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Effect of Different Shade Tree Species on the Growth and Yield of China Hybrid Tea (Camellia sinensis (L.) Kuntze) at Palampur Tea Research Station, H.P., India

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Abstract

The present investigation entitled, "Effect of different shade tree species on the growth and yield of China hybrid tea (*Camellia sinensis (L.)* Kuntze) grown in Kangra valley at Palampur Tea Research Station, H.P. India ". Objectives of the experiment were to study influence of shade tree species on growth and yield of tea plants. Experiment consisted of six shade tree species each forming one treatment viz., Albizia-tea (T1), Pinus-tea (T2), Aleurites-tea (T3), Calophyllum-tea (T4), Celtis-tea (T5), Prunus-tea (T6), and tea alone (T7). Crown area of each shade tree formed two sub-treatments i.e. C1 (inner 50 %) and C2 (outer 50 %). Tea growth attributes analysis have shown that number of primary shoots per bush, number secondary laterals per primary shoot, bush surface area and maintenance leaf area had their maximum value with albizia as a shade tree. It was followed by aleurites, calophyllum and celtis. Albizia increased the leaf area of top two leaves of plucked shoots significantly to its maximum. Aleurites followed the second position. Albizia followed by aleurites increased the yield of kilo made tea per hectare (KMTH1) by 55.55 and 41.25 per cent, respectively over tea alone. Whereas, pinus tree species decreased by 24 per cent. From the current investigation it was therefore inferred that *Albizia chinensis* followed by *Aleurites fordii* and *Calophyllum elantus* are the most propitious associate of a tea crop in the studied area. These species can also be used successfully for establishing new tea plantation under similar site and climatic conditions.

Keywords: growth, shade tree species, tea bush, yield, India

1. Introduction

The botanical name of the tea plant has been a chequered history, and only recently has uniformity in nomenclature been achieved by assigning to it the designation *Camellia sinensis* under which name tea is listed in the index kewensis. Now that uniformity has been reached. Sealy gives the complete designation as *Camellia sinensis*(L.) O. Kuntze. There has also been some variation in the name of family to which the genus camellia is assigned. Theaceae and terntroemiaceae are synonymously used with a growing preference for the former.

The earliest authenticated use of tea was in southern China, the centre of origin of *Camellia sinensis* var. sinensis. Initially its uses were in medicines, but it was later found that an enjoyable beverage could be made from the unfermented leaves (green tea). The drinking of tea became a ceremonial ritual, particularly in Japan, where the custom is still important. Fermented (black) tea developed later and now forms a very high proportion of the tea consumed in western countries. Tea is used almost entirely as beverages, which has a high nutritional and energy content. Moreover, very recent work has shown that chemicals present in tea have significant effects as anti-ulcer, anti-diabetic, anti-cholestrol and anti-cancer agents.

India, the largest producer, consumer and exporter of tea, cultivate over 4.4 lakhs hectares producing over about 870 million kg of made tea (Anonymous, 1999). Tea is one of the foreign exchange earning crops. In Himachal Pradesh tea is grown in the mid hills. The climate of the region is sub-temperate, sub-humid with moderate to strong acid soils. Tea plantations in the state cover an area of about 2313 ha, yielding 1.71 million kg of tea (Anonymous, 1997). The average yield in Himachal Pradesh (623 kg made tea ha) is very low as compared to the national average of 1948 kg made tea ha^{-1} (Anonymous, 1997). One of the reason for very low yield is lack of deep understanding of dynamic ecological interfaces those exist between shade trees and tea associations in context of limited resource (light, water and mineral nutrient) sharing and utilization.

Tea, non-alcoholic stimulant crop was evolved from understorey of a dense tropical forest south of the Himalayan mountain range and from a less heavily forested environment north of the Himalayas. These give an indication of the conditions natural to the plant. These include high rainfall, evenly spread over a large proportion of the year. Temperature would be lower than tropical ambient temperature at low altitude, because of shading in the forest, and humidity would be fairly high, soil temperature would not be excessive as surface would be shaded.

Interactions between species are mediated by the environment through the “response and effect” principle (Goldberg and Werner, 1983), which states that the plant and its environment modify one another so that the environment causes a response in plant function and growth, and the plant then has an effect upon the environment by changing one or more of its factors (Cloments, 1928; Goldberg and Werner, 1983). The nature of the interactions within and between species, therefore, concern the ways in which a plant can influence its neighbours by changing their environment, either, directly or indirectly. Likewise in tree-tea agroforestry systems shade tree species can affect tea bushes by modifying their environment. The modifications that can result, may have a positive consequence (complementarily) for tea plants due to amelioration of the environment, or a negative consequence (competitive) due to the deleterious (adverse) effect on the environment depending upon ecozone where, the shade tree-tea systems are existed, adopted and operated.

Othiono and Ng'etich (1993) reported that unfertilized shaded tea yields better than unfertilized unshaded tea. Therefore, in low input tree-tea systems (small holder tea gardens), shade trees should be an advantage. In some areas, temperatures are very high in the peak growing season and yield falls because tea leaf temperature exceed the critical value and photosynthesis slows down. In these areas, such as low altitude areas of north India and Bangladesh shade trees are used with success. Hadifield (1974) has studied shade and distribution of light under various shade patterns, suggested that slight to moderate shade found to increase yield and quality.

Shade trees became indispensable components of commercial plantation crops since time immemorial and time to come but the overall performance of shade tree-tea combinations very much depends upon the right choice of ideal shade tree species, density of shade trees, spatial arrangement and proper canopy management practices of shade trees. Historical record and present research results show that tea, as a natural forest component, grow under overhead tree canopy, is shade-tolerant and prefers warm, humid conditions. The total "shade light" which would reach under store bushes depend on tree crown architecture, foliar characteristics of the shade tree and would obviously differ between shade tree species.

Keep in view above mentioned evidence there is overwhelming need for a quantitative analysis of shade tree-tea system interactions to study the potential effect of different shade tree species on growth and yield of tea plants with respect to local edaphic and ecological conditions. Which will provide the scientific basis to screen out most compatible shade tree for tree-tea agroforestry systems and for designing yet more productive and sustainable land use system in humid and sub-humid tropical developing countries like India and Ethiopia. In shade tree-tea agroforestry systems the compatible shade tree species would likely to filter solar radiation by cutting off harmful infra-red sun flux and transmit sufficient light intensity for optimum photosynthesis; lower ambient leaf, soil temperature and retain soil moisture; increase leaf area, number of shoots (plucking points) per bush unit area, shoot growth and yield. To justify the said hypothesis, following objectives were set to be studied: The influence of shade trees on tea bush growth and tea leaf yield.

2. Materials and Methods

2.1. Site description

2.1.1 Location and climate

The experimental station is situated at an elevation of 1291 m above mean sea level, 32^{o}6'0"N latitude and 76^{o}3'3'0"E longitude. The climate of the area is transitional between humid sub-tropical to sub-temperate with maximum temperature rising up to 35^{o}c during summer and minimum 4.9^{o}c in winter. The MAT was 23.04^{o}c. April, May and June were the hottest months whereas, December to February the coldest. The annual rainfall was very high averaging about 2163mm of which 62.06 per cent was received during July and August. The period from April to June was usually dry spell. The mean maximum and mean minimum temperatures ranged from 27.71^{o}c to 18.37^{o}c during the plucking period i.e. April to October. The average humidity varied from 29 to 63 per cent during the dry and 82 to 85 percent during the wet/rainy season.

2.1.2 Soil

The experimental area has a silty loam (43.0% sand; 34.9% silt and 22.1% clay) soil texture with an average PH value of 4.82. Organic carbon content (%), available N,P,K, exchangeable Ca, Mg and available S (kg/ha) were 2.25, 564.04, 28.27, 244.72, 988.69, 274.29 and 56.55, respectively.

2.2 EXPERIMENTAL METHODOLOGY

The experimental details and methods used are described as below:

A. **Structure of the system**

System type	Components	Functional units	Purpose/role
Agrisilvi-cultural	i) Plantation crop	Tea (*Camellia sinensis (L.)O.*Kuntze)	Production (tea leaves)
	ii) Forest trees	a) Albizia (*Albizia chinensis)*	Protection (shade) and improvement (soil)
		b) Chir pine(Pinus roxburghii)	
		c) Tung (Aleurites fodii)	-do-
		d) Poonspar tree *(Calophylum elatum)*	-do-
			-do-
		e) Nettle tree (*Celtis australis)*	-do-
		f) Birdcherry (*prunus padus)*	-do-

B. Arrangement of components

Temporal arrangement : Continuous interpolated
Spatial arrangement : Scattered shade trees

C. Treatments

1. Shade trees

Sr. No.	Tree species+Tea bushes	Treat. Code	Height(m)	Diameter (cm)	Crown area (m^2)
1	Albizia + Tea bushes	T_1	17-18	105-120	80-90
2	Chir pine + Tea bushes	T_2	19-20	95-100	50-60
3	Tung + Tea bushes	T_3	7-8	26-30	45-50
4	Poonspare tree + Tea bushes	T_4	10-11	55-70	50-55
5	Nettle tree + Tea bushes	T_5	15-16	70-80	60-62
6	Bird chery + Tea bushes	T_6	9-10	60-70	55-60
7	Control (pure tea bushes)	T_7	-	-	-

II. Crown Classes

Code	Crown size	Crown dimension
C_1	0-50 per cent crown area	Inner crown
C_2	50-100 per cent area	Outer crown

D. Design : Spilt plot design

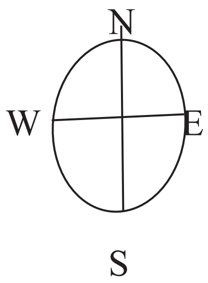
No. of treatments : 13
Main plot : Trees species -6
Sub-plot : Crown classes -2
Control : Unshaded tea bushes-1

Plot size : 45 m^2
No. of tea bushes per plot : 20
Spacing (tea bush) : 1.5 x 1.5 m
No. of trees per plot : 1 (one)
Replication : 3
Duration of study : 2 years

2.3 Growth and yield attributes of tea bushes

2.3,1 Tea bush area (m^2)

Bush area of all experimental tea plants was measured using meter tape from North to South and from East to West. Calculated as per the standard formula:



$$A = \left(\frac{L + B}{2}\right)^2 x\ 0.8$$

Where, A = Bush area (m^2)
L = Length from North to South (m)
B = Breadth (Width) from East to West (m)
0.8= Conversion factor

2.3.2 Pruned tea bush growth attributes

2.3.2.1 Primary shoot height growth (cm)

The shoot length was measured with the help of meter rod (tap) from pruning mark (35 cm above ground) to top tip (apex) of shoot and expressed as average shoot length by dividing with the total number of shoots per bush.

2.3.2.2 Number of primary shoots per bush (no.)

Total number of primary shoots per bush area were counted and expressed as number of shoots per bush unit area.

2.3.2.3 Number of secondary lateral per primary shoot (no.)

It has been recorded as per primary shoot.

2.3.2.4 Maintenance leaf area (cm)

Maintenance leaf area was measured with the help of leaf area meter model CI. 203 for second and third season from permanently marked bushes.

2.3.3 Unpruned bushes yield attributes

2.3.3.1 Leaf area of plucked leaves/top two leaves (cm^2)

Leaf area was measured with the help of leaf area meter model CI-203 after plucking of permanently marked bushes.

2.3.3.2 Average weight of plucked shoots (KMTH)

The tea bushes have been plucked every fortnight of each month during plucking season from April to October. The yield obtained was calculated separately for three main flushes viz. 1st Flush (dry season) from April to June, 2nd Flush (rainy season) for July and August and 3rd Flush (back-end season) for September and October. This attempt has been made in order to investigate the potential seasonal effects (influences) of shade tree species on tea yield. Obtained by dividing total weight of plucked shoots to number of bushes and recorded as kilo made tea per hectare (KMTH) and calculated as per standard formula:

$$KMTH = \frac{G.T. x2500}{T.S.A.B.}$$

Where; KMTH = Kilo made tea per hectare
G.T. = Grand total weight of plucked tea shoots(fresh weight of shoots)
T.S.A.B. = Total surface area of bushes
2500 = 25 per cent dry weight recovery from hectare(10,000m^2

3. Results

3.1. Pruned tea bushes growth attributes

The growth attributes of pruned bushes studied were bush surface area, primary shoot length, number of primary shoots, number of secondary laterals and maintenance leaf area. The data are tabulated in Table 1.

3.1.1 Bush surface area (m^2)

Bush surface area was influenced significantly by different shade tree species (Table 1). The maximum (1.74 m^2) bush area was recorded in T_1 i.e. *Albizia*. It was followed by T_3, T_5, T_4, T_6 and T_2. The minimum bush surface area was in T_7 i.e. unshaded tea bushes. The crown classes of different shade tree species also showed statistically significant impact on bush surface area. It was more in C_2 (outer crown class) than C_1 (inner crown class). Interaction between tree species x crown class was also significant. Among the tree species maximum value was observed at T_1C_1 and minimum at T_2C_1, T_1C_2 albeit showed statistically equal values. T_2C_1 and T_2C_2 were also at par statistically.

3.1.2 Primary shoot length

The primary shoot length was significantly influenced by different shade trees and their crown classes as well.

Maximum primary shoot length (88.95 cm) was observed in T_3, which remained statistically at par with T_1(88.60 cm). All other shade treatments gave significantly lesser shoot length values. It was minimum (57.04 cm) in T_2. Shoot length value at T_2 and T_6 were the lowest even to that of T_7 i.e. control. Crown class (C_2) gave significantly higher value of shoot length than C_1.

3.1.3 Number of primary shoots per bush

Maximum of primary shoots (165.30) were observed in T_1 followed by T_3 (162.60), T_5(162.3), T_4(159.30), T_7(153.6), T_6 (147.6) and minimum in T_2 (125.10). Primary shoots number at T_3 and T_5 was statistically at par with each other.

3.1.4 Number of secondary laterals per primary shoot

The number of secondary laterals per primary shoot was significantly influenced by tree species and crown class did not influence their number significantly. Interaction between Treatments x Crown class was however, significant. The maximum number of secondary laterals was observed in T_3 (8.5) which was statistically at par with T_1 (7.67). Shade tree treatments T_5, T_7, T_4, T_2 and T_6 bore significantly less number of secondary laterals as compared to T_3 and T_1. Minimum number was in T_6 (2.00) which was statistically at par with T_2 (2.17). Secondary laterals were more in outer crown class (C_2) than inner crown class (C^1).

3.1.5 Maintenance leaf area in IInd season (cm^2)

Shade tree species and crown classes had significant impact on maintenance leaf area.
maximum (22.38 cm^2) maintenance leaf area was obtained in T_1 i.e. *Albizia* trees.
The minimum (16.66 cm^2) maintenance leaf area was observed in T_7 i.e. unshaded tea bushes.

3.1.6 Maintenance leaf area of IIrd season (cm^2)

A significantly higher (22.71 cm^2) maintenance leaf area was observed in T_1 under *Albizia* trees followed by T_3, T_4, T_5, T_6 and T_7. Similarly significantly higher maintenance leaf area was recorded in C_2 over C_1 (Table 1).

3.2 Unpruned tea bushes yield attributes

The yield attributes of unpruned bushes studied were leaf area of top two leaves of plucked shoots, and average weight of plucked shoots (KMTH^{-1}).

3.2.1 Leaf area of plucked shoots (top two leaves)

The leaf area of plucked shoots top two leaves was significantly influenced by different shade trees during all the season viz. dry season, rainy season and back-end season (Table 2). In the dry season maximum leaf area was in T_3 followed T_1, T_4, T_6, T_5, T_2 and minimum in T_7 i.e. unshaded tea bushes, Leaf area under all tree species exceeded that of control. During the rainy season highest leaf area was in T_1 which was statistically at par with T_3. Crown class did not influence the leaf area during both the above season. Back-end season showed the trends similar to rainy season.

Table 1. Effect of shade tree species on growth attributes of pruned tea bushes

Shade tree Species	Year : 1999 – 2000 (Pooled)																	
	Bush surface area (m^2)			Primary shoot length (cm)			Number of primary Shoots per bush(No.)			Number of secondary Laterals per primary shoot			Maintenance leaf area (cm^2) 2nd season			Maintenance leaf area (cm^2) 3nd season		
	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**
T_1(Albizia)	1.74	1.74	**1.74**	88.14	89.05	**88.60**	164.8	165.9	**165.3**	7.33	8.00	**7.67**	22.07	22.68	**22.38**	22.58	22.85	**22.71**
T_2 (pine)	1.18	1.19	**1.18**	55.58	58.50	**57.04**	124.6	125.6	**125.1**	2.00	2.33	**2.17**	19.17	19.04	**19.10**	19.60	19.26	**19.43**
T_3(Aleurites)	1.56	1.57	**1.56**	87.09	90.81	**88.95**	162.4	162.8	**162.6**	8.00	9.00	**8.50**	20.07	20.36	**20.21**	21.73	21.79	**21.76**
T_4(Calophyllum)	1.42	1.45	**1.43**	68.62	71.31	**69.96**	159.3	159.3	**159.3**	3.33	3.67	**3.50**	20.12	20.28	**20.20**	21.29	21.91	**21.60**
T_5 (Celtis)	1.44	1.46	**1.45**	69.67	72.43	**71.05**	162.0	162.6	**162.3**	6.00	6.33	**6.17**	20.05	20.14	**20.10**	20.95	21.73	**21.34**
T_6 (Prunus)	1.33	1.37	**1.35**	59.89	62.38	**61.13**	147.2	148.1	**147.6**	1.67	2.33	**2.00**	19.92	19.90	**19.91**	19.95	20.74	**20.34**
T_7 (Tea alone)	1.14	1.14	**1.14**	62.26	62.26	**62.26**	153.6	153.6	**153.6**	5.17	5.17	**5.17**	16.66	16.66	**16.66**	17.89	17.89	**17.89**
Mean	**1.40**	**1.42**		**70.18**	**72.39**		**153.4**	**154.0**		**4.76**	**5.29**		**19.72**	**19.87**		**20.57**	**20.88**	

	SE(d)	**$CD_{0.05}$**	SE(d)	**$CD_{0.05}$**	SE(d)	**$CD_{0.05}$**	SE(d)	**$CD_{0.05}$**	SE(d)	**$CD_{0.05}$**	SE(d)	**$CD_{0.05}$**
T	0.009	**0.019**	1.82	**3.69**	1.87	**4.08**	0.46	**0.99**	0.043	**0.095**	0.020	**0.044**
C	0.005	**0.010**	0.52	**1.11**	0.61	**NS**	0.23	**0.50**	0.021	**0.046**	0.008	**0.017**
TxC	0.009	**0.019**	0.97	**2.08**	1.14	**2.44**	0.44	**0.94**	0.040	**0.086**	0.015	**0.032**

Table 2. Effect of shade tree species on leaf area of plucked shoots (cm^2)

Tree species	Season/Flush of the year 1999 - 2000								
	Dry season (1st Flush)			Rainy season (2nd Flush)			Back-end season (3rd Flush)		
	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**
T_1 (Albizia)	3.68	3.55	**3.62**	4.53	4.63	**4.58**	3.79	4.03	**3.91**
T_2 (Pine)	2.91	2.91	**2.91**	3.63	3.77	**3.70**	3.27	3.34	**3.31**
T_3 (Aleurites)	3.85	3.78	**3.81**	4.46	4.61	**4.54**	3.83	3.87	**3.85**
T_4 (Calophyllum)	3.51	3.58	**3.54**	3.94	4.00	**3.97**	3.63	3.79	**3.71**
T_5 (Celtis)	3.10	3.20	**3.15**	4.05	4.17	**4.11**	3.58	3.64	**3.62**
T_6 (Prunus)	3.52	3.54	**3.53**	3.94	3.63	**3.56**	3.66	3.75	**3.71**
T_7 (Tea alone)	2.60	2.60	**2.60**	2.82	2.82	**2.82**	2.70	2.70	**2.70**
Mean	**3.31**	**3.31**		**3.85**	**3.95**		**3.49**	**3.58**	

	SEd	$CD_{0.05}$	SEd	$CD_{0.05}$	SEd	$CD_{0.05}$
T	0.09	0.20	0.09	0.20	0.10	0.22
C	0.05	NS	0.07	NS	0.08	NS
S	0.18	0.39				
TxC	0.10	0.21	0.10	0.22	0.11	0.24
TxCxS	0.22	0.48				

3.2.2 Average yield of plucked shoots (KMTH[1])

Different shade tree species and their crown classes significantly influenced the yield of made tea per hectare (Table 3). The maximum annual yield was in T_1 (2289.5 $KMTH^{-1}$) i.e. Albizia followed by T_3, T_4, T_5, T_7 and T_6. The minimum yield was observed in T_2 (1121 $KMTH^{-1}$) i.e. pine trees. Having calculated the per cent increase or decrease in Kilo made tea per hectare due to different tree species over the control, a maximum increase of 55.55 per cent was found in T_1 followed by T_3 i.e. 41.25 per cent. Treatments T_2 and T_6 influenced this character negatively. Made tea yield was 24 per cent and 4.2 per cent less over control in T_2 and T_6, respectively (Table 3). During the dry season maximum yield of made tea was in T_1 followed by T_3, T_4, T_7, T_6 and T_2 (Table 3). However, in rainy season the trend was little different where maximum yield was in T_3. It was followed by T_1, T_4, T_5, T_6 and T_7. The minimum yield was in T_2.

Back end season showed the trend almost similar to rainy season with only exception that T_6 along with T_2 also produced less yield than the T_7. The difference in T_6 and T_7, aleurites was statistically non-significant. Among the three seasons back-end produced the lowest quantity of made tea whereas the rainy season produced the highest quantity of made tea. The crown class did not affect the yield of made tea significantly in any of the three seasons. The interaction effect between treatment x crown, treatment x season, treatment x crown x season were statistically significant. The treatment combinations T_3S_2 showed the maximum yield (1138.00 $KMTHA^{-1}$) and T_2S_3 (123.70 $KMTH^{-1}$) the lowest.

Table 3. Effect of shade tree species on yield of made tea ($KMTH^{-1}$)

Tree species	Season/Flush of the year 1999-2000 (pooled)												Percent increase over control
	Dry season (S_1) (1st Flush)			Rainy season (S_2) (2nd Flush)			Back-end season (S_3) (3rd Flush)			Annual yield			
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	
	950.15	966.40	**958.28**	1069.50	1092.00	**1080.75**	232.95	232.80	**232.88**	2253.00	2326.50	**2289.50**	55.55
T_1 (Albizia)	463.75	419.50	**441.63**	550.85	560.70	**555.78**	123.45	123.95	**123.70**	1138.00	1104.00	**1121.00**	-24.00
T_2 (pine)	682.80	703.35	**693.08**	1133.00	1143.00	**1138.00**	245.65	244.50	**245.08**	2061.50	2098.50	**2080.00**	41.25
T_3 (Aleurites)	678.65	689.45	**684.05**	915.00	908.45	**911.73**	176.60	181.45	**179.03**	1770.00	1777.00	**1773.50**	20.30
T_4 (Calophyllum)	475.60	484.25	**479.93**	863.55	855.85	**859.70**	150.70	149.35	**150.03**	1490.00	1489.50	**1489.50**	1.00
T_5 (Celtis)	447.10	460.60	**453.85**	822.60	836.95	**829.78**	127.95	131.00	**129.48**	1397.50	1428.50	**1413.00**	-4.20
T_6 (Prunus)	546.80	546.80	**546.80**	790.70	790.70	**790.70**	136.25	136.25	**136.25**	1473.50	1473.50	**1473.50**	-
T_7 (Tea alone)													
	606.40	**610.05**		**877.88**	**883.95**		**170.51**	**171.32**		**1654.78**	**1677.14**		

	SED	$CD_{0.05}$	SED	$CD_{0.05}$	SED	$CD_{0.05}$	SED	$CD_{0.05}$
T	18.33	**39.94**	17.93	**39.09**	7.95	17.32	21.54	46.69
C	13.10	**NS**	14.62	**NS**	5.79	**NS**	16.02	**NS**
S	23.63	**50.69**	19.99	**42.89**	9.03	19.36	23.29	**49.95**
TxC	13.22	**28.36**						
TxS	27.14	**59.14**						
CxS	23.63	**50.69**						
TxCxS	26.53	**56.**						

4. Discussion

4.1 Pruned bushes growth attributes

The pruned bushes growth attributes namely bush surface area, primary shoot length, number of primary shoots per bush, number of secondary laterals (branches). Per primary shoot and maintenance leaf area were influenced significantly by different shade tree treatments (Table 1). The tree species *Albizia* (T_1) found to be the most propitious tea associate which enhanced the growth of all attributes studied over the control and also to the maximum among all the shade tree species. The *per se* interactive influence is equally true for yield attributes also. In contrast pine tree species (T_2) association have shown adverse/deleterious effect on growth attributes of the pruned bushes. Sole tea crop (T_7) produced minimum values of bush surface area, maintenance leaf area, lesser primary shoot length, number of shoots per bush and number of secondary laterals per primary shoots. Prunus (T_6) association with tea has exerted negative influence on primary shoot height, number of primary and number of secondary laterals per primary shoot by decreasing their values even over the control i.e. tea alone.

The above shade tree treatments influence on the pruned tea bush growth attributes may be due to the following reasons. First, pruned bushes grown in association with Albizia obtained sufficient light intensity, relative humidity, optimum leaf and air temperature, adequate soil moisture, soil nutrients. Hence, Albizia tree species has been found to be the beneficial and less competitive association of tea bushes in comparison with other examined shade tree species. Aleurites followed the second position. However, prunus and pine tree species hampered the growth attributes and thus termed as bad associate tree species.

It may be also inferred from the studies that tree shade is absolutely necessary for better (improved) bush growth since tea growth parameters respond positively to tree shade (Table 1). Bush surface area and maintenance leaf area of the pruned bushes was also higher under the shade compared to control (tea alone). The lowest value of growth attributes of pruned bushes under prunus (T_6) may be due to its heavy (hard) shade which resulted in reduced photosynthetic efficiency of under storey tea bushes. The minimum values of growth parameters under pine association (T_2) and tea alone can be ascribed to lower nutrient content (N,P,K,Ca,Mg and S) in soils than other tree associates. More light and higher air as well as leaf temperatures can be other reasons.

The similar results were obtained by Shanqing *et al.* (1991) who reported that suitable shading rate increased the growth parameters of shaded tea bushes. Gogoi (1976) established the fact that shade causes significant increase in leaf area.

4.2 Unpruned bushes yield attributes

The leaf area of top two leaves of plucked shoots were influenced significantly by different shade tree treatments (Table 2). T_1 gave the highest plucked leaf area and T_7 the least. The leaf area of two leaves of plucked shoots was higher under shade grown tea bushes than grown in sunlight. The highest leaf area of unpruned bushes in T_1 may be due to favorable micro-climate influences and higher nutrient concentration both in tea shoots and soil during the growth season. Moreover, the maximum values of leaf area of tea bushes *per se* was indicator of the suitability of shading rate and shade trees in situ. In contrast the minimum values of leaf area in T_7 may be due to lack of shade trees beneficial influences on tea bushes. Also in order to withstand sun scorch and excessive transpiration open grown tea bushes naturally reduce their leaf area.

The results are in line with findings of Shanqing *et al.* (1991) who reported that bud length, leaf length, leaf width, weight of hundred buds and mean length were more under shading conditions than open grown bushes. Gogoi (1976) also reported significant decrease in leaf area and dry weight of tea under full sun.

In contrast the reduced growth attributes and yield in T_7 can be due to the low light saturation point in open sun grown tea bushes. This is evident from the highest values of air temperature, relative light intensity. leaf temperature, soil temperature, soil temperature, the lowest relative humidity and soil moisture content. The results obtained from the present studies are in conformity with the findings of Huang *et al.* (1991) who reported that under higher temperature and dry day in summer, a suitable shading increased the growth attributes and yield. Barua (1979) reported that tree shade can increase photosynthetic rate and yield by 10 to 30 per cent, especially during hot summer in north-eastern India. Daily average values of tea plants photosynthesis was slightly higher in suitable shading than control and hard (heavy) shading fields. T_1 (Albizia) gave the highest yield of made tea per hectare, which was 55.55 per cent more over control (unshaded tea bushes). More light intensity decreased the yield by 24 per cent i.e. association with pine (Table 3). The lowest yield of kilo made tea per hectare was obtained in T_7 i.e. in open (full sun) grown tea bushes.

The similar type of findings were reported by Dutta (1961) who found that the yield of kilo made tea per hectare was the higher under six different shade tree species without applying nitrogenous fertilizers for five successive years than control (unshaded tea bushes). Gogoi *et al.* (1976) mentioned that the yield of plucked shoots of all the four clones was maximum under 50 per cent light intensity. Ni (1990) reported that the yield under medium shade was increased by 10.2 per cent over no shade control. But under severe shade it was decreased by 26.8 per cent. Barua (1979) reported that tree shade can increase photosynthesis and yield by 10 to 30 per cent. Ding *et al.* (1992) found that tree shade protection from heat and possible dry sells in summer increased the yield by 10.1 per cent in a normal year and by 25.7 per cent in a drought year.

5. Conclusion and Recommendation

Growth attributes viz., bush surface area, primary shoot length, number of primary shoots per bush, number of secondary laterals per primary shoot and maintenance leaf area responded significantly to the association of different shade tree species. Yield attributes also behaved similarly. Having analyzed the individual effect of shade tree species association on growth parameters shade tree species followed the order of preferences: Albizia>Aleurites> Calophyllum> Celtis> Tea alone >Prunus> Pine.

Albizia followed by Aleurites increased the yield of kilo made tea per hectare ($KMTH^{-1}$) by 55.55 and 41.25 per cent, respectively over tea alone. Albizia and aleurited transmitted 65 and 62 per cent relative light intensity, respectively. The relative light intensity ranging between 52 to 65 per cent moderated the soil microenvironment as well as soil environment in terms of relative humidity, air temperature, leaf temperature, soil temperature and soil moisture efficiently resulting into the enhancement of the yield of kilo made tea per hectare over the tea alone.

On other hand, the studies also revealed that prunus transmitted only 25 per cent of total solar radiations available and hence influenced the micro-environment adversely. However, soil properties viz, soil nutrients and soil moisture were not influenced adversely. Pine trees intercepted very low amount of total solar radiation and allowed about 72 per cent of the sun light to transmit. The species did not help in moderating the microclimate as well as soil properties to favor the better growth and yield of tea bushes. Hence termed as the most incompatible associate of tea.

The current studies therefore concluded from the above finding that *Albizia chinensis* followed by *Aleurites fordii* and *Calophyllum elatum* are the most propitious associates of tea. For establishing new tea plantations, the above three species should be preferred as the shade tree in the area or under similar agro-ecological regions.

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