Influence of soil type on the development of moisture stress in coconut (*Cocos nucifera* L.) genotypes(1)

S.R. VOLETI[(2)], K.V. KASTURI BAI, V. RAJAGOPAL and C.K.B. NAMBIAR

Abstract. — The response of three coconut genotypes namely West Coast Tall (WCT), WCT × Chowghat Orange Dwarf (COD) and COD × WCT to moisture stress on red sandyloam and laterite soils was studied. High evaporative demand in the atmosphere combined with high soil water deficit during March 1988 (stress period) affected coconut palms to different degrees on the two soil types. The palms suffered more on red sandy loam soil than on laterite soil, as shown by the stomatal regulation and leaf water potential components. Both the hybrids could withstand drought better on laterite than on sandyloam soil. A preliminary understanding of the genotype-environment interaction in coconut was thus achieved.

Key words. — *Cocos nucifera* L., moisture stress, soil type, genotype-environment interaction.

INTRODUCTION

The annual rainfall ranging from 1300 to 2500 mm is considered most essential for good growth and yield of coconut palms (Murray, 1977). However, the palms are affected by prolonged drought ranging from four to six months in North Kerala. Bending of leaves, shedding of buttons and reduction in nut yield are some of the adverse effects of drought on coconut. Recent studies have shown the influence of both soil and atmospheric drought on stomatal regulation of coconut palms (Rajagopal *et al.*1989, Kasturi Bai *et al.* 1988).

The impact of drought depends on the soil type as coconut palms are mainly grown on sandy, red sandy loam or laterite soils (Menon and Pandalai, 1960, Shanmuganathan, 1987). Laterite soils (Mu 1a, FAO classifications) are deep with low hydraulic conductivity (11.9 - 30.8 cm/hr) and have higher cation exchange capacity than red sandy loam soils (Mu 3a), which are rich in coarse sand, have low cation exchange capacity and higher hydraulic conductivity, 40-114 cm/hr (Haridasan 1978). These differences in the textural properties influence the water holding capacity of the soils. The performance of coconut palms under different soil types are generally known but not with reference to the occurence of field stress. Hence, the investigation was aimed at assessing the response of three coconut genotypes viz. WCT, WCT × COD and COD × WCT to varying soil moisture profile in red sandy loam and laterite soils over time.

MATERIALS AND METHODS

Coconut palms WCT, WCT × COD and COD × WCT were planted in randomised block design comprising three replications with six palms each in the Institute farm in 1965. This monocrop experiment with a spacing of 7.5 m × 7.5 m was laid out on red sandy loam and laterite soils. N, P and K fertilizers were applied at the rate of 500: 320: 1200 g/palm/year in two split doses 1/3rd during June-July and 2/3 during October-November. The palms maintained under rainfed conditions are used in the experiment.

Measurement of light, air temperature and relative humidity (later converted into Vapour Pressure Deficit-VPD) were made in the vicinity of experimental palms, using a steady state porometer (Lico-1600, Lambda Instruments, Nebraska, USA). The determinations were made between 10.00 and 12.00 h during November (non-stress) and March (stress) periods. As all the days during the entire season would not be similar either in terms of climatological or plant behaviour the data collected was restricted to five to eight consecutive days each during non-stress and stress periods (Kasturi Bai *et al.*, 1988) which ensured the measurements under similar environmental conditions.

Soil moisture content was determined at three depths viz., 0-25, 25-50 and 50-100 cm in the basins (1m away from the bole of the palm) of two to three palms per replication for each genotype by following the gravimetric procedure. From the soil moisture data the Soil Water Deficit (SWD) was calculated based on the field capacity (23.6 and 9.4mm for laterite and sandy loam soils respectively) as per procedure of Dastane (1972) and Rajagopal *et al* (1989).

The stomatal resistance (rs), transpiration rate (E) and the leaf temperature were determined with the steady state porometer on the leaves from the middle whorl (11th) as described earlier (Rajagopal *et al.*, 1986). Briefly, the method consisted of determination of temperature and rs in two leaflets (6 measurements on either side of the midrib of each leaflet) on the lower surface (hypostomatic type). Thus 12 measurements were made quickly on each palm and the average of six palms per genotype was presented. This was done both during nonstress and stress periods.

Leaf water potential, osmotic potential and epicuticular wax content (Ψ, Π and ECW) were determined only during stress period (March). The leaflets opposite to those used for rs were used for Ψ determination by using a Scholander pressure chamber (Plant water Console 3000, Soil Moisture Company, Santa Barbara, USA) according to the method of Milburn and Zimmermann (1977) and Rajagopal *et al.*, (1987). The cell

(1) CPCRI contribution N° 656
(2) Central plantation Crops Research Institute - Kasaragod 671 124, Kerala (India)

sap was extracted from the frozen leaf bits and the osmotic potentials were determined by vapour pressure osmometer (Rajagopal *et al.*, 1987). The difference between Ψ and Π is expressed as turgor (P) potential.

The ECW was extracted from the leaflets by the method described by Ebercon *et al.*, (1977). Segments of 3 × 1 cm were cut and 20 segments were plunged into 15ml chloroform and vigorously shaken for 15 seconds and decanted. This procedure extracts wax from both the surfaces of leaflets. The colour developed with dichromate was read at 590 nm using the Perkin-Elmer spectrophotometer.

Statistical analysis : Agrometeorological parameters during non-stress and stress periods were compared by using paired 't' test. Analysis of variance technique is used for comparing genotypes and their interaction between non-stress, stress and depth of soils.

RESULTS

Agrometeorological parameters and soil water deficit (SWD)

Light, ambient-temperature and vapour pressure deficit in the vicinity of experimental palms showed a significant increase from non-stress to stress period (Table I). During the same period, the pan evaporation registered an increase of 66% between non-stress (3.5mm day^{-1}) and stress period (5.8mm day^{-1}). Thus, the occurence of atmospheric drought during March was evident.

The SWD was significantly higher during stress than that during non-stress at all soil depths in both the sandyloam and laterite soils (Table IIa and IIb). In general, the sandy loam soil had significantly lower SWD than the laterite soil. The three genotypes exhibited significant differences in the SWD under different depths between the sandy loam and laterite soils. The stress period was characterized by high SWD in all the genotypes, the values being significantly more in laterite than in sandy loam. The 'F' values were significant at 1% level for stress, soil depth and stress × depth (73.68, 518.05 and 8.03) in red sandy loam, whereas in laterite it was genotype, stress and depth (22.11, 21.24 and 247.44).

TABLE I. — **Agrometeorological condition in the experimental plots during non-stress (NS) and stress (S) periods**

Parameters	NS	S	'T' Value
Light (Watts m^{-2})	176.5	263.9	-14.69
Air temp.°C	30.1	33.2	-9.06
VPD (mb)	19.4	26.7	-2.99
Pan evaporation (mm)	3.5	5.8	-18.57

Value at fourteen degrees of freedom and is significant at 1% level for all the agrometeorological parameters

TABLE II a. — **Soil water deficit (mm) in the basins of coconut genotypes grown on red sandy loam soil during non-stress (NS) and stress (S) periods**

Stress × depth	0-25 cm	25-50 cm	50-100 cm	Total
NS	17.5	21.4	45.6	84.6
S	23.5	25.6	58.0	107.1
Genotype × depth	**WCT**	**WCT × COD**	**COD × WCT**	
0-25 cm	20.9	19.1	21.4	
25-50 cm	23.4	23.6	23.3	
50-100 cm	48.2	53.1	54.1	
Total	92.5	96.1	98.8	
Genotype × stress				
NS	27.2	28.5	28.8	
S	34.4	35.5	37.1	

S.E. plot	2.63		
C.D. for G	2.25	C.D. for S	1.84
C.D. for D	2.25	C.D. for G × S	3.19
C.D. for G×D	3.90	C.D. for S × D	3.19
C.D. for G×S×D	5.52	C.V. (%)	8.22
		Gen.Mean	31.9

TABLE II b. — **Soil water deficit (mm) in the basins of coconut genotypes grown on laterite soil during non-stress (NS) and stress (S) periods**

Stress × depth	0-25 cm	25-50 cm	50-100 cm	Total
NS	44.2	43.7	84.7	172.7
S	53.1	49.5	94.8	197.4
Genotype × depth	**WCT**	**WCT × COD**	**COD × WCT**	
0-25 cm	42.7	51.7	51.6	
25-50 cm	39.7	48.0	52.1	
50-100 cm	77.5	98.6	93.3	
Total	159.9	198.3	197.0	
Genotype × stress				
NS	48.0	60.5	64.2	
S	58.6	71.7	67.1	

S.E. plot	5.36	C.D. for S	3.75
C.D. for G	4.59	C.D. for G × S	6.50
C.D. for D	4.59	C.D. for S × D	6.50
C.D. for G×D	7.48	D. for G×S×D	11.26
		Gen.Mean	61.7
		C.V. (%)	8.69

Stomatal resistance (rs), transpiration rate (E) and leaf temperature (LT)

The rs during non-stress period was low with significant differences among the genotypes in both the soils (Table III). With the onset of drought in March, the rs increased to different degrees in the genotypes depending on the type of soil. The significant response of genotypes to adverse situations was discernible from the percentage values on non-stress. The WCT registered higher increase in rs in sandy loam soil (355%) than in laterite (216%), while the opposite trend occured in both the hybrids.

The occurence of moisture stress resulted in marked differences in E among the genotypes grown in red sandy loam and laterite soils (Table III). When the E values of the stress period was expressed as percentage decrease on non-stress, then the significant variations between the genotypes became apparent. For instance, the hybrid COD × WCT recorded 65% decrease in E over non-stress in red sandy loam, as against only 35% decrease in laterite.

A significant increase in LT was observed between non-stress and stress periods in the three genotypes, with COD × WCT recording higher values than the other two, in both the soil types (Table III).

Water potential components and epicuticular wax content

In general, the Ψ was lower in all the genotypes in red sandy loam than in laterite soil (Table IV). WCT had higher Ψ in both the soils than the hybrids. The values for osmotic potential (Π) did not differ much among the genotypes in the two soil conditions. However, the leaf turgor potential (P) was influenced by the soil type in that it was higher in all the genotypes in laterite than in red sandy loam soil, with WCT being superior to the other two. The ECW showed marginal difference among the genotypes in red sandy loam, while in laterite the content was higher in COD × WCT than in the other two genotypes.

TABLE III. — **Stomatal resistance (rs) transpiration rate (E) and leaf temperature (LT) in coconut genotypes in two soil types during non stress (NS) and stress (S). Values are means of 10 to 12 measurements on each leaflet with two to three leaflets per palm and six palms. ± denotes S.E. of the mean**

Parameter	Stages	Red sandy loam soil			Laterite soil		
		WCT	WCT × COD	COD × WCT	WCT	WCT × COD	COD × WCT
rs, $s.cm^{-1}$	NS	1.69	3.02	3.09	2.39	2.83	2.36
	±	(0.2)	(0.2)	(0.3)	(0.3)	(0.5)	(0.2)
	S	5.98	6.10	4.81	5.16	9.35	9.01
	±	(0.4)	(0.3)	(0.6)	(0.5)	(0.5)	(0.6)
E, $mg.cm^{-2}s^{-1}$	NS	7.61	6.65	6.42	6.3	4.62	7.77
	±	(1.2)	(0.4)	(0.5)	(0.3)	(0.5)	(0.5)
	S	3.03	2.90	4.19	2.94	1.83	2.65
	±	(0.3)	(0.5)	(0.4)	(0.2)	(0.4)	(0.2)
LT,°C	NS	31.4	31.9	31.6	30.4	30.6	31.1
	S	32.3	33.7	34.2	32.3	33.1	35.4

TABLE IV. — **Leaf water potential components and epicuticular wax content in coconut genotypes on two soil types during stress. Values are means of two leaflets per palm and six palms per genotype. ≠ denotes S.E. of the mean**

Genotype	Ψ -MPa	Π -MPa	P +Mpa	ECW $mg.cm^{-2}$
Sandy loam soil				
WCT	-1.38 ≠ 0.03	-1.70 ≠ 0.13	0.320	109 ≠ 0.97
WCT × COD	-1.43 ≠ 0.11	-1.63 ≠ 0.05	0.200	117 ≠ 4.31
COD × WCT	-1.46 ≠ 0.17	-1.67 ≠ 0.04	0.210	111 ≠ 4.24
Laterite soil				
WCT	-0.90 ≠ 0.04	-1.61 ≠ 0.02	0.710	106 ≠ 3.73
WCT × COD	-1.00 ≠ 0.07	-1.64 ≠ 0.03	0.640	108 ≠ 3.43
COD × WCT	-0.96 ≠ 0.04	-1.64 ≠ 0.01	0.680	128 ≠ 4.40

DISCUSSION

The coconut palm experiences severe stress due to both the soil and atmospheric drought (Rajagopal *et al.*, 1989, Kasturi Bai *et al* ., 1988). Theses studies revealed the significant influence of SWD and the environmental variables on the stomatal regulation of coconut palms. Further evidence is produced in the present study on the response of coconut genotypes to the SWD in the two soil types with different water holding capacities. Haridasan (1978) showed 8% water retention in laterite soil as against only 4% or less in red sandy loam soil between 0.1 and 15 bars.

When exposed to the progressive developement of moisture stress between November and March, caused by high evaporative demand in the atmosphere and high SWD, coconut palms exhibited adaptability to the adverse conditions. This adaptability depended on the genotypes and the types of soil in which they were grown. Since the water holding capacity was low in red sandy loam as compared to laterite (Haridasan, 1978), the response to moisture stress also varied among the genotypes. For instance, during the non-stress period the SWD was higher in laterite than in red sandy loam and the same trend prevailed even during the stress period (Table II). That the root system of genotypes might vary depending on the type of soil was only indirectly indicated by the SWD pattern at different depths, representing root growth. However, the picture on root system is not conclusive with the present data.

The variations in water availability in the two types of soil greatly influenced the genotypes, as revealed by leaf temperature, rs, E, Ψ and ECW (Tables III and IV). These interrelated stress sensitive responses ultimately reflected on the performance of the genotypes under the stress-conditions. There was significant raise in leaf temperature between pre-stress and stress in both the soils ; the hybrid COD × WCT registered significantly higher leaf temperature than the other genotypes. These changes in leaf temperature could be related to transpiration rate, which in turn was controlled by the stomatal resistance. Exposure of palms to adverse conditions led to regulation of water balance through stomatal mechanism. Although the general tendency of palms was to show increased stomatal resistance with the onset of stress, there was significant genotypic variation which again differed depending on soil types.

The significantly higher stomatal resistance in the two hybrids in laterite soil than in sandy loam and an opposite trend in WCT apparently reveals the genotype-environment interaction in combating the adverse conditions. This is further substantiated by the differences in the transpirational loss of water exhibited by the genotypes. It is interesting to note that both WCT and WCT × COD showed only marginal difference in the percentage decrease in transpiration rate during stress as compared to non-stress in relation to soil types, whereas COD × WCT registered highly significant difference between the sandy loam (65% decrease) and laterite (35%).

The changes in stomatal regulation are viewed in relation to water potential components. Maintenance of higher leaf turgor potential by all the genotypes in laterite than in sandy soil clearly signifies that the same genotype respond differently to moisture stress occuring in two types of soil (Table IV). The ECW, which has protective role under stress (Ebercon *et al.*, 1977, Rajagopal *et al.*, 1989) differed significantly in the case of COD × WCT between the soil types.

The response of genotypes to moisture stress was critically examined taking into account all the factors together. As compared to WCT, the hybrid COD × WCT had significantly high SWD and rs with low E and high leaf turgor potential in laterite soil, while WCT × COD was intermediate. COD × WCT also had an added advantage of heavy deposition of wax content on the leaf surface. These desirable traits might have enabled the hybrid to withstand drought in laterite. Conversely, relatively low rs with high E, resulting in low leaf turgor potential appeared to make COD × WCT susceptible to stress in red sandy loam soil. This would mean that both high rates of E and SWD in sandy loam causes an imbalance in the water economy of palms, as revealed by leaf turgor. Under such conditions, a genotype which has good stomatal regulation with high turgor, like WCT, withstands stress better than others. Stomata playing a key role in coconut palms as a protective mechanism under water deficit was highlighted by Milburn and Zimmermann (1977). Various moisture conservation mechanisms to reduce the effect of drought (Liyanage 1987) and the importance of breeding for drought resistance in coconut palm have been reported (Wickramavatne 1987, Rajagopal *et al.*, 1990).

This was the first attempt to understand the soil water plant relations in coconut palms with emphasis on the genotypic responses to an environment characterized by moisture stress in two types of soil. It became evident that the capacity of the same genotype to withstand moisture stress depends on the type of soil through the operation of stomatal mechanism. The main point that emerged from the investigation was that COD × WCT may not be recommended for red sandy loam soil in view of its high sensitivity to moisture stress. Secondly, the drought screening may be in relation to the type of soil in which the palms are grown.

Acknowledgements. — We thank Dr M.K. Nair, Director CPCRI, Kasaragod for providing the facilities. Our thanks are also due to Dr M. Yusuf, Head, Division of Crop Management and Shri K. Vijaya Kumar for allowing to use their experimental palms and for statistical analysis.

REFERENCES

[1] DASTANE NG. (1972). —Certain common formulae used in irrigation practices. *In* : A practical manual for water use research in Agriculture, 30 Navabharat Prakashan, Poona.

[2] EBERCON A., BLUM A and JORDON W.R. (1977). —A rapid colorimetric method for epicuticular wax content of sorghum leaves. *Crop Sci.* **17** : 179-180.

[3] HARIDASAN M. (1978). —Soil water characteristics curves and hydraulic conductivity of some laterite and red sandy loam soils of Kasaragod area. In "*PLACROSYM I*" Ed. EV Nelliat, held at RRI Kottayam, 179-185.

[4] KASTURI BAI K.V., VOLETI S.R. and RAJAGOPAL V. (1988). —Water relations of coconut palms as influenced by environmental variables. *Agric. For. Meteorol.* **43** : 193-199

[5] LIYANAGE L.V.K. (1987). —Moisture conservation in coconut lands. *Cocon. Bull* **4** n°2 : 1-5.

[6] MENON K.P.V., PANDALAI K.M. (1960). —Climate and soil. *In* "The coconut Palm". A monograph. Indian central coconut committee, Ernakulam P : 111-125.

[7] MILBURN J.A. and ZIMMERMANN M.H. (1977). —Preliminary studies on sap flow in *Cocos nucifera*, L.1. Water relations in xylem transport. *New phytol* **79** : 535-541.

[8] MURRAY D.V. (1977). —Coconut palm. *In* "Ecophysiology of tropical crops" EDs Alvin P de T and TT Kozlowski, Academic press, New York. 24-27.

[9] RAJAGOPAL V., PATIL K.D. and SUMANTHYKUTTYAMMA B. (1986). —Abnormal stomatal opening in coconut palms affected with root (Wilt) disease *J. Exp. Bot.* **37** : 1398-1405

[10] RAJAGOPAL V., SUMANTHYKUTTYAMMA B. and PATIL K.D. (1987). —Water relations of coconut palms affected with root (wilt) disease. *New phytol.* **105** : 289-293.

[11] RAJAGOPAL V., RAMADASAN A., KASTURI BAI K.V. and BALASIMHA D. (1989). —Influence of irrigation levels on the leaf water relations and dry matter production in coconut palms. *Irrigation Sci.* **10** : 73-81

[12] RAJAGOPAL V., KASTURI BAI K.V. and VOLETI S.R. (1990). — Screening of coconut genotypes for drought tolerance. *Oléagineux*, **45** : 215-223

[13] SHANMUGANATHAN R.T. (1985). —Soils of coconut areas. *Cocon. Bull* **2** : 8-10

[14] WICKRAMARATNE M.R.T. (1987). —Breeding coconut for adaptation to drought. *Cocon. Bull* **4** n°1 : 16-23

RESUME

Influence du type de sol sur l'évolution du stress hydrique chez les génotypes de cocotier (*Cocos nucifera* L.)(1)

S.R. VOLETTI, K.V. KASTURI BAI, V. RAJAGOPAL et C.K.B. NAMBIAR, *Oléagineux*, 1993, **48**, N°12, p.505-509

Le comportement de trois génotypes de cocotier, à savoir le Grand Côte Ouest (GCO), le GCO × Nain Orange Chowghat (NOC) et le NOC × GCO, soumis à un stress hydrique sur un sol rouge sablo-limoneux et un sol latéritique a été étudié. Une demande évaporative atmosphérique importante en liaison avec un déficit hydrique du sol élevé pendant le mois de mars 1988 (période de stress) a eu un effet plus ou moins important sur les cocotiers en fonction du type de sol. Les cocotiers souffrent davantage sur un sol rouge sablo-limoneux que sur un sol latéritique, comme le montrent la régulation stomatique et le potentiel hydrique des feuilles. Les deux hybrides supportent mieux le stress hydrique sur un sol latéritique que sur un sol sablo-limoneux. On a ainsi obtenu une connaissance préliminaire de l'interaction génotype-environnement chez le cocotier.

Mots-clés. — *Cocos nucifera* L., stress hydrique, type de sol, interaction génotype-environnement

(1) CPCRI contribution N° 656