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# Morphological and physiological characterization of guava (*Psidium guajava*) under hot-arid zone of Rajasthan

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ABSTRACT

This study was carried out to investigate morpho-physiological and productivity characteristics of four genotypes of five years old guava (*Psidium guajava* L.) trees, grown under hot-arid zone of Rajasthan. Preliminary investigation indicated that all four cultivars of guava could survive except merely 10.0% field mortality in guava cv. L-49. The maximum increase in plant height (25.93%) and number of new leaves/branch (4.66) over six months of planting were recorded in Sweta, followed by Lalit, while during fruiting (August for rainy season guava) highest number of new shoot sprouts/branch was found in Allahabad Safeda, followed by Sweta. Lalit and Sweta also produced substantial number of new leaves/branch during fruiting, than the other cultivars. Chlorophyll *a* ($Chl_a$), chlorophyll *b* ($Chl_b$) and total chlorophyll ($Chl_{total}$) contents were highest in L-49, followed by Lalit. The leaves produced on Sweta received lesser photosynthetically active radiations (PAR) but had highest leaf area (80.91 $cm^2$), specific leaf area (SLA; 36.61 $cm^2/g$) and relative water content (RWC; 60.19%). Although L-49 had thicker leaves (lowest SLA; 33. 29 $cm^2/g$), indicating better adaptation towards resource poor environment but other cultivars of guava also had SLA at par among other three cultivars. Allahabad Safeda received maximum PAR (1066 $\mu E/m^2/s$), also had highest internal $CO_2$ concentration (*Ci*; 207.76 µmol/mol), while highest net photosynthesis rate ($P_N$; 10.84 µmol $CO_2/m^2/s$), carboxylation efficiency (CE) and water use efficiency (WUE) were observed in Lalit. Guava cv. L-49, however, showed lowest $P_N$ (6.31 µmol $C0_2/m^2/s$), Ci, WUE, transpiration rate (E) and CE. Thus, guava cultivars Sweta followed by Lalit performed better under hot-arid environment with better growth and physiological adaptation. L-49 was not found suitable for the area.

**Key words:** Arid environment, Chlorophyll, Growth, Guava, Leaf water, Photosynthesis

Guava (*Psidium guajava* L.) the apple of the tropics, is a popular fruit of India and cultivated in many tropical and sub-tropical countries for its edible fruit. It prefers full sun and survives in dry summers with little water, but does best with regular watering. It exceeds the majority of tropical and sub-tropical fruit trees in adaptability, productivity, and tolerance to mild cold and light frosts (Yadav 1996). Mature trees of most varieties thrive in both humid and dry climates. It is fairly cold-hardy and can survive as low as 5°C (41°F) for short periods of time at night (Wei 2008). Guava seems indiscriminate to soil conditions, doing equally well on heavy clay, marl, light sand, gravel bars near streams, or on limestone; and tolerating a pH range from 4.5 to 9.4. It is somewhat salt-resistant. Guavas can take considerable neglect, withstanding temporary water-logging and very high temperatures. The tree is drought-tolerant but in dry regions, which receive only 15 to 20 inch (38–50 cm) rainfall annually, respond to irrigation once every 15–20 days in summer and once at monthly interval in winter. Some guava cultivars (L-49 can tolerate salt up to pH: 9.30 and ESP: 30) are clearly more flexible than others in their requirements for survival in salty environments. Native plants in each country often have greater adaptability and higher resistance to adverse environmental conditions. However, in most cases the characteristic of these plants have not been well studied (Sanchez-Blanco *et al*. 1998).

The western part of Rajasthan where agriculture is not very modern and where guava crop is being introduced, the information supplied by environmental physiologists will be highly valuable for deciding on the distribution and performance of this fruit crop. Knowledge on the responses of horticultural crops to changing environmental factors such as temperature, water availability, light or carbon dioxide concentration will be useful in determining the effect of suboptimal environmental conditions and to manage crops for maximum productivity (Schaffer and Andersen 1994). In addition, a better understanding of the interaction between environmental factors and physiological processes contributes to horticultural breeding programs, production

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sustainability and efficient agricultural zoning (Campostrini and Glenn 2007).

At present guava is being grown in some districts of Rajasthan, viz. Sawai Madhopur, Jaipur, Ajmer, Udaipur, Chittorgarh, Kota, Bhilwara, Bundi, Jhalawar etc (Anonymous 2013). However, north-western parts of Rajasthan, where hardly any guava cultivation has taken place, could be potential area under dry land horticulture for its expansion due to better sunshine, low rainfall and relative humidity, and ensure better quality fruits (especially for rainy season crop). Proper selection of varieties for different agro-climatic zones is very essential for obtaining good yield and quality of guava (Dolkar *et al*. 2014). So far little information is available on the varying environmental responses of guava trees and therefore, the research was aimed to investigate growth and physiological responses/ adaptations of guava trees under hot-arid environment.

## MATERIALS AND METHODS

Plant material for the present study comprises 5 year old uniformly growing plants of four guava cultivars, viz. Sweta, Lalit, Allahabad Safeda and L-49 at the Research Farm of ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan, and the experiment was carried out from June to September 2010. Experiment was laid out in randomized block design, planted in square system at a distance of 6 m × 6 m, with cultivars as four treatments, and four replications.The study area extends from 27° 15' to 29° 5' north latitude and 71° 54' to 74° 12' east longitude and experiences arid climate, high temperature during summer (45 to 50 °C) and low freezing temperature in winter (–0.5 to–1.5°C), high wind velocity during summer (20–30 km/h), low precipitation (250 mm), and high potential evapo-transpiration (1200 to 1700 mm/year). The soil is sandy loam, low in fertility and water holding capacity, with pH 8.4, organic carbon: 0.09%, available N: 110 kg/ha, available P: 4 kg/ha and available K: 224 kg/ha.

The selected trees were marked with metal tags for recording observation for morphological and physiological adaptations under hot-arid zone of Rajasthan. Field mortality percentage was calculated by counting number of plants died over number of plants planted in a particular block. Plant height measured with meter scale and shoot thickness by vernier calipers. The increase in plant height was calculated using formulae as increase in height (%) = [height of plant (at the time of planting)–height of the plant (during first fruiting, i.e during August)/height of the plants during planting] × 100. Number of new shoot sprouts/branch was counted during August (one month after outbreak of monsoon in the region, when plants show first fruiting) from five selected shoot from each direction and mean of three branches was noted and average was calculated. The number of new leaves/branch (not more than 15 days old) was estimated by counting on each of the tagged (individual) branches during August.

The chlorophyll *a* (Chl a), chlorophyll *b* (Chl b), and total chlorophyll contents of fully-mature, opened leaves from shoot tips were analysed following the method of Barnase *et al.* (1992). Mature leaves were randomly selected from interior and peripheral branches from tagged plants used for estimation of leaf area ($cm^2$) using formula suggested by Kobayashi (1987): A = 16.44 - 3.11 L + 0.58 sq L, where A is leaf area (sq cm) and L is leaf length (cm).

Leaf length was measured from the base to the tip of the leaf blade. Specific leaf area (SLA) was calculated by dividing total leaf area by dry mass of leaves ($cm^2/g$) as suggested by Yulin *et al*. (2005).

For leaf relative water content (RWC), the fresh weight, saturated fresh weight, and dry weight of leaves were determined for each cultivar. After measuring the fresh weight of freshly harvested leaves, they were placed into containers with distilled, deionized water for 4 to 8 h to a constant weight and saturated fresh weight was measured for each sample. Dry weight was obtained after drying these leaves at 70°C in an oven for 48 to 72 h to a constant weight. In all measurements, fully expanded leaves of a similar age were used. Leaf relative water content (RWC) was calculated as [FW–DW)/TW–DW)] × 100, where FW is leaf fresh weight; DW is leaf dry weight and TW is leaf saturated fresh weight (Peng *et al*. 2007).

Gas exchange measurements were made once in a day (from 9.00 to 11.00 AM) on south facing mature leaves by using Hand-held photosynthesis system with an 11 $cm^2$ window leaf chamber at $CO_2$ concentration of 360 $cm^3/m^3$ and 21% $O_2$ or 2% $O_2$ air conditions (to inhibit the apparent photosynthesis) for net photosynthesis rate, transpiration rate, internal $CO_2$ concentration (*Ci*) and photosynthetically active radiation (PAR). The gas exchange rates were determined at each step after maintaining the leaf for 5–10 min at the new $CO_2$ concentration. All measurements were done in fully expanded leaves (usually the sixth to eighth from the top) of four different plants just before midday to reduce diurnal variation interference (Cartechini and Pallioti 1995). The data was stored in the data logger in the equipment and analyzed statistically. The instantaneous leaf water use efficiency (WUE) (μmol/mol) was calculated as $P_N/E$, and the instantaneous carboxylation efficiency (A/Ci) (μmol/$m^2$/·s/ μmol/mol) was calculated as suggested by Silva-Marcelo de Almeida *et al*. (2013).

Number of flowers/branch, number of blackened fruits/ tree were estimated through counting on tagged shoots or plants. The fruits of different cultivars were harvested with secateurs keeping a small intact pedicel with each fruit and sampled separately from each tree at full maturity. Weights of five randomly selected mature ripe fruits from four trees per plot were recorded. Total soluble solids (TSS) were measured by a hand refractometer and the values were corrected at 20°C. The data was analyzed by analysis of variance (ANOVA) and LSD was calculated at $P \leq 0.05$.

## RESULTS AND DISCUSSION

Drought and extreme high temperature are considered as one of the most important factors limiting fruit yields in the world. Exposure of plants to gradually increasing stress might initiate physiological and biochemical adjustment that protect them from injury when environmental stresses abruptly occur. Growth characteristics of four guava cultivar studied are shown in Table 1. According to these results, there were noticeable differences among survival and growth parameters like increment in height, shoot thickness, number of shoot sprouts per plant and number of new leaves per branch during first fruiting (August) over time of planting of the same year, i.e February.

Except for 10.0% field mortality in guava cv. L-49, rest of the guava cultivars had no field mortality; in fact tropical guava once established did very well in summer. The maximum increase in plant height (25.93%) and number of new leaves/branch (4.66) at the time of first fruiting (August) over month of planting (February) were recorded in Sweta, followed by Lalit. L-49 had maximum tree girth, while lowest shoot thickness was found in Sweta. The highest number of new shoot sprouts/branch was found in Allahabad Safeda, followed by Sweta, Lalit and Sweta also produced higher number of new leaves/branch than other cultivars (Table 1).

Light harvesting pigments are involved in photosynthesis in leaves. Hence, changes in pigment content in leaves can affect rate of photosynthesis of plants. Variations in leaf morphological characters and chlorophyll content directly influence the leaf gas exchange (Takayoshi *et al*. 2001). The results presented in (Fig 1c) showed that chlorophyll a, chlorophyll b and total chlorophyll contents were highest in L-49 (0.421, 0.769, 1.20 mg/g, respectively). Since chlorophyll pigments may have been resistant to dehydration (Luvaha *et al.* 2007) and leaves of this cultivar had least transpiration rate (2.8 m mol/m). The total chlorophyll content of Sweta was at par with L-49, may be due to water stresses as it reduces total chlorophyll content.

Maintenance of high relative water content (RWC) in leaves is an adaptive trait for hot-arid conditions (Irigoyen *et al*. 1992), and plants with high RWC are more resistant to drought condition/desiccation (Hao 2008). Guava cv. Sweta had highest relative water content (60.19%), while lowest RWC was found in Allahabad Safeda and Lalit (Fig 1a). The data on leaf area are showed that cv. Sweta had highest leaf area, followed by L-49 and Lalit, while the least was observed in Allahabad Safeda (Fig 1a).

Table 1 Plant survival and growth characteristics of guava cultivars under hot-arid environment

| Cultivar | Field mortality (%) | Increment in tree height (%) | Shoot thickness (cm) | No. of new shoot sprouts/ branch | No. of new leaves/ branch |
|---|---|---|---|---|---|
| Sweta | 0.0 | 25.23 | 1.90 | 12.00 | 29.00 |
| Lalit | 0.0 | 25.77 | 1.63 | 6.33 | 28.66 |
| Allahabad Safeda | 0.0 | 24.48 | 1.60 | 5.33 | 26.66 |
| L-49 | 10.0 | 11.02 | 1.73 | 5.66 | 29.33 |
| SEm± | 0.45 | 1.19 | 0.12 | 1.42 | 4.10 |
| LSD (P≤0.05) | 1.46 | 1.89 | 0.38 | 4.54 | NS |

Phenological phases as well as weather conditions influence photosynthesis, and thereby plant's carbohydrate and nitrogen metabolism (Taiz and Zeiger 1998). Gas exchange characters and related traits are highly important for the growth and yield in plants. The poor yield and low quality fruits are largely due to poor photosynthetic efficiency, poor distribution of light, coupled with other compounding factors (Singh and Singh 2007). Though Guava cv. Sweta received lesser photosynthetically active radiations (PAR), but had highest leaf area (80.91 $cm^2$) (Fig 1a), specific leaf

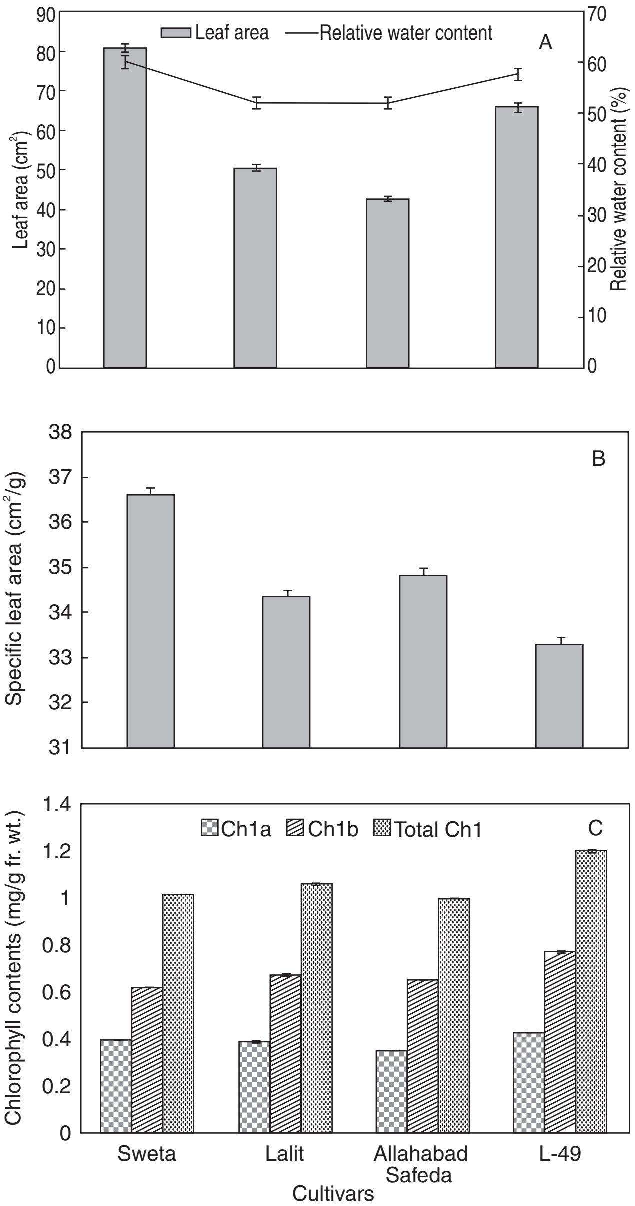


Fig 1 Variations in leaf area and relative water content (A), specific leaf area (B) and chlorophyll a, b, and total chlorophyll contents (C) in different guava cultivars under hot-arid environment. Vertical bars represent ±SE of means (n=4).

Table 2 Photosynthetic attributes and leaf water use efficiency of guava cultivars under hot-arid environment

| Cultivar | Photosynthetically active radiations (μE/m$^2$/s) | Net photosynthesis rate (μmol $CO_2$/ m$^2$ /s) | Transpiration rate (mmol $H_2O$ m$^2$/s) | Internal $CO_2$ concentration (μmol/mol) | Carboxylation efficiency[ (μmol $CO_2$/ m$^2$/s) (μmol/mol)$^{-1}$] | Water use efficiency (μmol/mol) |
|---|---|---|---|---|---|---|
| Sweta | 894 | 8.01 | 2.98 | 206.32 | 0.038 | 2.68 |
| Lalit | 1041 | 10.84 | 4.02 | 173.30 | 0.062 | 2.69 |
| Allahabad Safeda | 1066 | 10.38 | 4.41 | 207.76 | 0.045 | 2.35 |
| L-49 | 1064 | 6.31 | 2.80 | 160.43 | 0.042 | 2.25 |
| SEm± | 53.63 | 0.96 | 0.25 | 15.75 | 0.005 | 0.027 |
| LSD (p≤0.05) | 171.59 | 3.07 | 0.81 | NS | 0.011 | 0.085 |

area (36.61 cm$^2$/g) and thus also is likely to exhibit high productivity and do better in resource rich environments (Yulin *et al*. 2005) due to better photosynthesis. Singh and Singh (2007) reported increase in photosynthesis in guava with increasing irradiance, however, in the present study highest photosynthesis (15.0 μmol $CO_2$/m$^2$/s) was observed in Lalit guava at PAR of 900 μmol/m$^2$/s, and beyond 900 μmol/m$^2$/s no significant change in the rate of photosynthesis was observed.

L-49 had thicker leaves (lowest SLA, 33. 29 cm$^2$/g) (Fig 1b), which tend to have a lower transmittance due to an increased multiple scattering and optical path length (detour effect) through the leaf as compared to thinner leaves (Vogelmann 1993), indicating better adaptation under resource poor environment. However, other cultivars of guava also had SLA at par with other three cultivars (Fig 1b). Data showed that Allahabad Safeda received maximum PAR (1066 μ*E*/m$^2$/s), had highest internal $CO_2$ concentration (Ci: 207.76 μmol/mol) but had lower $P_N$, because of damaging effect of high fluxes of PAR on photosynthetic apparatus (Nogues and Baker 2000), i.e. photo-oxidation of chlorophyll, as is clear from its lower total chlorophyll content. Study suggests higher value of PAR in L-49 triggered the inhibition of photosynthesis (Table 2).

Internal $CO_2$ concentration of leaves has a profound effect on $CO_2$ assimilation rate, though in the present study no varietal variations were observed (Table 2). In many species sub-stomatal $CO_2$ concentration tends to remain constant over a range of environmental conditions (Pearcy 1981). Highest carboxylation efficiency (CE: 0.062 μmol/m$^2$/s/μmol/mol) was observed in Lalit, probably due to highest rate of net photosynthesis (10.84 μmol $CO_2$/m$^2$/s) and water use efficiency (WUE: 2.69 μmol/mol). Water use efficiency provides information regarding the carbon fixed by photosynthesis per unit of water lost by stomatal conductance and transpiration or capacity of plants to preserve water and maximizing carbon fixation (Laurent *et al*. 2006). The variation among cultivars for these characters might be due to unique genetic features of individual cultivars under the same environmental condition. Guava cv. L-49, however, had lowest $P_N$, Ci, WUE, E and CE (Table 3), which could be attributed to lower level of xylem water potential as it had least water used efficiency (Scholefield *et al*. 1980).

Table 3 Floral and fruit quality parameters of guava cultivars under hot-arid environment

| Cultivar | Number of flowers/ branch | No. of blackened fruits/tree | Average fruit weight (g) | Total soluble solids (°brix) |
|---|---|---|---|---|
| Sweta | 9.33 | 3.33 | 107.408 | 11.60 |
| Lalit | 5.66 | 0.66 | 92.272 | 11.22 |
| Allahabad Safeda | 3.33 | 0.33 | 40.694 | 10.10 |
| L-49 | 2.66 | 0.33 | 45.800 | 9.70 |
| SEm± | 0.59 | 0.14 | 13.80 | 0.43 |
| LSD (p≤0.05) | 1.83 | 0.46 | 43.01 | 1.36 |

Number of flowers per branch was highest (9.33) in Sweta than other cultivars as well as greater number of blackened fruits (3.33), due to its vulnerability to high intensity sunlight in the region and bearing more number of fruits per branch. The average fruit weight (107.4 g) and TSS (11.60 °B) was also highest in Sweta, possibly due to moderate $P_N$ and lower level of transpiration rate, indicating that $P_N$ in Sweta is probably inhibited by non-stomatal effects, i.e. enzyme inhibition in comparison to Lalit. Maintenance of high RWC by the cultivar may also be attributed to high TSS and fruit size. Aziz-e-Chakherchaman *et al*. (2009) have also reported that the genotypes with higher leaf RWC under severe water stress condition show high yield. Guava cv. L-49 has least number of flowers per branch, lesser sized fruit that too with insipid tastes (TSS: 9.90 $^0$B). The variations among cultivars with regard to physical characters could be due to genetic variability and climatic adaptability in a particular region, which might prove to be an important diagnostic character for selection of germplasm for local conditions (Dholkar *et al*. 2014).

Based on the results on growth, physiological and fruit parameters, guava cultivar Sweta and Lalit were identified as best for cultivation under hot-arid environment of Rajasthan. However, L-49 may not be suitable for cultivation in arid climate. In another word, red guava (Lalit) is more suitable for adverse environmental conditions than the white cultivar (L-49, Sweta). Though guava can perform relatively better in western parts of Rajasthan, but for wide cultivation of this fruit in the region long term experiments are required on evaluation of different guava cultivars for suitability and adaptability for the region.

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