Role of certain biochemical compounds in adaptation of coconut to different weather conditions – A study in two agro-climatic regions of India

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ABSTRACT

As a perennial palm of the tropical region, coconut is exposed to frequent fluctuations in weather conditions in its life span. Plants in general, adapt to variations in weather conditions by adopting different methods. Leaf biochemical constituents of coconut palm were studied in relation to weather conditions in two agro-climatic regions represented by Kidu (Karnataka) and Veppankulum (Tamil Nadu). Concentrations of leaf epicuticular wax, proline, reducing sugars and amino acids increased during summer and decreased thereafter at both the locations. Higher concentration of these compounds in palms grown at Kidu may be attributed to the rapid fluctuations in micro-climatic conditions. The pattern of accumulation varied among cultivars at two locations indicating the influence of genotype-environment interaction on these parameters. Tall cultivars *viz.*, WCT and LCT, with wider adaptability to diverse environments, exhibited more accumulation of these compounds. The results indicated possible role of biochemical compounds in cultivar adaptability to different environments which can be exploited for screening the germplasm.

Key words: Coconut, agro-climatic zones, epicuticular wax, proline, osmoregulation.

INTRODUCTION

Accumulation of various biochemical compounds is an immediate defence against stress conditions in many plants. Biochemical compounds help in maintaining cell water potential by osmotic adjustment and normal cell activities under conditions of soil and atmospheric stress. Increase in concentration of proline was noted in many crops in response to various environmental stresses. Different roles have been suggested for proline accumulation as an adaptive response (Charest and Phan, 2). Accumulation of amino acids and sugars as compatible solutes maintaining cell water potential has been found in many cultivated crops under unfavourable conditions. The leaf epicuticular waxes (ECW) play important role in protecting the plant from abiotic and biotic stresses, apart from playing the key role in determining the water use efficiency of plants and in uptake, retention and leaching of solutes (Jenks and Ashworth, 6). Environmental conditions also influence the concentrations of protein (Zayed and Zeid, 20), and total carbohydrates (Vassey and Sharkey, 19), even though the response varied with species.

Coconut is an important perennial palm of the tropical region. In India, coconut is cultivated in different agro-climatic regions. Since it is a perennial crop with continued productivity, adaptation of the palms with the climatic conditions is very important for sustained productivity. Coconut cultivars develop anatomical (Naresh Kumar *et al.*, 12), physiological (Rajagopal *et al.*, 15) and biochemical (Kasturi Bai and Rajagopal, 7) adaptations to tolerate adverse environmental conditions. Since the biochemical compounds are very dynamic and serve as the first line defence against fluctuations in environment, identification of traits involved in adaptation to variations in weather conditions provide necessary information for breeding suitable cultivars for climatically different areas. This work was undertaken to study the influence of biochemical constituents in adaptation of coconut to fluctuations in meteorological conditions in two different agro-climatic regions of India.

MATERIALS AND METHODS

The experimental sites were situated at CPCRI, Research Centre, Kidu, Karnataka (Western Ghats-hot sub-humid per humid agro-climatic region) and at Coconut Research Station (CRS), Veppankulam, Tamil Nadu (Eastern coastal plains-hot sub-humid region). Kidu (12.67°N and 75.6°E, 291 m above MSL) is a high rainfall area with a mean annual precipitation of 2989 mm. High relative humidity prevails (annual average of 88%) at this location. Soil is red laterite type at Kidu with a pH of 5.2 and high organic matter content. On the other hand, at Veppankulam (10.29°N and 79.23°E, 20 m above MSL), average annual rainfall is 1117 mm. Annual mean relative humidity is 76% and soil type is sandy loam with 6.0 pH. Weather parameters during the observation time are given in Fig. 1.

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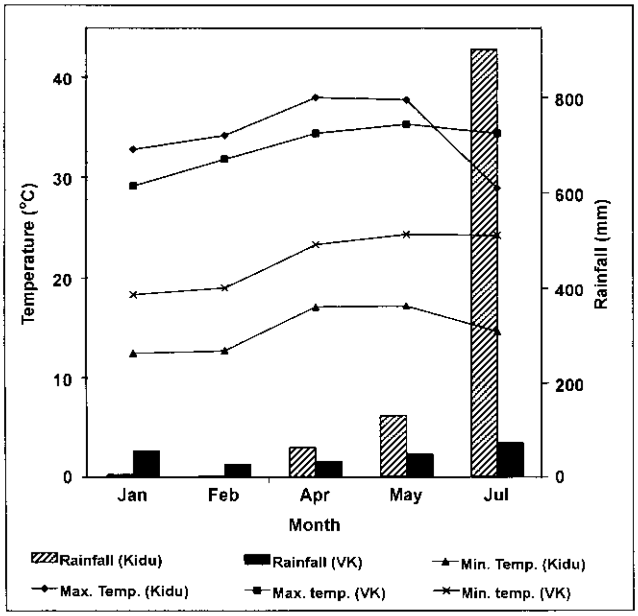

Fig. 1. Weather parameters at the two agro-climatic regions during the months of observation.

Four popular cultivars of coconut *viz.*, East Coast Tall (ECT), West Coast Tall (WCT), Laccadive Ordinary (LCT) and Chowghat Orange Dwarf (COD) were selected for the study. Six palms per cultivars were selected from an existing monocrop based on uniformity of palms in age, growth, morphology and stabilized yield. The palms were maintained under recommended agronomic practices.

The biochemical parameters were estimated during three seasons, i.e., post monsoon (January and February), summer (April and May) and monsoon (July) for consecutive years from 1999 to 2002. For the analyses, six leaflets, three each from both sides of rachis were collected from middle portion of the sixth leaf from top. The oven dried powdered (Cyclotec sample mill, Foss Tecator, Sweden) samples were used for analysis. Fresh samples from the same leaf were used for estimation of proline and epicuticular wax (ECW) concentration.

Epicuticular wax from leaflet samples was extracted using chloroform and quantified as per Ebercon *et al.* (4) standardized for coconut by Rajagopal *et al.* (13). Concentration of proline was estimated following the method of Bates *et al.* (1) and reducing sugars by Somogyi's (18) method. Free amino acids were estimated as per the method of Lee and Takahashi (9). Protein concentration was estimated following method developed by Lowry *et al.* (11) and total carbohydrates by the phenol: sulphuric acid method of Dubois *et al.* (3). The biochemical parameters were estimated spectrophotometrically by using UV-visible recording spectrophotometer (Shimadzu UV - 160A, Japan).

RESULTS AND DISCUSSION

Concentrations of the biochemical constituents in the leaves varied among cultivars grown at both locations. The seasonal variations and variations with locations were also observed. Among the cultivars at Kidu region, mean concentration of ECW and proline was high in LCT, whereas local tall cultivar WCT had higher concentration of amino acids and reducing sugars (Table 1). Concentration of leaf surface waxes was more in WCT at Veppankulam, while another tall cultivar LCT had higher concentration of amino acids and reducing sugars at this location. Irrespective of locations, COD and ECT maintained higher concentrations of proteins and carbohydrates,

Table 1. Leaflet biochemical constituents of coconut cultivars at two agro-climatic regions.

Location	Cultivar	Biochemical constituents					
		ECW (mg cm^{-2})	Proline (mg g^{-1} fw)	Amino acids (mg g^{-1} dw)	Proteins (mg g^{-1} dw)	Reducing sugars (mg g^{-1} dw)	Total carbo-hydrates (mg g^{-1} dw)
Kidu	ECT	80.18	104.6	3.49	219.1	18.65	130.3
	WCT	90.63	95.6	3.79	214.9	28.22	125.3
	LCT	95.89	116.3	3.34	217.1	21.38	123.4
	COD	74.26	104.6	3.68	221.4	24.37	121.3
	Mean	85.24	105.3	3.58	218.1	23.16	125.1
Veppankulam	ECT	78.85	81.0	4.29	223.5	11.28	139.9
	WCT	87.37	76.9	4.94	221.9	19.42	135.6
	LCT	83.97	77.1	5.79	208.6	21.67	137.9
	COD	75.33	73.5	4.89	248.3	18.79	127.1
	Mean	81.38	77.1	4.98	225.6	17.79	135.1
CD at 1%		4.74	4.63	0.44	9.27	2.40	NS

respectively. At Veppankulam, proline concentration was also high in ECT.

In general, the palms accumulated biochemical constituents with the onset of summer at both locations (Fig. 2). Concentration of ECW was low in cultivars at Veppankulam during January. However, in the subsequent months, ECW concentration increased and cultivars at both locations maintained relatively same amount of ECW. Conditions of high atmospheric temperature, solar radiation and a decrease in humidity are known to enhance ECW development on leaves as an adaptive mechanism. The accumulation of waxes on leaf surface during summer was more in palms at Veppankulam (91%) compared to Kidu (34%). Deposition of ECW helps maintaining water balance of coconut palm (Rajagopal *et al.*, 14) by checking the

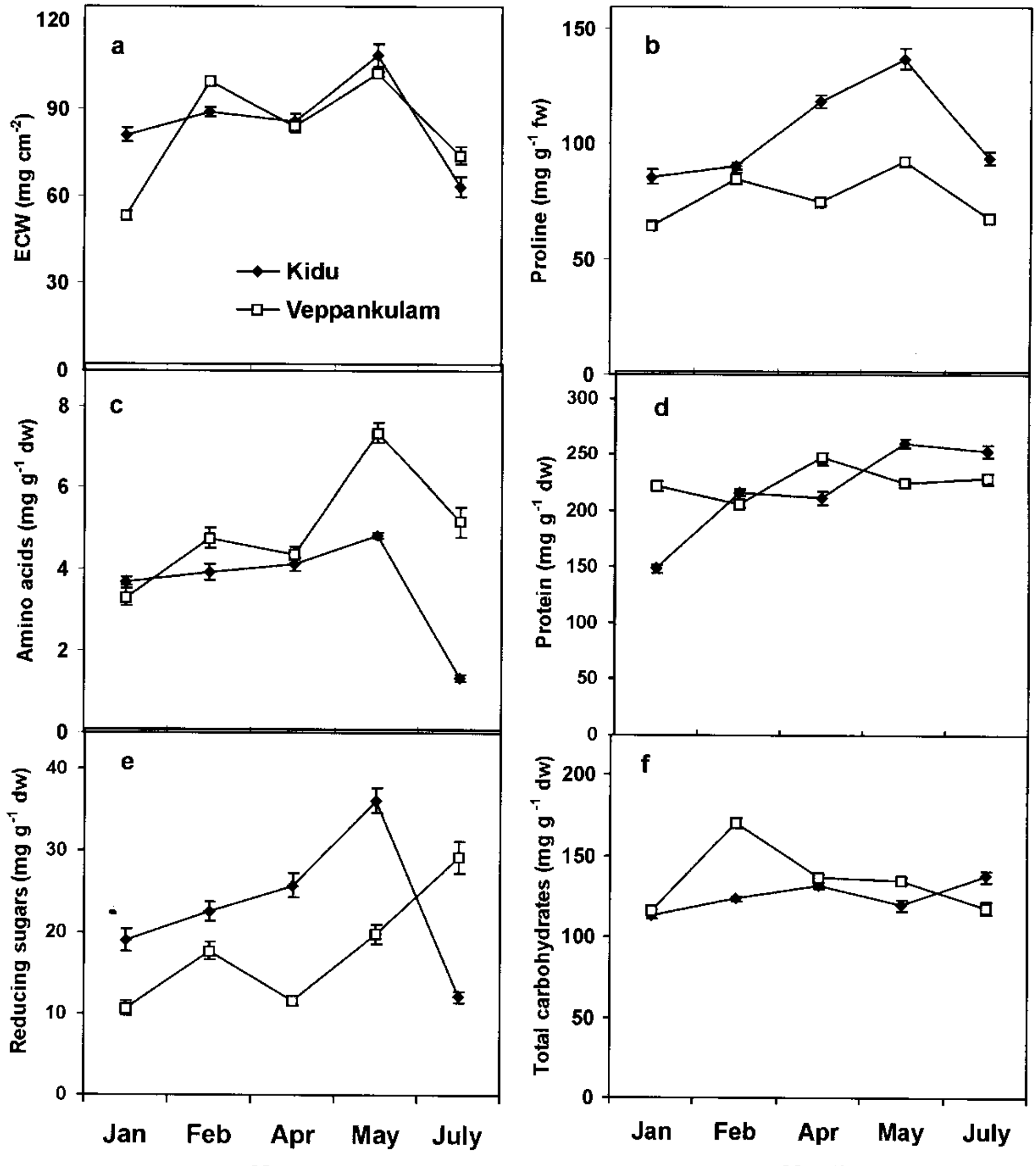

Fig. 2. Concentration of biochemical compounds in the leaflets of coconut palms during different months at two agro-climatic regions (a. ECW; b. proline; c. amino acids; d. protein; e. reducing sugars and f. total carbohydrates).

transpiration rates as ECW concentration is negatively correlated with transpiration rates (Naresh Kumar *et al.*, 12). This would be an advantage to the plant under conditions of atmospheric / soil stress during summer which in turn, improve the water use efficiency of the palms. Since the palms were irrigated in this experiment, it is the atmospheric stress for which the palms were predominantly responding. Epicuticular waxes also help in reflecting the excess solar radiation and thereby maintaining leaf temperature during stress conditions. This will probably help the plant from damaging the photosynthetic system.

Concentration of proline and reducing sugars was consistently higher in cultivars at Kidu, while amino acid concentration was higher in palms at Veppankulam region during the experimental period. At both agro-climatic regions, concentration of these compounds in coconut cultivars increased gradually and reached a maximum during May, when the intensity of summer was high. During May, at both regions, high day temperatures prevailed with high solar radiation and relatively low humidity, creating an atmospheric stress condition. Such conditions seem to affect the physiological status of the palms, even though they are irrigated (Rajagopal *et al.*, 16). High light intensity and high temperature enhance proline accumulation in many crops. In coconut, an increase in concentration of proline during dry months (Jayasekara *et al.*, 5) or during extreme stress conditions (Shivashankar, 17) were reported earlier. The accumulated proline may act as an osmoticum to maintain cell turgor, an immediate source of energy after relief of stress and a compatible solute that protects enzymes (Charest and Phan, 2), thereby helping the plant to tide over the unfavourable situations.

Changes in concentration of free amino acids and reducing sugars in response to environmental and edaphic factors have been reported in many crops (Munns and Weir, 11). In coconut, 16.3 to 60.2 and 38% increase in sugar and free amino acid concentrations were noted under stress conditions (Kasturi Bai and Rajagopal, 7), indicating the contribution of these solutes for osmotic adjustment alongwith other compatible solutes. Higher reducing sugar concentration during summer can also be due to reduced conversion of hexose sugars to sucrose or starch. In bean plants, mild water deficits caused a decline in the starch/sucrose partitioning ratio (Vassey and Sharkey, 19).

In general, concentration of ECW, proline, amino acids and reducing sugars decreased during the monsoon season (July). The occurrence of rains and reduction in temperature during July make the weather conditions more favourable and the palms stop accumulating these compounds. Also, rainfall can wash away some amount of ECW (Kurup *et al.*, 8), causing further reduction in ECW concentration during July. In the case of proteins and total carbohydrates, a definite trend was not found in the present study at both locations with seasons, even though the protein concentration increased in palms at Kidu during summer season.

The relationships of ECW and proline with net photosynthesis (Pn) and physiological water use efficiency (Pn/E, WUE) indicated that as ECW accumulation increased over leaf surface, the Pn rates decreased (Figs. 3 and 4). Earlier anatomical studies indicated low or negative relationship between Pn and cuticle thickness in coconut cultivars (Naresh Kumar *et al.*, 12). Even though ECW helps in leaf thermoregulation by reflecting excess light, it lowers the transpiration rates and improves water use efficiency (Kurup *et al.*, 8; Jenks and Ashworth, 6). Proline accumulation in leaf tissue helped in maintaining Pn rates to certain extent probably by maintaining the leaf water potential. However, at high proline levels, when the stress levels are also high both Pn and WUE decreased.

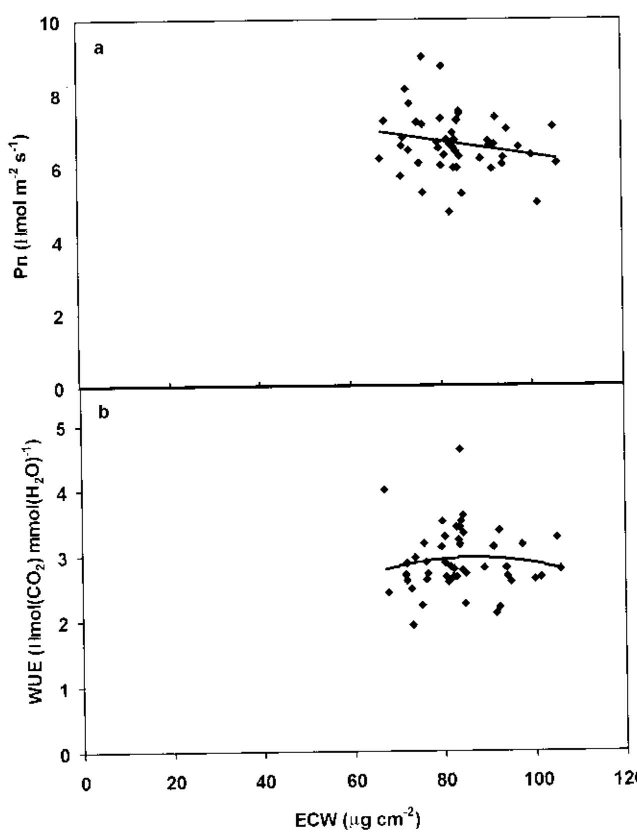

Fig. 3. Relationship of ECW with net photosynthesis (Pn, a) and water use efficiency (WUE, b) of coconut palms.

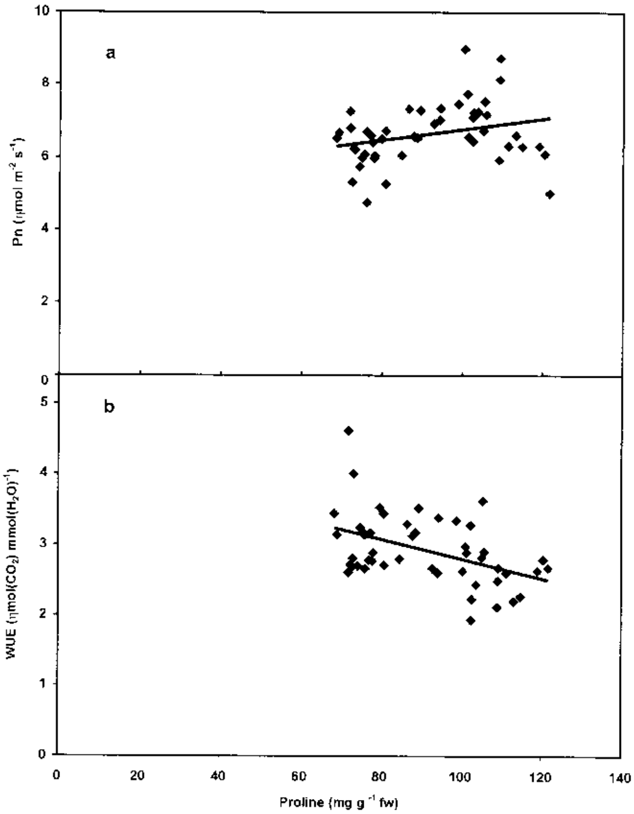

Fig. 4. Relationship of proline with net photosynthesis (Pn, a) and water use efficiency (WUE, b) of coconut palms.

In general, cultivars growing at Kidu region maintained higher concentration of ECW, proline and reducing sugars during summer, though percent increase was more at Veppankulam region. This can be due to the variation in climatic pattern at the two agro-climatic regions, indicating a genotype-environment interaction. At Kidu region, rainy season ends by October and higher temperatures are maintained thereafter till May possibly resulting in continuous accumulation of these compounds. On the other hand, at Veppankulam, where North-East monsoon is prominent and rains are common even in January and temperature fluctuations are low as compared to Kidu.

Cultivar variation in accumulation of these compounds involved in adaptation were noted when the cultivars were compared irrespective of agro-climatic regions (Fig. 5). Differences among cultivars were low during the post-monsoon months. However, during summer months, variation among cultivars increased as the palms started accumulating these compounds to different degrees and the rate of accumulation was more in tall cultivars. This difference among cultivars during summer clearly indicates the existence of cultivar variation in adapting to changing environmental conditions. Biochemical constituents, such as ECW, proline, reducing sugars and amino acids, involved in adaptive mechanisms were higher in tall cultivars, especially in LCT and WCT which enable them to maintain optimal metabolic activities and higher production even during dry periods.

It can be concluded from the results that the concentration of ECW, proline, amino acids and reducing sugars in coconut are responding to fluctuations in weather conditions within a location and across agro-climatic regions and help the plant in adaptation to adverse weather conditions. Variations among cultivars in efficiency to accumulate these compounds can be exploited while breeding palms for climatically different areas. Accumulation of ECW and proline seems to influence the photosynthesis and WUE in coconut palms. Further, these results highlight the wide adaptability of LCT and WCT to diverse environments and the superiority of tall cultivars over dwarf cultivar to survive in unfavourable climatic conditions.

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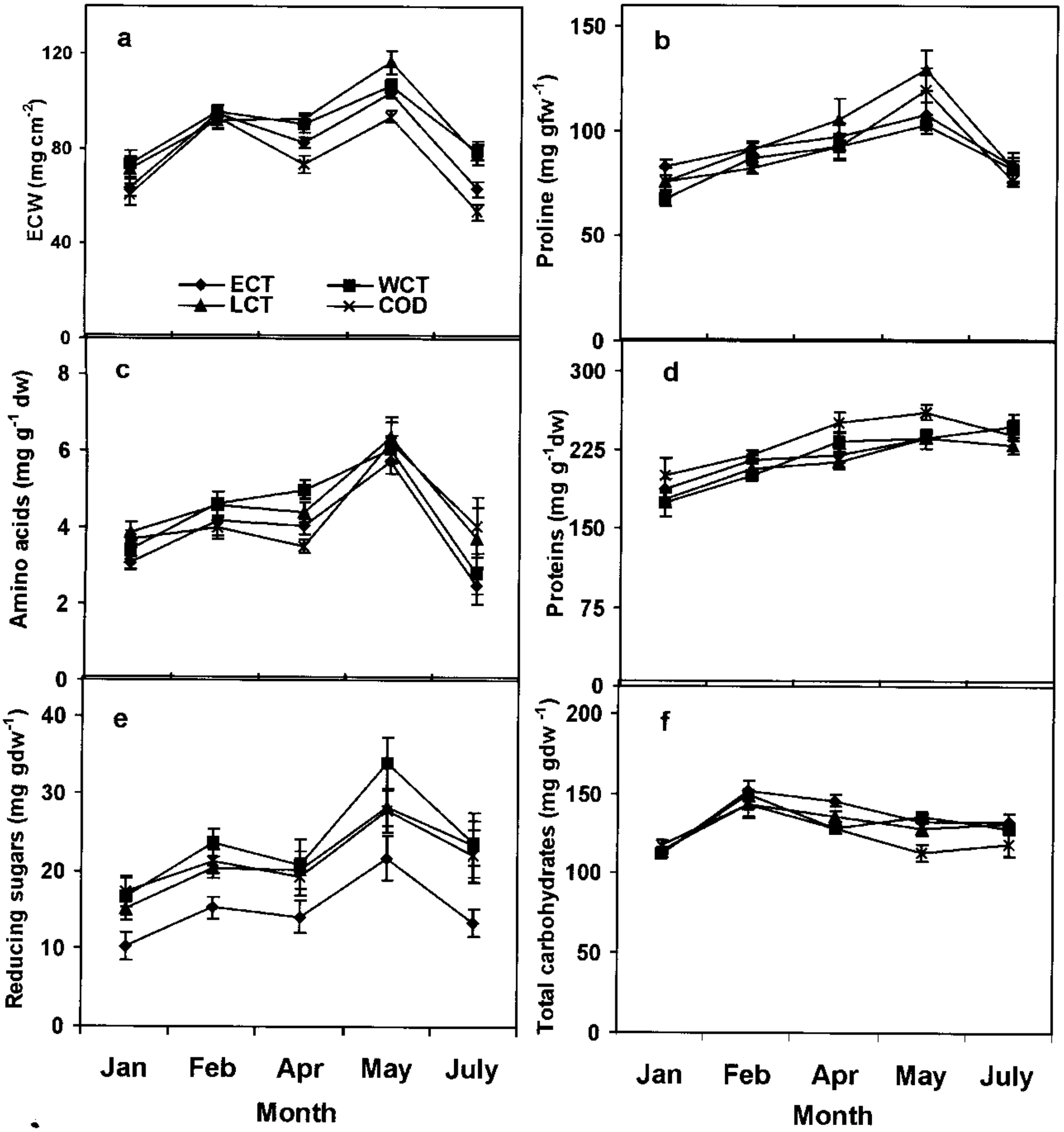

Fig. 5. Concentration of biochemical compounds in the leaflets of four coconut cultivars during different months (a. ECW; b. proline; c. amino acids; d. protein; e. reducing sugars and f. total carbohydrates).

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