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Radiant energy distribution in guava (*Psidium guajava* L.) plants at different spacings

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ABSTRACT

The study on radiant energy distribution in guava was carried out to optimize the planting density with respect to solar radiation interception by the plants to get higher yield of good quality fruits per unit area. The present investigations reveals that with increase in plant spacing from 6x2m to 6x4m the interception of radiation increased significantly during both rainy and winter crop seasons. However, it starts declining with further increase in plant spacing to 6x5m level. The interception of radiation remains somewhat static during the summer and rainy season months (May-September) and then starts decreasing with the advent of winter season upto April with sharp decline during the month of December to February. In the upper 1/3rd portion of plant canopy, more than 75% radiations were intercepted irrespective of plant spacing followed by 12-16% in middle and 6-9% in the lower 1/3rd parts of plant canopies. The plant spacing of 6x2m and 6x3m was found to be not encouraging owing to lower distribution of radiations particularly in middle and lower parts of plants. The plant spacing of 6x4m was found to be best due to maximum absorption of solar radiation for higher fruiting of better quality fruits.

Key words: Guava, solar radiations, plant canopy

Guava (*Psidium guajava* L.) is an important tropical fruit crop grown in India. It is a hardy, prolific bearer and highly remunerative fruit crop and also can be grown satisfactorily even in adverse soil and climatic conditions. It is the fifth major fruit crop in India occupies an area of 0.17 million ha with an annual production of 1.97 million MT with productivity of 11.1 MT per ha (Anon, 2008).Guava fruit is rich in vitamin C with fair amount of Ca, P, pantothenic acid, riboflavin, thiamin and niacin. The fruits are used for making juice, jam jellies and various culinary products. Guava fruit also have certain antioxidant properties and is known to control systolic blood pressure.

Presently the productivity of guava is much below its potential, which is due to a traditional system, under which it is cultivated and prevalence of old and unproductive orchards with declining yield efficiency. Moreover, large trees take several years before they come into bearing and less number of trees per unit area are another constraints in guava production. Therefore, the main emphasis should be laid on management of tree canopy in such a way that leads to high density planting system so as to get higher production of good quality fruits per unit area. Guava is generally recommended to be planted in various parts of the country at 6x6 m spacing but there is always a scope to increase production and income from a unit land area by proper management of tree canopies. In the present scenario, high density plantation with managed canopies is the need of the hour to obtain high productivity per unit area.

Under high density planting system, light and other microclimatic conditions are important aspects which directly or indirectly affect the vegetative growth, yield and quality of guava fruits. In case of temperate fruits extensive study on such aspects has been made but little work has been done on tropical and sub-tropical fruit crops. 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 and Singh,2007).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 of fruit trees (Jackson,1980, Palmer,1989).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 (Singh *et al* 2005).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 distribution of solar radiation in various parts of the plants at different spacings so as to optimize the planting density in relation to radiant energy distribution.

MATERIALS AND METHODS

The present investigation on seven year old guava plants cv. Sardar were carried out at the New Orchard,

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Department of Horticulture, PAU, Ludhiana in the year 2007 to 2009 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^{-1}) 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 =

$$\frac{I - (I_1 + A)}{I} \text{ x } 100 = X\%$$

Radiation intercepted in the middle part =

$$\frac{I - (I_2 + A)}{I} \text{ x } 100 = Y\%$$

Radiation intercepted in the lower part =

$$\frac{I - (I_3 + A)}{I} \text{ x } 100 = (X\% + Y\%) = Z\%$$

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

RESULTS AND DISCUSSIONS

Solar radiation interception

The data in Table 1 reveals that in rainy crop season (March- August), the mean total radiation intercepted by the plants of Sardar guava was significantly higher i.e. 71.34 % in plants at wider spacings of 6x4m which was significantly at par with 69.64% in plants at widest (6x5m) spacing. Minimum radiation i.e. 62.77 % were intercepted in 6x2m spaced plants. The radiation interception in the different parts of the canopy (upper, middle and lower) also had significantly affected in all plant spacing levels. The upper part (53.41%) of the canopy intercepted significantly higher mean radiation compared to the middle (9.44 %) and lower (4.91%) parts irrespective of plant spacings. Similarly, the mean radiation interception during winter crop season (September- February) was found to increase with increase in plant spacing upto 6x4m spacing (Table 2). The mean maximum radiation (66.48%) was intercepted in plants at wider (6x4m) spacings, which was significantly higher than all other spacing levels. Least amount of radiation (57.83%) was intercepted in plants at closest spacing of 6x2m. The mean radiation interception in upper, middle and lower canopies of plants was 48.03, 9.47 and 5.06 %, respectively. From the overall appraisal of the data it is apparent that during winter crop season (September-February), radiation interception in the upper part of plant 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. Upper 1/3rd part of plants irrespective of plant spacing, intercepted 75-80% of total intercepted radiations followed by 12-16 % in middle and 6-9% in lower parts (Fig 2 &3) of plant canopy during both the crop seasons.

The interaction between spacings and parts of canopy do not differ significantly during both crop seasons. However, the radiation intercepted in wider spacing of 6x4m was significanly highest i.e.55.07 and 50.05 per cent in upper part of canopy as compared to other spacing levels during rainy and winter crop seasons, respectively. In the middle and lower parts of the plant canopy the interception of solar radiation was found to increase with increase in plant spacing during both crop seasons. Solar radiation in the lower parts of canopies in plants at higher density was quite less due to reduced light penetration. The light interception in middle and lower parts of plant canopy was slightly higher than rainy crop season. This may be ascribed to the partial shedding of leaves during winter due to which more light was penetrated in the middle as well as lower parts of plant canopies. The radiations were found to increase with increase in plant spacing upto 6x4m spacing and again reduced in widest spacing of 6x5m in both crops. In general, the lower parts of the plants intercepted least radiation in all spacing levels. The reduction in radiation intercept at closer spacing of 6x2m and 6x3m may be due the somewhat vertical orientation of

Table 1 : Effect of plant spacings and parts of the plant canopy on solar radiation interception (%) of guava during season cropping period (March-August)

Spacings (m)	Parts of the canopy			
	Upper	Middle	Lower	Total
6x2m	50.46	8.19	4.12	62.77
6x3m	54.55	8.37	4.37	67.29
6x4m	55.07	10.59	5.68	71.34
6x5m	53.57	10.60	5.48	69.64
Mean	53.41	9.44	4.91	67.76

CD at 5% Planting distance (A) : 1.39
Part of canopy (B) : 1.20
Interaction: A x B : NS

Table 2 : Effect of plant spacings and parts of the plant canopy on solar radiation interception (%) of guava during winter season cropping period (September-February)

Spacings (m)	Parts of the canopy			
	Upper	Middle	Lower	Total
6x2m	45.4	8.23	4.20	57.83
6x3m	47.83	8.35	4.44	60.62
6x4m	50.05	10.66	5.77	66.48
6x5m	48.85	10.63	5.83	65.31
Mean	48.03	9.47	5.06	62.56

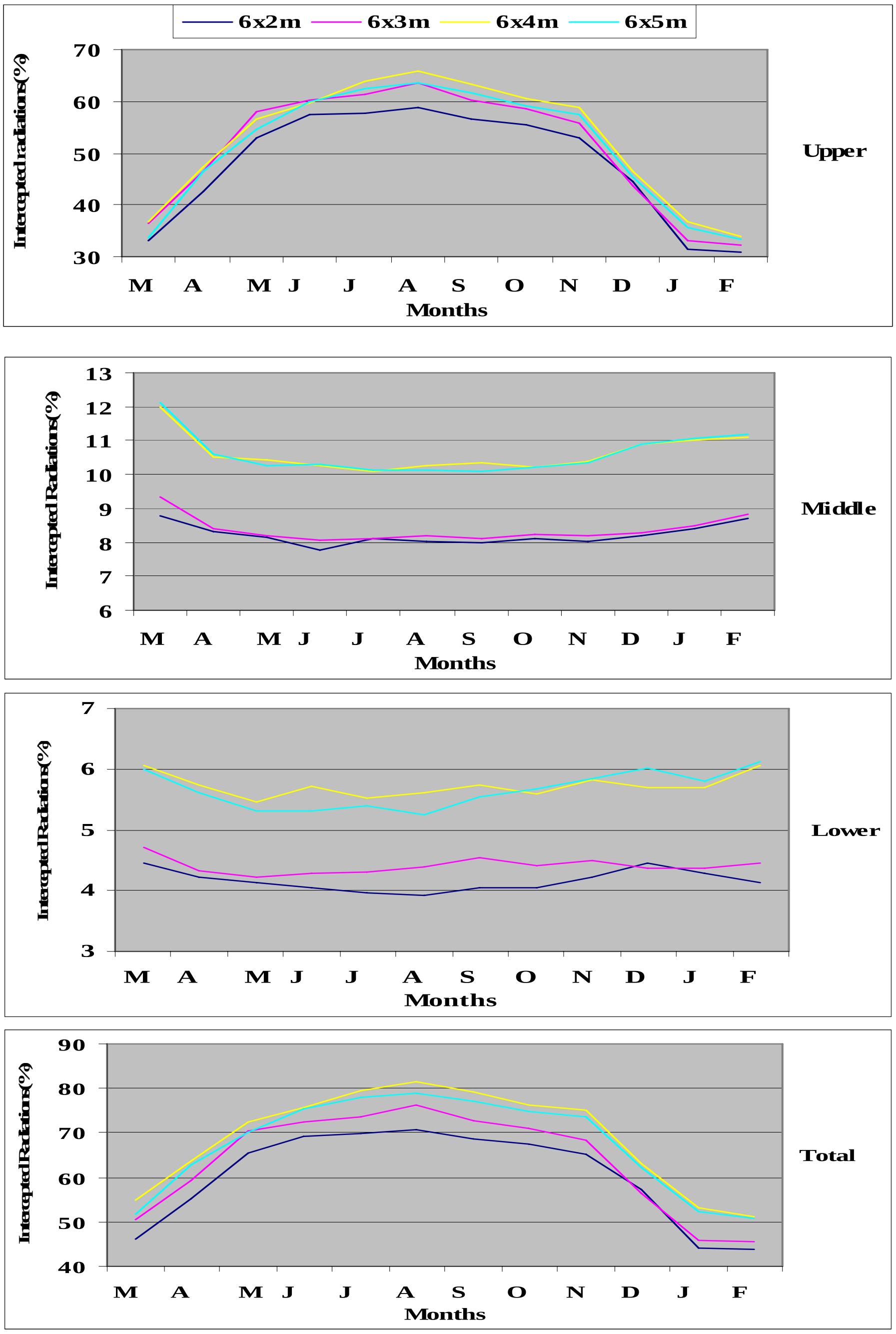
CD at 5% Planting distance (A) : 0.80
Part of canopy (B) : 0.71
Interaction : A x B : NS

auxiliary shoot and leaves causing less absorption and more reflection of incoming solar radiation. The plants at 6x4m spacing were found to intercepted highest radiation owing to higher foliage and more horizontal orientation of shoots and leaves. The reduction of solar radiation interception at widest spacing of 6x5m may be due to less dense foliage per unit exposed area to solar radiation as the plants at such spacing level had sufficient space to spread. 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. Jackson (1970) also revealed the similar findings in Apple. However, in Apple it was found that higher tree density leads to increased light interception through greater leaf area and more even distribution of light (Palmer *et al,* 1992). The present findings are in accordance with Singh *et al* (2005) and Singh and Dhaliwal (2007) who also found that, radiation interception by the guava tree increased with increasing planting distance. At Lucknow, Singh and Singh (2007) studied the light penetration was maximum in trees pruned at the height of 1.5m and 2.0m and minimum in unpruned trees. The other related findings 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 1978) 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)

Daily radiation interception

The daily radiation interception during rainy crop season (March- August) in Sardar guava plants at varied plant spacing was found to be less in the month of March and then gradually increased upto the month of June and then remains almost constant till the month of August (Fig.1). During rainy season high temperature coupled with high humidity leads to profuse vegetative growth, therefore more leaf area absorbing more light.

The radiation interception during the period of September – February decreased gradually with sharp decrease from the month of December. The leaf shedding during the cool months of the year reduces the total leaf area of the plants which leads to less light interception of light in the upper parts of the canopy and it was also observed that during this period there was slight increase in light interception in the middle and lower parts of the canopy. The lesser radiation intercepted during this period may be attributed to loss of foliage, leaf area index (LAI) during



M, A, M….. March, April, May……..Months of the year.

Fig 1: Average daily radiation interception by guava plants at different spacings

the winter months. Therefore, due to these factors, less radiation may be intercepted in the upper parts of the plant canopies.

This may be ascribed to the senescence of old leaves causing fewer leaves on the plants as the light interception is the function of leaf area. Moreover the old leaves turning yellow as well as the new leaves have relatively high transmissibility (Mavi,1986), thus less radiation was intercepted during this period in the upper part of the plant canopies and more of radiation reached in the middle and lower parts of the canopies. Singh et al (2005) and Singh and Dhaliwal (2007) also reported that radiation interception was found to decrease progressively with the height of the canopy from top to bottom. Radiation interception was similar from May to January in the upper one-third of the tree and decreased from January to March.

CONCLUSION

The distribution of solar radiation in various parts of the plants at different spacings was conducted to optimize the planting density in relation to radiant energy distribution. From the study it is concluded that the plant spacing of 6x4m with 420 plants per hectare was found to be best with respect to interception of solar radiations. The increasing plant density leads to decrease in solar radiation distribution in the plants thereby decreases the fruit yield and quality. Similarly, spacing of plants more than 6x4m also found to intercept lesser radiation. More than 3/4th of total intercepted radiations were found to be absorbed by the upper 1/3rd part of plant canopy irrespective of plant spacings. The radiant energy in the bottom part of canopies of plants at closer spacing of 6x2m and 6x3m was found to be drastically reduced. The maximum radiations were intercepted during the summer and rainy months of the year and with the advent of winter and fall season the radiation absorption by the plants was reduced significantly at all spacing levels.

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