

CHLOROPHYLL FLUORESCENCE AND GAS EXCHANGE CHARACTERISTICS OF COCOA

D. BALASIMHA and E.V. DANIEL

Central Plantation Crops Research Institute, Regional Station, Vittal - 574 243, Karnataka, India.

ABSTRACT

The chlorophyll fluorescence, net photosynthesis (P_n) and related stomatal characters were studied in cocoa trees. There were significant seasonal variations in chlorophyll fluorescence indices and gas exchange characteristics in cocoa. The F_0 value was significantly higher in drought susceptible accession type showing that PS II was affected to a greater extent. However, F_M and F_V were lower in drought tolerant trees as compared to susceptible ones. This was in parallel with lower P_N in tolerant type. Drought tolerant accession had higher stomatal diffusive resistance resulting in decreased transpiration rate. The r_s was negatively correlated with transpiration. These fluorescence signatures reflect on the intactness of the photosystems even at closed stomata in tolerant types during stress periods. The relationships between P_N and fluorescence quenching parameters have also been studied.

INTRODUCTION

Light absorbed by photosynthetic pigments is primarily used in the two photosystems and a fraction of it may be dissipated as heat or fluorescence. Under various stress conditions, P_N is considerably reduced and chlorophyll fluorescence indices are thereby affected (Lichtenthaler, 1990). Quantum efficiency of PSII and quenching of chlorophyll fluorescence have been studied (Genty *et al.*, 1989; Weis and Berry, 1987). Fluorescence provides a useful indicator of photosynthetic efficiency and is affected by stress conditions (Bruggemann, 1992; Govindjee *et al.*, 1981; Lichtenthaler, 1990; Krause and Weis, 1984). Relationships between chlorophyll fluorescence and photosynthesis have been investigated in some crops (Ireland *et al.*, 1984; Oquist and Chow, 1992).

Cocoa widely cultivated as a mixed crop in arecanut and coconut gardens in Southern India experiences periodic droughts. Effective stomatal control is mainly attributed to drought tolerance in cocoa (Balasimha and Rajagopal, 1988; Balasimha *et al.*, 1988). The photosynthesis of cocoa as influenced by

environmental factors was studied in the field (Balasimha *et al.*, 1991). There was no significant difference due to accession type or season in internal CO_2 despite stomatal closure showing that mesophyll factors were not affected (Balasimha, 1993; Balasimha *et al.*, 1991). In this paper seasonal and accession type variations in fluorescence signature and its relationships with photosynthesis of cocoa trees are reported.

MATERIALS AND METHODS

The cocoa trees (*Theobroma cacao* Linn.) used in the present study were planted in 1985 under arecanut palms. Eight trees each belonging to drought tolerant (NC 42/94) and susceptible (I-56) were sampled. Each tree was fertilized annually with 100 g N, 40g P_2O_5 and 140 g K_2O .

Measurements of light (Q_N), temperature (Tair), vapour pressure deficit (VPD), relative humidity (RH), r_s , E and P_N were made on leaves from outer canopy using LI-6200 portable photosynthesis system as described earlier (Balasimha *et al.* 1991). Chlorophyll fluorescence was measured using the Plant Efficiency Analyzer (Hansatech Instruments Ltd., USA) according to

Balasintha (1992). These measurements done during 1992-1994 were pooled and statistically analysed.

RESULTS AND DISCUSSION

The microclimatic variables recorded during the months are given in Table I. Light, Tair and VPD were higher in summer months.

Table I. Seasonal means of microclimatic variables, soil moisture and leaf water potential (WP)

Month	Q _N (μ mol 1 m ⁻² s ⁻¹)	Tair (°C)	RH (%)	VPD (kPa)	Soil Moisture(%)	WP (MPa)
Jan	429	30.96	62.56	1.67	12.42	- 0.61
Feb	654	32.31	41.11	3.03	11.39	- 0.78
Mar	653	34.60	52.33	2.76	13.28	- 0.88
Apr	640	35.69	49.50	3.13	13.19	- 0.75
May	370	32.77	61.59	1.96	16.33	- 0.83
Sep	475	31.64	61.72	1.83	19.09	- 0.72
Oct	516	32.35	61.61	1.89	15.89	- 0.79
Nov	268	32.59	67.03	1.34	18.95	- 0.72
Dec	484	29.68	56.67	1.88	13.49	- 0.73

Table II. Chlorophyll fluorescence parameters (relative units) of cocoa

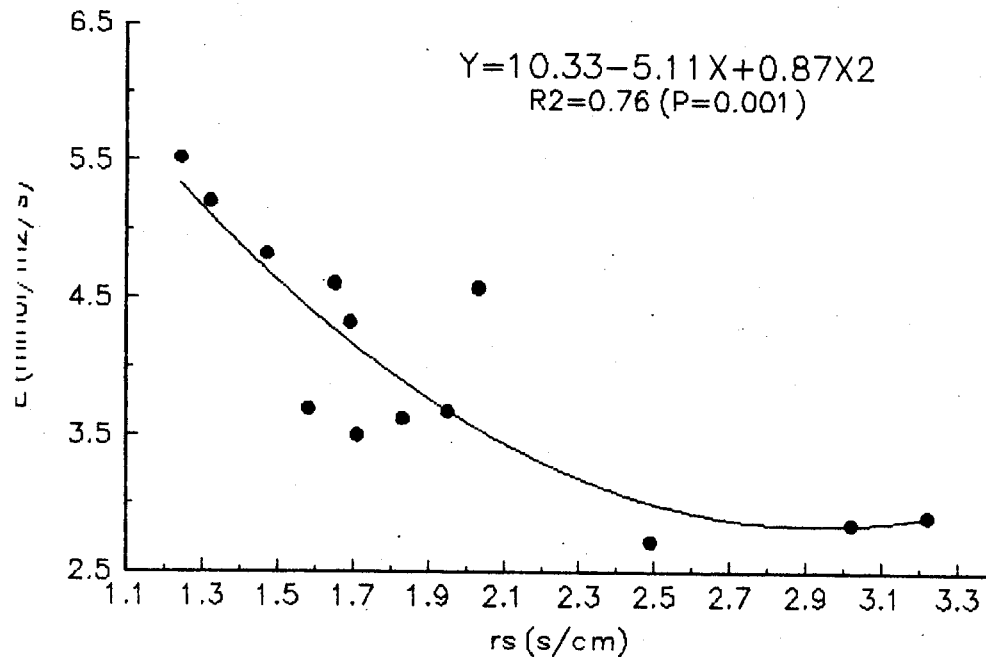
Treatment	FO	FM	FV	FV/FM
Accession type				
Tolerant	599	2659	2059	0.771
Susceptible	660	2826	2162	0.761
CD	40 *	98 **	ns	ns
Season				
Jan	609	2781	2172	0.775
Feb	656	2879	2202	0.764
Mar	631	2577	1943	0.747
Apr	638	2728	2089	0.765
May	686	2676	1989	0.740
Sep	622	2870	2248	0.782
Oct	614	2612	1997	0.763
Nov	586	2696	2109	0.782
Dec	624	2862	2244	0.779
CD	41 **	167 **	2173 **	0.022 **

Significant at P = 0.05 (*) or 0.01 (**)

Table III. Gas exchange characteristics of cocoa

Month (M)	E (mmol m ⁻² s ⁻¹)		Pn (μ mol m ⁻² s ⁻¹)		r _s (sec ⁻¹)	
	Tol.	Susc.	Tol.	Susc.	Tol.	Susc.
Jan	3.82	4.13	4.43	4.66	1.64	1.42
Feb	3.70	4.73	3.40	4.11	3.20	2.37
Mar	4.41	5.02	4.11	4.39	2.67	1.80
Apr	4.16	4.82	3.35	3.78	4.12	2.05
May	3.41	3.18	3.85	3.90	2.89	1.61
Sep	4.43	4.30	4.02	4.64	1.33	1.43
Oct	4.51	5.63	4.06	4.37	1.24	1.19
Nov	3.67	3.86	3.92	3.43	1.74	1.30
Dec	3.68	4.47	3.71	3.98	1.74	1.61
Mean	3.98	4.46	3.87	4.20	2.21	1.64
CD (A)	0.42 *		ns		0.44 **	
CD (M)	0.59 **		0.72 *		0.45 **	

Significant at P = 0.05 (*) or 0.01 (**), Tol. : Tolerant, Susc. : Susceptible

Fig. 1. Relation of E to r_s in Cocoa

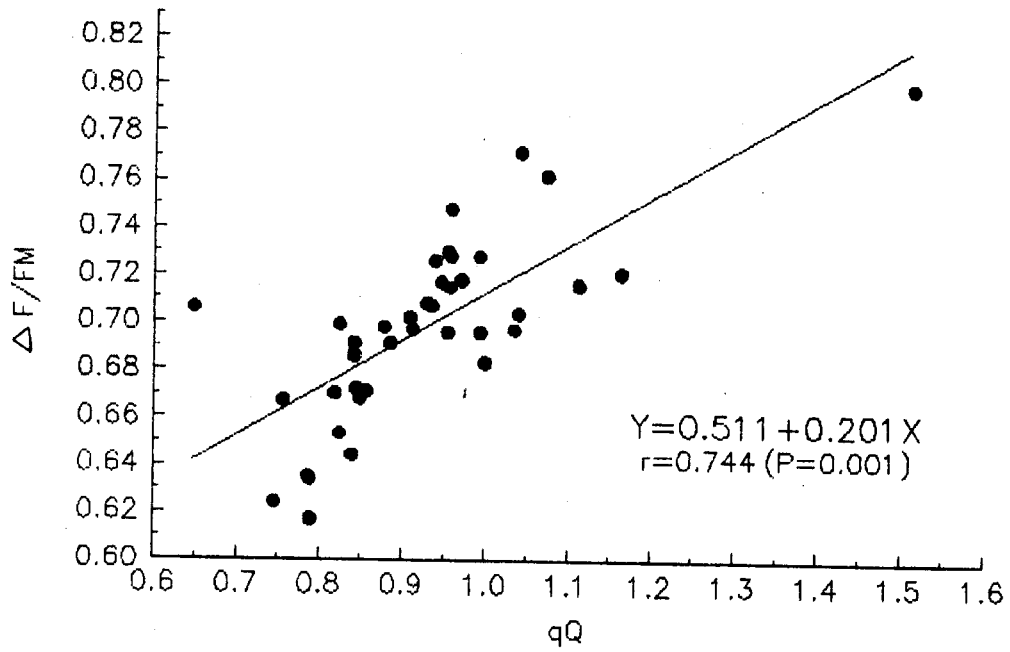


Fig. 2 Relation of $\Delta F / F_m$ with qQ in Cocoa.

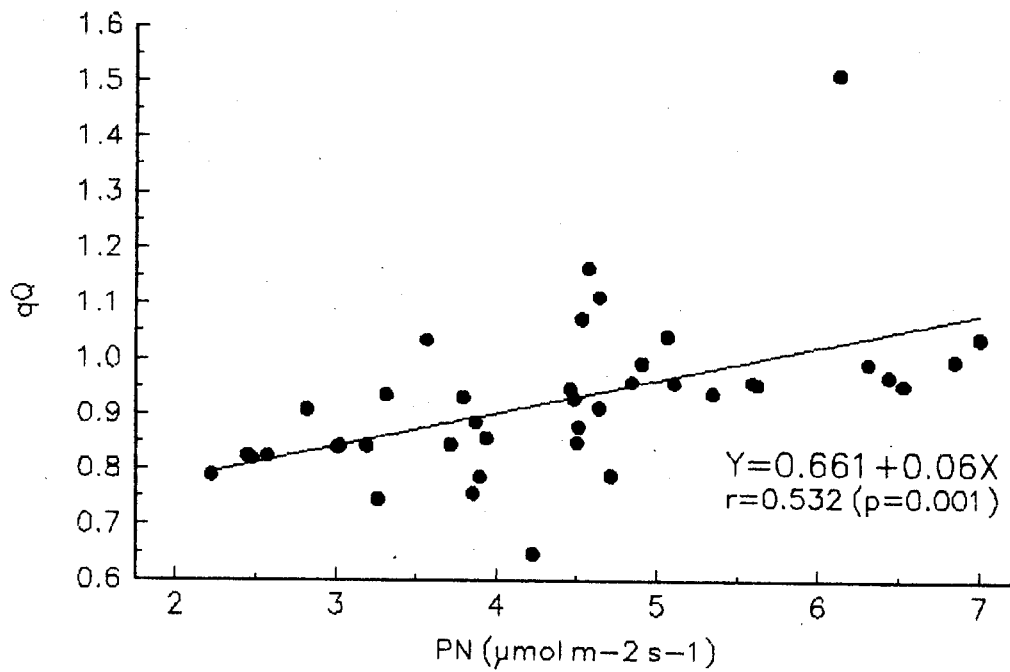


Fig 3. The relationship between qQ and PN in Cocoa.

Soil moisture content decreased during dry months. Chlorophyll fluorescence parameters showed significant differences at seasons and between accession types (Table II). The F_v values were lower during drier months (March to May) as compared to other months. The fluorescence signatures could describe seasonal photosynthetic activity in Spruce needles (Lichtenthaler *et al.*, 1989). The F_o was significantly higher in susceptible accession type showing that PS II was affected to a greater extent (Demmig and Bjorkman, 1987). However, F_M and F_V were lower in tolerant type.

The P_N did not show any significant difference between tolerant and susceptible accessions, but monthly values were significantly different (Table III), confirming earlier results (Balasimha *et al.*, 1991). Balasimha *et al.* (1988) indicated that cocoa effectively conserves water by stomatal closure; the view supported by higher r_s and lower E (Table III). There was in fact a curvi-linear negative relationship of r_s with E (Fig. 1). This type of stomatal closure have been reported in cocoa and other crop species (Balasimha *et al.*, 1988; 1991; Guehl and Assenac, 1987; Jarvis, 1980; Raschke, 1975; West and Gaff, 1976). These P_N values and fluorescence signatures in cocoa reflect the intactness of photosystems even at closed stomata during dry season.

Correlation analysis between P_N values and fluorescence quenching parameters were done to know the nature of relationships. The simple fluorescence parameter ($\Delta F/F_M$) can be used to estimate quantum yield of non-cyclic electron transport and derived as $F_M - F_s/F_M$. These values were found to be directly proportional to the fluorescence quenching (qQ) in cocoa (Fig. 2). The photochemical quenching (qQ) is derived as $F_m - F_s/F_v$. Such relationships have been described in other crops (Genty *et al.* 1989; Weis and Berry, 1987). There was a linear

correlation of P_N with qQ (Fig. 3). In accordance with Weis and Berry (1987) model, most plants exhibit an approximately linear relation between P_N and qQ (Oquist and Chow, 1992). Thus, the data presented demonstrate that the P_N shows linear relationships with $\Delta F/F_M$ and qQ. As a consequence of this the relatively simple fluorescence parameters viz., photochemical yield of PSII i.e., $\Delta F/F_M$ and photochemical quenching (qQ) can be used for routine measurements of photosynthetic performance of leaves.

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