



Effect of plant spacing and fertility level on leaf area variation at different phenological stages of cape gooseberry (*Physalis peruviana* L.) grown in sodic soil

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Received: January 28, 2016; Revised received: October 26, 2016; Accepted: January 26, 2017

Abstract: Vegetative and reproductive growth in cape gooseberry (*Physalis peruviana* L.) proceed concomitantly during the greater part of the life cycle thereby foliar traits (e.g. leaf area) become important in photosynthetic action of the plant. In present study, the leaf area variation in cape gooseberry was studied at five phenological stages i.e. pre-flowering (30 DAT), start of flowering (60 DAT), early fruiting (120 DAT), peak fruiting (180 DAT) and late fruiting (240 DAT), grown at three spacings (60 × 75, 75 × 75 and 75 × 90 cm) and four NPK levels (control, 60:40:40, 80:60:60 and 100:80:80 kg ha⁻¹). Leaf area increased from pre-flowering (73.51 cm²) to start of flowering (82.26 cm²) and thereafter, it was decreased gradually at later stages i.e. early fruiting (79.17 cm²), peak fruiting (73.15 cm²) and late fruiting (60.21 cm²). Spacing had no significant effect on leaf area at pre-flowering and start of the flowering, but at later stages, widest spacing (75 × 90 cm) exhibited significantly maximum leaf area at early fruiting (82.44 cm²), peak fruiting (78.22 cm²) and late and fruiting (65.31 cm²). Leaf area increased due to increased NPK levels with maximum values under 100:80:80 kg NPK ha⁻¹ at all the phenological stages: pre-flowering (78.99 cm²), start of flowering (90.97 cm²), early fruiting (88.47 cm²), peak fruiting (80.74 cm²) and late fruiting (67.22 cm²). Spacing × NPK Interactions was significant only at peak fruiting and late fruiting stages with maximum leaf area (75.22 and 71.02 cm², respectively) at 75 × 90 cm + NPK @ 100:80:80 kg ha⁻¹. These findings can be further helpful in leaf sclerophylly studies in cape gooseberry.

Keywords: Cape gooseberry, Leaf area, NPK, Phenological stage, *Physalis peruviana* L., Spacing

INTRODUCTION

Morphometric monitoring of crops plants during the growing season becomes increasingly important in order to adjust the crop husbandry and to provide information for obtaining optimum yield. In growing crop canopies, foliar traits such as leaf area index and leaf mass per unit area are the important factors in leaf light harvesting capacity and photosynthetic potentials. Leaf area of crop is one of the most important parameter required in the estimation of several plant growth indices and various models for predicting crop growth and dry matter production, development rate, yield potential, radiation use efficiency (Centritto *et al.*, 2000; Williams and Martinson, 2003), quantifying crop-weed competition, energy and water exchanges in the plant soil-atmosphere continuum, as they are associated with photosynthesis and evapo-transpiration (Guo and Sun, 2001). Leaves of the same canopy often show different rates of photosynthesis and transpiration, therefore, estimations of leaf area linked to physiological characteristics are essential to define the overall contribution of each canopy portion to fruit quality and

yield (Serdar and Demirsoy, 2006; Ribeiro and Machado, 2007).

Apart from genetic potential of the crop, the growing environments have profound effects on crop development resulting in modified overall canopy structure and appearance. Altering the soil fertility by providing balanced nutrition as per the crop requirements is one of the easiest ways to boost up crop productivity. A reliable supply of nitrogen, phosphorus and potassium is crucial and especially significant for synthetic events within growing cells. Leaf expansion is particularly sensitive to nutrient supply (especially nitrogen, phosphorus and potassium), primarily to the needs of enlarging cells for synthesis of new materials and generation of turgor. Leaf area and vertical L profile influence the interception and utilization of solar radiation of crop and consequently, the dry matter production (Boote *et al.*, 1998). Better correlation appeared between leaf areas and weights at the high nitrogen rate than at the low nitrogen rate (Miller *et al.*, 1967). Since the interception in the supply of major nutrients even for a brief period is determined by pattern of crop growth and development which may

produce less yield and poor quality and it cannot be corrected or altered at later stages of the crop growth even by supplying with heavier doses of major nutrients (Dwivedi *et al.*, 2002). Further, spatial arrangement of a crop affects plant biomass allocation and yields. The interaction between vegetation surface and the atmosphere is substantially determined by the vegetation surface (Monteith and Unsworth, 1990), consequently the variation in canopy light availability is a result of foliage structural and canopy architectural characteristics (Maddonni *et al.*, 2001). Plant leaf area is an important determinant of light interception and consequently of transpiration, photosynthesis (Goudriaan and Laar, 1994), and hence has a substantial influence plant productivity.

The cape gooseberry (*Physalis peruviana* L.; Family: Solanaceae) is a soft wooded, herbaceous crop has long been a minor fruit of the Andes and also been grown in California, South Africa, East Africa, India, New Zealand, Australia, and Great Britain, so far, now becoming popular in several countries like California, South Africa, New Zealand, Australia, East Africa, and tropical south America. Cape gooseberries are mainly cultivated for its delicious fruits that fetches very high price, for example, Europeans, often pay premium prices for the fruits, which are dipped in chocolate or used to decorate cakes and tortes (Ramadan and Morsel, 2003). Beside several well documented phytochemical values of this crop, the nutritional value of the fruits is excellent and comparable with any other major fruit crops of India. Although, it is a minor crop in India, but deserves special attention particularly due to wide adaptability, quick growing in nature, high productivity, non-perennial occupation of land, availability delicious fruit with pleasing acetic taste in lean period of time. According to Morton (1987), cape gooseberry is said to succeed wherever tomatoes can be grown. While for tomatoes and other major solanaceous crops, there generally exists a lot of information and practical recommendations; the literature sources for cape gooseberry are very limited. Although, few studies have been carried out so far, but still there is lack of knowledge for various physiological traits, particularly variations in leaf area during growth and development of plant under varying growing conditions. This work aims to investigate the leaf area variation in during different phenological stages of cape gooseberry (*Physalis peruviana*) under varying plant spacing and fertility levels.

MATERIALS AND METHODS

Location and site characteristics: The study was conducted at Main Experimental Station of the Department of Horticulture, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (latitude 26°47' N, longitude 85°12' E and 113 m elevation) during two consecutive cropping seasons

2004-05 and 2005-06. The location falls under Indo-Gangatic plains of Eastern Uttar Pradesh of India. This site is characterised by sub-humid and sub-tropical climate observing mean annual rainfall 1190 mm, mainly received during July to September, however, the occasional showers during winter (October - mid February) and also in summer (April - mid June) also not uncommon. The summer months are hot, dry and desiccating. The corresponding clay loam sodic soil had the following chemical properties: pH 8.56; EC 0.42 dSm⁻¹; organic carbon 0.35%, available nitrogen 190.44 kg ha⁻¹ %, available phosphorus 17.86 kg ha⁻¹ and available potassium 229.34 kg ha⁻¹.

Plant material and treatments: Cape gooseberry genotype S-101 (Suttind Seeds Pvt. Ltd.) was used in this study for raising the seedlings for transplants. The treatment consisted of three plant spacing (S₁ - 75 × 60 cm, S₂ - 75 × 75 cm and S₃ - 75 × 90 cm) and four fertility (NPK) levels (F₀ - control - without NPK fertilizers, F₁ - 60:40:40, F₂ - 80:60:60 and F₃ - 100:80:80 NPK kg ha⁻¹). The experiment was laid out in Split Plot Design with four replications, wherein main plot was assigned with plant spacing and levels of NPK in the sub-plots. Five phenological stages of plant were also considered as sub-sub plot treatment for obtaining statistical significance of phenological stages. The seedlings raised in semi-controlled polyhouse having uniform vigor and size were transplanted in evening hours in second week of August for both year's experiments. The size of individual plots was 9.0 × 3.0 m. The source for nitrogen, phosphorus and potassium fertilizers was ure, single super phosphate and murate of potash. One-third nitrogen and full amount of phosphorus and potassium were applied during last preparation of experimental soil. Remaining quantity of nitrogen was divided into two equal parts and top dressed at 45 and 75 days after transplanting. Other cultural operations were similar for all the treatments.

Data collection and analysis: Twenty fully expanded leaves were randomly selected from each treatment for measuring the leaf area at pre-flowering (30 DAT), starts of flowering (60 DAT), early fruiting (120 DAT), peak fruiting (180 DAT) and late fruiting (240 DAT). The leaf area of each leaf was recorded with the help of Leaf Area Meter (Delta Devices, Cambridge, UK) and the average values were expressed in cm². Data collected during two consecutive cropping seasons were pooled and analyzed as per standard procedure as advocated by Panse and Sukhatme (1986) at 5% level of level of significance.

RESULTS AND DISCUSSION

Data depicted in Fig. 1 revealed that the leaf area was significantly varied at different stages of plant. Among five stage of plant growth, there was significant

Table 1. Effect of plant spacing on leaf area (cm²) of cape gooseberry at different phenological stages .

Spacing (S)	Phenological stage					Mean
	Pre- flowering (30 DAT)	Start of Flowering (60 DAT)	Early fruiting (120 DAT)	Peak fruiting (180 DAT)	Late fruiting (240 DAT)	
S ₁ -75 x 60 cm	72.80	80.87	75.54	67.76	55.03	70.40
S ₂ -75 x 75 cm	73.78	82.39	79.45	73.34	60.31	73.85
S ₃ -75 x 90 cm	73.97	83.52	82.44	78.22	65.31	76.69
CD _(P=0.05) S	NS	NS	2.33	2.19	1.96	-

Table 2. Effect of NPK levels on leaf area (cm²) of cape gooseberry at different phenological stages.

NPK Level (F)	Phenological stage					Mean
	Pre- flowering (30 DAT)	Start of Flowering (60 DAT)	Early fruiting (120 DAT)	Peak fruiting (180 DAT)	Late fruiting (240 DAT)	
F ₀ -control	65.31	69.04	66.29	58.83	48.33	61.56
F ₁ -60:40:40 kg ha ⁻¹	73.28	80.77	76.97	74.11	61.45	73.32
F ₂ -80:60:60 kg ha ⁻¹	76.47	88.08	84.83	78.74	63.86	78.50
F ₃ -100:80:80 kg ha ⁻¹	78.99	90.97	88.47	80.74	67.22	81.28
CD _(P=0.05)	2.32	2.93	2.25	2.60	1.85	-

increase in leaf area from pre-flowering to start of flowering stage, and thereafter gradual decrease in leaf area was noted with advancement of later stages of plant (early fruiting, peak fruiting and late fruiting stage). Maximum leaf area was measured at start of flowering (60 DAT) followed by early fruiting (120 DAT), peak fruiting (180 DAT) and pre-flowering (30 DAT). Among different phenological stages of plant, lowest leaf area was recorded at late fruiting (240 DAT). Reduced leaf area during later phenological stages might be attributed to the facts that strong competition for assimilate availability among developing leaves, flowers and fruits occurs with the advancement of phenological stages particularly after start of flowering which leads to the partitioning of the available metabolites in developing plant parts. Dalal *et al.* (2013) also noted seasonal variation in leaf area in kinnow mandarin that the spring flush leaves had the minimum values of leaf area as compared to rainy and winter fall flushes leaves, implying that spring season growth most serves as a sink to developing fruits.

Plant spacing had non-significant effect on leaf area measured at pre-flowering (30 DAT) and start of flowering (60 DAT), but at later stages of plant i.e. early fruiting (120 DAT), peak fruiting (180 DAT) and late fruiting (240 DAT), significant difference in leaf area was observed due to plant spacing treatments (Table 1). At all the phenological stages, maximum leaf area

was recorded with widest plant spacing (75 × 90 cm) followed by medium spacing (75 × 75 cm) and minimum with closest spacing (75 × 60 cm). Camacaro, *et al.* (2004) and Sonkar *et al.* (2012) found that wider plant spacing increased leaf area in strawberry, while in an experiment under greenhouse conditions, Um *et al.* (1997) reported that planting density did not affect the leaf area in tomato. While increasing the plant populations per unit area, intra-plant competition becomes more important and light interception also varied with crop development; the planting pattern optimises the available natural and unnatural resources and row spacing become important in crop canopy structure (Andrade *et al.*, 2002; Reta-Sanchez and Fowler, 2002; Sharratt and McWilliams, 2005). The state of development of the plant determines the pattern distribution of dry matter in different organs of the plant, and the leaf area growth determines the light interception pattern (Heuvelink and Marcelis, 1989). As strong competition between developing leaves and apical meristem influences plant growth, high assimilate availability under high light intensity conditions stimulates both meristem activity and leaf growth (Hussey, 1963a), but when plants are source-limited, young leaf growth is favoured at the expense of apical development; hence, continuous removal of young leaves counteracts this effect (Hussey, 1963b, Kinet, 1977). In cape gooseberry, vegetative growth and reproductive development proceed concomitantly during the

Table 3. Interaction effect of plant spacing x NPK levels on leaf area at peak fruiting (180 DAT) in cape gooseberry

Spacing (S)	Leaf area (cm ²) at peak Fruiting			
	NPK levels (F)			
	F ₀	F ₁	F ₂	F ₃
S ₁ -75 x 60 cm	50.84	57.34	61.37	63.74
S ₂ -75 x 75 cm	59.27	66.19	69.93	70.71
S ₃ -75 x 90 cm	66.39	74.45	74.83	75.22
CD _(P=0.05) S x F	4.53			

Table 4. Interaction effect of plant spacing x NPK levels on leaf area at late fruiting (240 DAT) in cape gooseberry

Spacing (S)	Leaf area (cm ²) at Late fruiting			
	NPK levels (F)			
	F ₀	F ₁	F ₂	F ₃
S ₁ -75 x 60 cm	42.15	54.85	58.58	64.54
S ₂ -75 x 75 cm	48.50	62.02	64.61	66.10
S ₃ -75 x 90 cm	54.35	67.47	68.38	71.02
CD _(P=0.05) S x F	3.20			

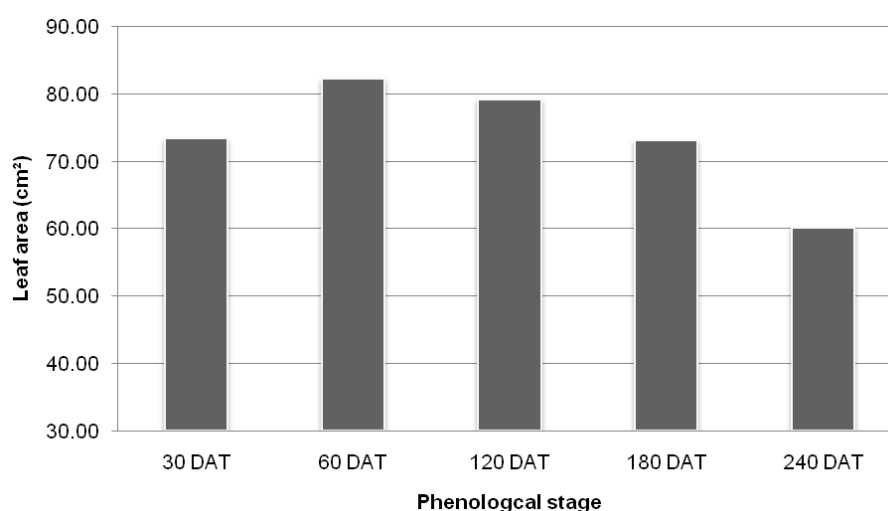


Fig. 1. Leaf area variation during different phenological stages of cape gooseberry. Bars with different letters within the same year differed significantly at P=0.05. DAT= days after transplanting.

greater part of the plant life. Lower leaf area at later stages of plant was might be due to source-limited and low root activity with aging process.

Application of NPK fertilizers significantly increased leaf area in cape gooseberry at all stages of plant growth (pre-flowering, early fruiting, starts of flowering, peak fruiting and late fruiting stages) during both year’s study (Table 2). Maximum leaf area was measured with the application of highest level of NPK (100:80:80 kg ha⁻¹) followed by 80:60:60 kg NPK ha⁻¹ and 60:40:40 kg ha⁻¹ at all the five stages under study. Minimum leaf area was recorded in control (no NPK fertilizers) at all the phenological stages. Increase in leaf area with the application of N,

P and K in alone or in combinations have been reported in tomato by researchers viz. N (Varia *et al.*, 1998), P (Basirat *et al.*, 2011), N and P (Regina and Robert, 1991), N, P and K (Baldissera, 2004; Adekiya and Agbede, 2009). In potato, low P supply reduced total leaf area per plant (Balemi, 2009). Shabani *et al.*, (2012) reported increased leaf area in salinity stressed cherry tomato with increased K⁺ concentration. It is well evident from the available literatures that N, P and K are required in large quantity by the plant, where nitrogen is the most limiting nutrient to crop production (Pionke *et al.*, 1990). Nitrogen mediates leaf expansion via increase in cell number, rather than cell size, maintenance of leaf turgor and enhancing the availabil-

ity of assimilates (Sivasankar *et al.*, 1993). Phosphorus helps in better utilization of water and other nutrients in the soil and promotes a sturdy growth of stem and healthy foliage (Nelson, 1978). Potassium plays key role in metabolic and transport processes, charge balance, and generation of turgor pressure (Dorais *et al.*, 2001). An increased K concentration in root can increase photosynthetic efficiency possibly by increasing the number of chloroplast per cell per leaf and consequently leaf area (Possingham, 1980. Lopez and Sattii (1996) observed a great decrease in photosynthetic activity with decreasing supply of K to the roots. Furthermore, K is required for activity of some enzymes (Shafeek, *et al.*, 2005). Beneficial effects of NPK on leaf area in our study were attributed to increased nutrient availability and root growth leading to enhanced uptake of mineral nutrients and water. Beaton (1987) observed that biweekly application of 20N-4.3P-8.3K fertilizers enhanced leaf area and runner production in strawberry.

Interaction effect of plant spacing and NPK levels was significant ($P=0.05$) with respect to leaf area at peak fruiting and late fruiting (180 DAT and 240 DAT, respectively). At peak fruiting, maximum leaf area was recorded with the treatment combination of widest spacing (75 × 90 cm) + highest level of NPK (100:80:80 kg ha⁻¹) (Table 3). At late fruiting, leaf area was also highest with the treatment combination of widest spacing (75 × 90 cm) + highest level of NPK (100:80:80 kg ha⁻¹) (Table 4). Minimum leaf area at peak fruiting and late fruiting in both year experiments was recorded at closest spacing (75 × 60 cm) without NPK fertilizers (Tables 3 and 4). The phenological stages of peak fruiting and late fruiting were the most critical period of the fruit growth and development in the plant that had high demands of the plant nutrients (nitrogen, phosphorus and potassium) required for growth and development. Higher leaf area under wider plant spacing + higher levels of applied NPK fertilizers might be attributed to limited possibility of plant competition for these nutrients while close plant spacing + lower levels of applied NPK fertilizers had limited supply of nutrients resulting in lower leaf area in the plants.

Conclusion

In present study, leaf area increased from pre-flowering to start of flowering, and thereafter it was gradually decreased at each later phenological stage. Plant spacing did not affected the leaf area during early stages (pre-flowering and start of flowering) but at later stages (early fruiting, peak fruiting, and late fruiting), wide-space planting resulted higher leaf area. The NPK application increased leaf area at all the phenological stages with maximum value at 100:80:80 kg NPK ha⁻¹. Spacing × NPK interactions were significant

only at later stages (peak fruiting and late fruiting stages) showing maximum leaf area at 75 x 90 cm with NPK @ 100:80:80 kg ha⁻¹. Leaf area variations at different phenological stages observed in present study can be further helpful in leaf sclerophylly studies in cape gooseberry.

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