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LEAFLET ANATOMICAL ADAPTATIONS IN COCONUT CULTIVARS FOR DROUGHT TOLERANCE*

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Anatomical features of coconut leaflet were studied in talls, dwarfs and hybrids. Variation in anatomical features between the cultivars was evident. Based on anatomical adaptations, characterized by thicker leaflets, thick cuticle on both sides, larger palisade and spongy parenchyma cells, larger hypodermal cells, water cells and sub-stomatal cavity, genotypes like WCT, FMS and PHO and WCT x COD hybrid were identified as relatively tolerant to drought.

INTRODUCTION

Coconut is largely maintained as a rainfed plantation in many parts of the country, particularly in Kerala. It experiences water stress during February to May. Importance of screening the cultivars has been realized particularly in the wake of low nut production during the unprecedented drought years in early 80's. Since then extensive work had been done at CPCRI to understand the physiological basis and also to screen the coconut cultivars for high tolerance to drought (Rajagopal *et al.*, 1990; Kasturi Bai, 1993). The anatomy of coconut leaflet has already been described (Menon and Pandali, 1960). However, anatomical adaptations of leaflet were not well understood with reference to drought tolerance and genotypic variations. The present experiment was carried out to study the genotypic variations in anatomical features of leaflet and to relate the same to the degree of tolerance against drought.

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MATERIALS AND METHODS

Leaflet samples were collected from seven indigenous/exotic coconut cultivars which include talls, dwarfs and hybrids viz., West Coast Tall (WCT), Federated Malay States (FMS), Philippines Ordinary (PHO), WCT x Chowghat Orange Dwarf (COD), COD x WCT, Malayan Yellow Dwarf (MYD) and Gangabondam (GBD). Leaflets were sampled between 30 and 35th position from the base of the sixth leaf from top (inclusive of spindle leaf). Washed samples were cut across from top, middle and bottom portion of the leaflet and then fixed in Carnoy's fluid (alcohol:chloroform:acetic acid, 60:30:10) for 24 h. Dehydration, wax infiltration and staining the microtome sections were done adopting the standard procedures (Johnsen, 1940) with slight modification, wherever necessary. Observations on leaf thickness, cuticle thickness, size of hypodermal cells, palisade and spongy parenchyma cells, water cells, guard cells, sub-stomatal cavity and xylem scalariform thickness were made using Leitz Diaplan microscope equipped with camera. Data were analysed statistically.

RESULTS AND DISCUSSION

Bottom portion of the leaflet was thicker and tapered towards tip portion. Epidermal cells are compact and the upper epidermis was thicker and composed of large cells than the lower epidermis. Cuticle on upper epidermis was two fold thicker than the cuticle of lower epidermis (Table 1) and it was even thicker at midrib and edges of leaflet. Coconut leaflets are hypostomatus. Guard cells have hook-like protuberances at both ends. This character is typical to Palmae (Fahn, 1989). Elongated epidermal cells surrounded the guard cells along their entire length. On the lower epidermis, multicellular, shortly stalked scales occur at regular intervals in short depressions which contain tannins (Menon and Pandali, 1960). Beneath the upper epidermis, two layers of large hypodermal cells are present which serve as water storage tissue whereas above the lower epidermis, a broken layer of hypoderma is present. Outer margins of leaflets are folded like a hook. Thin walled water tissue or epithelium occur at the upper and lower angles of the straightened margin of the leaflet. Beneath the upper hypoderma is the multilayered palisade parenchyma spreading nearly to the lower hypoderma. Closely packed, thin walled, broad and elongated palisade cells become shorter towards the center of the leaf. Spongy parenchyma is scanty, just above the lower hypodermis and characterized by the presence of lobes by which the neighbouring cells are connected. Presence of spongy parenchyma makes the leaflet dorsiventral. Leaflet thickness and cell size varied significantly from bottom to tip of the leaflet (Table 1).

There are about 22 to 27 vascular bundles running length wise on each side of the midrib. Each of them occupy the space between upper to lower hypoderma. Each vascular bundle, encircled in a fiber ring, had a few tracheids, one big vessel and a band of phloem elements on lower side. Smaller or diminutive vascular bundles consisting a few tracheids with scalariform thickening, phloem fibers in between the two big vascular bundles. The midrib of leaflet is strong with group of seven to eight large vascular bundles which are encircled with fibrous sheet. Xylem tracheids have thick lignification and are in conformity with the observations made by Menon and Pandali (1960).

Leaflets are significantly thicker in WCT, FMS (405 and 363 μm, respectively) compared

Table 1. Anatomical features of coconut leaflet

Parameter		Portion of the leaflet: Upper	Middle	Lower	Mean	CD at P=0.05
Leaflet thickness (μm)		261.61	346.88	415.81	341.43	8.120
Cuticle thickness (μm)	Upper	3.91	5.08	5.55	4.85	0.236
	Lower	2.15	2.38	2.94	2.49	0.237
Epidermal cell size (μm^2)	Upper	133.92	140.68	146.23	140.28	NS
	Lower	62.97	81.83	95.54	80.11	9.932
Parenchyma cell size (μm^2)	Spongy	105.28	115.62	161.13	127.34	13.700
	Palisade	326.59	327.38	424.73	359.57	34.960
Guard cell size (μm^2)		68.37	79.29	106.19	84.62	7.000
Hypodermal cell size (μm^2)		571.23	755.39	830.56	699.06	77.730
Water cell size (μm^2)		247.84	303.84	352.37	301.35	39.140
Sub-stomatal cavity size (μm^2)		459.77	645.29	654.36	586.47	85.390
Xylem lignification thickness (μm)		2.76	3.36	3.29	3.14	0.331

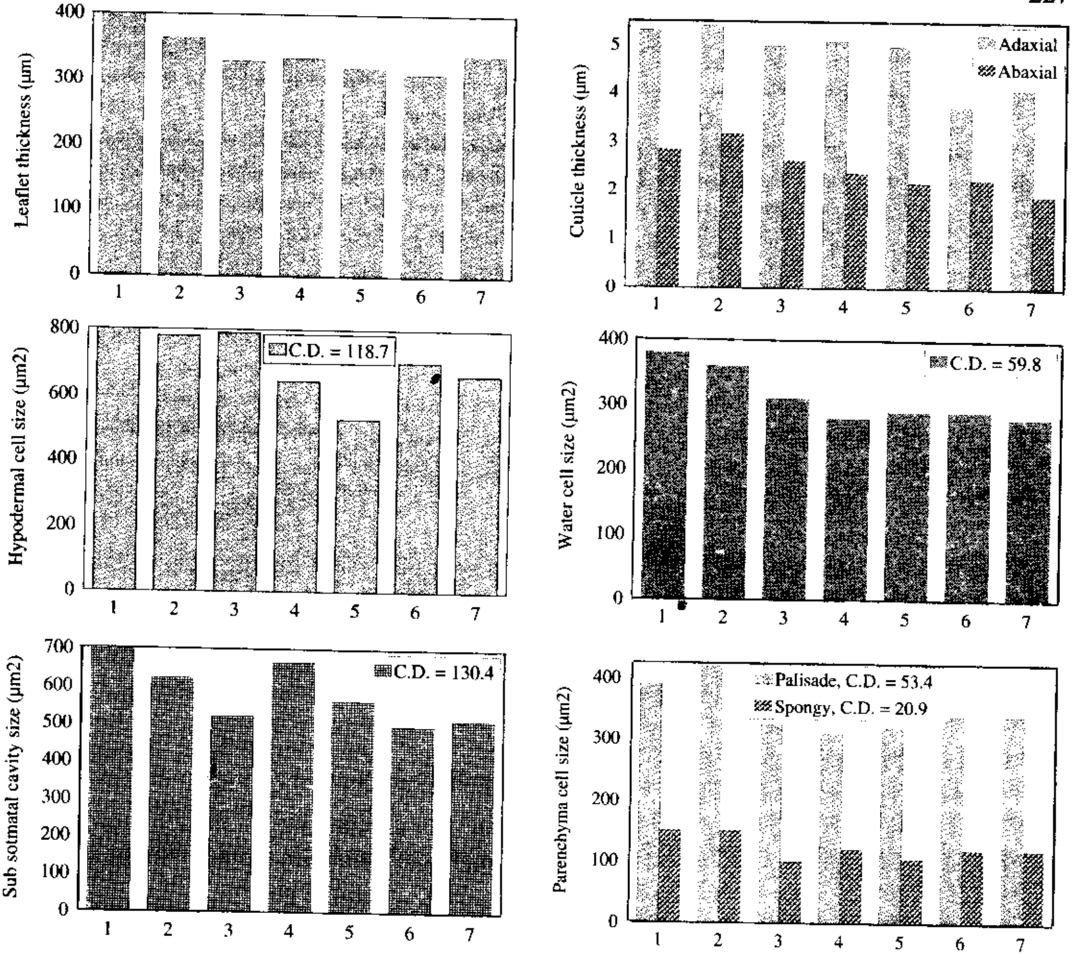

Fig. 1. Leaflet anatomical features of different coconut cultivars viz., 1-WCT; 2-FMS; 3-PHO;4-WCT x COD; 5-COD x WCT; 6-GBD; 7-MYD.

to any other cultivars (Fig.1a). Thicker leaves in WCT compared to GBD and their cross combinations were reported earlier (Ramadasan and Satheesan, 1980). WCT and FMS had thicker cuticle while GBD and MYD had very thin cuticle on both sides (Fig.1b). Upper epidermal cell size was maximum in FMS followed by WCT x COD whereas it was minimum in COD x WCT (Table 2). However, size of the lower epidermal cell did not differ significantly among the cultivars.

Parenchyma cells were significantly bigger in WCT and FMS compared to other cultivars (Fig.1f). Palisade parenchyma cells were smallest in WCT x COD. PHO had smaller spongy parenchyma cells than other cultivars. Xylem tracheids in vascular bundles had scalariform thickenings ranging from 2.85 µm in MYD to 3.38 µm in WCT. Guard cell size also did not vary much among cultivars but COD x WCT had significantly bigger guard cells. WCT, WCT x COD and FMS had significantly larger sub-stomatal cavity and it was smaller in GBD and MYD (Fig.1e). CODxWCT had significantly smaller hypodermal cells (Fig.1c) while WCT, PHO and FMS contain large hypodermal cells. Water cells were significantly bigger in WCT and

Table 2. Certain anatomical features of leaflet from different cultivars of coconut

Cultivar	Epidermal cell (μm^2) Adaxial	Epidermal cell (μm^2) Abaxial	Size of the Guard cell (μm^2)	Xylem lignification (μm)
WCT	140.6	86.6	77.8	154.2
FMS	179.6	85.5	79.4	153.2
PHO	127.1	87.7	79.1	104.0
WCT x COD	151.2	71.2	88.0	123.0
COD x WCT	115.2	73.8	94.9	107.0
GBD	126.9	70.9	86.3	125.4
MYD	141.2	85.0	86.9	125.6
C.D. at P = 0.05:	23.6	NS	10.7	20.9
C.V. (%)	33.0	37.2	24.8	32.0

FMS (Fig. 1d). In all other cultivars their size was in the range of 268 to 296 μm^2.

Data on leaflet anatomy indicated that the indigenous cultivars had extreme values for all the traits related to drought tolerance (WCT had maximum values followed by GBD and COD x WCT). However, the exotic cultivars had medium values thus indicating the possibility of using some of these parameters to identify ecotypes of coconut.

Leaflet thickness increased mainly due to increase in parenchyma cell size (Table 3) which is associated with lowered stomatal frequency, an indication of adaptation to drought. Increased leaf thickness and thick cuticle are some of the xeromorphic characters (Belhassen, 1996) as observed in WCT and FMS. Increase in leaflet thickness causes decrease in the ratio of the external surface to its volume (Oppenheimer, 1960). Correlations between anatomical features and physiological parameters (Table 3) also indicated thick cuticle lower the transpirational losses. Water is conducted not only by the veins and bundle sheath extensions but also by the mesophyll cells and epidermal cells of the leaf. Water transport towards the epidermis is much higher through the palisade tissue than the spongy parenchyma. Increased parenchyma cells size as observed in tolerant types WCT and FMS, reduced the intercellular space/unit area. This may help in reducing the water conductance towards epidermis thereby reducing the transpirational rates and maintaining high water potentials (Table 3). The volume of intercellular spaces in xeromorphic leaves is low thus reducing the water transport to epidermal cells (Fahn, 1989). Decrease in surface area of palisade parenchyma/unit area, lowered photosynthetic rates (Table 3). The ratio of internal to external surface is strongly and positively correlated with the rate of transpiration (Turrell, 1944). Thus, drought susceptible types

Table 3. Correlations between anatomical features and physiological parameters

Parameters		r value
Leaflet thickness	Palisade cell size	0.73
	Spongy cell size	0.82
	Stomatal frequency	-0.67
	Photosynthetic rate (Pn)	-0.41
	Transpiration rate	-0.12
Cuticle thickness		
Adaxial	cuticular wax (ECW)	0.86
	Transpiration rate	-0.69
	*Pn	0.13
	Leaf water potential	0.64
Abaxial	ECW	0.72
	Transpiration rate	-0.79
	Pn	-0.59
	Leaf water potential	0.50
Sub-stomatal cavity (size)	Stomatal frequency	-0.54
	ECW	0.61
	Transpiration rate	-0.15
	Photosynthetic rate	-0.11
Palisade cell size	Pn	-0.77
	Transpiration rate	-0.38
	Leaf water potential	0.11
Spongy cell size	Pn	-0.67
	Transpiration rate	-0.05
	Leaf water potential	0.10

'r' value greater than 0.62 is significant at five per cent probability have higher photosynthetic and transpirational rates and stomatal conductance compared to the tolerant ones (Rajagopal *et al.*, 1990; Kasturi Bai, 1993).

Cultivars having thick cuticle are able to maintain higher leaf water potentials. Higher content of epicuticular wax and leaf water potentials are certain drought tolerant traits (Rajagopal *et al.*, 1990; Voleti and Rajagopal, 1991; Kasturi Bai, 1993; Kurup *et al.*, 1993) besides the scalariform thickening on xylem tracheids in vascular bundles and large sub-stomatal cavities. These traits are lesser in moderately tolerant cultivar like PHO and WCT x COD and least in susceptible type (COD x WCT, GBD x MYD). Cumulative effect of all these traits contribute to the adaptation to drought tolerance.

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