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QUANTIFICATION OF OIL PALM BIOMASS AND NUTRIENT VALUE IN A MATURE PLANTATION. I, ABOVE-GROUND BIOMASS

Keywords: Above-ground biomass, nutrient stocks, nutrient value, oil palm components.

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Oil palm biomass in a mature plantation was quantified and the availability of its nutrient contents and values was estimated. In the present study, the nutrient stocks of above-ground standing oil palm biomass and the contribution of each palm component were quantified and measured directly in order to obtain more precise values. The total above-ground biomass amounted to about 85t ha^{-1} and the trunk contributed the major portion to about 48% of oil palm standing biomass. The total nutrient stocks of above-ground biomass produced at felling of old stands based on per hectare basis are 577kg N, 50kg P, 1255kg K, 141kg Mg and 285kg Ca which could be recycled in the plantation both as organic matter and savings in monetary value worth about RM 2550 ha^{-1}. Removal of this biomass for other value-added products has implications forplantation management in terms of losses of nutrients and organic matter to maintain soil fertility. Appropriate management of this biomass could enable its carry-over of nutrients necessary to support the growth of the following rotation of crop.

INTRODUCTION

The oil palm as a perennial crop has grown into prominence, firstly, as a major source of oils and fats for human food. secondly, as animal feeds, and, thirdly, for making of many domestic products such as cosmetics, soaps and detergents. Replanting of oil palm normally carried out after about 25-30 years. is due to tall palm harvesting problem and other economic considerations. The expected replanting area of oil palm in Malaysia from 1997 until 2000 is estimated to be about 82 000 hectares per year (Mohamad et al., 1985). During replanting, the main components of above-ground oil palm biomass available are the trunks and fronds of the old stand. Appropriate management of this biomass following felling may enable the carryover of its nutrient contents to support the growth of the following rotation. This could provide a significant nutrient supplement, particularly for N and K, to offset the high external inputs of fertilizers required to maintain maximum yield potential. However with alternative use, these sources of biomass could generate high amount of valuable lignocellulosic materials for industrial purposes and for animal feed.

In order to estimate the availability of oil palm biomass and its nutrient contents, it is necessary to quantify the biomass of each component in the mature stand. Most previous studies on estimation of oil palm biomass and its nutrient availability tend to be based solely on the availability of nutrients in the above-ground biomass but exclude the significant contribution from the root biomass. Thus, it would be more accurate to include both the above- and below-ground biomass in estimating the nutrient reserves as both are available for recycling in the ecosystem at replanting.

A considerable amount of work has been done on the estimation of oil palm biomass at various ages and of old palms during replanting in Malaysia (Ng et al., 1968; Gray, 1969; Corley et al., 1971; Chan et al., 1980; Tan et al., 1985; Mohamad et *al.,* 1985; Mohd Hashim et al., 1993) and in other countries such as Nigeria (e.g. Rees and Tinker, 1963). Many of these studies involve the estimation of potential biomass and nutrient contents derived from earlier analyses reported in the literature (e.g. Chan et al., 1980; Tan *et al.,* 1985; Mohamad et al., 1985) and there is little detailed information on the various components of above- and below-ground biomass of mature plantations. Hence, it is important to make direct measurements of the standing palm biomass in the specific area of study to obtain more precise values of the nutrient pools and the availability of biomass.

A study was made to measure the nutrient stocks of above-ground standing oil palm biomass and the contribution of each palm component. In addition, the below-ground oil palm biomass, mainly root biomass, and its nutrient content were computed.

This paper is aimed at providing information on the potential availability of above-ground mature oil palm biomass and its nutrient value.

MATERIALS AND METHODS

Estimates of Standing Above-ground Biomass and Destructive Sampling

A study was conducted to estimate the standing above-ground biomass of oil palm at the PORIM Research Station, Kluang, Johor in a region which has fairly typical agroecological conditions of inland soils in West Malaysia. The area selected for this study was a 23-year old oil palm plantation of first rotation planted at a density of $136 ha^{-1}$.

Oil palm biomass in mature plantations can be measured directly by destructive sampling of a few palms and weighing all the major biomass constituents. Fortunately, this procedure is less tedious compared to other tree species since the oil palm has a single growing apex without branches. The above-ground biomass of the plantation can be easily estimated with some accuracy from allometric relationships of trunk height and diameter established by Corley et *al.* (1971).

Ten palms were sampled to confirm the published allometric relationship used to estimate total biomass for the stand.

The selected area was divided into four blocks and palms of average height and trunk diameter at breast height were chosen on a random basis from each of the block size classes. The palms selected for felling ranged between 42cm to 46cm in diameter and were approximately 6m to 9m tall. Palm height was measured from ground level to the base of Frond 33 following the standard procedure (Corley et al., 1971). The number of fronds were recorded and all unripe and ripe fruit bunches pruned off from each palm before felling.

The palms were felled by cutting with a chain saw close to the ground. Four palms, one from each block, ware then partitioned into major components and weighed. The trunks of the other six palms were cut into equal sections and loaded, with the crown, onto a trailer so that the total mass could be determined at a local weighbridge. This procedure provided a check of the errors involved in partitioning and weighing of the various components during destructive sampling.

The persistent cut bases of the fronds remaining from earlier harvesting of fruit bunches may continue to be attached to the palm trunk or become dislodged. These frond bases, when present, constitute a significant source of biomass. In this study, of the four palms selected for sectional destructive sampling, one was chosen with full frond bases on the trunk and three palms were without frond bases, Similarly, for the non-sectional sampled palms, three were chosen with frond bases on the trunk and another three without frond bases. This procedure enabled an estimation of the biomass of cut frond bases on the trunks.

For sectional destructive sampling, the palms were separated into various components. The fresh components were weighed and recorded immediately in the field and sub-samples of each component collected for moisture content determination and analysis of nutrient content.

The palm was partitioned into seven components as follows:

1. Leaflets.
2. Rachis (including petiole).
3. Spears.
4. Growing point or 'cabbage'.
5. Trunk.
6. Frond bases.
7. Inflorescences.

Each component involved different handling procedures:

Leaflets. Leaflets for nutrient analysis were sampled from every frond (two leaflets per frond) and the sub-samples bulked into one composite sample. The fresh leaflets were stripped off the rachises and weighed in sacks. Sub-samples from each frond were obtained for dry matter and moisture content determination.

Rachis (including the petiole). Each rachis was cut as close to the trunk as possible and sectioned into three equal parts. The fresh weight was recorded and sub-samples of each section from the middle part for each rachis were collected and bulked for dry weight and nutrient analysis.

Spears. The spears were sub-sampled the same way as the frond but the leaflets were not separated. No distinction was made between rachis and leaflets in the spears. The sub-samples were collected for the dry weight and nutrient analysis.

'Cabbage'. The 'cabbage' was cut off from the apex of the trunk and sub-samples taken for moisture content determination and nutrient content analysis.

Trunk. The trunk was cut into three equal sections and weighed. Sub-samples of trunk from each section were collected for nutrient analysis and moisture content determination.

Frond ***bases.*** The biomass of frond bases was estimated from one of the four sectional destructive sampling palms which had full frond bases on the trunk. All the frond bases were removed from the trunk by cutting off as close to the trunk as possible and the fresh weight recorded. Sub-samples were collected for nutrient analysis and moisture content determination.

Inflorescences. Inflorescences were collected and weighed to obtain the fresh weight and sub-sampled for nutrient analysis and moisture content determination.

Analyses

The moisture contents of all palm components were determined by collecting small samples about 1-2kg. These samples were weighed and dried to a constant weight at 105°C. Sub-samples for nutrient analysis were oven dried at 80°C and the materials were then ground and analysed to determine concentrations of C, N, P, K, Ca and Mg using standard analytical procedures. The total nutrient contents of various palm components on a plot basis were calculated from the dry matter content of the standing biomass based on a palm density of 136 palms ha^{-1}.

RESULTS AND DISCUSSION

Measurements of Above-ground Biomass

The fresh weights of the component parts of the sampled palms are shown in Table *1.* The fresh weight was included in this study to compare the weight of sectional (Samples 1 to 4) and non-sectional destructive palms (Samples 5 to 10). The palms ranged between 5.92m to 9.12m in height, and the total number of fronds ranged from 32 to 47 fronds, with an average of 41 fronds, except for one palm which had 23 fronds. The trunk diameter ranged from 0.39m to 0.43m at the top, 0.42m to 0.46m in the middle and 0.55m to 0.80m at the bottom. The lower part of the trunk has a conical shape but this variation does not contribute to significant errors to biomass estimates using the simple allometric functions.

The fresh weights of sectional palms (without frond bases) ranged between 1972 to 2386kg palm' and were comparable to the fresh weights of non-sectional palms (without frond bases1 which ranged from 1830 to 2530kg $palm^{-1}$ at various heights. The data indicate that no significant error was introduced by dividing and weighing each palm component in sections. Tan et *al.* (1985) determined the fresh weight of a 25-year old palm as 1934kg with a trunk length of 7.9m and 32 fronds. This value was slightly lower than those obtained in this study for a palm of 7m to 8m height.

The relationship between total fresh weight of palms and palm height using sample Palms 1 to 7 without frond bases is shown in *Figure 1.* The other three palms (8 to 10) were not

TABLE 1. FRESH WEIGHTS OF THE ABOVE-GROUND COMPONENT PARTS OF TEN MATURE OIL PALMS

	* Without frond bases (sectional)					Without frond bases (non-sectional)			With frond bases (non-sectional)		
Sample No.	1	2	3	4	(Mean ±S.E)	5	6	7	8	9	10
Palm height (m)	8.72	7.26	5.92	8.00	(7.48 ±0.6)	8.00	9.12	6.20	8.05	9.12	6.50
No. of fronds	39	37	44	39	(40 ±1.5)	47	32	41	47	41	23
Trunk diameter (m)											
Top	0.37	0.40	0.43	0.41	(0.40 ±0.013)	0.39	0.42	0.40	0.43	0.43	0.39
Middle	0.42	0.42	0.45	0.42	(0.43 ±0.008)	0.42	0.43	0.46	0.45	0.45	0.45
Bottom	0.58	0.80	0.79	0.74	(0.73 ±0.05)	0.70	0.76	0.75	0.64	0.63	0.55
Wt.of fresh component (kg)											
1) Trunk	1660	1480	1350	1540	(1508 ±64)	–	–		–	–	
2) Leaflets	152	143	125	160	(145 ±8)		–	–	–		
3) Rachis	460	433	425	492	(453 ±15)		–	–	–		–
4) spears	42	46	33	50	(43 ±4)	–	–	–	–	–	–
5) 'Cabbage'	45	43	35	55	(45 ±4)				–		–
6) Inflorescences	27	30	4	40	(25 ±8)				–	–	–
7) Frond bases	538	0	0	0			–	–	–	–	–
Total wt. (kg $palm^{-1}$)	2386"	2175	1972	2337	(2218 ±93)	2350	2530	1830	2900	3160	2190

* Palm with full frond bases on the trunk and the frond bases were removed after felling.

** Total wt. of palm without frond bases.

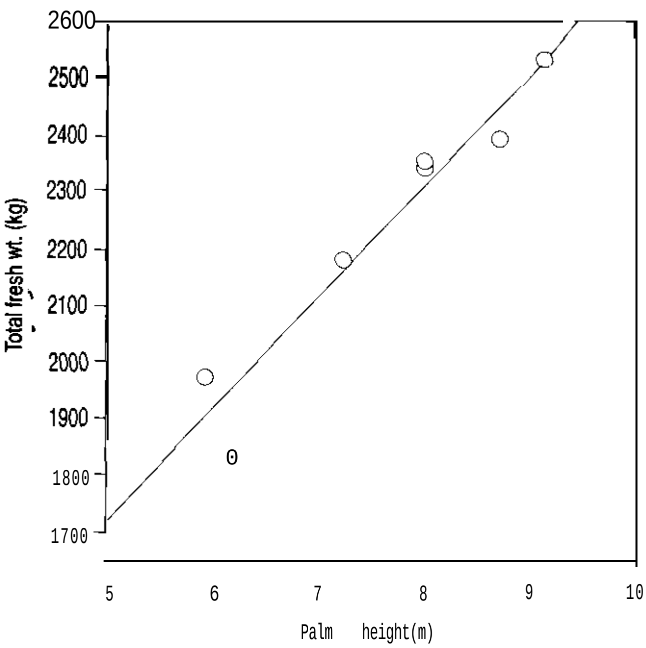

Figure 1. Relationship between palm height (H) and total fresh weight (W) of palm. The plotted regression line is the function of W = 725 + 197H (r = 0.96, P < 0.001).

included due to the presence of frond bases on the trunk which gave additional total weight. The total fresh weight was significantly correlated with palm height ($r = 0.96$, $P < 0.05$) according to the regression function:

$$W = 725 + 197H$$

where H is the palm height (m) and W the total fresh weight (kg).

In calculating the biomass of frond bases, by substracting sampled palms without frond bases from sampled palms with frond bases, it was found that the frond bases contributed to about 18%-22% of the total standing biomass, This proportion is in agreement with the estimates of frond bases constituting 20% of standing biomass by Henson (1993).

The weights of dry matter of the various palm components obtained *from* sectional samples are shown in *Table 2. The* average values for the four sectional palms obscure the variation in pool size. However, the standard errors are less than 10% of the mean

TABLE 2. DRY WEIGHTS OF THE ABOVE-GROUND COMPONENTS OF FOUR MATURE OIL PALMS

	Parameters			Dry wt. (kg palm^{-1})						
Sample No.	Height to base frond 33 (m)	Trunk diameter (m)	No. of fronds	Trunk	Leaflets	Rachis	Spears	'Cabbage'	Frond bases	Inflorescences
1	3.72	Top : 0.37 Middle : 0.42 Bottom: 0.58	39	332	60.80	119.60	9.24	4.50	129.12	6.75
2	7.26	Top : 0.40 Middle : 0.42 Bottom: 0.80	37	296	57.20	112.58	10.12	4.30	0	7.50
3	5.92	Top : 0.43 Middle : 0.45 Bottom: 0.79	44	270	50.00	110.50	7.26	3.50	0	1.00
4	8.00	Top : 0.41 Middle : 0.42 Bottom: 0.74	39	308	64.00	127.92	11.00	5.50	0	10.00
Mean	7.48	Top : 0.40 Middle : 0.43 Bottom: 0.73	40	302	58.00	117.65	9.40	4.45	0	6.31

for all components except the inflorescences. The palm trunks contained only about 20% of dry matter from fresh material. The trunk biomass ranged from 270kg to 332kg palm^{-1} with the mean value of 302kg palm.'. This agrees with Corley et al. (1971) who estimated the weight of palm trunk at an age of 27.5 years to be about 300kg. Ng et al. (1968) reported that the trunk weight at 15 years was 651kg palm-' whereas Corley et al. (1971) estimated a value of 233kg palm-' for dry weight of trunk at 14.5 years old. The high value obtained by Ng et al. (1968) could be due to the weight of frond bases remaining on the trunk. Tinker and Smilde (1963) reported that the trunk dry matter weight in a 22-year old oil palm in Nigeria amounted to 344kg palm-' which is comparable to the figures obtained in this study.

The biomass of leaflets ranged from 50 to 64kg palm-' with the mean value of 58kg palm^{-1}. The biomass of leaflets was about half the biomass of rachises which had a mean value of 118kg palm^{-1}. The dry weight of leaflets was closely related to dry weight of rachis by the regression:

$$WR = 189 + 1.82\ WL\ [r = 0.90,\ P < 0.11$$

where WR is the weight of rachis (kg) and WL the weight of leaflets (kg).

Spears, 'cabbage' and inflorescences made only a small contribution to the total dry matter with mean values of 9.40 (1.5%), 4.45 (0.7%) and 6.31 (1.0%) kg palm-' respectively.

As mentioned earlier, the frond bases contributed quite a substantial biomass, of about 130kg palm' and about 20% of the total standing biomass, and therefore cannot be ignored in the estimation of biomass and nutrient capital in oil palm plantation.

Nutrient Concentrations in Biomass Components of Oil Palm

Nutrient concentrations in the above-ground biomass of the various palm components varied widely as shown in ***Table*** 3. Nitrogen concentrations showed nearly a 14 fold variation from 0.23% in frond bases to 3.12% in 'cabbage'. Frond bases, rachis and trunk had lower N concentrations than leaflets, spears, 'cabbage' and inflorescences.

TABLE 3. MEAN NUTRIENT CONCENTRATIONS ON DRY MATTER (%) OF 'VARIOUS OIL PALM COMPONENTS

Component	N	P	K	Mg	Ca
Trunk	0.56	0.054	1.62	0.15	0.31
	(0.54-0.59)	(0.047-0.059)	(1.03-2.13)	(0.11-0.16)	(0.21-0.40)
Leaflets	2.18	0.116	0.98	0.21	0.52
	(1.97-2.34)	(0.092-0.137)	(0.81-1.13)	(0.17-0.24)	(0.39-0.63)
Rachis	0.45	0.049	1.52	0.11	0.43
	(0.39-0.50)	(0.043-0.055)	(1.16-2.10)	(0.09-0.15)	(0.24-0.58)
Spears	2.14	0.152	1.72	0.23	0.42
	(1.90-2.44)	(0.126-0.165)	(1.43-2.10)	(0.17-0.31)	(0.31-0.60)
'Cabbage'	3.12	0.387	3.45	0.51	0.38
	(2.63-3.57)	(0.319-0.472)	(2.69-3.83)	(0.41-0.56)	(0.31-0.45)
Frond bases	0.23	0.027	1.18	0.20	0.20
Inflorescences	1.94	0.254	2.24	0.43	0.55
	(1.90-1.97)	(0.236-0.271)	(2.08-2.40)	(0.38-0.48)	(0.54-0.56)

Figures in parentheses are the concentration ranges of the four destructively harvested palms.

The phosphorus concentration also varied 14 fold from 0.027% in frond bases to 0.387% in 'cabbage'. The woody frond base, rachis and trunk had much lower concentrations of P than the more vegetative components of leaflets, spears, 'cabbage' and inflorescences.

Potassium concentrations were lowest in the leaflets at 0.98% but concentrations in the trunk, rachis and spears were higher and quite similar at 1.62%, 1.52% and 1.72% respectively. The concentration of K was highest in the 'cabbage' at 3.45%.

Magnesium concentrations varied 4.6 fold from 0.11% in rachis to 0.51% in the 'cabbage'. The concentration of Mg in leaflets was almost double that in the rachis. The concentration of Mg in the trunk was intermediate between the rachis and leaflets.

Calcium concentrations in the tissues showed the least variation, ranging only 2.8 times from 0.20% in frond bases to 0.55% in inflorescences. The 'cabbage' had the highest concentrations of all other nutrients except Ca.

N was significantly correlated with P ($r = 0.879$. $P > 0.01$) and the P concentration was also significantly correlated with K ($r = 0.905$, $P > 0.01$) in all the palm components. The K concentration was also correlated with Mg ($r = 0.902$, $P > 0.01$).

Nutrient Stocks and Percentage Dry Matter Contribution in Above-ground Biomass

The total nutrient stocks in the various oil palm components expressed on a per palm and per hectare basis are shown in *Tables* 4 and 5. Estimation of nutrient stocks per hectare was based on a planting density of 136 palm ha'. The palm contains about 4kg N reserve whereas K at about 8kg palm-' was double that of N (*Table 4*). The figure agrees with Teoh and Chew (1987) who reported that manured older mature palms contained 8 to 14kg K palm^{-1}. The quantity of K in the palms at replanting is substantial and should be conserved through recycling. Mg content was about lkg palm-' and Ca content was double that of Mg at about 2kg palm^{-1}. P was less than 0.4kg palm-'.

TABLE 4. ABOVE-GROUND NUTRIENT POOLS IN PALM COMPONENTS OF MATURE PALMS

Palm components	Dry matter kg palm-'	N		P		K		Mg		Ca	
		%	kg palm^{-1}	%	kg palm-'	%	kg palm^{-1}	%	kg palm^{-1}	%	kg palm^{-1}
Trunk	302.00	0.56	1.691	0.054	0.163	1.62	4.892	0.15	0.453	0.31	0.936
Leaflets	58.00	2.18	1.264	0.116	0.067	0.98	0.568	0.21	0.122	0.52	0.302
Rachis	117.65	0.45	0.529	0.049	0.058	1.52	1.788	0.11	0.129	0.43	0.506
Spears	9.40	2.14	0.201	0.152	0.014	1.72	0.162	0.23	0.022	0.42	0.039
'Cabbage'	4.45	3.12	0.140	0.387	0.017	3.45	0.153	0.51	0.023	0.38	0.017
'Frond bases	129.12	0.23	0.297	0.027	0.035	1.18	1.524	0.20	0.258	0.20	0.258
Inflorescences	6.31	1.94	0.122	0.254	0.016	2.24	0.141	0.43	0.027	0.55	0.035
Total (without frond bases)	498		3.947		0.335		7.704		0.776		1.835
Total (with frond bases)	627		4.244		0.370		9.228		1.034		2.093

* Estimated from one palm.

TABLE 5. TOTAL ABOVE-GROUND BIOMASS. PERCENTAGE BIOMASS CONTRIBUTION AND NUTRIENT CONTENTS OF VARIOUS OIL PALM COMPONENTS

Components	Dry wt.		Nutrient content (kg ha⁻¹)				
	(tonnes ha-')	% total	N	P	K	Mg	Ca
Trunk	41.07	48.17	230.0	22.2	665.3	61.6	127.3
Leaflets	7.69	9.25	171.9	9.1	77.2	16.6	41.1
Rachis	'16.00	18.77	71.9	7.9	243.2	17.5	68.8
Spears	1.28	1.50	27.3	1.9	22.0	3.0	5.3
'Cabbage'	0.60	0.70	19.0	2.3	20.8	3.1	2.3
Frond bases	17.56	20.60	40.4	4.8	207.3	35.1	35.1
Inflorescences	0.86	1.01	16.6	2.2	19.2	3.7	4.8
Total	85.26	100.00	577.1	50.4	1255.0	140.6	284.7

Note: calculation was based on 136 palms ha^{-1}.

The total above-ground dry matter and nutrient pools produced by the oil palm components on per hectare basis at felling are shown in *Table* 5. The total above-ground biomass amounted to about 85t ha-' of which the trunk produced the greatest amount of dry matter contributing about 48% to the total above-ground biomass.

Frond bases, rachises and leaflets contributed about 21%, 19%, and 9% of the total above-ground biomass respectively. The rest of the components which include spears, 'cabbage' and inflorescences contributed about 3.2% of the total above-ground biomass.

The total nutrient stocks of above-ground biomass available at felling on a per hectare basis was 577kg N, 50kg P, 1255kg K, 141kg Mg and 285kg Ca. In terms of inorganic fertilizers, the quantity of nutrients is equivalent to approximately 2.75 tonnes of sulphate of ammonia (A/S), 0.32 tonne of Christmas Island rock phosphate (CIRP), 2.51 tonnes of muriate of potash (MOP) and 0.91 tonne of kieserite. In monetary value, this is worth about RM 2550 ha' *(Table 6)*. Mohd Hashim et al. (1993) quoted slightly lower values for nutrient inputs from a hectare of whole stand residues at replanting which were about 339kg

TABLE 6. NUTRIENT CONTENT, FERTILIZER EQUIVALENT AND MONETARY VALUE OF OIL PALM BIOMASS AT REPLANTING

Palm residues	Dry matter (tonnes ha⁻¹)	Nutrient (kg ha-')			
		N	P	K	Mg
Above-ground biomass	85.26	577	50	1255	141
Fertilizer equivalent		A/S	CIRP	MOP	KIES.
		2748	318	2510	908
*Monetary value (RM)		989	95	1104	363
Total monetary value	RM 2551 ha⁻¹				

*Based on government price: A/S: RM 360 tonne⁻¹, CIRP: RM 300 tonne⁻¹, KCI: RM 400 tonne.', Kieserite: RM 400 tonne⁻¹.

TABLE 7. PERCENTAGE CONTRIBUTION OF TOTAL NUTRIENT CONCENTRATION IN VARIOUS OIL PALM COMPONENTS TO TOTAL ABOVE-GROUND BIOMASS

Component	N	P	K	Mg	Ca
Trunk	39.85	44.05	53.01	43.81	44.71
Leaflets	29.79	18.06	6.15	11.81	14.44
Rachis	12.46	15.67	19.38	12.45	24.17
spears	4.73	3.77	1.75	2.13	1.86
'Cabbage'	3.29	4.56	1.66	2.21	0.81
Frond bases	7.00	9.52	16.52	24.96	12.33
Inflorescences	2.88	4.37	1.53	2.63	1.68

N. 32kg P. 424kg K and 76kg Mg based on measurements of the palm residues of trunks and fronds only. Earlier, Chan et al. (1980) estimated that about 90t ha^{-1} dry matter can be obtained at felling in mature plantation which contains about 518kg N, 49kg P, 721kg K, 112kg Mg and 182kg Ca. Both of these studies did not take into account the amount of biomass and nutrients from other components such as spears, 'cabbage', frond bases and inflorescences. Significant amount of nutrients, especially N and K, can be obtained from the frond bases which could be recycled in the plantation and thus, should have been added in the calculation of nutrient stocks at replanting, even though most of these would have fallen off by then. The order of magnitude of total nutrients immobilized in the whole palm is: K > N > Ca > Mg > P which is in agreement with the findings of Gray (1969), Chan et al. (1980) and Mohd Hashim et *al.* (1993) except for Ca which was not determined in the last study.

Most of the N was found in the trunk and leaflets amounting to about 70% of the total N in the palm. The trunk contributed 40% and the leaflets 30% (Table 7). Here, it should be noted that the leaflets contributed only about 9% of the total dry matter compared with the trunk which contributed about 48% of the total biomass (Table 5). The rachis contributed about 12% to the total N, followed by the frond bases which contributed about 7%.

The trunk and leaflets also contributed a greater amount of P which was 44% and 18% respectively followed by the rachis which contributed about 16% whilst the remaining palm components gave less than 10%.

In the case of K, the trunk and rachis contributed about 72% of the total K in the palm with 53% coming from the trunk and 19% from the rachis. Frond bases also contributed a significant amount of K which was about 16.5% of total K, while leaflets only contributed 6% of total K.

The trunk also contributed large quantities of Mg and Ca amounting to 45% of the total for these elements. This reflects the importance of the trunk as the main storage pool of nutrients in above-ground biomass.

CONCLUSIONS

The above-ground biomass and nutrient stocks of oil palm at replanting were quantified using destructive method. The total above-ground biomass amounted to about 85t ha-' and the trunk contributed the major portion of oil palm standing biomass which was about 48% of the total. This was followed by the frond bases, rachis and leaflets which contributed about 21%, 19%, and 9% respectively. The rest of the components contributed less than 2% of total standing biomass.

The total nutrient stocks of above-ground biomass produced at felling of old stands on a per hectare basis, an estimates of 577kg N, 50kg P, 1255kg K, 141kg Mg and 285kg Ca which could be recycled in the plantations which in monetary terms is worth about RM 2550 ha-'. The order of magnitude of total nutrients in the whole palm was K > N > Ca > Mg > P. Removal of oil palm biomass for making of other value-added products has implications for plantation management in terms of nutrients and organic matter to sustain soil fertility. Appropriate management of this biomass would enable the carry-over of nutrients to support the growth of the following rotation as well as contributing to the environmental benefits of zero waste in the oil palm industry.

Despite the above quantities of nutrients estimated, further studies are in progress to understand the mineralization or nutrient release patterns of the various palm components under different environments and the carry over of nutrient from oil palm biomass in relation to various residue management practices. Such studies are important in formulating fertilizer recommendations in the replanting of oil palm.

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