INDIAN JOURNAL OF ARID HORTICULTURE
2008, Vol. 3 (2) : 56-60

Distribution of solar radiations in guva (Psidium guajava L.) plants at different spacing : influence on fruit quality

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Abstract

The study was conducted to examine the solar radiation distribution in different parts of 7- year's old guava plants and its subsequent effect on fruit quality. The interception of solar radiation was decreased markedly with the depth of plant canopy from top to bottom as well as with increase plant density. More than 3/4[th] of incoming radiations were intercepted by upper one meter periphery of guava plants irrespective of plant spacing. The fruit quality in terms of size, weight, TSS, vitamin C and overall palatability was significantly reduced with the depth of plant canopy and decrease in plant spacing. The upper canopy fruits particularly of widely spaced plants were better than others. Winter season fruits were double in weight and more palatable as compared to rainy season fruits.

Key words: *Guava, fruit size, solar radiations, quality.*

Introduction

Guava (*Psidium guajava* L.) is an important fruit crop grown in India. Although, the area and production of guava increased significantly in last decade, but there is no significant increase in productivity. Therefore, to increase the productivity level to its maximum productive potential, certain important strategies have been identified. One such strategy is the high density plantation (HDP). However, in high density planting system, interception of solar radiations and other microclimatic conditions such as canopy temperature and relative humidity are important aspects which directly or indirectly affect the vegetative growth, yield and quality of guava fruits. Guava has a higher proportion of 'shade' to 'sun' leaves and their leaves are found photosynthetically inactive under deeper shade and act as unproductive sink (Singh et al, 2005).Therefore, vegetative growth, fruit yield and quality are functions of light interception and translocation of light energy into chemical energy. Production of good quality fruit is function of absorption of light and light is directly proportional to the yield and quality of fruit trees (Jackson, 1980, Palmer, 1989, 1992). Brar *et al* (2009) investigated that light interception was more in guava trees planted at wider spacing and decrease significantly with the depth of the canopies irrespective of the planting densities. Similarly Singh and Dhaliwal (2007) reported that fruit yield and quality of guava fruits decreased with poor light interception at higher planting densities. Therefore, the present investigations were made to study the radiation penetration in guava plants at different spacing and its effect on physical and chemical characteristics of fruits.

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Materials and Methods

The present investigation on seven year old guava plants cv. 'Allahabad Safeda' at different spacing viz. 6x2m, 6x3m, 6x4m and 6x5m were carried out at the New Orchard, Department of Horticulture, PAU, Ludhiana in the year 2007-08 to 2008-09 for both rainy (March-August) and winter (September-February) crop seasons. The solar radiation measurements were recorded in clear days thrice a day viz. 8.00-10 am, 12.00-2.00 pm and 4.00-6.00 pm by recording the sensor output from Pyranometer using a Digital Multi-Volt Meter. The Pyranometer measures the total direct and diffuse solar radiation. Incoming solar radiation measurements (Cal/cm^2/min) were recorded at one foot above the canopy and at the centre of the upper, middle and lower parts of the tree by facing Pyranometer upward. The Pyranometer was inverted at a height of one foot above the canopy to see the tree canopy below and thus the amount of reflected short wave radiations [Albedo (A)] was recorded. The radiation/light interception was calculated as the difference between incoming radiations received in each of the three different parts of the tree canopy and was expressed as intercepted radiation at a particular time of observation.

Radiation intercepted in the upper part = $\frac{I-(I1+A)}{I} \times 100 = X\%$

Radiation intercepted in the middle part = $\frac{I-(I2+A)}{I} \times 100 - X\% = Y\%$

Radiation intercepted in the lower part = $\frac{I-(I3+A)}{I} \times 100 - (X\%+Y\%) = Z\%$

Total light intercepted by the tree canopy = X+Y+Z

Where,

I = Incoming solar radiation received one feet above top of the tree canopy.

I_1= Incoming solar radiation received in the upper part of the tree canopy.

I_2= Incoming solar radiation received in the middle part of the tree canopy.

I_3= Incoming solar radiation received in the lower part of the tree canopy

The physico-chemical characteristics of both rainy and winter season crops were recorded in July-August and November-December respectively. The observations on physical characters of fruits of all canopy parts of plants at different spacing were noted in terms of fruit size, fruit weight and seed number per fruit. Similarly, the quality characters of both rainy and winter season fruits were recorded in July-August and November-December, respectively during the year of 2007 and 2008. The data on quality characters of fruits were determined in terms of palatability rating, total soluble solids, acidity and vitamin C content according to the method of AOAC (2000).

Results and Discussion

The total radiation intercepted by Allahabad Safeda guava plants was maximum i.e. 72.76 % and 67.93% of 6x4m followed by 70.94% and 66.49% in 6x5m spaced plants during rainy and winter season, respectively (Table 1). Decrease in radiation interception with the increasing plant density and depth of canopy was observed during both seasons. Minimum total radiations i.e. 61.13% and 57.64% were intercepted in 6x2m spaced plants during rainy and winter crop seasons, respectively.

The upper part of plants at 6x4m spacing intercepted highest solar radiations during rainy (56.10%) as well as winter (51.25%) season and least in 6x2m spaced plants with 48.7% (rainy) and 45.2% (winter) radiation interception. Similar trend of radiation interception with plant density and depth of plant canopy was recorded during both seasons. During winter crop season (September-February), radiation interception in the upper part of plants in all spacing levels as well as total radiation intercepted was recorded lesser as compared to the rainy crop season i.e. March – August due to the difference in inclination of solar radiations during winter and summer seasons. Moreover the old leaves turning yellow as well as the new leaves have relatively high transmissibility (Mavi, 1986), thus less radiations were intercepted during this period in the upper part of the plant canopies and slightly more of radiations were reached in the middle and lower parts of the canopies.

Somewhat vertical orientation of auxiliary shoot and leaves causing less absorption and more reflection of incoming solar radiations results reduction in radiation interception in plants at closer spacing of 6x2m and 6x3m. The plants at 6x4m spacing were found to intercepted highest radiations owing to higher foliage and more horizontal orientation of shoots and leaves. The results obtained in the present study are in line with that of Heinicke (1963) and Loony (1968) who also found rapid decrease in light intensity with increasing depth of plant canopy. The present findings are in accordance with Singh *et al* (2005) and Singh and Dhaliwal (2007) who also found that, in guava radiation interception by the guava tree increased with increasing planting distance. The other related finding are also in accordance with the present investigation e.g. light intensity of full sun light (100 per cent) available at periphery of the round headed apple tree canopy fell to 34 per cent at the depth of 1m (Jackson, 1976) and 42 per cent at the depth of 2m (Heinicke, 1966). In citrus 90 per cent of solar radiation is absorbed by the first 3 feet (0.9m) of tree canopy (Green and Gerber, 1967).

Quality characteristics of guava fruits

Fruit size: Reduction in fruit size was recorded with the increase in plant density as well as with the depth of plant canopy (Table 2). Size of fruits obtained from the upper parts of plants at 6x4m spacing during rainy season was found maximum (length 5.10cm and breadth 5.25cm). During winter season fruit length was recorded maximum i.e. 6.70cm in 6x4m and fruit breadth 6.67cm in 6x5m spaced plants. Smallest fruits were obtained from the lower parts of plant canopy i.e length (4.48 and 5.75cm) and breadth (4.62 and 5.82cm) during rainy and winter season, respectively. Higher fruit size during winter season might be due to quite less number of fruit bearing during winter season and also due to more accumulation of carbohydrates at low temperature in winter season. Higher availability of photosynthates and less competition for nutrients and microclimatic parameters in plants at wider spacing and upper parts of canopy contributed increment in fruit size. The reduction in fruit size due to poor light penetration subsequently affecting carbohydrate supply in apple supports the results of present investigations (Tustin et al, 1989). The present results are also in agreement with the findings of Lal *et al* (2000) and Singh and Bal (2002) in a similar study on guava.

Fruit weight: The mean fruit weight was found to be increased with increase in plant spacing particularly during winter season. Maximum mean fruit weight of 94 and 95g per fruit during rainy season (Table 2) and 162 and 160 g per fruit during winter season was recorded in upper parts of plants at 6x5m and 6x4 m spacing, respectively. Size of fruits obtained from the lower parts of plants reduced significantly in all spacing levels during both seasons. The winter season fruits were much heavier than rainy season fruits (Table 3). The results are in agreement with the findings of Rathore (1976) in guava that cessation of vegetative growth during cool climate results divertion of food reserves to fruit development causing higher fruit size and weight. The fruits were weighted less in plants at closer spacing and lower parts of plant canopy; this may be ascribed to the reduced availability of photosynthates to the developing fruits due to smaller canopies of the trees and less light penetration. The similar results were obtained by Lal *et al* (2000) and (Kundu, 2007) in guava.

Seed number: Seed numbers in fruit of both season exhibited positive relationship with increase in spacing. However, middle canopy fruits contained higher seed content as compared to lower and upper canopy fruits during rainy (Table 2) and winter (Table 3) seasons. Maximum mean number of seeds were counted in fruits obtained from middle parts of the plants during rainy (239) and winter (326) season. Fruits taken of lower canopy of plants at closest spacing of 6x2m exhibited least seed numbers during rainy (185) as well as winter (267) season. Reduction in seed proportion in fruits of lower parts of plant at closer spacing may be attributed to uncongenial microclimatic conditions resulting poor germination of pollens on the stigma or poor pollen tube growth *in vivo* under such conditions. Since the seed number of guava is due to pollen germination on stigma/pollen tube penetration through style dependent, therefore, stigma desiccation due to high velocity winds might have created unfavorable conditions for pollen germination thereby fertilizing less number of ovules per fruit of upper parts of canopy of plants at wider spacing (Singh, 2003).

Palatability rating (PLR)*:* The palatability rating of fruits was increased with increase in plant spacing as well as height of plant canopy in both rainy (Table 4) as well as winter (Table 5) season crops. The upper canopy fruits of plants at 6x5m spacing were maximum palatable with rating of 8.38 during winter and 6.70 during rainy season. The fruit PLR of both seasons decreased significantly with the depth of plant canopy and increase in plant density. The least PLR during rainy (6.10) and winter (8.0) was recorded in lower canopy of plants at highest density plants. Decrease in palatability rating with decrease in plant spacing and depth of plant canopy may be due to reduced interception of solar radiations and uncongenial microclimatic conditions leading to reduced TSS, reducing sugars, higher acidity, poor fruit size and lesser colour development as compared to fruits obtained from plants at wider spacing and upper parts of canopy. These results are in the same line with the results recorded by Singh (2005) who obtained significantly higher PLR in widely spaced and upper parts of plants of guava.

Total soluble solids (TSS)*:* The upper canopy fruits of plants exhibited maximum mean TSS i.e. 9.77 and 11.26% and minimum of 9.49 and 10.36% in lower canopy fruits during rainy (Table 4) and winter (Table 5) season crop, respectively. Highest TSS content in rainy (9.90%) and winter (11.80%) season was recorded in upper canopy fruits of 6x5m spaced plant and least 9.13% (rainy) and 10.20% (winter) in lower canopy fruits of 6x2m spaced plants. Decrease in TSS in fruit of closely spaced plants particularly at lower canopy areas may be ascribed to the upright and compact canopies which interfere in radiation penetration during the critical period of fruit development and also lesser source to sink ratio at smaller canopies of plants at high density. Amiable microclimatic conditions results higher TSS in upper parts of plants. Lal *et al* (2000) Singh and Bal (2002) and Singh *et al* (2007) also recorded increase in brix degree with increase in plant spacing. Singh and Dhaliwal (2004) also reported higher TSS in fruits of upper parts of plant canopy in guava.

Acidity*:* Decreasing trend of acidity in guava fruits with increasing plant spacing and height of plant canopy was observed during both seasons. Lower canopy fruits of both seasons contained average maximum acidity of 0.213% (Table 4 &5) followed by middle and upper canopy fruits. Least ascorbic acid content was analyzed in fruits of upper canopy of plant at wider spacing of 6x5m during rainy (0.185%) seasons. The reduction in acid content in fruits of upper parts of plants and plants at wider spacing may be accredited to the possible conversion of organic acids into total sugar content or increased fruit volume may also be the another reason to reduce the acidity level in larger fruits. These findings are in agreement with that of Singh and Dhaliwal (2004) that the acidity was increased with the increase in planting density in guava.

Vitamin C*:* In rainy season, average vitamin C content of upper canopy fruits was significantly higher i.e. 152.3 mg /100g fruit in rainy and 178.4 mg/100 g fruit in winter season. Highest vitamin C content was recorded in upper canopy fruits of plants in rainy (158.1 and 160.5 mg) and winter (190.0 and 185.5 mg) season at 6x5 m and 6x4m spaced plants, respectively. Increment in vitamin C content of fruits of widely spaced and upper canopy fruits may be owing to higher radiation interception and assimilation of better nutrition and photosynthates as compared to the plants at closer spacing. Similar results were obtained by Singh and Dhaliwal (2004) and Singh and Bal (2002) also reported that ascorbic acid content was increased with increase in plant spacing in different cultivars of guava.

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Table 1. Distribution of solar radiations in different parts of plants at different spacing.

Spacing (m)	Solar radiation interception (%) Rainy Season				Winter Season			
	U	M	L	T	U	M	L	T
6x5m	54.25	10.73	5.96	70.94	49.80	10.78	5.91	66.49
6x4m	56.10	10.71	5.95	72.76	51.25	10.79	5.89	67.93
6x3m	53.12	8.32	4.29	6 5.73	49.50	8.56	4.36	62.42
6x2	48.70	8.25	4.18	61.13	45.20	8.25	4.19	57.64
CD (P=0.05)	Spacing (A): 1.31 Part of plant (B): 2.26 AxB: NS				Spacing (A): 2.07 Part of plant (Ɓ). 0.75 AxB : NS			

Table 2. Physical characters of rainy season fruits obtained from upper (U), middle (M) and lower (L) parts of plants at different spacing.

Spacing (m)	Solar radiation interception (%) Fruit length (cm)			Fruit breadth (cm)			Fruit weight (g)			Seed number		
	U	M	L	U	M	L	U	M	L	U	M	L
6x5m	5.10	4.72	4.65	5.23	5.13	4.82	94	76	64	243	252	245
6x4m	5.10	4.70	4.63	5.25	5.09	4.85	95	74	65	250	255	248
6x3m	4.95	4.62	4.52	5.10	5.03	4.70	82	67	58	221	235	210
6x2m	4.87	4.55	4.48	4.90	4.75	4.62	68	62	52	209	213	185
Mean	5.01	4.65	4.57	5.12	5.00	4.75	84.8	69.8	59.8	231	239	222
CD (P=0.05)	A: 0.09 B: 0.11 AxB: NS			A: 0.08 B: 0.09 AxB: NS			A: .9.4 B: 5.8 AxB: 6.5			A: 21.2 B: 18.5 AxB: 16.3		

Table 3. Physical characters of winter season fruits obtained from upper (U), middle (M) and lower (L) parts of plants at different spacing.

Spacing (m)	Fruit length (cm)			Fruit breadth (cm)			Fruit weight (g)			Seed number		
	U	M	L	U	M	L	U	M	L	U	M	L
6x5m	6.60	6.35	6.10	6.35	6.24	6.10	162	151	136	310	327	357
6x4m	6.70	6.32	6.10	6.33	6.20	6.05	160	155	135	302	342	322
6x3m	6.40	6.20	5.85	6.25	6.13	5.90	150	133	128	284	317	308
6x2m	6.25	6.08	5.75	5.80	6.05	5.82	132	125	119	285	319	267
	6.49	6.24	5.95	6.18	6.16	5.97	151.0	141.0	129.5	295	326	314
CD (P=0.05)	A: 0.12 B: 0.10 AxB: NS			A: 0.07 B: 0.06 AxB: NS			A: 6.7 B: 7.2 AxB: 3.8			A: 10.5 B: 13.3 AxB: 12.2		

Table 4. Quality of rainy season fruits obtained from upper (U), middle (M) and lower (L) parts of plants at different spacing.

Spacing (m)	PLR (out of 9)			TSS (%)			Acidity (%)			Vitamin C(mg/100 g pulp)		
	U	M	L	U	M	L	U	M	L	U	M	L
6x5m	6.65	6.45	6.35	9.88	9.75	9.83	0.185	0.190	0.203	158.1	152.5	147.1
6x4m	6.70	6.45	6.29	9.90	9.72	9.66	0.192	0.191	0.210	160.5	150.5	148.5
6x3m	6.25	6.18	6.20	10.00	9.66	9.35	0.190	0.200	0.225	145.5	148.2	140.5
6x2m	6.15	6.10	6.05	9.55	9.33	9.13	0.210	0.215	0.215	145.0	140.5	138.6
Mean	6.44	6.30	6.22	9.77	9.62	9.49	0.194	0.199	0.213	152.3	147.9	143.7
CD (P=0.05)	A:0.09 B:0.12 AxB: NS			A:0.04 B:0.05 AxB: NS			A:0.04 B:0.07 AxB: NS			A: 10.1 B:9.5 AxB: 8.6		

[A: Plant spacing, B: Parts of plant canopy AxB: Interaction of spacing and parts of plant canopy, U: Upper, M: Middle, L: Lower parts of plant canopy, T: Total light interception in whole plant, PLR: Palatability rating; NS: Non-significant]

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