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BRIEF COMMUNICATION

Variations in photosynthetic rate and associated parameters with age of oil palm leaves under irrigation

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Abstract

Net photosynthetic rate (P_N), transpiration rate (E), and stomatal conductance (g_s) in an adult oil palm (*Elaeis guineensis*) canopy were highest in the 9th leaf and progressively declined with leaf age. Larger leaf area (LA) and leaf dry mass (LDM) were recorded in middle leaves. P_N showed a significant positive correlation with g_s and a negative relationship with leaf mass per area (ALM). The oil palm leaf remains photosynthetically active for a longer time in the canopy which contributes significantly to larger dry matter production in general and greater fresh fruit bunch yields in particular.

Additional key words: area leaf mass; chlorophyll; *Elaeis*; leaf area; leaf dry mass; stomatal conductance; transpiration rate.

Oil palm (*Elaeis guineensis*) has been introduced to India as an irrigated crop in several southern parts of the country. The growth of the crop has to be defined under this new environment which is much different from the traditional oil palm growing areas like Malaysia, Indonesia, Costa Rica, and Papua New Guinea. The environment differs from other oil palm growing areas in terms of total rainfall, distribution of rainfall, mean maximum temperature, and relative humidity. To offset for the low rainfall and humidity prevailing in the regions, the crop is being grown under irrigation. The leaves of many tropical perennial crops may have a long life, but the photosynthetic activity over the life of a leaf has been sparsely studied in few crops. According to Nixon and Wedding (1956) the leaves of the subtropical date palm remain active for four years. Yamaguchi and Friend (1979) found little decrease in the activity of coffee leaves up to 150 d after emergence but other researchers of tropical perennials have examined photosynthesis only over the first few weeks of leaf life. Photosynthesis of oil palm has been evaluated in several countries like Cote de Ivoire, Indonesia, Malaysia, and Papua New Guinea (Corley *et al.* 1973, Corley 1976, 1983, Gerritsma 1988, Henson 1990, Dufrêne and Saugier 1993, Lamade *et al.* 1996). As there is no previous study of photosynthesis in oil palm grown under irrigation in India, we studied it to fill this gap.

Nine six-year-old oil palms grown under identical management at the National Research Centre for Oil Palm, Pedavegi, India were studied. In all the palms, the leaves were numbered from 1 to 33, marking the youngest fully open leaf as 1. The four leaflets from the central portion of the leaves 1, 9, 17, 25, and 33 were used. The net photosynthetic rate (P_N), stomatal conductance (g_s), transpiration rate (E), and leaf temperature (T_L) were recorded under bright sunlight between 10.00 and 11.30 h using the Portable Photosynthesis System (*LCA-4*, *ADC*, UK). The PAR was always more than 1 400 µmol m^{-2} s^{-1} during the entire study. Non-destructive growth analysis was carried out to estimate the leaf area (LA) and leaf dry mass (LDM) as per Corley *et al.* (1971). The leaf area per palm was calculated by multiplying mean leaf area (LA) and number of leaves per palm (n) using mean of length × mid-width for a sample of the largest leaflets, and correction factors. LDM [kg] was calculated by using the formula LDM = 0.1023 P + 0.2062 where P is petiole width × depth [cm^2]. Chlorophyll (Chl) content was estimated as per Hiscox and Israelstam (1979) by using dimethyl sulfoxide extraction. The same extract was also measured at 480 and 510 nm for checking the amount of carotenoids (Cars).

Maximum P_N was found in 9th leaf, which differed significantly from that of other leaves (Table 1), minimum in the 1st leaf. E and g_s followed a similar trend as P_N. T_L decreased with increasing leaf age. Maximum LA was found in leaves 9–25. The minimum LA was

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Table 1. Variation in the net photosynthetic rate, P_N [µmol m^{-2}.s^{-1}], stomatal conductance, g_s [mol m^{-2} s^{-1}], transpiration rate, E [mmol m^{-2} s^{-1}], leaf temperature, T_L [°C], leaf area, LA [m^2], leaf dry mass, LDM [kg], area leaf mass, ALM, chlorophyll (Chl) and carotenoid (Car) contents [g kg^{-1}(f.m.)] with leaf age in oil palm. Values with the same letters do not differ significantly from each other.

Leaf No.	P_N	g_s	E	T_L	LA	LDM	ALM	Chl	Car
1	2.94 ^{e}	0.01 ^{a}	0.72 ^{c}	47.5 ^{a}	2.15 ^{b}	1.80 ^{c}	0.85 ^{ab}	1.14 ^{e}	0.40 ^{c}
9	9.18 ^{a}	0.03 ^{a}	2.26 ^{a}	46.1 ^{b}	3.38 ^{a}	2.61 ^{b}	0.78 ^{ab}	1.59 ^{d}	0.55 ^{bc}
17	6.16 ^{b}	0.03 ^{a}	1.58 ^{b}	46.8 ^{ab}	3.28 ^{a}	3.08 ^{a}	0.94 ^{a}	1.78 ^{b}	0.61 ^{ab}
25	5.23 ^{c}	0.02 ^{a}	1.32 ^{b}	43.9 ^{c}	3.26 ^{a}	2.59 ^{b}	0.81 ^{ab}	2.08 ^{a}	0.73 ^{a}
33	4.38 ^{d}	0.02 ^{a}	1.27 ^{b}	41.8 ^{d}	2.96 ^{a}	2.37 ^{b}	0.75 ^{b}	1.75 ^{c}	0.61 ^{ab}
LSD (p=0.05)	0.64	0.05	0.36	1.24	0.43	0.46	0.19	0.05	0.16

observed in the 1st leaf. LDM varied from 1.80 to 3.08 kg among the different leaves, maximum was observed in 17th leaf, minimum in 1st leaf. Area leaf mass (ALM), which is a measure of the thickness of the leaf, was highest in the 17th leaf. The total Chl content was greatest in the 25th leaf followed by 17th leaf, the 1st leaf recorded significantly the lowest content. The Cars' content was highest in the 25th leaf followed by leaves 17 and 33, while the 1st leaf recorded the significantly lowest value.

The relationship between morphological and physiological parameters indicated that P_N had a significant positive correlation with morphological parameters such as LA, LDM, and ALM (Table 2). P_N exhibited a significant positive correlation with g_s ($r = 0.73$).There was a negative correlation between ALM and P_N.

Table 2. Relationship between photosynthetic rate and other leaf characters in oil palm. For abbreviations see Table 1. *Significant at 5 % level.

	LA	LDM	ALM	Chl	Car	E	T_L	g_s	P_N
LA	-	0.58*	–0.22	0.57*	0.55*	0.70*	–0.19	0.51*	0.64*
LDM		-	–0.62*	0.55*	0.56*	0.42*	–0.09	0.42*	0.45*
ALM			-	0.03	0.08	–0.16	0.21	–0.04	–0.03
Chl				-	0.99*	0.27	–0.56*	0.42*	0.29
Car					-	0.24	–0.54*	0.38	0.27
E						-	0.01	0.77*	0.88*
T_L							-	–0.19	0.11
g_s								-	0.73*
P_N									-

The canopy of oil palm has older leaves at the base and is always shaded by the upper leaves. Under such conditions, the ability of the palms to have a better P_N at low irradiance assumes greater significance. Leaves of many species show a steady increase in their P_N during leaf expansion (see Šesták 1985), but the oil palm leaflets remain tightly folded against the rachis during the expansion phase and photosynthesis might not take place. The experimental results fully agree with those of Nixon and Wedding (1956) in showing that both the younger and older leaves of date palm recorded lower P_N than intermediate leaves, but there was no clear indication of such a trend in the study.

Corley (1983) also reported that the leaves of ten year old palms remained photosynthetically active for at least 21 months. He also indicated that P_N saturated with radiant energy was lower in leaves aged 16 and 21 months and there was no decline in the photochemical efficiency with leaf age. Żelawski (1976) reported that P_N in evergreen temperate species remained low during winter even though their leaves remained active for several years. In the humid tropical regions, temperatures remain favourable for plant growth throughout the year and perennial species can achieve high productivities due to their higher photochemical efficiency (Corley 1983). The rate of leaf production in oil palm is 24–30 leaves per year for a mature palm and leaf life is prolonged due to a smaller number of leaves produced. Finally, the results indicate that the leaf of oil palm remains photosynthetically active for a longer time, which results in a higher DM production and fresh fruit bunch yields in oil palm grown under irrigation.

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