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PAR distribution and radiation use efficiency in tomato (*Lycopersicon esculentum* Mill.) crop canopy

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ABSTRACT

The ultimate capacity of a plant community to produce dry matter depends on the degree of exploitation of solar radiation. An experiment was conducted to study the PAR distribution and radiation use efficiency in tomato crop canopy for two consecutive spring summer seasons with three varieties in three different dates of sowing. PAR interception by the whole canopy was maximum in morning and afternoon and decreased at noon in both the seasons. All the three dates of sowing in both the years influenced both radiation interception and RUE significantly and maximum PAR interception was observed during fruit development stage of the crop. In general RUE was more in first sowing compared to second and third sowing as first sown crop recorded more yield compared to other two dates of sowing.

Key Words: PAR, Radiation use efficiency Radiation interception, Albedo

Tomato is one of the most popular and widely grown vegetables in the world ranking second in importance to potato in many countries. Solar radiation is a natural resource, which essentially controls plant growth, development and production of dry matter. The ultimate capacity of a plant community to produce dry matter depends on the degree of exploitation of solar radiation. PAR interception by crop canopies depends on leaf growth and architecture of the canopy while the light use efficiency, in addition depends on the photosynthetic characteristics of the individual leaves in the canopy. Thus a study of light interception in crop canopies assumes great significance. The present study was carried out with the objective of understanding the distribution pattern of PAR in tomato crop canopy and to study its interception and use efficiency in tomato crop.

MATERIALS AND METHODS

Field experiments were carried out for two consecutive seasons (1998-1999 and 1999-2000 spring summer) in the experimental farm area of the Indian Agricultural Research Institute New Delhi. Three cultivars of tomato (Pusa Sadabahar, Pusa Sheetal and Pusa Gaurav) were raised with three dates of sowing (second and third weeks of November and first week of December in both the years) with three

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replications. The experimental layout consisted of 27 plots of size 6m x 3m laid in randomized block design. Fertilizer and pesticide were applied as per the recommended practice. Crops were raised under well-irrigated conditions and irrigation was given at 7-10 day interval if there was no rain.

Observations of plant and meteorological parameters were recorded at different phenological stages. PAR was measured with line quantum sensor placed above and under the crop canopy, on clear days at weekly intervals between 11.30 and 13.00 hrs IST using a radiation integrator LICOR model 191B. Diurnal variation of PAR interception was studied in tomato crop canopy at hourly intervals during first spring summer season (1998-1999).

Intercepted PAR (IPAR) and absorbed PAR (APAR) were calculated as

$$IPAR = 1 - I_h / I_O$$
$$APAR = 1 - I_h / (I_O - I_{ref})$$

where I_O, I_h and I_{ref} are is the incident PAR, PAR at height h and reflected PAR respectively.

RESULTS AND DISCUSSION

Diurnal variation of PAR interception

In all the three varieties and in all date of sowings the interception by the whole canopy was more in the morning decreased till noon, after that showed an increasing trend up to 4 PM. After that it decreased (Fig.1). Maximum PAR absorption (average of three dates of sowing for different varieties) was found in cultivar Pusa Sheetal (82.3%) and least in cutivar Pusa Gaurav (80.1%) at 0900 hrs. This was due to more plant biomass accumulated in cultivar Pusa sheetal than the other two. Similar trend was also observed by Sastri *et al.* (2000) in Brassica spp. The reflection coefficient decreased from about 8 percent at 9 hours to about 6.5 percent at 12 hours. The PAR interception at other sowing date treatments showed similar trend as that of the first sowing.

Seasonal variation in PAR

Seasonal variation in the intercepted PAR was studied at total canopy level of the tomato crop. It ranged between 1258 to 1438 μE m^{-2} sec^{-1} throughout the growth period of first season; in the second season it varied from 1263 to 1496 μE m^{-2} sec^{-1}. Lower values of PAR interception were observed during December and January in both the seasons because of seasonal variation. In both seasons the intercepted PAR for the whole canopy showed a rapid increase from the end of the vegetative stage, reaching a peak between fruit development and picking stage (Table 1).

The pattern of PAR interception is same for all the three cultivars, a rapid increase in the end of vegetative stage followed by a relatively slow fall during picking and maturation period. Peak interception was observed in case of cultivar Pusa Sheetal at 91, 83 and 79 DAT in first season and 102, 100 and 91 DAT in second season. Among the three dates of sowing maximum interception was observed in first sowing followed by second

Table 1: Variation of PAR distribution in different varieties of tomato crop in spring summer season (mean values of 1998-1999 and 1999-2000)

DAT	Pusa Sadabahar			Pusa Sheetal			Pusa Gaurav		
	IPAR%	TR%	RE%	IPAR%	TR%	RE%	IPAR%	TR%	RE%
10	18.5	63.0	18.5	22.0	58.5	19.5	18.5	61.0	20.5
20	25.5	57.5	17.0	28.0	54.5	17.5	21.0	59.5	19.5
32	32.0	53.0	15.0	35.5	49.0	15.5	33.5	49.0	17.5
43	40.5	45.0	14.5	42.5	45.0	12.5	40.0	43.0	17.0
51	49.5	37.0	13.5	53.5	36.5	10.0	46.5	39.0	14.5
62	64.0	23.5	12.5	68.0	23.5	8.5	54.0	34.5	11.5
70	74.5	14.5	11.0	80.0	11.5	8.5	63.0	27.5	9.5
82	80.0	11.5	8.5	84.0	9.0	7.0	74.5	17.0	8.5
90	83.5	9.5	7.0	87.0	8.5	4.5	80.5	12.5	7.0
100	87.0	7.5	5.5	91.5	3.0	5.5	89.0	4.5	6.5
113	83.5	8.5	8.0	88.0	3.5	8.5	82.5	9.5	8.0
125	80.0	10.5	9.5	82.0	8.5	9.5	80.0	9.0	11.0

DAT - Days after transplanting, RE - Reflected PAR, TR - Transmitted PAR, IPAR - Intercepted PAR.

and third sowing in all the three cultivars. PAR interception was more in first season than second season due to more LAI, biomass and plant height.

Radiation use efficiency (RUE)

Due to different canopy architecture, LAI and biomass production, different cultivars of tomato intercepted different amounts of PAR. For this reason, RUE of different cultivars varied (Table 2) in this season and ranged from 1.95 g MJ^{-1} (third sown crop of Pusa Sadabahar) to 2.65 g MJ^{-1} (first sown crop of Pusa Sheetal). During second tomato crop season the RUE values ranged from 1.93 g MJ^{-1} (in third sown crop of Pusa Sadabahar) to 3.05 g MJ^{-1} (in first sown crop Pusa Ankur). The RUE values were appreciable in all the three cultivars.

In general, second season recorded higher RUE than the first crop season. This may be due to higher biomass production in second season than first season, though APAR values were comparatively more in first season (Table 2). The RUE values obtained in our study are in close agreement with those reported by Kinry *et al.* (1988) who obtained mean values ranging from 2.2 to 3.5 g MJ^{-1} in five crops viz., maize, sorghum, wheat, rice and sunflower, respectively. Kar (1996) and Sastri *et al.* (2000) calculated RUE for Brassica spp. in semi arid conditions of Delhi. The values ranged from 2.13 to 3.22 g MJ^{-1} and 2.27 to 3.72 g MJ^{-1}.

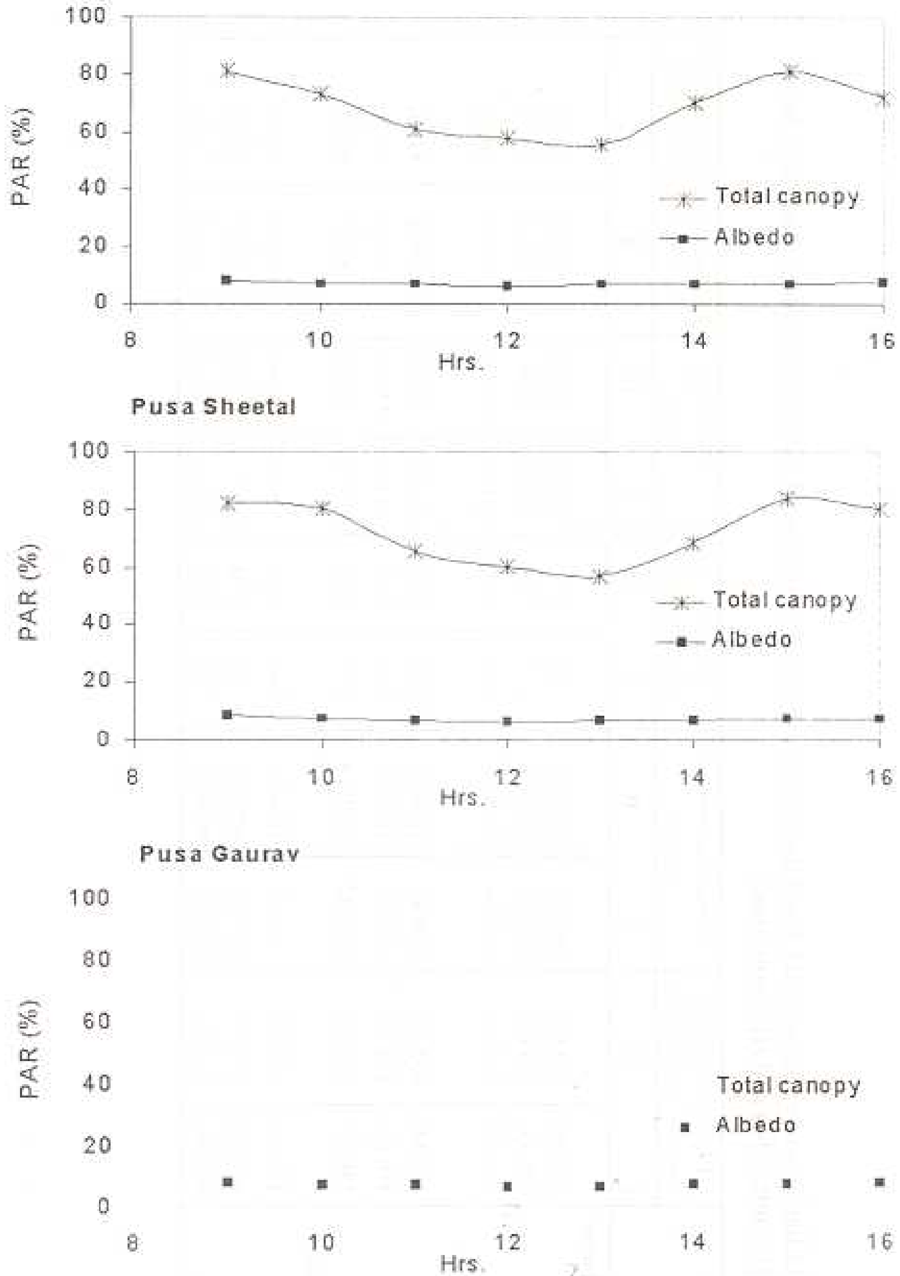

Fig. 1: Semidiurnal PAR distribution and albedo in tomato crop in spring summer season (1998-1999) at fruit development stage (90 DAT)

Table 2 : Radiation use efficiency (RUE) of three tomato cultivars in terms of biomass and economic yield during (I) 1998-1999 and (II) 1999-2000

Treatments	PAR at maximum biomass level (MJm^2)		Maximum biomass (gm^2)		Radiation use efficiency (gMJ^{-1})		Fruit yield (gm^2)		Radiation use efficiency for economic yield ($g MJ^{-1}$)	
	I	II	I	II	I	II	I	II	I	II
Pusa Sadabahar										
1st sowing	439.88	411.68	966.48	980.42	2.20	2.38	29200	30400	66.38	73.84
2nd sowing	426.43	398.60	905.55	918.69	2.12	2.30	26300	28200	61.67	70.75
3rd sowing	391.95	395.66	765.98	763.72	1.95	1.93	24800	26200	63.27	66.22
Pusa Sheetal										
1st sowing	462.54	452.67	1224.65	1263.92	2.65	2.79	36200	37100	78.26	81.96
2nd sowing	456.60	441.13	1177.05	1204.55	2.58	2.73	34400	35600	75.34	80.70
3rd sowing	398.27	406.30	1024.82	1029.24	2.57	2.53	32400	33900	81.35	83.43
Pusa Gaurav										
1st sowing	423.88	412.42	1106.47	1258.09	2.61	3.05	32600	34200	76.90	82.93
2nd sowing	408.10	409.07	965.45	972.36	2.37	2.38	28300	30100	69.35	73.58
3rd sowing	400.80	404.38	929.42	940.20	2.32	2.35	26700	28500	66.61	70.48

RUE in terms of economic yield

RUE in terms of economic yield ranged from 66.38 to 81.35 g MJ^{-1} and from 66.22 to 83.43 g MJ^{-1} in the two crop seasons respectively (Table 2). Highest values were observed in first sowing in respect of cultivars Pusa Sadabahar and Pusa Gaurav and in third sowing in Pusa Sheetal. It can be concluded that first sowing of tomato crop results in higher RUE, except in case of Pusa Sheetal where it was higher in third sowing.

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