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The diurnal leaf water potential patterns of pruned and un-pruned tea clones in Darjeeling Hill

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Tea is one among the economically important plantation crops predominantly grown in humid tropical and subtropical area. Tea produced in Darjeeling Hill is famous for its muscatel flavour. Darjeeling is located in the lower Himalayas and suffers from various types of stress conditions, such as low temperature, low soil moisture during winter, high humidity and low levels of solar radiation, which are likely to affect growth and yield of tea significantly (Ghosh Hajra, 1992). Pruning is one of the most important operations in tea plantation with a primary objective to replace the old set of maintenance foliage by a fresh one and continue to provide succulent harvestable shoots to maintain the quality. Repeated pruning and skiffing under certain intervals keep the tea bushes under vegetative phase and thus encourage shoot growth for optimum harvest. Every phase/facet of plant life is governed by environmental conditions. Temperature is considered to be cardinal to shoot growth of tea though the relationship between temperature and shoot growth varies according to the growing conditions. Like temperature, light intensity strongly influenced the growth, development and yield of tea (Huang 1989). During the summer months, dry weather with high evaporative demand results in soil and atmospheric drought of varying degree of severity. Tea bushes suffer from drought and lead to cell desiccation and wilting (Barman, 1997). Tea is one of the plant species which has been shown to be highly sensitive to atmospheric vapour pressure deficit (VPD). During the dry periods of many tea growing regions of the world, VPD could rise to levels which would influence stomatal conductance (gs), leaf water potential (ψ_L) and the rate of shoot initiation and extension. The present investigation was, therefore, undertaken to determine the diurnal patterns of the leaf water potential of pruned and un-pruned popular tea clones, both under stress and non stress conditions.

The study was conducted at the experimental farm of Darjeeling Tea Research and Development Centre, Kurseong (26^{0}9'N, 88^{0}12'E, altitude 1240 m) during 2010-11. The topography comprised of moderate slope (25-30%). The soil texture is sandy loam. The topsoil is about 45 cm in depth and the sub soil is stony. The soil of Kurseong is an Umbric Dystrochrept, moderately permeable and well drained. Infiltration rate is 4 – 6 cm h^{-1} measured by water hydrograph method in the field (unsaturated) conditions. Four popular Darjeeling tea clones *viz*. T135, AV2, T383 and P312 were selected for the study with 90 cm x 60 cm x 60 cm plant spacing. There were three replications of each clone with 50 plants per replication. Ten plants of each clone under each replication were pruned during the end of November, 2010 for the comparative studies. The plants were not irrigated as this is the general practice in Darjeeling region.

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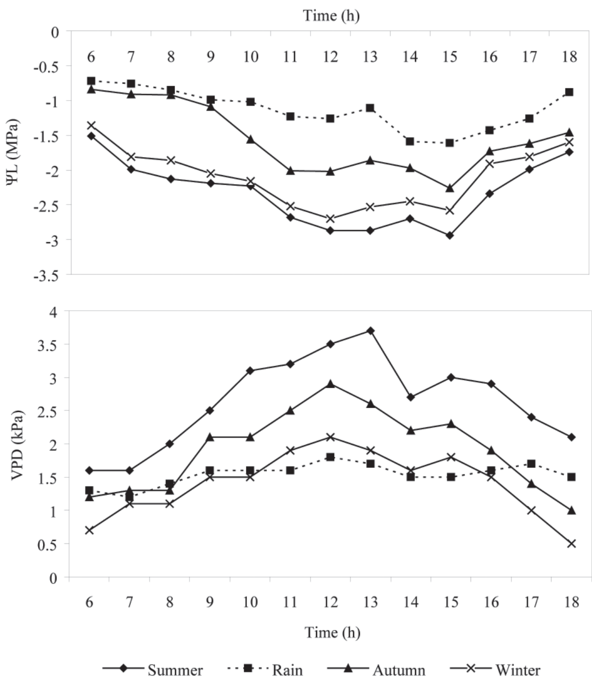

Fig. 1. Diurnal variation of Leaf water potential (MPa) and vapour pressure deficit (VPD) during 2010-11 in Darjeeling tea clones

Dark-green healthy mature and fully expanded leaves at the surface of the canopy that is fully exposed to incident sunlight were used for the observations. Such leaves are often referred to as 'maintenance' foliage. Three leaves were randomly selected from each clone and the leaf water potential (ψ_L) was measured at hourly intervals from 06:00 to 18:00 hours IST by a dew point hygrometer (model C-52 sample chamber connected to an HR 33T microvoltmeter, Wescor Inc., Logan, USA) as described by Wescor Inc. (1988). Small circular leaf discs from the leaves on the opposite branches were used for leaf water potential measurement expressed in megapascals (MPa). Photosynthetic photon flux density (PPFD), vapour pressure deficit (VPD) and leaf temperature (^{o}C) were measured by a portable photosynthetic system (Li 6200, Licor, Nebraska, USA) with a well mixed 390 cm^3 chamber as described (Li-Cor Inc., 1987). All data points during a measurement period were fitted using linear regression techniques. The humidity within the chamber was kept constant during the measurement period in order to get satisfactory results as observed by Leuning and Sands (1989).

Table 1. Diurnal leaf water potential (ψ_L) patterns of pruned (P) and un-pruned (UP) Darjeeling tea clones after three months of pruning

Time	Leaf water potential of tea clones (-MPa)							
(h)	T135		AV2		T383		P312	
	P	UP	P	UP	P	UP	P	UP
6:00	-0.72	-1.26	-0.68	-1.19	-1.15	-1.49	-1.23	-1.68
7:00	-0.76	-1.44	-0.80	-1.69	-1.30	-1.61	-1.29	-1.70
8:00	-0.87	-1.71	-0.91	-1.76	-1.42	-1.80	-1.45	-1.93
9:00	-0.96	-2.03	-1.07	-1.80	-1.52	-2.04	-1.50	-2.13
10:00	-1.02	-2.20	-1.21	-2.34	-1.78	-2.81	-1.80	-2.76
11:00	-1.21	-2.40	-1.39	-2.51	-1.85	-3.02	-1.85	-3.09
12:00	-1.27	-2.57	-1.45	-2.75	-1.94	-3.21	-1.84	-3.42
13:00	-1.19	-1.94	-1.42	-1.90	-2.00	-3.01	-1.91	-3.29
14:00	-1.45	-1.71	-1.88	-1.64	-2.14	-2.78	-2.11	-2.97
15:00	-1.43	-1.70	-1.87	-1.74	-1.95	-3.09	-2.09	-2.96
16:00	-1.42	-1.45	-1.79	-1.75	-1.69	-1.92	-1.94	-2.38
17:00	-1.30	-1.32	-1.32	-1.70	-1.30	-1.52	-1.61	-2.11
18:00	-0.70	-1.12	-0.89	-0.92	-1.24	-1.47	-1.29	-1.86
SEM	0.0	0.04	0.03	0.03	0.03	0.04	0.03	0.04
CD at 5%	0.09	0.13	0.09	0.09	0.10	0.12	0.08	0.13

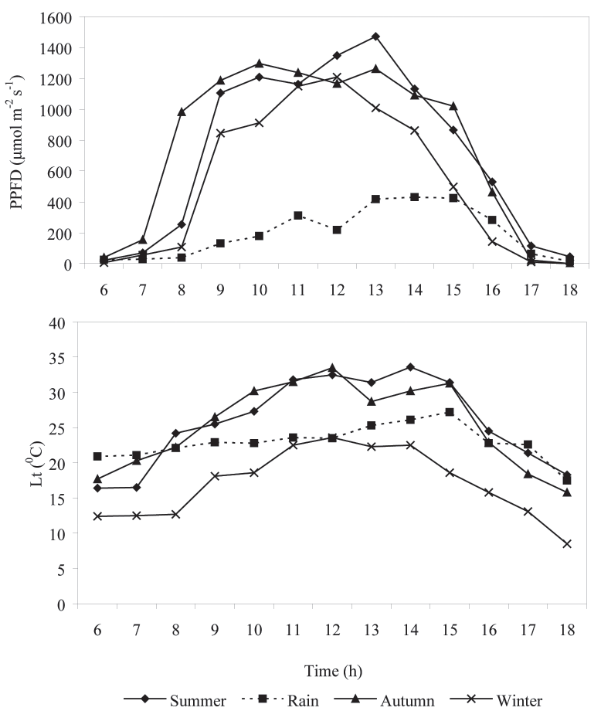

Fig. 2. Diurnal patterns of photosynthetic photon flux density (PPFD), and leaf temperature (Lt) during 2010-11 in Darjeeling hill

The results obtained during the study emphasized the importance of studying the leaf water potential at hourly intervals during the day. Maximum ψ_L was recorded during rainy season followed by autumn, winter and summer season (Fig. 1). The early morning hours showed higher ψ_L irrespective of all the seasons. A gradual reduction of ψ_L till 12.00 hrs was observed in winter. However, in general, ψ_L was low at noon during all seasons (Fig. 1). There are some differences in the diurnal leaf water potential patterns of pruned and un-pruned tea clones. The leaf water potential of the pruned plants is constantly higher than the un-pruned tea clones (Table 1). Among the clones, T135 showed higher ψ_L followed by AV2, P312 and T383.

Higher value of leaf water potential (ψ_L) was associated with low PPFD, higher atmospheric temperature, soil moisture and relative humidity (RH 94 - 95%) during rainy season. The minimum ψ_L was observed in summer, when PPFD has increased from lower intensity to a saturation level (about 1350 µmol $m^{-2} s^{-1}$) by 10:00 to 12:00 hrs as compared to rainy season which was less than 380 µmol $m^{-2} s^{-1}$ which is turn also affected the ψ_L (Fig. 2)

Table 2. Diurnal leaf water potential (ψ_L) patterns of pruned (P) and un-pruned (UP) Darjeeling tea clones after six months of pruning

Time	Leaf water potential of tea clones (-MPa)							
(h)	T135		AV2		T383		P312	
	P	UP	P	UP	P	UP	P	UP
6:00	-0.87	-1.27	-0.76	-1.11	-1.23	-1.46	-1.33	-1.66
7:00	-0.93	-1.31	-1.00	-1.49	-1.56	-1.81	-1.48	-1.78
8:00	-1.15	-1.80	-1.19	-1.99	-1.66	-2.09	-1.59	-2.39
9:00	-1.21	-2.29	-1.24	-2.12	-1.81	-2.78	-1.71	-2.69
10:00	-1.32	-2.60	-1.42	-2.52	-1.98	-2.93	-1.88	-3.00
11:00	-1.74	-2.85	-1.79	-2.83	-2.15	-3.37	-2.05	-3.22
12:00	-1.92	-2.80	-1.89	-2.87	-2.40	-3.92	-2.34	-3.75
13:00	-1.44	-2.21	-1.49	-2.20	-2.66	-3.56	-2.46	-3.45
14:00	-1.80	-1.99	-1.92	-2.05	-2.61	-3.58	-2.50	-3.43
15:00	-1.70	-2.05	-1.91	-2.30	-2.26	-3.70	-2.31	-3.88
16:00	-1.45	-1.61	-1.53	-1.85	-1.75	-2.18	-2.05	-2.79
17:00	-1.10	-1.35	-1.31	-1.73	-1.55	-1.60	-1.74	-1.63
18:00	-0.89	-1.13	-0.96	-1.25	-1.29	-1.57	-1.40	-1.43
SEM	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
CD at 5%	0.10	0.08	0.08	0.10	0.10	0.09	0.08	0.10

During the dry period of many tea growing regions of the world, vapour pressure deficit (VPD) could rise to a level which would influence g_s, shoot ψ_L and the rate of shoot initiation and extension (Squire and Callander. 1981). During wet periods with frequent rain, ψ_L of tea has an inverse, linear relationship with VPD (Williams, 1971; Squire, 1976). This probably operates through the influence of VPD on transpiration, which increases with increasing VPD causing a decrease in shoot ψ_L. During these wet periods, VPD did not exceed 2.0 kPa and shoot ψ_L did not decrease below –1.0 MPa. However, it broke down during dry periods, with shoot ψ_L quickly falling to around -1.5 to -2.0 MPa during the early part of the day around 09:00 hr and then remaining at this minimum level while the VPD continued to increase up to 4.0 kPa. Moreover, even if the VPD decreased during the later part of the day, shoot ψ_L remained at its minimum until the end of the day. When ψ_L began to rise again during late afternoon, it showed hysteresis and lagged behind the decrease of VPD. Interestingly, when the soil was re-wetted by rain at the end of the dry season, the linear relationship between shoot ψ_L and VPD was re-established and shoot ψ_L quickly returned to its higher values (*i.e.*> -1 MPa). This indicated that the roots in the top soil (0-15 cm) had remained alive during the dry period despite the absence of a clear relationship between shoot ψ_L and VPD during dry periods on a diurnal basis.

After a long time of pruning, the difference in leaf water potential in pruned and un-pruned tea plants observed marginal (Table 2). After six month of pruning, among clones T135 and AV2, there was not much difference between the pruned and un-pruned tea plants while clones T383 and P312 showed a considerable difference in ψ_L. The reason for the higher ψ_L values was may be due to pruning the total leaf area is reduced however, the root system remains the same. In other words the plants have an extensive and efficient root system and a reduced leaf area, resulting in a less atmospheric demand and hence reduced transpiration rate. As the plants grow and the leaf area increases the difference will gradually become smaller.

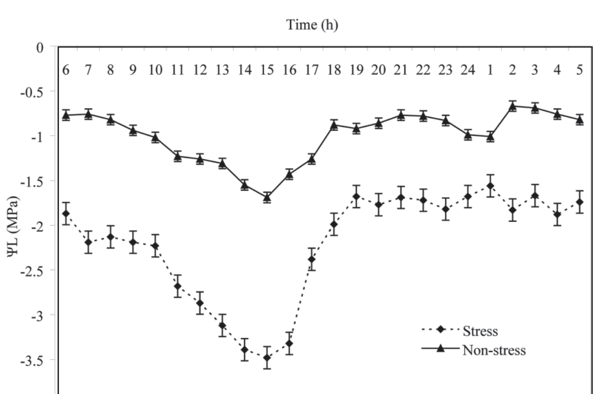

Fig. 3. Diurnal pattern of leaf water potential (MPa) in stress and non-stress period in Darjeeling hill. Vertical bars indicate standard error of the means

In the present study, the diurnal pattern of ψ_L from 6:00 AM to 6:00 AM (24 hours) was also recorded in stress and non stress period. It was found that leaf water potential of tea plant was higher during non-stress period than stress period. In both the condition, ψ_L was recorded gradually decreasing trend and reached minimum at 15:00 hrs then gradually increased (Fig. 3). However, during stress period, ψ_L gradually decreased and reached minimum (-3.5 MPa) at 15:00 hrs then gradually increased.

The leaf water potential pattern in pruned and un-pruned tea plants increased in the pruned tea plant at midday (Table 2). This rise could be explained by a partial or total stomatal closure when atmospheric demand is too high. Laker *et al.* (1991) found the same phenomenon in maize. They stated that afternoon reductions in stomatal conductance, due to extreme evaporative demand and/ or low soil water availability, facilitate recoveries in leaf water status to the benefit of the plant and also improve water use efficiencies. This effect is not found in the un-pruned plants except in clones T135 and AV2. Clone T135 performed well which showed some distinct differences in their leaf water potential patterns. The leaf water potential of T383 and P312 dropped sharply during the morning and was constantly lower than T135 (Table 2).

The study has shown that there are distinct differences in plant behaviour between pruned and un-pruned tea plants. The leaf water potential values of pruned tea clones is constantly higher those of un-pruned plants. Pruned plants show a midday increase in leaf water potential, caused by stomatal closure, whereas the un-pruned plants do not show signs of stomatal closure. The data showed that the leaf water potential could be a potential indicator of drought sensitivity in tea clones. Vapour pressure deficit value of 2.5 kPa appears to be a critical value at which the leaf water potential drops below –1.0 MPa for drought sensitive plants but stays above –1.0 MPa for plants that are not sensitive to drought. However, more data need to be generating to confirm leaf water potential to be a drought sensitivity indicator.

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References

Barman, T.S. 1997. Transpiration in tea [*Camellia sinensis* (L) O. Kuntze]. *Two and a Bud* **44**:8-12.

Ghosh Hajra, N. 1992. Strategies for improvement of tea production in Darjeeling hills;Indian Rev. *Life Science* **12**: 195-210.

Huang, S. 1989. Meteorology of the tea plant in china: A Review. *Agricultural and Forest Meteorology* **47**: 19-30.

Laker, M.C., Ceulemans, R.J.M. and Vanassche, F.M.G. 1991. Effects of soil water stress on stomatal diffusion conductance and leaf water potential in maize (*Zea mays* L) at flowering stage. *Water* SA **17**: 255-262.

Leuning, R. and Sands, P. 1989. Theory and practice of a portable photosynthesis instrument. *Plant, Cell and Environment* **15**: 669-678.

Li-Cor Inc. 1987. Li-6200 Portable Photosynthesis System, Instruction Manual.Li- Cor, Lincoln, NE, USA.

Squire, G.R. 1976. Xylem water potential and yield of tea (*Camellia sinensis*) clones in Malawi. *Experimental Agriculture* **12**: 289-297.

Squire, G.R. Callander B.A. 1981. Tea plantations. In: *Water Deficits and Plant Growth*, (Ed). Kozlowski T.T., Vol. VI, Academic Press, New York. pp. 471-510.

Wescor Inc. 1988. HR-33T microvoltmeter, Instruction Manual. Wescor Inc., Logan, Utah, USA.

Williams, E.N.D. 1971. Investigations into certain aspects of water stress in tea. In: *Water and the Tea Plant*. (Eds.) Carr, M.K.V, Carr, S., Tea Research Institute of East Africa, Kericho, Kenya. pp. 79-87.