}$)

T_1	1.79^{b}	0.52^{a}	0.67^{b}
T_2	1.53^{e}	0.47^{b}	0.62^{d}
T_3	1.77^{c}	0.39^{e}	0.64^{c}
T_4	1.56^{d}	0.41^{d}	0.61^{e}
T_5	1.84^{a}	0.45^{c}	0.70^{a}
SEm±	0.01	0.004	0.004
CD(0.05)	0.02	0.014	0.012

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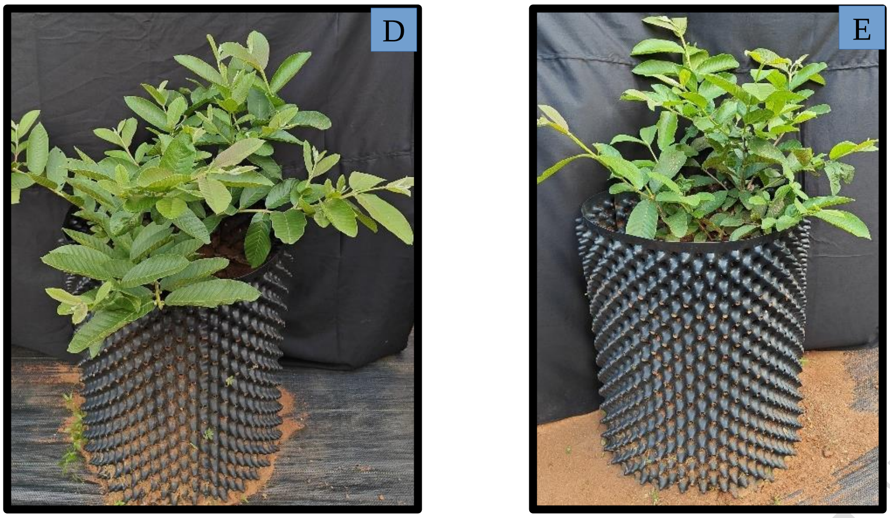

Fig. 1. Variation in plant height among different varieties of guava (A. Arka Mridula; B. Allahabad Safeda; C. Lucknow 49; D. Arka Kiran; E. Arka Rashmi)

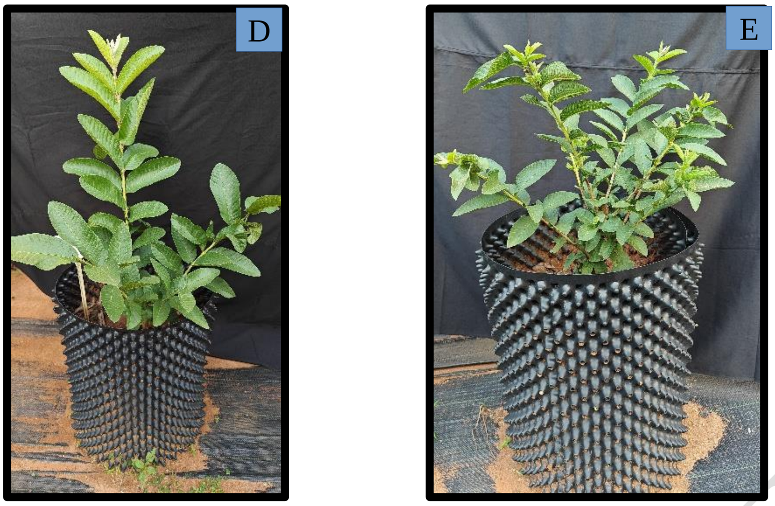

Fig. 2. Variation in plant spread among different varieties of guava (A. Arka Rashmi, B. Arka Kiran, C. Allahabad Safeda D. Arka Mridula and E. Lucknow 49)