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WATER RELATIONS OF COCONUT PALMS AS INFLUENCED BY ENVIRONMENTAL VARIABLES*

K.V. KASTURIBAI, S.R. VOLETI and V. RAJAGOPAL

Central Plantation Crops Research Institute, Kudlu Post, Kasaragod- 670 124 Kerala (India)

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ABSTRACT

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The influence of the agrometeorological parameters of radiation, temperature and vapour pressure deficit (VPD) on the development of stress in coconut palms (*Cocos nucifera* L.) was studied. A steady state porometer was employed to measure both meteorological parameters and stomatal resistance under field conditions. Between 10.00 and 12.00 hours there were increases in radiation, temperature and vapour pressure deficit (VPD). During this period the stomatal resistance reached a maximum and the leaf water potential (Ψ) was reduced. During the wet season there was low radiation, temperature and VPD which resulted in the palms showing low stomatal resistance, whereas during the dry season the reverse situation occurred. West Coast Tall palms responded to dry weather through a high leaf diffusive resistance, while the hybrid dwarf × tall was susceptible to stress conditions.

INTRODUCTION

Coconut palm grows well in warm weather with abundant sunshine and a mean annual temperature of 27°C (Murray, 1977). A well distributed rainfall was found to favour good growth and nut yield. However, a prolonged dry spell extending from 3 to 6 months affects the palm. Such severe drought occurs once in 4–5 years in Northern Kerala. During the summer months dry weather prevails with high evaporative demand, resulting not only in atmospheric drought but also soil drought. Thus coconut palms experience moisture stress to different degrees depending on the soil conditions, rainfall pattern and other environmental variables. Milburn and Zimmermann (1977) suggested that the water balance of coconut palms is protected in the dry season by the controlling influence of stomata.

The influence of agrometeorological parameters such as light, temperature

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and relative humidity on stomatal regulation is well documented in many crops (Raschke, 1975). Among tree crops the information is scanty apparently because of their perennial nature, but there are reports on the stomatal physiology of conifers (Jarvis, 1980). Response of stomata of five tree crop seedlings to light and humidity was studied but under growth chamber conditions (Davies and Kozlowski, 1974). The present paper aims at understanding the impact of environmental variables on the development of stress in the field-grown adult coconut palms through the season and the day. The response of two coconut genotypes to the same stress conditions has also been assessed.

MATERIALS AND METHODS

Coconut palms (*Cocos nucifera* L. var. West Coast Tall, WCT and the hybrid Chowghat Dwarf Orange × West Coast Tall, D × T) were planted in the Institute Farm in 1965 as randomized block design comprising two treatments with three replications and six palms per replication. This monocrop experiment with a spacing of 7.5 m × 7.5 m was laid out on a red sandy loam soil. Recommended levels of fertilizers were applied in two split doses. Among the two treatments, irrigated and rainfed, two palms per replication under rainfed condition alone were taken up for the present studies.

Measurements of light, temperature and relative humidity (later converted into VPD) were made in the vicinity of the experimental palms using a steady state porometer (Li-Cor 1600, Lambda Instruments, Lincoln, Nebraska, U.S.A.). The same equipment was used to measure the stomatal resistance on the lower surface (hypostomatic) in three leaflets (six measurements on either side of the midrib of each leaflet) of the middle whorl leaves, i.e., 14th leaf, as described earlier (Rajagopal et al., 1986). Determination of leaf water potential (Ψ) was carried out with a Scholander chamber (Plant Water Console 3000, Soil Moisture Co., U.S.A.) in the leaflets opposite to that used for the stomatal resistance (Rajagopal et al., 1987a). All the determinations were made between 10.00 and 12.00 hours which was found to be the appropriate time to study the stomatal regulation in coconut particularly in response to dry weather, this being the time of peak opening of the stomata (Rajagopal et al., 1986). In one of the experiments, both the meteorological data and stomatal resistance were recorded between 10.00 and 12.00 hours from August to May at monthly intervals with two to three consecutive observations in a month. The observations were not carried out during the months of June, July and October due to the heavy rainfall. During the dry season soil moisture content was also determined at four depths (0–30, 30–60, 60–90 and 90–120 cm) in the basins of two palms which include the zone of maximum root density, with Troxler neutron probe moisture meter (U.S.A.)

RESULTS AND DISCUSSION

Observations were recorded for three consecutive days and the average values of six palms are given in Figs. 1 and 2 and Table 1. As all the days during the entire season would not be similar either in terms of climatological variables or plant behaviour the data collected were restricted to three days in a particular month. This resulted in minimum variation in the parameters studied.

During the dry months, there were increases in radiation, temperature and VPD with time, the increase being sharp during the first half an hour (Fig. 1). The seasonal fluctuations in these parameters were clearly indicated between wet months (August to December) and dry months (January to May) (Fig. 2). The percent soil moisture content was 8.5, 9.7, 10.8 and 13.1 respectively at 30, 60, 90 and 120 cm of soil depth and the mean pan evaporation was 5.5 mm during the peak summer month.

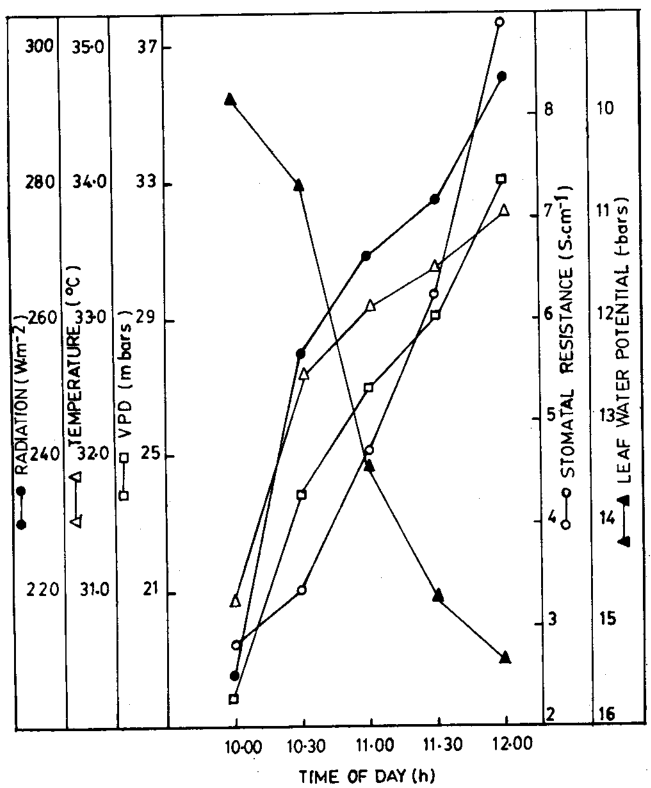

Fig. 1. Relationship between the environmental variables (scales on the left side) and the stomatal resistance and leaf water potential (scales on the right side) in coconut palms determined in March, during the dry season. Each data point is the average over three days and from six palms.

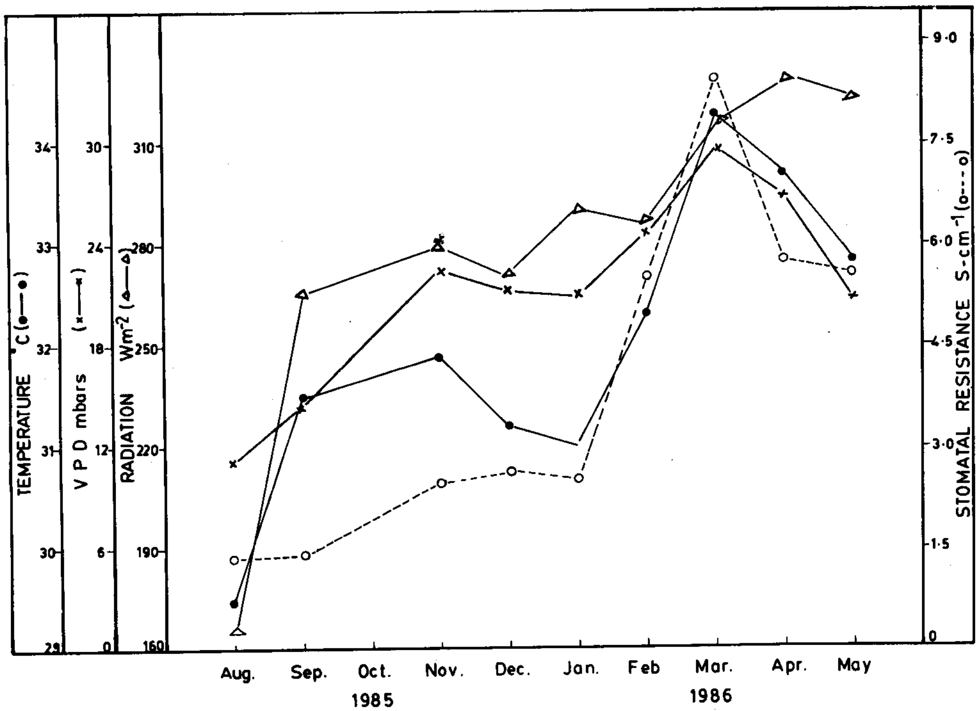

Fig. 2. Monthly variations in the environmental variables as reflected by the stomatal resistance in coconut palms (var. WCT). Measurements were taken on three consecutive days each month. Values are means for six palms. Measurements were not taken in the rainy months of June, July and October.

Stomatal resistance of the leaves registered a threefold increase (2.8 to 9.05 S cm^{-1}) during the experimental period (Fig. 1) while the Ψ decreased from -9.8 bar to -15.3 bar. From Fig. 2, it is clear that the stomatal resistance which was low during wet months, increased rapidly from January, reaching a peak in March followed by a decline.

Table 1 shows the response of two genotypes at two distinct seasons namely wet (August) and dry (March). The leaf diffusive resistance of both genotypes was low during the month of August and high during the month of March. There was a sixfold increase in the stomatal resistance in WCT and D×T palms between the wet and dry seasons. In both periods WCT had higher resistance than D×T.

From the present study it is evident that the agrometeorological variables play a major role in the water balance of coconut palm through stomatal regulation (Milburn and Zimmermann, 1977; Rajagopal et al., 1986). There was progressive increase in atmospheric demand from December to March and this resulted in increased leaf diffusive resistance. There were parallel increases in the stomatal resistance with radiation, temperature and VPD, while Ψ showed

TABLE 1

Seasonal variations in the environmental variables as reflected on the stomatal resistance in coconut palms

	Dry season				Wet season			
	Temperature °C	Radiation $W\ m^{-2}$	VPD mbar	S.R. $S\ cm^{-1}$	Temperature °C	Radiation $W\ m^{-2}$	VPD mbar	S.R. $S\ cm^{-1}$
WCT								
Day-I	31.2	287.0	20.7	7.66	28.6	69.6	9.76	1.08
	31.2	271.7	21.1	9.23	28.2	47.8	8.73	1.98
Day-II	31.0	265.0	20.9	9.19	30.8	95.7	11.1	1.25
	30.6	260.9	20.0	9.31	29.0	80.4	10.9	1.63
Day-III	31.0	282.6	20.5	7.38	29.2	171.7	11.5	1.21
	30.8	272.0	20.3	8.35	30.0	126.1	11.5	1.42
Mean	30.9	273.2	20.6	8.52	29.3	98.55	10.58	1.42
S.E.±	0.087	3.74	0.15	0.32	0.356	16.61	0.413	0.123
D×T								
Day-I	31.0	267.4	21.2	6.66	28.2	60.9	7.54	1.02
	31.0	265.0	20.5	7.91	30.2	182.6	14.6	1.10
Day-II	30.4	267.4	19.8	5.86	30.6	132.6	13.7	1.10
	31.0	260.9	20.5	7.22	30.0	102.7	9.7	1.23
Day-III	31.0	282.6	20.9	5.72	28.2	45.7	13.5	1.26
	30.8	271.3	20.7	6.26	29.6	97.8	11.9	1.14
Mean	30.9	269.1	20.53	6.61	29.5	103.7	11.84	1.14
S.E.±	0.09	2.78	0.168	0.314	0.386	18.54	1.05	0.033

a rapid decline (Fig. 1). During the dry period the soil water content was less than the field capacity (14%), thus indicating the existence of soil drought. Ehlig and Gardner (1964) observed a decrease in Ψ in a number of species as the soil water potential declined after irrigation. Recently, Rajagopal et al. (1987b) showed that there is a threshold level of soil moisture for enhanced stomatal resistance in coconut palms. The decrease in the stomatal resistance after March, could be attributed to the non-seasonal rains during the period (Fig. 2).

The stomatal resistance below 3.00 $S\ cm^{-1}$ is indicative of fully open stomata, whereas the process of closure appeared to have been initiated between 3.50 and 4.05 $S\ cm^{-1}$ and complete closure was achieved around 8.00 $S\ cm^{-1}$. In other crops the measurement of stomatal resistance has also been used to indicate the dimension, i.e., opening and closing of stomata (Brown and Rosenberg, 1970; Ritchie and Jordan, 1972). Under these experimental conditions stomatal closure sets in when coconut palms are exposed to an environmental situation with irradiation around 265 $W\ m^{-2}$, temperature of 33 °C and VPD of 26 mbar (Fig. 3). It should be mentioned here that it is not

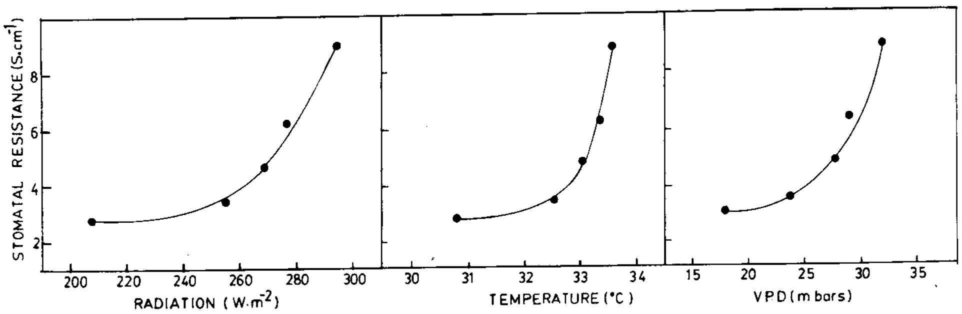

Fig. 3. Stomatal resistance in coconut palms during March plotted against radiation, temperature and VPD. Each point is the mean calculated from measurements between 10.00 and 12.00 hours over three days on six palms.

the individual effect but an interdependent effect, in the sense that radiation causes an increase in temperature, which in turn affects the VPD which directly influences the stomatal regulation. Field values of the variables exceeding that mentioned above definitely lead to severe stress on coconut palms. The values lower than that given for the three variables have favourable influence on stomata (i.e., low resistance) as indicated by the wet season data (Table 1). In oil palm the midday closure of stomata was reported to occur at 35°C (Rees, 1961).

Water loss from coconut palm is reduced in the dry season by stomatal resistance higher than that which occurs in the wet season. This higher resistance could be caused by the prevailing high VPD during the dry months. The significance of VPD in the stomatal regulation has been reviewed extensively (Schulze, 1986). Even if the soil moisture content remains high, high VPD can close stomata as reported in Cocoa (Balasimha and Rajagopal, 1988). That the WCT palms have a better ability to conserve water under conditions of stress than D×T palms indicates that the former may be relatively more tolerant to drought than the hybrid. This was substantiated by other physiological and biochemical parameters (Rajagopal et al. unpublished).

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