Gas exchange parameters and canopy area in relation to coconut productivity in two agro-climatic regions of India

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Coconut (*Cocos nucifera* L.) palms exhibit variation in productivity across different agro-climatic regions of India. It is important to study the factors contributing to such variation in order to increase the productivity of palms. The present study was intended to elucidate the physiological basis of yield variability in coconut across different agro-climatic regions. With this objective, seasonal variations in leaf gas exchange parameters and morphological and dry matter production characteristics of four coconut cultivars were studied at two different agro-climatic regions. Results indicated variation in gas exchange parameters of cultivars with seasons and with regions suggesting genotype-environment interactions. Overall net photosynthetic rates were higher in cultivars grown at Western ghats-hot sub humid per humid region (Kidu). Palms growing at Eastern coastal plains-hot sub humid region (Veppankulam), on the other hand, maintain greater water use efficiency. The results also indicate that, under dry conditions both stomatal and non-stomatal factors impose limitations to photosynthesis in coconut. The physiological efficiency coupled with superior morphological characters such as a larger canopy, and favourable climatic conditions for a longer period, in addition to the soil type at Veppankulam region enabled the palms to attain more of their potential productivity.

Keywords: Coconut, Gas exchange characters, Dry matter, Canopy area, Agro-climatic regions

Abbreviations: ΔT – leaf surface to air temperature difference; C_i - intercellular CO_2 concentration; COD - chowghat orange dwarf; E - transpiration rate; ECT - east coast tall; g_s - stomatal conductance; LAVPD - leaf to air vapour pressure deficit; LCT - laccadive ordinary; PAR - photosynthetically active radiation; P_n - net photosynthesis; P_n/C_i - mesophyll efficiency; P_n/E - instantaneous water use efficiency; P_n/g_s – intrinsic water use efficiency; TDM - total dry matter; VPD - vapour pressure deficit; WCT - west coast tall; WUE - water use efficiency

The coconut palm is the most useful among tropical palms and is grown in more than 93 countries with an area of 12.8 million hectares and production of 10.9 million metric ton copra equivalent (Rethinam and Taufikurahman, 2002). India ranks third in the world in area under coconut cultivation, the first and second being Philippines and Indonesia (www.fao.org). In India, coconut is grown on about 1.84 million hectares with a productivity of 6847 nuts per hectare (http://coconutboard.nic.in /statisti.htm).

Coconut palms grow well within 23°North and South latitudes and up to an altitude of 600 m above mean sea level. It is believed that the coconut palm requires a mean annual temperature of 27 °C, a rainfall of 1000 to 3000 mm distributed throughout the year, and 120 hours of sunshine per month for proper growth and yield (Child, 1974; Murray, 1977). Although the coconut growing area in India is spread along the entire coastal belt, it falls under different agro-climatic regions, characterized by distinct weather patterns. The palm is adapted to grow in the coastal alluvium of both the West and East coast, river alluvium of the deltaic regions and the laterite and red loam soils of the inland areas. However, sandy loam soils with good cation-exchange capacity and a soil water level at about 4 m depth is considered as suitable conditions for coconut (Ohler, 1999).

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Studies on leaf gas exchange characteristics, which are sensitive to environmental variables, are of importance because they indicate the physiological efficiency of the crop for higher production. Variations in photosynthetic (P_n) rate with fluctuations in atmospheric humidity and vapour pressure deficit (VPD) were reported in perennial crops like oil palm (Smith, 1989; Dufrene and Saugier, 1993; Lamade and Setiyo, 1996). Cultivar and seasonal variations in gas exchange characteristics of coconut palms in a particular area have been reported in earlier studies (Rajagopal *et al.,* 1989; Kasturi Bai *et al.,* 1996; Jayasekara *et al.,* 1996). In coconut, higher P_n rates were observed during the post-monsoon season than during the summer season (Jayasekara *et al.,* 1996; Kasturi Bai *et al.,* 1998). Eschbach *et al.* (1982) observed a reduction in photosynthesis of coconut seedlings when the ambient temperature is above 30 ^oC. High VPD induced stomatal closure can be considered as the main cause of decline in photosynthetic rate (Paulson *et al.,* 2002). In coconut also, a decrease in stomatal conductance was observed with increasing VPD, even when the soil moisture content was adequate (Rajagopal *et al.,* 2000) and according to Repellin *et al.* (1997), P_n rates in coconut are highly dependent on stomatal conductance. The positive relationship of water use efficiency (WUE) with dry matter characteristics of coconut palm (Kasturi Bai *et al.,* 1996) highlight the impact of gas exchange characteristics on crop productivity. Coconut cultivars that are tolerant to stress had higher photosynthetic rates and instantaneous WUE compared to stress susceptible ones (Rajagopal *et al.,* 1993; Naresh Kumar *et al.,* 2002). The ratio of net photosynthesis to intercellular CO_2 concentration is considered as an indirect estimation of mesophyll efficiency (Farquhar and Sharkey, 1982). This indicates the ability of the mesophyll cells to fix carbon in a given intercellular CO_2 concentration. In addition to atmospheric variables, soil factors also contribute to variations in gas exchange parameters in coconut (Voleti *et al.,* 1993; Nainanayake and Bandara, 1998).

Canopy area is an important character determining dry matter production and hence, nut yield. Stem height and number of leaves were positively correlated with nut yield in coconut palms (Satyabalan *et al.,* 1972) indicating that increased light interception by greater leaf area might result in increased yield potential (Kasturi Bai and Ramadasan, 1990). Coconut cultivars in different agro-climatic regions may show morphological variations as a result of interaction with climatic conditions, as reported in oil palm (Ong *et al.,* 1985), which in turn can influence the dry matter production and yield characteristics of the palms.

So far, no work has been done to study the influence of climatic factors on gas exchange of coconut palms in different agro-climatic regions and its relationship with yield variations. Hence, this study was conducted to obtain a clear understanding of the gas exchange characteristics of coconut palms in relation to environmental factors in two different agro-climatic regions, and to integrate it with canopy area and dry matter production in order to understand the physiological basis of yield variability across locations. Such physiological data would greatly assist plant breeders to overcome production constraints in different regions.

Materials and Methods

Experimental locations

Two different agro-climatic regions, *viz*., Western ghats - hot sub humid per humid region (Central Plantation Crops Research Institute (CPCRI), Research Centre, Kidu, Dakshina Kannada district, Karnataka) and Eastern coastal plains - hot sub humid region (Coconut Research Station (CRS), Veppankulam, Thanjavur district, Tamil Nadu) were selected for the present study. They also represent two major coconut growing regions in India. The climatic and soil conditions of the regions show distinct variations (*Table 1, Figures 1 and 2*).

Table 1 Geographical position, weather and soil characteristics of experimental locations

Parameters	Locations	
	Kidu	Veppankulam
Altitude (m above MSL)	291	20
Latitude	12.67° N	10.29° N
Longitude	75.6° E	79.23° E
Temperature (°C)		
Minimum	16.6	22.1
Maximum	33.2	32.6
Relative humidity (%)	88	76
Rainfall (mm)	2989	1117
Rainy days (No.)	132	57
Soil type	Red laterite	Sandy loam
pH	5.2	6.0

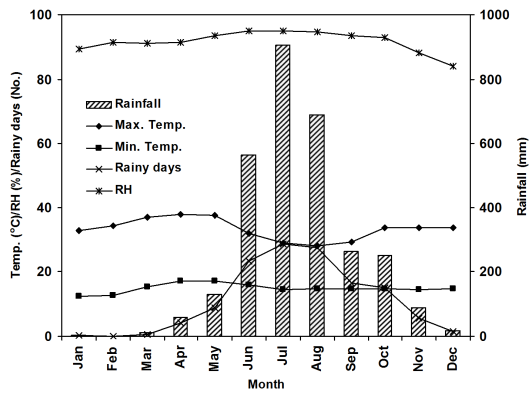

Figure 1 Monthly fluctuations in weather parameters at Western ghats-hot sub humid per humid region (Kidu).

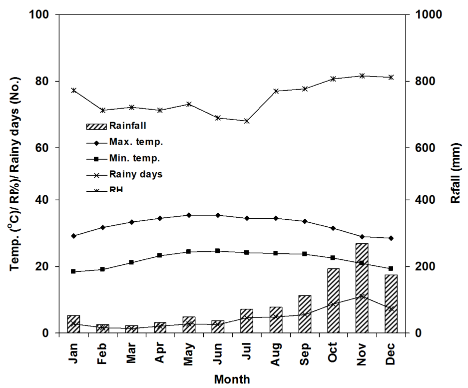

Figure 2 Monthly fluctuations in weather parameters at Eastern coastal plains-hot sub humid region (Veppankulam).

Plant material

Four popular cultivars of coconut, *viz*., East Coast Tall (ECT), West Coast Tall (WCT), Laccadive Ordinary (LCT) and Chowghat Orange Dwarf (COD) were used for the study. ECT and WCT are the local tall cultivars of Veppankulam and Kidu region respectively, where as, LCT is a popular high yielding tall cultivar and COD is a dwarf cultivar used mainly for tender nuts. Six palms were selected in each cultivar based on uniformity in growth and morphology. The experimental palms were of same age group and had attained the stabilized yield stage. The palms were maintained as a monocrop under recommended agronomic practices.

Experimental observations

Meteorological parameters such as maximum and minimum temperature, rainfall, number of rainy days and relative humidity were collected from the weather stations at respective locations. Data on photosynthetically active radiation (PAR), leaf surface temperature and leaf to air vapour pressure deficit (LAVPD) were recorded using the portable photosynthesis system (LCA 4, Analytical Development Company, UK) at the time of recording of gas exchange characteristics.

Leaf gas exchange characteristics were recorded during different months representing post-monsoon (January and February) and summer (April and May) seasons. The parameters were measured using a portable Infra Red Gas Analyzer (LCA 4 fitted with PLC 4, Analytical Development Company, UK). Braconnier (1998) suggests measurement of photosynthesis in intact leaves of coconut. However, he obtained steady photosynthetic rates up to two minutes on detached leaves also. Experiments conducted at CPCRI also indicated that, gas exchange characters of intact and detached leaves are not significantly varied if observations are taken within two minutes after detaching, and values obtained on 6th and 11th leaves from top are comparable (Rajagopal *et al.*, 1982; Rajagopal *et al.*, 1987; Kasturi Bai, 1993). Hence, to take observations from a large number of palms, measurements on gas exchange characters were made on detached middle leaflets of 6th leaf from top. Middle leaflets from both sides of the rachis were used for the measurements. At least 24 observations were made per cultivar at an observation time. Care was taken to record observations within 90 seconds after detaching the leaflets from leaf and to keep the position of leaflet as naturally occurred. Leaf chamber parameters were maintained uniformly throughout the experimentation period. Observations were recorded between 9.00 and 11.00 am Indian time. The gas exchange parameters were recorded under full sunlight with an average PAR around 1200 (μmol m^{-2} s^{-1}). Set gas flow rate in the leaf chamber was 200 mL min^{-1} and boundary layer resistance was 0.08 m^2s mol^{-1}. Recordings were made in ambient CO_2 mode at 330 vpm. Instrument calibrations were done for CO_2 and H_2O before actual measurements.

Also, observations on growth, dry matter production, yield and yield components were carried out on all experimental palms (Ramadasan and Mathew, 1987; Kasturi Bai, 1993).

All the experimental observations were carried out during 1999 to 2002.

The data were subjected to statistical analysis using the GLM in SPSS package and the CDs at P=0.05 were used to compare the means.

Results

Gas exchange characteristics of coconut cultivars varied with fluctuations in weather variables during different months. The average net photosynthetic rates, stomatal conductance (g_s) and transpiration rate (E) were higher in palms growing in Western ghats - hot sub humid per humid region (Kidu) compared to Eastern coastal plains - hot sub humid region (Veppankulam) (Figure 3a, b, c). Cultivars growing at Veppankulam had higher mean value for instantaneous (P_n/E) and intrinsic (P_n/g_s) water use efficiencies as well as mesophyll efficiency (P_n/C_i) (Figures 3d, e, g). On the other hand, palms at Kidu region had higher mean values of C_i and leaf to air temperature difference (ΔT) (Figures 3f, h). At Kidu region, dwarf cultivar COD recorded higher mean P_n rates followed by the local cultivar WCT (Table 2). In Veppankulam, the local cultivar ECT registered higher photosynthetic rates followed by LCT.

Table 2 Net photosynthetic rate in four cultivars of coconut during post-monsoon and summer months at two agro-climatic regions

Location	Cultivar	Net photosynthetic rate (μmol m^{-2} s^{-1})				
		Jan	Feb	April	May	Mean
Kidu	ECT	7.31	9.30	9.12	2.88	7.15
	WCT	6.79	8.96	7.36	4.56	6.92
	LCT	5.59	8.38	8.20	2.03	6.05
	COD	7.68	9.39	8.83	5.30	7.80
Veppankulam	ECT	7.53	5.24	11.82	3.09	6.92
	WCT	7.11	4.64	10.50	2.14	6.10
	LCT	9.14	4.50	10.03	2.01	6.42
	COD	7.75	5.00	9.11	1.36	5.81
Mean		7.36	6.93	9.37	2.92	6.65
CD for Months		0.458**				
CD for LxC		0.647**				
CD for LxCxM		1.295**				

L=Locations; C=Cultivars; M=Months ** Significant at 1% level

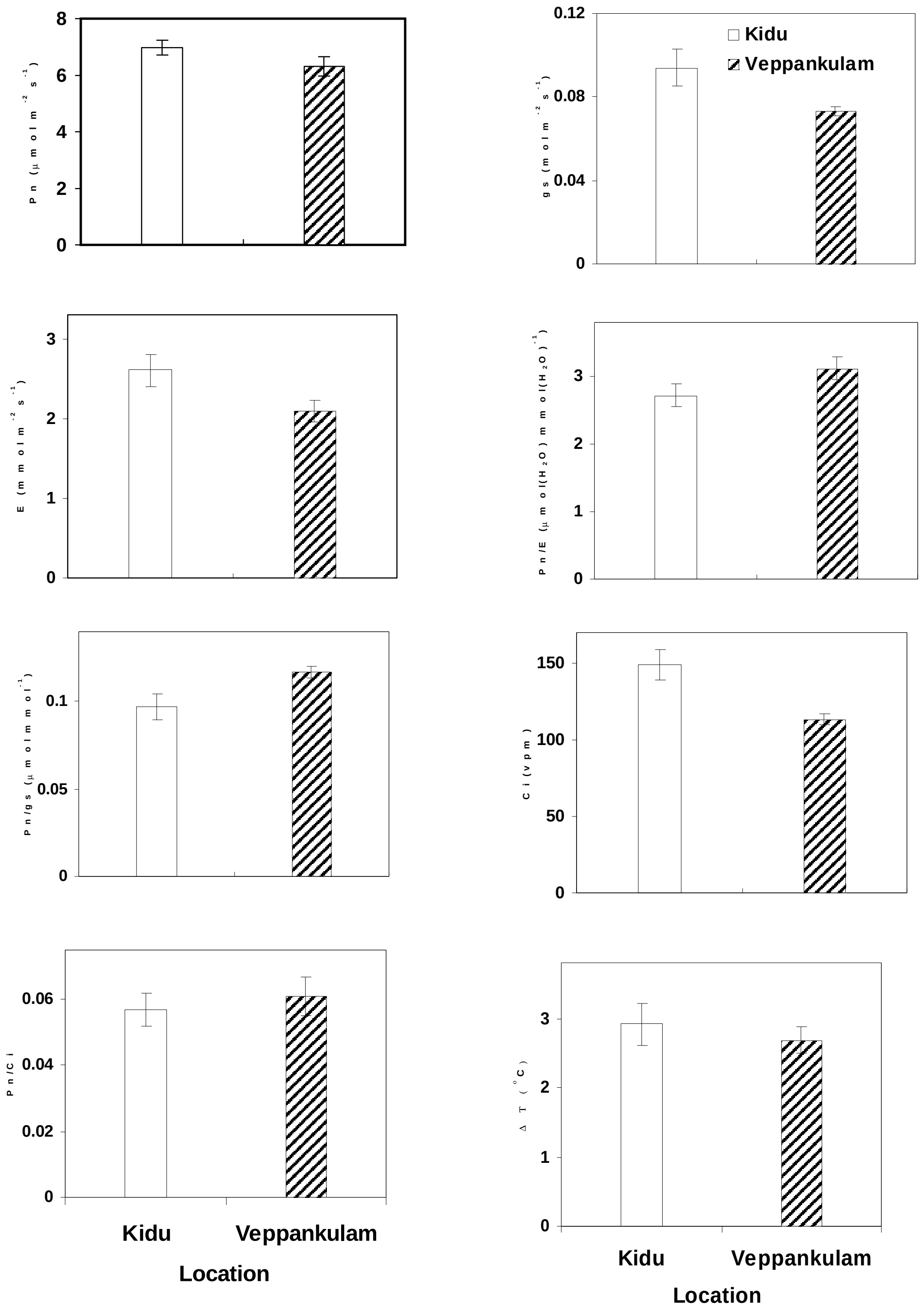

Figure 3 Gas exchange parameters of coconut cultivars at two agro-climatic regions. (a) Net photosynthesis, Pn. (b) stomatal conductance, gs. (c) transpiration rate, E. (d) instantaneous water use efficiency, Pn/E. (e) intrinsic water use efficiency, Pn/gs. (f) intercellular CO_2 concentration, Ci. (g) mesophyll efficiency, Pn/Ci. (h) leaf to air temperature difference, ? T.

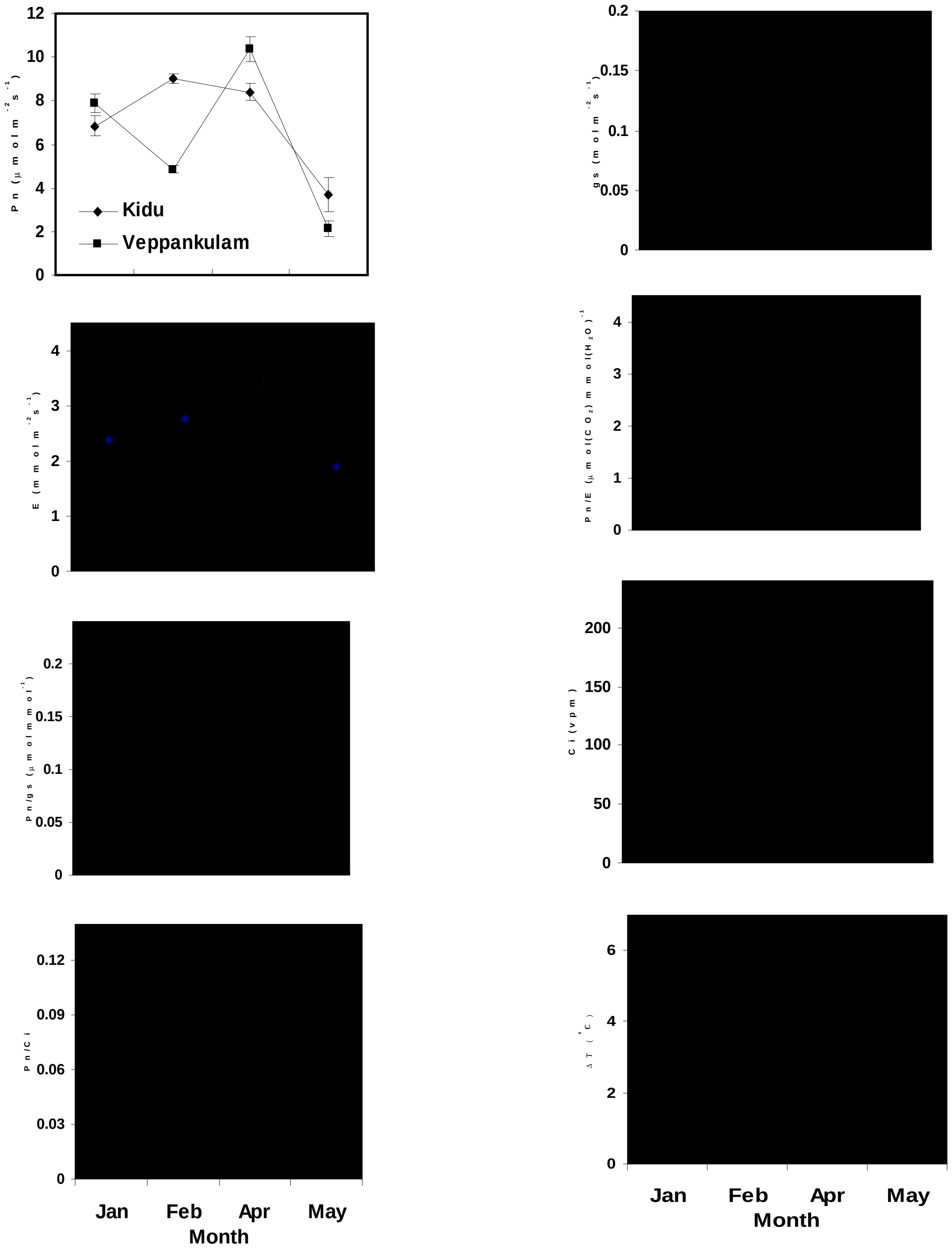

Figure 4 Variations in gas exchange parameters of coconut cultivars during post-monsoon and summer months at two agro-climatic regions: (a) Net photosynthesis, Pn. (b) stomatal conductance, gs. (c) transpiration rate, E. (d) instantaneous water use efficiency, Pn/E. (e) intrinsic water use efficiency, Pn/gs. (f) intercellular CO_2 concentration, Ci. (g) mesophyll efficiency, Pn/Ci. (h) leaf to air temperature difference, ? T.

The cultivars, in general, maintained relatively higher P_n rates during post-monsoon and early summer period (Figure 4a). The overall P_n rates were higher during February at Kidu where as, at Veppankulam, P_n rates were high during April. However, 56% and 79% reduction in P_n rates was observed during May, as compared to previous month, at Kidu and Veppankulam, respectively. Among the cultivars, within each location, reduction was more in LCT (75.2%) at Kidu and in COD (85.1%) at Veppankulam. Stomatal conductance and transpiration rate followed trends more or less similar to the P_n rates (Figure 4 b, c). When compared across the locations, stomatal conductance was higher in palms at Veppankulam during January, while in subsequent months, higher g_s was maintained by cultivars at Kidu. In the post-monsoon months, cultivars at both locations had relatively same instantaneous WUE. But as the summer progressed, P_n/E decreased in palms at Kidu, while those at Veppankulam maintained steady P_n/E rates (Figure 4d).

Fluctuations in intercellular CO_2 concentration (C_i) followed similar trends at both locations (Figure 4f). Palms at Kidu maintained higher C_i, even though the ratio of net photosynthesis to intercellular CO_2 concentration (mesophyll efficiency - P_n/C_i) was generally higher in palms at Veppankulam during the experimental period.

The P_n/C_i ratio decreased during May, while an increase in the P_n/g_s ratio was noted during the same period (Figure 4e, g). The difference between leaf and air temperature (ΔT) decreased during January-April period and rapidly increased during May irrespective of location (Figure 4h).

The palms at each agro-climatic location, irrespective of cultivars, were grouped based on their canopy size to draw the relationship of P_n rates with canopy area so as to analyse how these factors contribute to total dry matter (TDM) production and nut yield (Table 3). In general, the canopy size of palms growing at Veppankulam is larger (varies form 86.6 to 210.6 m^2), with two palms having canopy size above 200 m^2, compared to those at Kidu (varies from 87.2 to 167.7 m^2).

Table 3 Net photosynthesis, total dry matter (TDM) production and nut yield of coconut palms of different canopy size at two agro-climatic regions (values in parenthesis indicate range)

Location	Canopy area (m^2)	Net photosynthesis (μmol m^{-2} s^{-1})					TDM (Kg/palm /year)	Nut yield (/palm /year)
		Jan	Feb	April	May	Mean		
Kidu	<100	7.94 (6.2-10.9)	7.91 (7.5-8.5)	7.68 (6.7-8.3)	5.55 (5.2-5.8)	7.3	43.37 (39.4-48.7)	51.33 (49-56)
	101-125	7.49 (6.6-8.9)	10.37 (8.6-12.6)	10.26 (8.7-11.3)	4.58 (3.2-6)	8.2	55.35 (43.6-77.7)	55.75 (50-72)
	126-150	6.33 (3.2-8.5)	8.71 (5.4-9.8)	7.76 (5.1-10.2)	3.34 (1.9-5)	6.5	77.54 (67.2-85.5)	81.39 (66-92)
	>150	6.68 (4.4-8.1)	9.06 (7.7-10.3)	8.39 (6.3-10.3)	2.94 (1.3-4.7)	6.8	81.40 (71-89.7)	81.48 (62-93)
Veppankulam	<100	7.3 (6.0-7.8)	4.9 (3.5-7.2)	9.0 (8.1-8.9)	1.2 (1.1-1.4)	5.6	49.4 (44.2-58.1)	74.5 (63-86)
	101-125	8.7 (7.8-9.7)	5.2 (4.4-5.9)	9.4 (8.7-10.1)	1.6 (1.0-2.2)	6.2	60.1 (53.8-66.4)	81.2 (80-82)
	126-150	8.7 (7.9-9.1)	4.5 (3.4-5.3)	9.5 (6.7-11.2)	2.2 (1.8-2.7)	6.2	97.2 (83.0-108.9)	125.1 (96-152)
	151-175	8.0 (7.1-9.6)	5.1 (3.3-6.7)	11.0 (9.8-12.2)	2.8 (1.8-3.4)	6.7	104.2 (86.1-123.2)	125.8 (96-163)
	>175	7.5 (6.5-10)	4.6 (3.9-5.7)	11.0 (9.6-13.1)	2.1 (1.6-3.4)	6.3	107.8 (90.3-129.3)	139.5 (104-175)
CD				1.295**			8.306**	14.627**

** Significant at 1% level

At both agro-climatic regions, palms with canopy size above 125 m^2 had more or less uniform P_n rates (between 6 and 7μmol m^{-2} s^{-1}). However, palms with canopy size below 125 m^2 maintained higher mean P_n rates at Kidu, contrary to the same group at Veppankulam, which had P_n rates lower than the other groups.

The mean TDM production and nut yield was higher in palms at Veppankulam compared to those at Kidu. Canopy area was positively correlated with TDM (R^2=0.8908) and nut yield (R^2=0.7642) irrespective of agro-climatic regions. Maximum increase in TDM and nut yield was observed when the canopy area increased from below 125m^2 to up to 150m^2, and the percent increase was more in palms at Veppankulam compared to Kidu. Interestingly, at both regions, the increase in canopy size above 150m^2 did not result in any significant increase in TDM and nut yield.

Discussion

Gas exchange parameters of the plants are highly influenced by variations in micrometeorological conditions of the growing region (Nunes 1988; Rajagopal *et al.*, 2000; Gonzalez-Rodriguez *et al.*, 2002). In the present study, net photosynthetic rates showed variation at both agro-climatic regions with COD and ECT having higher rates of P_n, indicating inherent variability among cultivars for carbon assimilation. Such genotypic differences were observed in coconut by Kasturi Bai *et al.* (1998). Even though the cultivars, in general, maintained higher overall P_n rates at Western ghats hot sub humid per humid region, the relative ranking of cultivars for P_n rates varied with locations, indicating genotype-environment interactions. Prevailing climatic conditions like higher relative humidity and low VPD at Kidu for longer duration were favourable for high g_s, thus improving the overall P_n rates at this agro-climatic region. A strong positive relationship of g_s with P_n and E also indicate inter-dependence of these parameters as reported earlier in coconut (Katuri Bai, 1993; Rajagopal *et al.*, 2000) and also in other crops (Lamade and Setiyo, 1996; Jiang *et al.*, 2000; Subrahmanyam, 2000).

Coconut cultivars maintained higher P_n rates during January-April which were drastically reduced as summer aggravated in May, regardless of locations. Variations in net photosynthesis are mainly associated with stomatal responses to environment (Raschke, 1975; Yordanov *et al.*, 2000). Since the palms were provided with irrigation, stomatal conductance was not affected during mid summer (April) and palms maintained higher g_s during that period. However, during severe summer (May), in response to higher day temperatures (>35°C at both locations) and increased VPD, cultivars reduced stomatal conductance in order to minimize transpirational water loss. A reduction in stomatal conductance with higher VPD during summer was reported in coconut (Kasturi Bai *et al.*, 1988; Rajagopal *et al.*, 2000) and in oil palm (Dufrene and Saugier, 1993).

Reduction in stomatal conductance causes a reduction in CO_2 availability at assimilation sites, causing limitation to P_n during summer. High VPD induced stomatal closure can be considered as the main cause of decline in photosynthetic rate (Paulson *et al.*, 2002), which is often associated with a reduction in C_i (Farquhar and Sharkey, 1982). Thus the reduction in P_n rates of coconut during summer (Jayasekara *et al.*, 1996; Kasturi Bai *et al.*, 1998) could be ascribed to the decrease in g_s and associated reduction in C_i. Such interdependence of these parameters indicates predominance of stomatal limitation to photosynthesis in coconut. According to Repellin *et al.* (1997), P_n rates in coconut are highly dependent on stomatal conductance. Stomatal factors are considered more important than non-stomatal factors in affecting photosynthesis, mainly because of leaf stomatal heterogeneity (Farquhar and Sharkey, 1982).

High P_n/C_i and P_n/g_s ratio observed in cultivars at Veppankulam suggest a more efficient carboxylation mechanism in palms growing at this region resulting in relatively higher carbon assimilation even at reduced g_s. Irrespective of locations, the P_n/C_i ratio decreased as the summer progressed, while P_n/g_s ratio increased during the same period since stomatal conductance is more affected than the net photosynthesis. Such trends were observed earlier in trees (Gonzalez-Rodriguez *et al.,* 2002). A decrease in mesophyll efficiency during summer season shows that non-stomatal factors also contribute to limitation to photosynthesis in coconut under conditions of high VPD and temperature (Repellin *et al.*, 1997; Kasturi Bai *et al.*, 1998; Rajagopal, *et al.*, 2000). The increased leaf temperature and ΔT as a result of stomatal closure and reduced transpiration (Rajagopal *et al.*, 2000) probably affects the mesophyll efficiency for photosynthesis during summer (May). About 4 to 7^{o}C increase in ΔT was found in the present study during May. This situation adversely affected the photosynthetic efficiency as indicated by low P_n rates during May, probably due to breakdown of chlorophyll (Nainanayake and Bandara, 1998) or by affecting enzymatic pathways (Teeri, 1980; Salvucci, 2001).

Stomatal responses to atmospheric and soil conditions influence the WUE of the crop. The present study revealed the higher WUE of coconut cultivars grown at Eastern coastal plains-hot sub humid region. Instantaneous water use efficiency of coconut cultivars at Kidu region reduced after February, while, at Veppankulam, higher WUE was maintained without much fluctuation even during summer season. Existence of relatively higher day/night temperatures for longer duration coupled with low humidity and higher VPD creates a mild atmospheric stress condition at this location. Hence, palms at this region regulate their stomata in such a way to minimize transpirational water loss relative to P_n rates and maintain higher WUE. Such increase in WUE with mild stress has been reported in coconut (Rajagopal *et al.*, 2000; Naresh Kumar *et al.*, 2002) and in other crops (Dufrene and Saugier, 1993; Deng *et al.*, 2000). Earlier reports suggest that, palms tolerant to water deficit maintain lower transpiration rates and higher water use efficiency by effective stomatal control than susceptible ones (Rajagopal *et al.*, 1990). On the other hand at Kidu, which is a high humid area with high rainfall, high transpiration rates reduced the water economy of the palm. WUE is positively correlated with dry matter production characteristics of coconut (Kasturi Bai *et al.*, 1996), hence maintenance of steady water use efficiency coupled with higher dry matter production resulted in higher nut yield as observed in palms at Eastern coastal plains-hot sub humid region.

Relationship of net photosynthesis with canopy area, dry matter production and nut yield indicate that, at both regions, palms with larger canopy maintained relatively similar P_n rates. Higher P_n rates, observed in cultivars with smaller canopy size at Kidu region, suggest a compensation mechanism for reduced canopy size. However, no such trend was found in Veppankulam, where P_n rates of different groups are relatively same. TDM production and nut yield rapidly increased as the canopy area increased from 100-150 m^2, possibly, due to more light interception resulting in high canopy photosynthesis. Increased light interception has been positively correlated with dry matter production and yield characters in many crops (Thomas and Balasimha, 1992; Naresh Kumar and Singh, 1999). However, the increase in canopy size above 150 m^2 could not produce any further significant increase in TDM production or nut yield. This may be due to shading effect (Shibles and Weber, 1965) and/or higher maintenance respiration (Pearce *et al.*, 1965) of larger canopy limiting the dry matter accumulation.

The higher productivity of coconut palms at Eastern coastal plains hot sub humid region, even with same canopy size as compared to those at Kidu region, could be explained based on both the climatic conditions and soil characteristics. Since Kidu is a high rainfall area with long rainy season, photosynthesis during this season could be affected by cloudy weather reducing the available light levels. According to Peiris (1993), periods of high rainfall may be harmful to coconut growth and yield. On the other hand at Veppankulam, even though the total rainfall is low, it is relatively well distributed. The soil conditions at Veppankulam, with sandy loam soil, are considered more suitable for coconut growth and high yield compared to red laterite soils of Kidu region (Naidu *et al.,* 1997; Ohler, 1999). Palms at Veppankulam region also had higher water use efficiency. Hence, palms at this location with superior physiological characters coupled with favourable climatic conditions for longer duration and suitable soil conditions are able to attain higher dry matter production and nut yield leading to more potential productivity.

In conclusion, the results reveal association of both stomatal and non-stomatal limitation to photosynthesis in irrigated coconut palms during summer. Further, superiority of palms at Eastern coastal plains-hot sub humid region in attaining maximum production potential due to better morpho-physiological characters and existence of conducive climate for longer duration is also evident from the study. The results demonstrate that while breeding palms for higher productivity at different agro-climatic conditions, selection should be made for palms having a canopy size of around 150m^2 with steady photosynthetic rates and water use efficiency across the seasons.

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