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QUANTIFICATION OF OIL PALM BIOMASS AND NUTRIENT VALUE IN A MATURE PLANTATION. II. BELOW-GROUND BIOMASS

Keywords: below-ground biomass, nutrient stocks, nutrient value, oil palm roots.

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The below-ground biomass of oil palm in a mature plantation was sampled and its nutrient contents and values estimated. Root biomass in this study was quantified by using core sampling and excavation method. The estimated root biomass amounted to about 16 t ha^{-1} and the below-ground portions of trunk contributed little to the nutrient content of the stand. The total nutrient stocks from root biomass projected on per hectare basis were 65 kg N, 8 kg P, 128 kg K, 15 kg Mg and 12 kg Ca, in terms of monetary value worth about RM 278 ha-'. The results show that oil palm roots provide significant amounts of nutrients which can be recycled in the plantation ecosystem at replanting.

INTRODUCTION

Under zero burning practice, a large residual biomass from the previous stand is present on site at the time of replanting. This could provide a significant supplement of nutrients, particularly N and K, to the high external inputs of fertilizers required to support the growth of the replants, A considerable amount of work had been done on the estimation of oil palm biomass at different ages of the old stand at replanting in Malaysia. Most estimates of oil palm biomass and its nutrient availability were based solely on the availability of nutrients in the above-ground biomass excluding the significant contribution from the root biomass. It would be more accurate to include the below-ground biomass in estimating the nutrient reserves that are available for recycling in the ecosystem at replanting. Measurements were therefore made of the below-ground oil palm biomass, mainly root biomass, root bole biomass and their nutrient contents.

The root system of oil palm has been extensively studied in the past and its general structure and morphology are well known (e.g. Yampolsky, 1922; Wright, 1951; Fremond and Orgias, 1952; Lambourne, 1935; Purvis, 1956; Vine, 1956, Bachy, 1964; Ruer, 1967; Hartley, 1988; Tailliez, 1971). The oil palm has an adventitious root system consisting of primary, secondary, tertiary and quaternary roots. Primary roots emanate from the base of the trunk. Most of the primaries grow radially in a horizontal direction and can reach distances of more than 12 m away from the trunk (Wright, 1951). However, studies by Zaharah et *al.* (1989), using isotope technique on fertilizer placement, found that the lateral roots of mature oil palms can absorb nutrients as far as 36 m away from the point of application and hence, indicates extension beyond the rooting zone of adjacent palms at standard spacing.

The primary roots give rise to secondaries, of which about 70% will grow towards the soil surface, and 30% descend to considerable depths of more than 1 m. These secondaries will branch into tertiaries which in turn give rise to quaternaries. The diameter of the roots is also reduced progressively as they branch, *viz:* primary 5-10 mm, secondary l-4 mm, tertiary 0.5-1.5 mm, and quaternary 0.2-0.5 mm (Hartley, 1988).

The density of all classes of roots in the top 60 cm of soil usually decreases with distance from the palm, but with mature palms, the total quantity of absorbing roots in successive surrounding circles increases at least to radius of 3.5-4.5 m (Ruer, 1967). The greatest mass of roots is to be found between soil depths of 20 and 60 cm, and most of the adsorption of nutrients has been shown to be through the quaternaries and absorbing tips of primaries, secondaries and tertiaries to this depth (Taillez, 1971). The exact depth of root concentration however depends on the soil type (Chan, 1977). The concentration of roots at different depths also varies with soil type, water and nutrient availability, and physical and chemical properties of the soil.

In the present study, the root biomass of oil palm and its distribution patterns at different depths and positions were investigated and quantified. In addition, the biomass of the root bole and the palm trunk below the ground were also quantified.

MATERIALS AND METHODS

Measurements of Below-ground Biomass

Estimating below-ground root biomass involves more difficult field procedures compared to above-ground biomass and there are a variety of options available. The most common methods are by using excavation and core sampling. The excavation or trench method requires destructive procedures which can cause considerable disturbance to the plots. Core sampling involves removing soil samples to the required depths either with an auger or a cylindrical core sampler. The area selected for this study has been described in Khalid Haron et al. (1999).

Core Sampling

The method for quantifying root biomass and its distribution pattern in this study was adapted from Tailliez (1971) using a triangular sampling scheme and an auger method (Chan, 1977). This method enabled determinations of the root biomass at different locations, *e.g.* in the avenues and fronds piles, representing known areas of the plantation. The basic sampling unit consisted of a triangle with three neighbouring palms at the apices. It was subdivided into 16 sub-triangles with sides 2.20 m. One core was sampled at the centre of each triangle as shown in *Figure 1*. The corer consisted of a 15 cm steel tube with a serrated cutting edge, 8 cm internal diameter attached to a 1 m pipe marked at 15 cm intervals. The cores, with a volume of 754 cm^3, were taken to a depth of 60 cm in 15 cm increments.

A completely randomized block design was used for sampling the area of avenue and frond pile with four replicates or one replicate per block. Extraction of roots from the cores was carried out by pre-soaking the soil overnight in 5% sodium hexametaphosphate (Calgon) solution to disperse the clay and facilitate washing of the samples. The pre-soaked samples were then washed gently over two sieves with.2 mm and 0.2 mm mesh. The washed root samples were air dried followed by oven drying at 105°C to constant weight and then separated into primary, secondary and tertiary plus quaternary roots. No attempt was made to separate

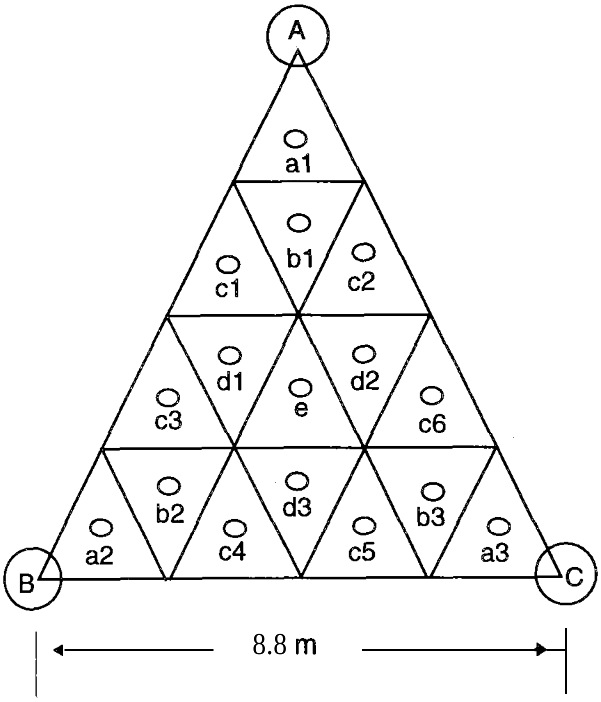

Figure 1. Schematic triangular sampling of root biomass using auger method (adapted from Tailliez, 1971).

the fine tertiary and quaternary roots. Samples of root for analysis of nutrient contents were collected separately, washed with water (without pre-soaking in sodium hexametaphosphate) and oven dried. Samples were ground and stored for analysis.

Excavation of Root Biomass at the Palm Base

The method of quantifying the root biomass at palm base involved digging a trench and using water jets to wash away the soil.

Three palms were used in this study where the palms were cut at ground level and the diameter of each palm recorded. The root biomass was determined in one quadrant of a circle of radius 1.5 m from the palm base to a depth of 100 cm. This sector was defined by digging a trench using an excavator *(Figure 2).*

The bulk of soil of the arc was then removed using high pressure water jets to wash away the soil. The sample of roots were collected by cutting the roots close to the trunk and separating them into O-50 cm and 50-100 cm depths.

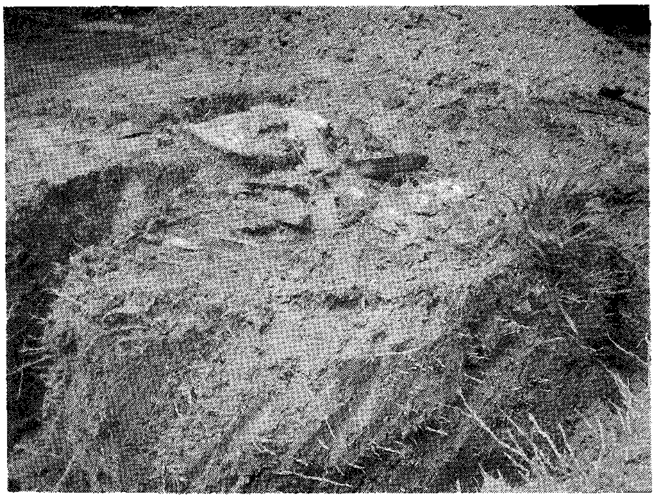

Figure 2. An arch of quarter circle for estimation of *root biomass at palm base.*

The bulk of roots were weighed and samples collected to determine the moisture content and dry weight.

Quantification of Root Bole Biomass

The method of quantifying root bole biomass involved removing the root boles of felled palms. Three palms were cut close to the ground and the base of the bole dug up using an excavator, approximately 1.5 m from the palm base and to a depth of 1 m ***(Figure 3).*** The earth from the root bole was washed away using a high pressure water jet. All the roots were cut close to the trunk and collected for biomass estimation. The palm trunk underneath the ground was also weighed and sampled for determinations of dry weights and nutrient contents.

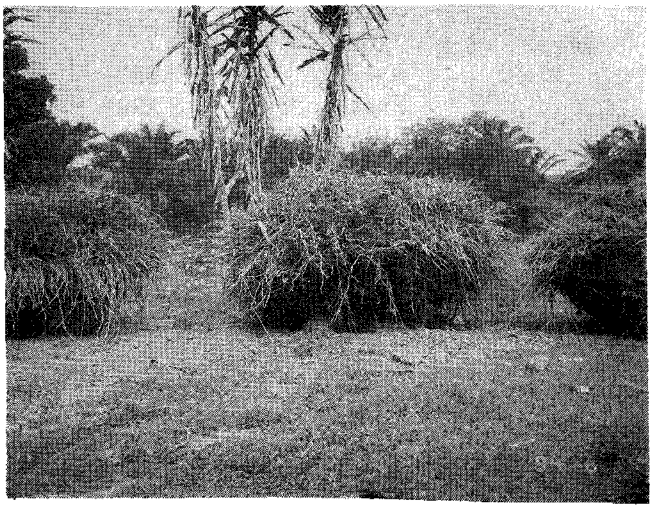

Figure 3. Root boles of oil palm (upside down).

RESULTS AND DISCUSSION

Quantification of Root Biomass Using the Auger Method

Table 1 shows data for root biomass at various depths in the avenue and frond pile within the plantation. At both locations, the primary roots contributed about 50% of total root, biomass followed by tertiary and secondary roots representing about 30% and 20% respectively.

The frond pile areas contained slightly higher root biomass amounting to 16.50 t ha-' compared with 15.28 t ha-" at the avenue giving a mean value of about 16.00 t ha-'. However, the difference was not significant and was mainly due to higher densities of primary and tertiary roots under the frond piles *(Table 1)*. The primary and secondary roots biomass at all depths showed no significant differences between the avenue and frond pile. In contrast, the tertiary root biomass of frond piles at O-15 cm depth was significantly higher compared to the avenues. However, there were no significant differences between both locations at greater depths. The higher root densities under the frond piles may be attributed to the good soil structure due to soil fauna activities and the availability of nutrients from decomposed pruned fronds. Bachy (1964) and Tailliez (1971) also found the highest concentration of roots in locations where there was better water and nutrient supplies such as under frond stacks.

Corley et *al.* (1971) estimated a root biomass of 130.8 kg palm^{-1} for 27.5-year-old palms to a depth of 90 cm. The value was equivalent to c. 17.79 t ha-" using 136 palms ha^{-1}. The value obtained in this study of 23-year-old palms was about 118 kg palm^{-1} which is relatively close to the value obtained by Corley *et al.* (1971).

Total root biomass obtained in this study was estimated to be about 16% of the total above- and below-ground biomass. The figure is similar to the average value obtained by Corley *et* al. (1971) for oil palm from 1.5 to 27.5 years old. However, in his study, the palms of 27.5 years age gave a higher value of about 24% where he found the root biomass at that age was almost double those from other age groups.

There was a similar trend of root biomass distribution by depth at both locations (*Figure 4*) where an increase was observed at 15-30 cm depth and a decline at 30-45 cm and 45-60 cm

TABLE 1. ROOT BIOMASS AT VARIOUS DEPTHS AND POSITIONS

Depth (cm)	position	Root dry matter (t ha^{-1})			
		Primary	Secondary	Tertiary	Total
o-15	Avenue	1.418	0.872	1.956	4.246
	Frond pile	0.917	0.837	2.620	4.374
	LSD (0.05)	0.651 (n.s)	0.183 (n.s)	0.522	
15-30	Avenue	2.987	1.064	1.161	5.212
	Frond pile	3.290	0.967	1.015	5.272
	LSD (0.05)	0.715 (n.s)	0.850 (n.s)	0.317 (n.s)	
30-45	Avenue	2.128	0.729	0.812	3.669
	Frond pile	2.578	0.824	0.873	4.275
	LSD (0.05)	0.960 (n.s)	0.404 (n.s)	0.433 (n.s)	
45-60	Avenue	1.055	0.551	0.543	2.149
	Frond pile	1.323	0.630	0.626	2.579
	LSD (0.05)	0.446 (n.s)	0.224 (n.s)	0.223 (n.s)	
O-60	Avenue	7.588	3.216	4.472	15.276
	Frond pile	8.108	3.258	5.134	16.500
	LSD (0.05)				1.803 (n.s)

Note: figures are mean of four replications.

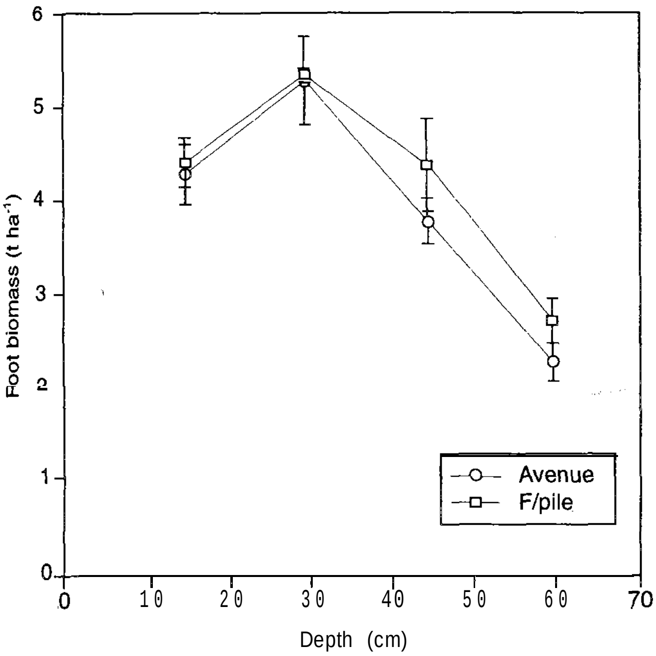

Figure 4. Depth distribution of total root biomass beneath the avenues and frond piles of a mature oil palm plantation.

depth. This was in agreement with Chan (1977) who found that root biomass increased from 15-45 cm and then decreased below this depth. Basically, the distribution of primary and secondary roots was similar except for the difference in their mass, while the total tertiary root biomass was concentrated in the top 30 cm and decreased with depth.

Most of the roots are concentrated round the stem base and within 50 cm from the ground surface (Hartley, 1988). As indicated in *Table* 2 and *Figure* 5, the density of roots decreased with distance away from the palm base. The density of roots in the middle of the triangle (c, d, and e sub-triangles) which was 3 m, 4 m, and 5m from the palm base respectively, was slightly higher in the frond piles compared with the same location at the avenue. However, there were no significant differences in roots densities between the two locations except the total root density in d1, d2, d3 triangles or 4 m from the palm base (Table 2).

TABLE 2. DENSITY OF ROOTS AT AVENUE AND FROND PILE POSITIONS AND VARIOUS DISTANCES FROM PALM BASE TO A DEPTH OF 60 cm

Distance (m)	Position	Root density ($kg\ m^{-3}$)			
		Primary	Secondary	Tertiary	Total
1m (a1, a2, a3)	Avenue	2.63	0.99	1.73	5.35
	Frond pile	2.77	0.94	1.98	5.69
	LSD (0.05)	0.467 (n.s)	0.688 (n.s)	0.776 (n.s)	0.925 (n.s)
2m (b1, b2, b3)	Avenue	1.39	0.61	0.90	2.90
	Frond pile	1.21	0.54	0.87	2.62
	LSD (0.05)	0.699 (n.s)	0.437 (n.s)	0.205 (n.s)	1.29 (n.s)
3m (c1, c2, c3, c4, c5, c6)	Avenue	1.11	0.49	0.59	2.19
	Frond pile	1.20	0.47	0.65	2.32
	LSD (0.05)	0.519 (n.s)	8.137 (n.s)	0.248 (n.s)	0.679 (n.s)
4m (d1, d2, d3)	Avenue	0.83	0.42	0.40	1.65
	Frond pile	1.16	0.57	0.62	2.35
	LSD (0.05)	0.436 (n.s)	0.366 (n.s)	0.245 (n.s)	8.646”
5m (e)	Avenue	0.80	0.33	0.34	1.47
	Frond pile	0.95	0.48	0.60	2.03
	LSD (0.05)	0.740 (n.s)	0.293 (n.s)	0.334 (n.s)	1.26 (n.s)

Notes: figures are mean of four replications.
*Significant at $P<0.05$.

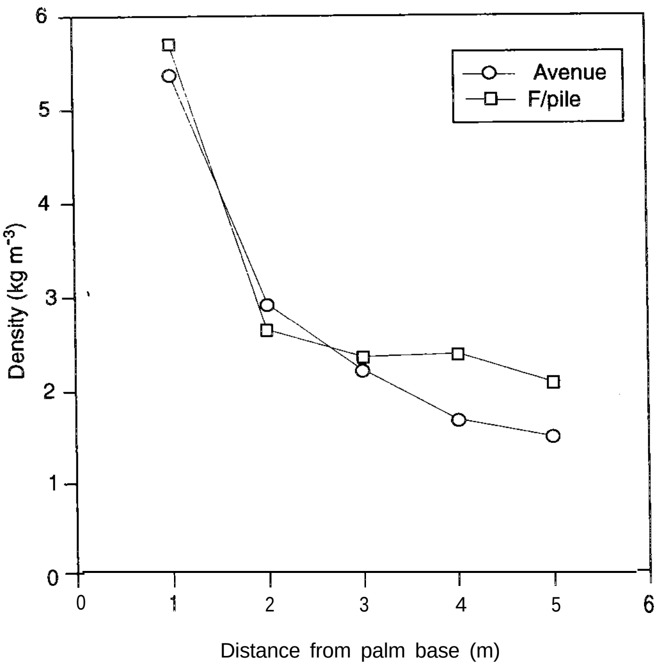

Figure 5. Density of roots from palm base at locations of avenue and frond pile.

Quantification of Root Biomass at the Palm Base

As mentioned earlier, roots are concentrated round the palm base because of the radial structure of the rooting system. Hence, it was important to quantify the root biomass at the palm base using methods other than the auger which is difficult to use in this zone. The use of two methods also enabled comparisons of the biomass estimates by the auger method with other methods involving trenching and excavation

Using the excavation method, it was found that the root biomass of three palms measured to a depth of 50 cm with 1.5 m radius ranged from 39.56 kg to 57.36 kg palm-' with a mean of 46.88 kg palm^{-1} (*Table 3*). The root biomass decreased with depth and at 50-100 cm, it was 20.18 kg to 25.60 kg palm-' with the mean being 23.31 kg palm-l. The mean value of total root biomass to a depth of 100 cm was 70.19 kg palm-l. The densities of roots at the palm base from O-50 cm, 50-100 cm and total O-100 cm depth were 8.94, 4.46 and 6.70 kg m^{-3} respectively *(Table 3)*.

Compared with the auger method, the density of roots obtained by the excavation method from O-50 cm depth, at 8.94 kg m^{-3}, was slightly higher than the mean value of 5.52 kg m^{-3} for the auger method at the frond pile and avenue locations near the palm base which were at al, a2, a3 triangles, about one metre from the palm base. This infers that estimation of root biomass at palm base to a depth of 50-60 cm using auger method only gave about 62% root recovery compared to biomass estimates using the excavation method. The recovery of roots in the auger method may, in fact, be less than 62% since some of the tertiary and quaternary roots were washed away by the high pressure water jet used in the excavation method. From the above, it appears that the auger method under-

TABLE 3. ROOT BIOMASS AND DENSITY AT PALM BASE USING EXCAVATION METHOD

	Sample No.			
	1	2	3	Mean (±S.E)
Trunk diameter (cm)	67	76	74	72
Root dry matter (kg palm^{-1})				
Q-50 cm	43.72	57.36	39.56	46.88 (5.38)
50-100 cm	25.60	20.18	24.16	23.31 (1.62)
Total	69.32	77.54	63.72	70.19 (4.01)
Root density (kg m^{-3})				
0-50 cm	8.55	10.77	7.50	8.94
50-100 cm	5.01	3.79	4.58	4.46
0-100 cm	6.78	7.28	6.04	6.70

estimated the measurement of root biomass, especially close to the plam base where high densities of primary and secondary roots were found,

Mass of Root Boles

These studies were aimed at quantifying the trunk biomass below the ground level and the associate root biomass at the base of the palm. The biomass of the root bole was estimated by excavating the bole with an excavator to a depth about 1.5 m and to a radius of about 1.5 m from the palm base. Studies by Vine (1956) found, in addition to the radiating horizontal primaries, an abundance of primary roots produced directly under the base of the palm for anchorage which descend vertically or diagonally into the soil.

Table 4 shows the trunk and root mass of the palm boles. The weight of roots ranged from 45.73 kg $palm^{-1}$ to 52.27 kg palm-l with a mean value of 49.40 kg palm-l and the weight of trunk below the ground ranged from 39.56 kg palm-l to 54.83 kg $palm^{-1}$ with a mean value of 45.01 kg palm-l. Using the above figures, it was estimated the biomass of trunk below the ground level was about 6.12 t ha^{-1} contributing little to the total biomass of the plantation.

Nutrient Stocks in Below-ground Biomass

The nutrient stocks of below-ground biomass were calculated from total root biomass from *Table 1* multiplied by the nutrient concentrations in *Table* 5. The calculated nutrient stocks of the below-ground biomass are given *in Table 6.*

Significant quantities of N and K amounting to 65 kg ha^{-1} and 128 kg ha-' respectively were found in the root biomass. However, compared to the above-ground biomass, the roots only

TABLE 4. DRY WEIGHT OF BELOW-GROUND TRUNK BASE AND ROOT MASS IN ROOT BOLES

Sample No.	Dry wt. (kg $palm^{-1}$) 1	2	3	Mean (±S.E)
Root mass	45.73	50.20	52.27	49.40 (1.93)
Trunk mass	54.83	40.65	39.56	45.01 (4.92)
Total	100.56	90.85	91.83	94.41 (3.09)

TABLE 5. MEAN NUTRIENT CONCENTRATION ON DRY MATTER (%) OF OIL PALM ROOTS '(using auger method) AND BELOW-GROUND PORTIONS OF TRUNK

Component	N	P	K	Mg	Ca
Primary root	0.41 (0.37-0.45)	0.037 (0.034-0.041)	0.88 (0.82-0.95)	0.07 (0.06-0.09)	0.07 (0.06-0.07)
Secondary root	0.54 (0.51-0.58)	0.047 (0.046-0.048)	0.87 (0.81-0.94)	0.12 (0.11-0.12)	0.07 (0.06-0.07)
Tertiary root	0.64 (0.54-0.69)	0.071 (0.058-0.081)	0.65 (0.62-0.68)	0.12 (0.10-0.16)	0.09 (0.06-0.12)
Below-ground trunk	0.39 (0.38-0.40)	0.018 (0.017-0.019)	0.99 (0.95-1.04)	0.08 (0.06-0.09)	0.19 (0.18-0.20)

Note: figures in parentheses are the concentration range of four replicates and three replicates for below-ground trunk.

TABLE 6. BELOW-GROUND NUTRIENT STOCKS OF ROOT BIOMASS AND TRUNK (kg ha-“) SAMPLED FROM ROOT BOLES

Component	Dry matter ($t\ ha^{-1}$)	N	P	K	Mg	Ca
		(kg ha-“)				
Primary root	7.85	32.19	2.90	69.08	5.50	5.50
Secondary root	3.24	13.28	1.52	28.19	3.89	2.27
Tertiary root	4.80	19.68	3.41	31.20	5.76	4.32
Total	15.89	65.15	7.83	128.47	15.15	12.09
Trunk	6.12	23.87	1.10	60.59	4.90	11.63

TABLE 7. NUTRIENT CONTENT, FERTILIZER EQUIVALENT AND MONETARY VALUE OF ROOT BIOMASS AT REPLANTING

Palm residues	Dry matter ($t\ ha^{-1}$)	Nutrient ($kg\ ha^{-1}$)			
		N	P	K	Mg
Root biomass	15.89	65	8	129	15
Fertilizer equivalent		A/S	CIRP	MOP	KIES.
		310	51	258	96
*Monetary value (RM)		111	15	114	38
Total monetary value RM 278 ha^{-1}					

Note: * Based on government price in 1996:- A/S: RM 360 t^{-1}, KCl: RM 400 t-l, CIRP: RM 300 t^{-1}, Kieserite: RM 400 t-l.

contributed about 10%-12% of total N and K. The amounts of P, Mg and Ca contained in the root biomass were relatively small and only amounted to about 8 kg ha-‘, 15 kg ha^{-1} and 12 kg ha^{-1} respectively. These represent only about 15% of P, 11% of Mg and 4% of Ca contained in the above-ground biomass. In monetary terms, the value of the root biomass was RM 278 ha^{-1} (*Table 7*) of fertilizer equivalent.

The nutrient contents of below-ground portions of trunk are also given in *Table 6*. They amounted to 24 kg N, 1 kg P, 60 kg K, 5 kg Mg and 11 kg Ca ha^{-1} and contributed little to the nutrient content of the stand.

CONCLUSION

In this study on the below-ground biomass of oil palm, it was found that about 16 t ha^{-1} of root biomass was present at the time of felling containing a nutrient stock of about 65 kg N, 8 kg P, 129 kg K, 15 kg Mg, and 12 kg Ca ha-’ with a monetary value of RM 278 in fertilizer equivalent. The nutrient reserves that were available from below-ground biomass could be recycled in the ecosystem at replanting and need to be considered in formulating fertilizer rates for the replants

The below-ground portions of trunk contributed very little nutrient compared with the nutrient stocks for the whole oil palm biomass. The stumps and major roots of the palm also constitute localized masses of nutrients inputs.

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