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Productivity and radiation use efficiency of tea grown under different shade trees in the plain land of West Bengal

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ABSTRACT

Tea is grown under shade trees at higher elevation to attain better quality and higher productivity of the leaf. Hence, a field study was carried out to study the influence the shade trees on productivity and radiation use efficiency of the tea, when grown under plain at the Krishi Ban (Tea garden) of Bidhan Chandra Krishi Viswavidyalaya, Gayespur, West Bengal (Latitude 22^0 58$^/$ N, Longitude 88^0 31$^/$ E, altitude 9.75 m amsl). Different shade trees namely *Acacia auriculiformis, Albizia lebbeck, Dalbergia sissoo, Glyricidia sepium, Casuarina equisetifolia, Gmelina arborea and Eucalyptus hybrid* were taken for screening. Observation on yield and components of Photosynthetic Active Radiation (PAR) were taken at four periods. Each period began from one day after a plucking date and continued to the next plucking date. In total there were four periods as: Period I (7.9.01-3.10.01), Period II (4.10.01-13.11.01), Period III (14.11.01-22.2.02) and Period IV (23.2.02-19.3.02). Irrespective of periods, maximum productivity level (398.1 Kg ha^{-1}) of tea was attained under *Dalbergia sissoo* and it was minimum (271.7 Kg ha^{-1}) under *Glyricidia sepium*. Irrespective of periods the highest level (0. 438 g MJ^{-1}) of radiation use efficiency (RUE) was attained under *Gmelina arborea*. Tea grown under *Glyricidia sepium* and *Casuarina equisetifolia* resulted lowest RUE value.

Key words: Tea, radiation use efficiency, productivity

Tea is one of the major commercial shrubs in India and contributing 8.8 percent of the total agricultural export (Boriah, 2002). This is a shade loving crop and showed maximum leaf area under 35 to 50 percent light intensity but is minimum in full sun light (Barua, 1961). Thus, the crop is usually grown under different shade trees to attain better quality and higher productivity (Obaga, 1984; Carr and Stephens, 1992). Exposure of tea crop to strong radiation reduced the activity of photosynthetic component (Baker and Bowyer, 1994) resulting in lower productivity. However, very little efforts have been made to quantify the amount of incident radiation that has to be received by the shrub through shade trees. Varying canopy geometry of different trees in fact regulates the intensity of incident radiation. Thus the present study was carried out to screen the type of shade trees in relation to productivity and radiation use efficiency of the tea.

MATERIALS AND METHODS

The study was carried out from September 2001 to March 2002 in the tea garden of the Central Research Farm of the University (Latitude 22^0 58$^/$ N, Longitude 88^0 31$^/$ E, altitude 9.75 m amsl), Gayeshpur, West Bengal, India. The soil was fine loamy Fluventic ustochrept. Air temperature and relative humidity data during the study period were collected from a meteorological observatory situated at Kalyani, near the study site and presented in Fig 1. The experiment was set up in a split plot design with seven shade tree species (Table 1) as main plot treatments. Seven shade tree species were: *Acacia auriculiformis, Casuarina equisetifolia, Dalbergia sissoo, Glyricidia sepium, Albizia lebbek, Gmelina arborea and Eucalyptus hybrid*. The shade trees were fully grown with an average age of 15 years and not pruned during the study period and previous year. Plucking of tea leaves was done periodically from 1 m X 1 m area of each treatment (12m x 10m) and total span of investigation was divided into four periods (treated as subplots) based on plucking schedule. The periods are: September seventh to October third (Period I), October fourth to November thirteen (Period II), November fourteenth to February twenty second (Period III) and February twenty-third to March nineteen (Period IV). Each treatment

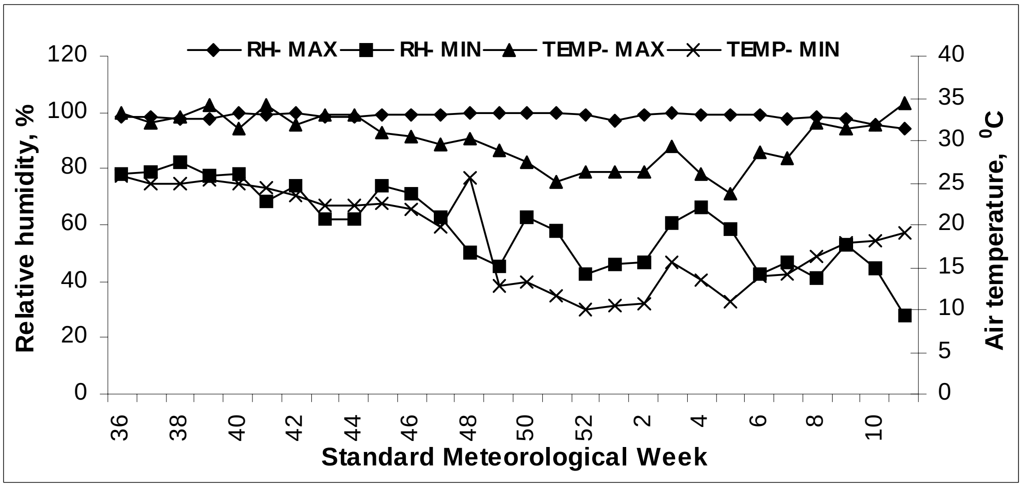

Fig. 1: Relative humidity and air temperature during the study period

combination was replicated three times.

Photosynthetic active radiation (PAR) was measured with a point quantum sensor (Model LI- 185 B, Li – Cor, Lincoln, NE) once in each week at 9 AM and 1 PM. During each of the said periods diurnal variation of PAR components were recorded separately for sunny and cloudy day and standard curve for PAR variation was prepared. These curves were used to determine the daily accumulated value from the measured PAR data at 9 A.M. and 1 P.M. The direct incident PAR on the tea canopy and ground surface (below the tea bushes) was measured by placing the sensor above tea canopy and above ground surface respectively. The reflected PAR was also measured from the same places by reversing the sensor. Another measurement was taken in the open field (without any shade) which was assumed as the incident PAR over the shade trees. The PAR photon flux density (m mol m^{-2} s^{-1}) is converted to irradiance (W m^{-2}) using a conversion factor of 4.6 m mol quanta J^{-1} (Li – Cor, 1991).

Absorbed PAR (APAR) was calculated as per the equation proposed by Gallo and Daughtry, 1986.

$$APAR = (IPAR + RPAR_S) - (TPAR - RPAR_C) \qquad (1)$$

Where IPAR is the incident PAR above the tea canopy i.e. PAR passes through the shade trees; TPAR is the transmitted PAR through the tea crop; $RPAR_S$ and $RPAR_C$ are reflected PAR from soil and crop surface respectively.

Within a period, the day to day APAR (extrapolated from weekly data) under different shade tree species was accumulated. Thereafter, the radiation use efficiency (RUE) was calculated as:

$$RUE = \frac{\text{Total dry yield of tea leaves}}{\sum APAR} \qquad (2)$$

The experimental database were analysed by using standard procedure of Randomised Complete Block Design pooled over different Periods (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Yield of tea

Significant variations in yield were observed between the shade tree species and within the periods. Irrespective of periods, tea shrub attained the highest productivity level (398.1 kg ha^{-1}) under *Dalbergia sissoo* (Table 1). It may be due to relatively higher PAR penetration through this shade tree (Table 2). The crop under *Glyricidia* produced 32 percent lower yield than that of under *Dalbergia sisoo* (Table 1). Probably the main reason for yield reduction is due to lowest amount of PAR (30 percent compared to unshaded condition) receipt of tea shrub grown under *Glyricidia*. The dense

Table 1: Impact of shade trees on yield (kg ha^{-1}) of dry tea leaves at various time span

Tree species	Periods				Total leaf yield*
	I	II	III	IV	
	Time span				
	7.9.01-3.10.01	4.10.01-13.11.01	14.11.01-22.2.02	23.2.02-19.3.02	
Acacia	135.3	54.2	85.3	120.1	394.9
Casuarina	132.7	30.8	98.5	65.0	327.0
Glyricidia	74.3	36.9	69.4	91.1	271.7
Eucalyptus	113.6	47.8	99.6	91.8	352.8
Albizia	84.3	69.3	85.9	108.9	348.4
Dalbergia	117.5	70.4	131.9	78.3	398.1
Gmelina	111.6	43.4	114.8	92.0	361.8
Mean (T)	109.9	50.4	97.9	92.5	

Statistical analysis		
Factor	S.Em (±)	C.D. (P =0.05)
Tree species (T)	5.82	17.94
Period (P)	3.22	9.18
T x P	8.51	24.29

canopy of *Glyricidia* may be the reason for such lower PAR penetration through it. Irrespective of tree species the highest yield (109.9 kg ha^{-1}) was attained at Period I (Table 1). This may be due to positive effect of post-monsoonal rainfall. On the other hand lowering of atmospheric temperature and radiation may be the possible reason for attaining lowest yield (50.4 kg ha^{-1}) during Period II.

Radiation use efficiency (RUE)

So far the RUE is concerned, a significant variation has been observed among the shade trees as well as among the periods. Irrespective of period, highest RUE value (0.438 g MJ^{-1}) was attained under *Gmelina* (Table 3). The foliage of *Gmelina* is such that the radiation that penetrates through it is uniform, which may be the cause for obtaining higher RUE. It was at the lowest level under both *Glyricidia* and *Casuarina* shades, due to conspicuous shading. The gap between the maximum and minimum value was 49.9 percent. Irrespective of tree species, maximum RUE value (0.604 g MJ^{-1}) was obtained during Period I and the same was at the minimum level at Period III, which was 308 fold less than the previous one. During the time span of Period II and III the cold climatic conditions seen to have restricted the growth of tea and as a result the RUE values were the lower region at this time (Table 3).

CONCLUSION

Crop yield touched the maximum point under *Dalbergia sissoo* and the minimum was under *Glyricidia sepium* due to difference in PAR receipt over the tea bushes through the tree species. Considering both yield and radiation use efficiency values *Acacia auriculiformis* and *Dalbergia sisoo* have been found most suitable shade trees in this agro-climatic region.

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Table 2: Impact of shade trees on penetration of photosynthetically active radiation (%) above tea canopy at different time span

Tree species	Periods				Mean over phases
	I	II	III	IV	
	Time span				
	7.9.01-3.10.01	4.10.01-13.11.01	14.11.01-22.2.02	23.2.02-19.3.02	
Acacia	37	50	26	33	36
Casuarina	49	45	26	45	41
Glyricidia	36	34	22	30	30
Eucalyptus	46	30	25	39	35
Albizia	33	26	23	36	30
Dalbergia	47	46	38	47	44
Gmelina	26	29	26	39	30
Mean(T)	39	37	27	38	

Statistical analysis

Factor	S.Em. (±)	C.D. (P=0.05)
Tree species (T)	1.07	3.29
Period (P)	1.36	3.88
T x P	3.60	10.27

Table 3: Impact of shade trees on radiation use efficiency (g MJ^{-1}) of tea shrub at different time span

Tree species	Periods				Mean over phases
	I	II	III	IV	
	Time span				
	7.9.01-3.10.01	4.10.01-13.11.01	14.11.01-22.2.02	23.2.02-19.3.02	
Acacia	0.767	0.135	0.197	0.458	0.389
Casuarina	0.565	0.086	0.122	0.395	0.292
Glyricidia	0.423	0.131	0.199	0.414	0.292
Eucalyptus	0.550	0.203	0.178	0.452	0.346
Albizia	0.573	0.351	0.221	0.450	0.399
Dalbergia	0.486	0.215	0.093	0.475	0.317
Gmelina	0.867	0.182	0.175	0.527	0.438
Mean (T)	0.604	0.186	0.169	0.453	

Statistical analysis

Factor	S.Em (±)	C.D. (P = 0.05)
Tree species (T)	0.0245	0.0755
Period (P)	0.0189	0.0540
T x P	0.0500	0.1428

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