

Oil Palm Root Study at a Northern Region in Peninsula Malaysia

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Abstract – A study was carried out on the influence of seasonal rainfall and irrigation treatment on oil palm growth in Northern Peninsula Malaysia. The inland area experiences an annual 3 to 4 months of dry season starting in mid December and ending in March of the following year. Parameters measured were oil palm above-ground biomass, root biomass, soil moisture content and meteorological data. Total standing root biomass showed an increasing trend as the palm grew older. The palm root growth was significantly affected in 2005 during a prolonged dry period, which had a negative effect on root turnover. Differences in rainfall distribution were found to have a great influence on the palm root biomass production and root turnover.

Keywords – Oil Palm, Rainfall, Drought, Root Turnover, Root Biomass.

I. INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) is an important perennial crop that grows well under the tropical climate conditions in Malaysia. This rain-fed plantation crop requires an annual rainfall of more than 2,000 mm that is evenly distributed throughout the year. Apart from soil fertility and management inputs, its growth and yield can be strongly influenced by changes in the annual rainfall or its monthly distribution throughout the year. This perennial monocot has an extensive adventitious root system by the time it reaches maturity at about 6 to 7 years after field planting (YAP), which enables it to explore for water and nutrient resources in the soil. New root tips grow continuously throughout the life of the palm and provide new surfaces through which most of the nutrients and water are absorbed from the surrounding soil matrix.

The dynamics of oil palm root growth have not been comprehensively studied, but it's likely that they take priority over fruit bunches, similar to leaves. Oil palm root growth may not show the same trend as above-ground vegetative growth as shown by the large variation in measured root biomass between different soils and environments. Dufrene (1989) estimated the palm root biomass in Africa at 11.5 tonnes/hectare/year. While Khalid *et al.* (1999) estimated that the amount of oil palm root biomass at replanting (ca. 25 YAP) in Malaysia can be as high as 16 tonnes/hectare. This shows that palm root growth is less constant across environments than its above-ground vegetative growth. One reason for the high turnover in Africa may be that large portions of the root system die back during the annual dry season (Forde, 1972). Earlier estimate of oil palm root biomass production only consider the net annual increase in root biomass. Later it was recognized that there would be additional biomass used for replacement of old roots by

new ones (i.e. root turnover), which is difficult to measure. Lamade *et al.* (1996) estimated root turnover at 9 tonnes/hectare/year in Benin, Africa. Henson and Chai (1997) estimated root turnover in Malaysia at 4.5 tonnes/hectare/year (i.e. base on carbon balance or soil respiration measurements). Using soil core in-growth method, Henson and Chai (1997) estimated root turnover ranging from 1.2 to 4.4 tonnes/hectare/year from two age groups and six study sites. Root turnover was calculated from the difference between total root growth and net increase in root biomass. It ranges from zero to 4 tonnes/hectare in a group of 3-4 year old palms and 2.1 tonnes/hectare/year for four groups of 9-10 year-old palms. In general, the estimates of palm root turnover in Malaysia were found to be much lower than those in Africa.

Until today accurate estimates of oil palm root life-spans and turnover rates have been difficult, and the impacts of root turnover on above-ground or below-ground processes are still unknown. A study using the mini-rhizotron technique have shown that the weekly root length turnovers of secondary and tertiary roots of nine year old oil palm grown on inland mineral soil were about 17% and 19%, respectively (Haniff and Roslan, 2004). This implies that the rapid death of these old feeder roots and their replacement may impose a significant energy drain in the oil palm tree in terms of biomass partitioning. Zuraidah *et al.* (2012) reported a significant increase in palm fresh fruit bunch (FFB) yield due to reduction in assimilate partitioning to root and shoot biomass when mean soil bulk density was increased by compaction. The growth of oil palm roots were significantly affected by the compacted soil, resulting in lower primary and secondary root production, but compensated for by the production of longer and thicker feeder (i.e. tertiary and quaternary) roots. The palms showed adaptation to the change in soil properties and responded positively by producing an increase in FFB yield following the compaction treatments. Further information is needed to understand how palm roots response to the external factors and its relationship with above-ground growth.

This paper presents the result from a long term study conducted on irrigated and non-irrigated palms planted at a dry northern region in peninsula Malaysia. Work was carried out to investigate the above-ground biomass, below-ground root biomass and root turnover in response to irrigation and seasonal climatic variations.

II. MATERIAL AND METHODS

A. Site description

The experimental site was at Tanjung Genting Estet Pekebun Kecil Sdn Bhd (ESPEK) Plantation near Sintuk, Kedah, Peninsula Malaysia (6°27'N, 100°29'E). The area experiences an annual dry season starting in mid December and ending in March. It was previously planted with rubber trees (*Hevea brasiliensis*) before conversion to oil palm. Tenera (DxP) palms (*Elaeis guineensis*) were planted in July 2000, at a density of 148 palms per hectare of Tebok series soil (Typic Paleudult). Standard estate management practices (e.g. fertilizer rate, pest management and harvesting) were applied to all the study plots, with drip irrigation only to the irrigated plots. All study plots were located on a relatively flat terrain.

B. Drip irrigation

A drip irrigation system was installed in 2002 using Netafim tape (ca. flow rate 1.6 liters/hour/hole; 0.5 m/hole spacing). The Netafim tape was buried 10 cm below the soil surface, about one meter distance from each palm row and near the frond pile area. This arrangement irrigates about half of the palm's rooting zone. The irrigation schedule was based on the palm canopy diameter and daily evapotranspiration pan reading. The later was used for determining the irrigation time based on the amount of water loss due to evaporation from the previous day. The minimum irrigation time was about one hour during the wet season to prevent blockage of the system. Water was pumped from a nearby river (Sungai Badak) into a water tank (ca. 10,000 liters) elevated at 3 m above the ground. The sediments are allowed to settle overnight before the water is used to irrigate the palms by gravity flow. Three of the study plots received drip irrigation and three adjacent control plots were not irrigated. The control plots were separated from the irrigated palms by a few rows of guard palms and a field road. Each study plots consist of 16 recording palms. The study plots were arranged in a practical systematic design.

C. Measurements

The site was equipped with instruments to continuously monitor meteorological conditions, such as air temperature, atmospheric humidity and rainfall. All meteorology data were automatically logged as hourly means or totals. The vapour pressure deficit (VPD) was derived from the air temperature and relative humidity data recorded at the site (Murray, 1967).

The standard non-destructive method was used for evaluating dry matter production of fronds and trunk as described by Corley *et al.* (1971) and Corley and Breure (1981). Bunch dry matter production was obtained from harvested fresh fruit bunch (FFB) yield by assuming 53 per cent dry matter in bunches as described by Henson (1997). Standing biomass, comprising fronds, trunk and developing bunches, were assessed in the course of the above measurements annually.

Roots were sampled using a root auger to extract soil cores (8 cm in diameter by 15 cm length) to a depth of 90 cm. A triangular sampling design was used as described by Tailliez (1971), where sampling was done in 16 sub-triangles within a main triangle plot marked by three adjacent palms. A total of 192 root core samples were taken from both the frond pile and harvesting path areas in

each study plot. Annual root sampling was done from October to November in each study year prior to the dry season. Each soil core was placed in a plastic tray, the soil loosens and live roots were carefully separated and placed in labeled plastic bags to prevent drying. Samples were brought to the laboratory, washed and sorted into primary (ca. > 2 mm diameter), secondary (ca. 1-2 mm diameter) and feeder (ca. < 1 mm diameter tertiary plus quaternary) root classes. The roots were then oven dried in the oven at 80°C until constant weight and then weighed to determine their dry weight.

Estimation of new root production and turnover was done by the in-growth core method as described by Henson and Chai (1997). All auger holes created by removing the first core samples were refilled with the original soil after careful removal of roots, and their positions marked. The reconstituted cores were resampled after an interval of six months and any new roots which had grown into them were removed, sorted into classes and oven dried as described above. The principle of this approach has been used to assess root turnover in forestry plantations (Persson, 1979). The relatively long interval before resampling was found necessary due to the slow growth of new roots into the cores. Root turnover (R_t) was calculated as follows:

$$R_t = 2c - (b-a)$$

Where a and b represent the standing root biomass present in years n and $(n+1)$, and c is the biomass of new roots produced in the half-yearly interval. The method assumes that no turnover of the newly produced roots takes place before sampling and that the rate of root production in the six months after sampling is the same as during the previous six months. Total root dry matter production (i.e. turnover plus biomass increment) is taken to equal $2c$.

A two-way analysis of variance was performed on the data to evaluate interactions between treatments and years using SPSS version 15.0 software. Comparison of means were made by the Tukey test and considered significant at $p < 0.05$.

III. RESULTS AND DISCUSSION

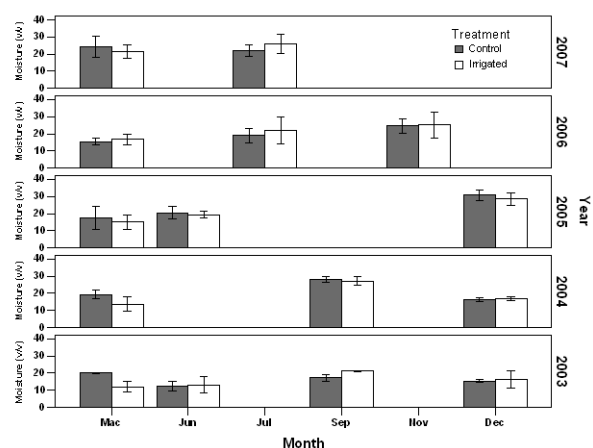


Fig.1. Gravimetric soil moisture content measured at suitable intervals (2003 to 2007) from the control and irrigated plots.

Fig. 1 shows that soil moisture content was not significantly different ($p < 0.05$) between the treatments or sampling intervals. Both control and irrigated plots had almost the same trend in soil moisture content ranging from 10 to 30% (v/v). This reflects the limitation of the gravity drip irrigation system that was implemented at the site. Another major constraint was the lack of water supply during the crucial dry month periods, which reduce the river water level.

Monthly rainfall events at the study plots from 2003 to 2007 are shown in Fig. 2. Between January 2005 and September 2005, there were nine months with rainfall less than 200 mm per month. The lowest monthly rainfall recorded was 0.2 mm in January 2005 and 8.5 mm in February 2005. Normally, the site receives an average annual rainfall of less than 2,000 mm per year, but in 2005 and 2007 it was greater than 2,000 mm (Fig. 2). This was due to the subsequent heavy rains received after the dry period. The highest monthly rainfall recorded was about 557.2 mm in December 2005 and the highest annual rainfall recorded was about 2,110.7 mm in 2007.

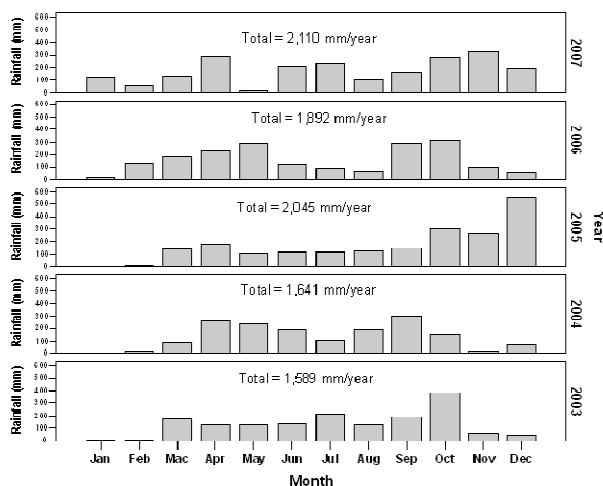


Fig.2. Monthly and annual rainfall recorded at the study site from 2003 to 2007.

Rainfall distribution has a great influence on palm growth, since the ideal requirement should be greater than 2,000 mm per year and evenly distributed throughout the year (Hartley, 1988; Goh *et al.*, 1994). In 2005, although there were nine months with less than 200 mm rainfall (Fig. 3), the annual rainfall received for 2005 was still greater than 2,000 mm (Fig. 2). For oil palm, a dry month is considered as a month with less than 100 mm of rainfall. However, Bakoume *et al.* (2013) reported the possibility of water deficits in months receiving up to 180 mm and that oil palm areas studied in Malaysia had an average of about 9 months water deficit.

High monthly vapour pressure deficit (VPD) values were observed from January to March of 2005 during the severe drought period, where values recorded were greater than 1.0 (Fig. 4). Similarly high VPD values were observed in February and March of 2007.

A high VPD value could impaired leaf gas exchange processes, such as photosynthesis and transpiration, largely due to stomatal closure in order to reduce water

loss through transpiration (Lorenzo *et al.*, 2003). This closing of the stomata will limit the rate of CO_2 uptake and hence limit photosynthesis and consequently affect plant growth. Kallarackal (1996) observed stomatal closure in oil palm when VPD was greater than 1.0 kPa. Evidently, VPD can have a major influence on palm canopy photosynthesis via its effect on stomatal conductance (Smith, 1989; Dufrene, 1989; Henson, 1991; 1995; Setyo *et al.*, 1996).

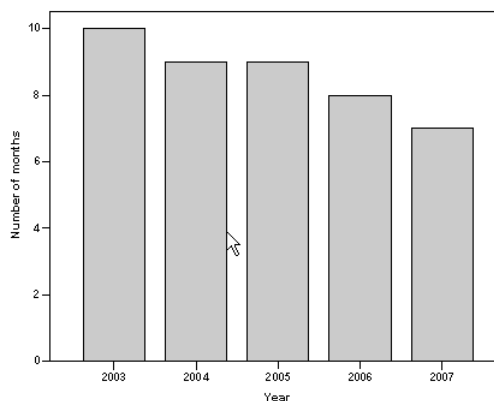


Fig.3. Number of months receiving less than 200 mm rainfall recorded at the study site from 2003 to 2007.

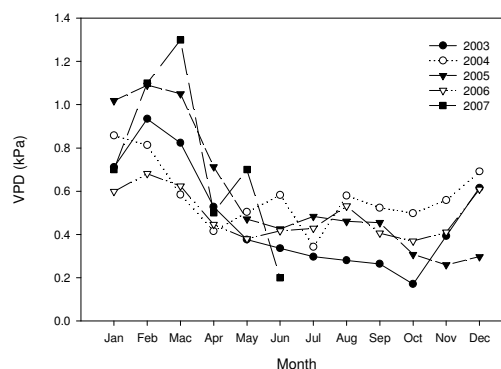


Fig.4. Monthly vapour pressure deficit recorded from the study site from 2003 to 2007.

Although the total aboveground biomass showed an increasing trend with increasing palm age from 3.5 to 7.5 YAP, there was no significant difference ($p < 0.05$) between control and irrigated palms (Table I). There was no significant difference ($p < 0.05$) in the root-to-shoot biomass ratio in both treatments, which showed an irregular trend with palm age. The standing root biomass contributed about 7 to 12 % of the total standing palm biomass. This was much lower than the values of 20 to 40% that was reported for coastal soils by Henson and Chai (1997). Irrigated palms had a slightly greater root-to-shoot ratio values as compared to control from 2004 to 2007. The annual FFB biomass was not statistical significant ($p < 0.05$) between the control and irrigated palms (Table I), but was significantly different ($p < 0.05$) between the years or palm age. Irrigated palms had a non-significant greater FFB biomass compared to control, except in 2006. During the drought in 2005, the irrigated palms had a non-significant increase of about 16% in

annual FFB biomass as compared to control. The high bunch load produced in 2005 might have contributed to the subsequent 3% reduction in FFB biomass yield in 2006. High bunch load often cause an increase in female inflorescence abortion that reduces the subsequent bunch number.

Table I: FFB biomass, total aboveground biomass and root-to-shoot biomass ratio from control and irrigated sites at Tanjung Genting ESPEK Estate in Sintuk, Kedah, Malaysia

Year	Palm age (year)	FFB Biomass (t/ha)		Total Above Ground Biomass (t/ha)		Root-to-Shoot ratio	
		Control	Irrigated	Control	Irrigated	Control	Irrigated
		2003	3.5	3.25±0.26Aa	3.59±0.14Aa	18.48±1.10Aa	18.12±0.52Aa
2004	4.5	6.71±0.41Ab	7.54±0.32Ab	27.31±0.51Ab	28.54±0.41Ab	0.07±0.01Aa	0.08±0.01Aa
2005	5.5	8.13±0.41Abc	9.48±0.95Abc	36.55±1.17Ac	36.95±0.98Ac	0.10±0.01Aa	0.12±0.02Aa
2006	6.5	10.77±0.37Acd	10.46±1.15Acd	48.90±1.67Ad	48.42±1.26Ad	0.08±0.01Aa	0.11±0.01Aa
2007	7.5	11.52±0.83Ad	11.79±0.85Ad	69.23±2.65Ae	68.98±1.54Ae	0.08±0.00Aa	0.09±0.02Aa

Means (± S.E.) in row followed by the same capital letter or in column followed by the same small letter are not significantly different at $p < 0.05$.

Note: Aboveground biomass excludes attached cut frond bases that were left on the trunk.

Table II: Oil palm root standing biomass, biomass increment, turnover and production from control and irrigated sites at Tanjung Genting ESPEK Estate in Sintuk, Kedah, Malaysia

Year	Palm age (year)	Root standing biomass (Rbi) (t/ha)		Root biomass increment (b-a) (t/ha/yr)		Root turnover (Rt) (t/ha/yr)	
		Control	Irrigated	Control	Irrigated	Control	Irrigated
		2002	2.5	1.07±0.24Aa	0.96±0.11Aa	-	-
2003	3.5	1.67±0.62Aa	1.43±0.39Aa	0.60±0.38Aab	0.47±0.28Aab	0.25±0.74Aab	0.15±0.48Aab
2004	4.5	2.03±0.24Aa	2.33±0.26Aa	0.36±0.56Aab	0.90±0.23Aab	1.24±0.41Abc	1.60±0.32Abc
2005	5.5	3.51±0.36Ab	4.46±0.59Ab	1.48±0.48Ab	2.13±0.61Ab	-0.50±0.87Aa	-0.55±0.72Aa
2006	6.5	4.15±0.62Abc	5.55±0.64Abc	0.64±0.28Aab	1.08±0.30Aab	2.18±0.20Ac	2.20±0.25Ac
2007	7.5	5.74±0.57Abc	6.58±1.74Abc	1.59±0.56Aab	1.04±1.27Aab	2.33±0.67Ac	3.38±0.70Ac
2008	8.5	5.64±0.77Ac	6.77±1.15Ac	-0.11±0.23Aa	0.19±0.59Aa	1.85±0.81Abc	1.78±0.39Abc

Year	Palm age (year)	Root production (Rp) (t/ha/yr)		% Root turnover (% Rt)		New root production (Rp/Rbi)	
		Control	Irrigated	Control	Irrigated	Control	Irrigated
		2002	2.5	-	-	-	-
2003	3.5	0.85±0.44Aa	0.62±0.22Aa	29.63	23.59	0.79	0.64
2004	4.5	1.60±0.56Aab	2.50±0.35Aab	77.53	63.97	0.96	1.75
2005	5.5	0.98±0.40Aa	1.58±0.32Aa	-51.10	-34.57	0.48	0.68
2006	6.5	2.82±0.31Abc	3.29±0.30Abc	77.35	67.03	0.80	0.74
2007	7.5	3.92±0.76Ac	4.41±0.57Ac	59.43	76.52	0.95	0.80
2008	8.5	1.74±0.58Aab	1.97±0.32Aab	106.08	90.44	0.30	0.30

Means (± S.E.) in row followed by the same capital letter or in column followed by the same small letter are not significantly different at $p < 0.05$.

The total standing root biomass and root biomass production of palms at the control and irrigated study plots over a six year period is presented in Table II. Results show no significant differences ($p < 0.05$) between control and irrigated plots, but there were significant differences ($p < 0.05$) between the years or palm ages. Standing root biomass shows an increasing trend with palm age for both control and irrigated palms. In contrast, root biomass increment, turnover and production showed an irregular trend with year or palm age. Root standing biomass was affected in 2005 during the drought, where irrigated palms had a non-significant 27% greater standing root biomass and 43.9% greater root biomass increment compared to control. During this drought period, both control and

irrigated palms had a negative root turnover, which indicates that root death was greater than new root production. This could be attributed to the 9 months with very low rainfall during the drought period. Although not significant, irrigated palms in general had a greater annual root biomass production as compared to control.

The total standing root biomass obtained from this northern peninsular dry site was much lower compared to the data from a west coast region of peninsular Malaysia reported by Henson and Chai (1997). They obtained a total standing root biomass of about 4.4 tonnes/hectare for four-year old palms on inland soil. In this study, the total standing root biomass was found to be much lower between 2.0 to 2.3 tonnes/hectare at 4.5 years after

planting, which was about 50% lower than that reported by Henson and Chai (1997). This could largely be attributed to differences in soil type and rainfall distribution between the two locations. Both factors could influence the amount of available water and nutrients required for oil palm growth.

IV. CONCLUSION

The belowground oil palm biomass was significantly affected by the dry climate in northern Peninsula Malaysia. Root biomass increment, turnover and production showed an irregular trend that was influenced by the seasonal variation in rainfall. The negative root turnover observed during a severe drought in 2005 indicates that root death was probably greater than new root production. Further studies are needed in order to have a better understanding of the overall oil palm growth under the different environmental conditions in Malaysia.

ACKNOWLEDGMENT

The authors thank the Director General of Malaysian Palm Oil Board for permission to publish this paper. We are most grateful to the management of Tanjung Genting ESPEK Plantation in Sintok, Kedah for their co-operation in conducting this study. We also like to thank staff from the Tropical Peat Research Institute, Agronomy and Farm Mechanization Units for their assistance in the field and laboratory.

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