NUTRIENT CYCLING IN AN OIL PALM PLANTATION: THE EFFECTS OF RESIDUE MANAGEMENT PRACTICES DURING REPLANTING ON DRY MATTER AND NUTRIENT UPTAKE OF YOUNG PALMS

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Oil palm residues during replanting contributed significant amount of nutrients that can be recycled in the plantation. The management of oil palm residues affects the release of nutrients and hence their uptake and the growth of young palms. Dry matter and nutrient uptake of young palms and ground cover were estimated. Planting young palms directly onto the residue pile is the most effective method of biomass management during replanting as it provides better synchronization between nutrient release and plant uptake.

The young palms only utilized about 10%-20% of the total nutrient uptake that is mostly found in the fronds. The young palms planted onto the residue pile without inorganic fertilizer inputs immobilized about 30 kg N ha^{-1}, 3 kg P ha^{-1}, 43 kg K ha^{-1}, 6 kg Ca ha^{-1} and 4 kg Mg ha^{-1} over the 18-month period of assessment. The results obtained showed that the chipped and shredded (C/S) treatment was the most efficient. More than 80% of the nutrients were consumed by the ground cover which comprised legumes and weeds. The ground cover immobilized about 254 kg N ha^{-1}, 19 kg P ha^{-1}, 181 kg K ha^{-1}, 56 kg Ca ha^{-1} and 28 kg Mg ha^{-1} over 18 months and became a transient pool that would recycle its nutrients at a later stage in the plantation life.

INTRODUCTION

The value of oil palm residues such as pruned fronds and other wastes from processing mills for mulch and organic manure is already well documented (Chan *et al.*, 1980; Teoh, 1993;

Chew et *al.,* 1994). A large volume of residual biomass from the previous stand is available on site at the time of replanting as a result of adopting zero burning practices. Management of organic resources in the plantation during replanting for nutrient conservation may also have beneficial effects in maintaining the biodiversity of soil fauna and microbial communities and ultimately have implications for pest and disease control. While the ecological processes and control of decomposition and nutrient release are rather complex, the main issues to be resolved from the agronomist's perspective are the effects on soil fertility and the performance of the young palms. The management of oil palm residues during replanting by adopting the zero burning practice needs to be developed by understanding the nutrient cycling processes in oil palm plantations. Different approaches in residue management during replanting will result in multiple effects on the properties and processes in soils and hence in the nutrient supplying capacity to the soil pool and on the growth performance of palms. One of the best approaches is to improve the efficiency of nutrient utilization. This will contribute to better synchronization between nutrient release from residue inputs and plant growth requirements by planting the young palms directly onto the residue piles. The palm growth performance and the total nutrient uptake will give an indication of the most efficient management practice of biomass during replanting.

A study was conducted to quantify the total dry matter and nutrient uptake of young palms and to partition the distribution of nutrients into the various palm components as affected by different residue management practices during replanting. In addition, the dry matter production and nutrient uptake of ground covers were quantified which enabled the estimate of the total nutrient uptake by the vegetation to be made.

The objective of this paper is to provide information on the potential availability of nutrients from the recycling of biomass of the previous stand, the quantification of the dry matter production and nutrient uptake of young palms with different residue management practices over 18 months after treatment. The importance of ground cover establishment, especially of the legume species to store and recycle nutrients in the plantation, is also discussed.

MATERIALS AND METHODS

The study was carried out in an oil palm plantation at the MPOB Research Station, Kluang, Johor. The soil was reddish-yellow sandy clay developed from granite and classified as an Ultisol of the Rengam series (Typic Paleudult). The experimental plots described in this study were set up after felling 23-year-old oil palm of the first rotation. The old stand was planted at a density of 136 palms ha-l. Routine fertilizer application had ceased one year before felling. The treatments were established immediately after felling and clearing, in line with the standard practice.

Treatments and Experimental Design

Four experimental treatments of residue management, namely, complete removal (C/R) C/S, chipping and pulverization (C/P) and partial burning (P/B) were established. The treat. ments, replicated four times, consisted of a total of 16 plots laid out in a randomized complete block design (RCBD). Each plot consisted 01 4 x 5 palms of 0.15 ha.

The details of the treatments were as follows:

- C/R: the trunks of palms were cut intc several pieces l-2 m in length without chipping, The cut trunks, together with fronds and other palm components, were loaded onto a lorry and removed from the plot.
- C/S: the palm trunks with fronds were C/S to pieces of about 10 cm thick across at 45°-60” angle and the C/S materials were spread evenly over 3-4 m wide to avoid a thick pile formation.
- C/P: the palm trunks with fronds were C/S and spread out as in the C/S treatment. However, within one week, these residues were pulverized into smaller pieces using a pulverizing machine.
- P/B: P/B of the C/S materials was conducted one month after felling. The unburnt materials, consisting mainly of about 50% of the chipped trunks, were left to decompose in

the field.

Legume seeds were sown after all the residue treatments had been completed and about one week after the P/B. At the same time, lining for the new planting points was laid down. The base line of the felled old stand was used as reference and new planting points were marked in old planting rows between the old stands. Commercial DxP 12-month-old seedlings were field planted one month after the treatments were established using 8.8 m x 8.8 m x 8.8 m triangular spacing. No fertilizers were applied during the experimental period except for an initial application of 250 g of phosphate rock in each planting hole at the time of transplanting. In normal estate practice, inorganic fertilizers, applied at six months and 12 months after field planting, were omitted in this study in order to enable nutrient transfer from the residues to the palms to be studied.

Destructive Analysis and Dry Matter Estimation of Young Palms

At 18 months after planting in the field, a total of 16 young palms (1 palm per plot) was sampled for destructive analysis. These palms, selected based on growth measurement data, were used to represent the mean size of palms (within ±SD). Destructive analysis for each component was conducted using the methods described for mature palms (Khalid et al., 1999). However, the root dry matter for each sampled palm was obtained by digging the soil surrounding the palm base with approximately 2-3 m radius to a depth of 60 cm and the bulk of the roots were collected by separating them from the soil. The area and depth were dependent on the distribution of roots for each palm. Total samples of roots were not sorted into size categories because of the large amount of material involved. The dry weight of each palm component, except the inflorescences, was obtained and the samples analyzed for nutrient contents.

Estimation and Sampling of Ground Cover Dry Matter

The dry matter of the ground cover was estimated 18 months after the treatments were established. One quadrat of 1 m x 1 m was sampled randomly in the avenue of each plot and all the delimited material (living plants, superficial roots which were just pulled up and undecomposed leaf litter of legumes and weeds) was collected and placed in bags. No attempt was made to estimate the dry matter and nutrient uptake of ground cover with the different residue management practices because most of the legumes were sown in the avenue and crept to the residue piles. The fresh above ground materials were hand sorted in the laboratory into the different species of legumes (*Pueraria phaseoloides*, *Centrosema pubescens* and *Calopogonium muconoides*) and types of weeds such as *Asystasia* and *Mikania*. The plant materials and litters were oven dried at 80°C until they reached constant weight before weighing and preparation for analysis of nutrient contents.

Analyses

The moisture contents of all the palm components and ground cover were determined by collecting small samples of about l-2 kg each. These samples were weighed and dried to 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 the concentrations of N, P, K, Ca and Mg using standard analytical procedures. The total nutrient contents of the 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-l. The total nutrient contents and dry matter of ground cover, obtained from quadrat sampling, were calculated on per hectare basis.

RESULTS AND DISCUSSION

Dry Matter and Nutrient Content of Young Palm Components

The dry matter and nutrient content produced by the young palm components expressed on a per palm basis at 18 months old are shown in *Table 1*. The dry matter for all components, except the roots, were significantly higher ($P < 0.05$) in the C/S treatment than in the other treatments. However, the dry matter of roots showed no significant differences between the treatments. The rachis produced the greatest amount of dry matter ranging from 4.83 kg palm^{-1} in the C/R treatment to the highest 9.52 kg palm^{-1} in the C/S treatment. Leaflets, trunk and roots produced dry matter in the range of 1.03-4.08 kg palm-l. The rest of the components, which include spears and cabbage, produced less than 1 kg palm-l of dry matter.

The leaflets of the young palm contained the highest amount of N ranging from 46.50-87.56 g N palm-l. K was immobilized mostly in the rachises ranging from 38.58-126.43 g K palm-‘. P was located mostly in the leaflets and rachises ranging from 2.69–4.81 g P palm^{-1} and 2.26-7.29 g P palm^{-1} respectively. Similarly, Ca and Mg were found mostly in the leaflets and rachises. In all cases, the amounts of N, P, K, Ca and Mg in the palm components were the lowest and significantly lower ($P < 0.05$) in the C/R treatment compared to the highest in the C/S treatment. The amount of nutrients in all the palm components in the P/B and C/P treatments was intermediate.

TABLE 1. DRY MATTER AND NUTRIENT CONTENT OF I&MONTH-OLD PALM COMPONENTS IN RELATION TO DIFFERENT RESIDUE MANAGEMENT TREATMENTS

Component	Treatment	Dry matter (kg palm^{-1})	Nutrient content (g palm”)				
			N	P	K	Ca	Mg
Leaflets	C/R	2.21	46.50	2.69	25.07	9.01	4.13
	C/S	4.08	87.56	4.81	50.90	16.35	10.41
	P/B	2.51	49.73	3.23	27.79	10.15	7.76
	C/P	2.87	59.97	3.42	31.94	11.82	8.13
	LSD (0.05)	0.63	20.36	1.06	8.43	4.07	2.70
Spear	C/R	0.34	4.76	0.56	5.29	0.83	0.59
	c/s	0.74	10.83	1.06	12.41	1.67	1.40
	P/B	0.42	6.03	0.76	7.07	0.93	0.98
	C/P	0.44	6.34	0.66	7.37	0.98	0.90
	LSD (0.05)	0.24	3.31	0.41	4.10	0.46	0.58
Cabbage	C/R	0.14	3.24	0.54	4.97	0.74	0.61
	c/s	0.42	8.34	1.31	18.56	1.59	1.78
	P/B	0.21	4.51	0.85	8.09	0.90	1.03
	C/P	0.30	5.63	1.00	12.08	1.49	1.29
	LSD (0.05)	0.12	2.59	0.44	5.92	0.68	0.57
Rachises	C/R	4.83	19.01	2.26	38.58	6.09	2.62
	c/s	9.52	39.95	7.29	126.43	13.22	6.42
	P/B	5.11	22.93	2.98	62.54	6.16	3.27.
	C/P	d.67	25.82	5.98	84.02	8.85	6.10
	LSD (0.05)	2.19	11.82	1.82	27.80	5.11	3.52
Trunk	C/R	1.03	5.61	0.92	8.31	1.47	0.72
	C/S	3.33	23.78	2.97	38.75	4.19	2.97
	P/B	1.45	7.79	1.46	14.44	1.73	1.18
	C/P	2.16	14.44	2.23	32.85	3.36	2.04
	LSD (0.05)	0.64	6.15	0.65	9.91	1.29	1.02
Roots	C/R	2.09	11.10	0.93	11.66	2.28	1.75
	c/s	2.84	16.29	1.46	23.99	2.66	2.56
	P/B	2.28	11.74	1.56	14.63	2.49	2.32
	C/P	2.40	13.44	1.29	16.83	2.59	2.32
	LSD(0.05)	0.96	5.44	0.79	7.31	1.28	0.89

Note: figures are means offourreplicates.

Total Dry Matter and Nutrient Content of Young Palms

The total dry matter and nutrient content of all components, except the inflorescences, are shown in *Table* 2. There was significantly higher ($P < 0.05$) dry matter in the C/S treatment than the other treatments at 20.93 kg palm^{-1} whereas the C/P, P/B and C/R treatments had values of 14.83, 11.98 and 10.64 kg palm^{-1} respectively. The total dry matter of the C/P treatment was significantly higher ($P < 6.05$) than the C/R treatment, but the C/P and P/B treatments showed no significant differences. The inputs of palm residues in the C/S and C/P treatments produced a positive response in palm size; however, the total dry matter in the C/R treatment was lower which reflected the low soil fertility due to no residue input except the root residue. The response in the P/B treatment was intermediate between the C/P and C/R treatments.

As shown in *Table* 2, the uptake of N, P, K and Ca at 18 months, obtained from destructive' analysis, showed that the C/S treatment was significantly higher ($P < 0.05$) than other treatments. The content of Mg in the C/S treatment was also significantly higher ($P < 0.05$) than the P/B and C/R treatments; however, the C/S and C/P treatments showed no significant difference in the Mg uptake.

The content of N in the C/S treatment was the highest with a value of 186.8 g N palm^{-1} compared to the C/P, P/B and C/R treatments which had values of 125.6, 102.7 and 90.2 g N palm^{-1} respectively. The C/P, P/B and C/R treatments showed no significant difference in N uptake. The mean concentration of N from total dry matter production of the young palms in the C/R, C/S, P/B and C/P treatments was 0.85%, 0.89%, 0.86% and 0.85% respectively. It was observed that the C/S treatment showed the most synchrony between nutrient release and uptake compared to other treatments.

The content of P in all treatments ranged from 7.89 g P palm-l to 18.90 g P palm^{-1} in which the C/S treatment had the highest value of P uptake. Also the C/P treatment was significantly higher in P uptake compared to the P/B and C/R treatments. However, the P/B and C/R treatments showed no significant difference in P uptake. The mean concentration of P from total dry matter production in the C/R, C/S, P/B and C/P treatments was 0.074%, 0.090%, 0.090% and 0.098% respectively. The C/S, P/B and C/P treatments showed almost similar P concentration indicating that the P synchrony in these treatments was quite similar and much better than the C/R treatment.

The K content ranged from 93.9 g K palm^{-1} to 271.0 g K palm-l with the uptake of K in the C/S treatment about three times higher than that in the C/R treatment. The mean K concentration of total dry matter in the C/R, C/S, P/B and C/P treatments was 0.88%, 1.29%, 1.12%

TABLE 2. TOTAL DRY MATTER AND NUTRIENT CONTENT OF I&MONTH-OLD PALMS IN RELATION TO DIFFERENT RESIDUE MANAGEMENT TREATMENTS

Treatment	Dry matter: (kg palm-')	Nutrient content** (g palm^{-1})				
		N	P	K	Ca	Mg
C/R	10.64	90.2	7.9	93.9	20.4	10.4
C/S	20.93	186.8	18.9	271.0	39.7	25.5
P/B	11.98	102.7	10.8	134.6	22.4	16.5
C/P	14.83	125.6	14.6	185.1	29.1	20.8
LSD (0.05)	3.89	40.86	3.43	51.25	9.26	4.91

Notes: figures are means of four replicates.

* Total dry matter of all palm components including roots.

** Total nutrient content of all palm components including roots.

and 1.25% respectively. The order of K concentration in the total dry matter was C/S > C/P > P/B > C/R. This may reflect the excess of K released from decomposed palm residues in the C/S and C/P plots resulting in higher concentrations of exchangeable K in these plots (Khalid, 1997). The C/P treatment also showed significantly higher K uptake compared to the C/R treatment but showed no significant difference to the P/B treatment.

In the case of Ca, the uptake of this element seemed to be quite similar for all treatments and ranged from 20.4 g Ca palm-' in the C/R treatment to 39.7 g Ca palm^{-1} in the C/S treatment. The Ca content in the C/S treatment was significantly higher ($P < 0.05$) than in the other treatments. However, Ca uptake in the C/P, P/B and C/R treatments showed no significant differences.

For Mg, the uptake ranged from 10.4 g Mg palm^{-1} to 25.5 g Mg palm-l. The uptake of Mg in the C/S, C/P and P/B treatments was significantly higher than in the C/R treatment. The uptake of Mg in the P/B treatment was also significantly lower than in the C/S treatment; however, the P/B treatment showed no significant difference compared to the C/P treatment. Similarly, there was no significant difference in the uptake of Mg between the C/S and C/P treatments. The mean Mg concentration in the total dry matter in the C/R, C/S, P/B and C/P treatments was 0.10%, 0.12%, 0.14% and 0.14% respectively. In all cases, the uptake of N, P, K, Ca and Mg in all the treatments was parallel with the levels of elements in the soil (Khalid, 1997).

An overall comparison between the four treatments showed that the C/S treatment gave the highest dry matter production and nutrient uptake during the course of the study. This indicated that the C/S treatment was more effective in improving efficiency of nutrient utilization by the young palms as a consequence of the slow release of nutrients from decomposed palm residues that gave better synchronization to plant growth requirements.

Dry Matter and Nutrient Content of Ground Covers

The total dry matter and nutrient content of legumes, weeds and litter (from legumes and weeds) are presented in *Table* 3. The total dry matter of legumes and weeds was 5370 kg ha^{-1} and 1930 kg ha^{-1} respectively, with a combined total weight of 7300 kg ha-l. The nutrient

TABLE 3. DRY MATTER AND NUTRIENT OUTPUT (kg ha-') RECOVERED FROM YOUNG PALMS, COVERS AND LITTER BIOMASS 18 MONTHS AFTER TREATMENT

Biomass	Dry matter (kg ha-')	Nutrient output (kg ha^{-1})				
		N	P	K	Ca	Mg
Recovered in:						
Young palm biomass*	2 846	25.40	2.57	36.86	5.40	3.47
Palm inflorescences**	272	4.11	0.57	5.66	0.41	0.71
	3 118	29.51	3.14	42.52	5.81	4.18
Legumes	5 370	113.3	11.28	105.8	**27.92**	9.13
Asystasicz, Mikania and other weeds	1 930	31.3	2.49	51.53	6.37	5.21
	7 300	144.6	13.77	157.33	**34.29**	14.34
Litter (from covers)	4 140	108.9	5.42	23.18	21.94	13.25
Total output	14 558	283.01	22.33	223.03	62.04	31.77

Notes: * figures obtained from palms in C/S treatment.
** Means of inflorescences from C/S treatment.

content of the legumes was quite high contributing about 113 kg N ha^{-1}, 11 kg P ha-l, 106 kg K ha^{-1}, 28 kg Ca ha^{-1} and 9 kg Mg ha-l. The dry matter and nutrient content of the legumes, which were mostly dominated by *P. phaseoloides* and C. *pubescens* species obtained in this study, were close to the values reported by Han and Chew (1981) with a mean total dry matter of 5167 kg ha^{-1} at 20 months after planting on Selangor series which contained about 125 kg N ha-l, 9.5 kg P ha^{-1}, 105 kg K ha^{-1} and 11 kg Mg ha^{-1}. The weed species, which were mostly dominated by *Asystasia* and *Mikania,* contained only about 31 kg N ha-l, 2.5 kg P ha-l, 52 kg K ha-l, 6 kg Ca ha^{-1} and 5 kg Mg ha-l. The dry matter of litter from the cover (both legumes and weeds) amounted to about 4140 kg ha^{-1} which contained about 109 kg N ha-l, 5.4 kg P ha^{-1}, 23 kg K ha-l, 22 kg Ca ha^{-1} and 13 kg Mg ha^{-1}.

Total Nutrient Uptake and Percentage Distribution in Young Palms and Ground, Covers

As shown in *Table* 3, the uptake of N by the palms and cover was about 29 kg N ha^{-1} and 145 kg N ha^{-1} respectively. The litters of legume cover and, weeds at 18 months after planting contained about 109 kg N ha-l. The total N-pool in the whole vegetation and ground cover litter was distributed in the young palms (10.4%), 51.1% in covers and 38.5% in litter *(Table 4)*, which amounted to about 283 kg N ha-l. More than 250 kg N ha^{-1} was utilized or taken up by the covers and about 109 kg N ha^{-1} were released or returned to the soil from the ground cover litter over 18 months. The estimated N cycling through ground cover litter was close to the value of 123 kg N ha^{-1} yr^{-1} reported by Agamuthu and Broughton (1985) while Han and Chew (1981) obtained a value of 115 kg N ha^{-1} yr^{-1} in leaf litter of *P. phaseoloides*.

The total P stock in palm biomass, ground cover and ground cover litter at 18 months was 3.14, 13.77 and 5.42 kg P ha^{-1} respectively *(Table* 3). The total uptake of 22.33 kg P ha^{-1} was distributed in the palms (14%), 61.7% in cover and 24.3% in the ground cover and legume litter *(Table* 4) that will be recycled in the plantation. The quantity of P required by the plant biomass is not large compared with the probable amounts of available P in the soil (Khalid, 1997).

In the case of K, the total uptake of K by the vegetation over the 18-month period was about 223 kg ha^{-1} *(Table* 3) with 42,157 and 23 kg K ha^{-1} found in the palms (19%), ground cover and legumes (70%) and residual ground cover and legume litter (11%) respectively (*Table* 4). Based on the amount of ground cover and legume litter biomass produced, it was estimated that more than 60 kg K ha^{-1} were released from the litter flux and returned to the soil system by leaching.

The total uptake of Ca by vegetation over 18 months was about 62 kg ha^{-1} *(Tables* 3 and 4) with 5.8, 34.3 and 21.9 kg ha^{-1} found in the palms (9.4%), cover legume (55.3%) and residual cover legume litter (35.3%) respectively.

TABLE 4. PERCENTAGE DISTRIBUTION OF DRY MATTER AND NUTRIENT CONTENTS IN THE VEGETATION

Vegetation	Dry matter (%)	Nutrient contents (% of total)				
		N	P	K	Ca	Mg
Young palms*	21.42	10.43	14.06	19.07	9.37	13.16
Legumes + weeds	50.14	51.09	61.67	70.54	55.27	45.14
Litter (from covers)	28.44	38.48	24.27	10.39	35.36	41.70
Total	100.0	100 .o	100.0	100.0	100.0	100.0

Note: * young palm + inflorescences.

The amount of Mg located in the palm biomass, covers and litter was 4.18, 14.34 and 13.25 kg ha^{-1} respectively, contributing a total of 31.77 kg ha^{-1} (*Table* 3). The Mg was distributed in the young palms (13.2%), 45.1% in the cover and 41.7% in the litter (*Table* 4). This meant that more than 86% of the exchangeable Mg in the soil was taken up by the ground cover.

The legume cover and weeds are, however, important as a transient pool that will become available later. When the palms canopy closes, which reduces light penetration, the ground cover will gradually die out. The cumulative benefits of leguminous cover crops appear to be considerable.

CONCLUSION

The growth of young palms and their nutrient uptake were significantly affected by different crop residue management practices. The importance of crop residue inputs for maintaining nutrient reserves in soils had been demonstrated in this study. The plots with crop residue inputs showed significant differences in the total dry matter of young palms and nutrient uptake compared with the plots without crop residue inputs. This was attributed to the significant increase in nutrient pools in these plots which were readily accessible and taken up by the young palms. The establishment of roots of the young palms were quite slow and therefore their ability to utilize nutrients from decomposing residues some distance away was limited. Thus, the location of organic input that released nutrients with respect to plant roots was found to be important and was in concurrence in terms of their spatial factor. Mineralization of decomposing residues is a major source of plant nutrients in a highly weathered environment with poor inherent soil fertility. The carry over of nutrient reserves from the recycling of oil palm residues during replanting provided a significant pool of nutrients for succeeding young palms.

The palm biomass and nutrient uptake gave an indication that greater synchrony between nutrient release and plant uptake was achieved as a consequence of improving the transfer efficiency of nutrient in these plots compared to the plots without crop residues.

The young palms only utilized about 10%-20% of the total nutrient uptake whereas the ground cover, which comprised legumes and weeds, utilized about 80%-90% of the total nutrient uptake. The nutrient content in legume cover and weeds will be recycled in the plantation and ultimately taken up by the palms at later stage.

The recycling of biomass accruing from replanting activities, together with proper agronomic management based on scientific approach; without doubt provide significant pools of nutrients to the succeeding young palms. Such a practice will directly reduce the production cost and indirectly cut down on pollution that is caused by over dependence on fossil fuel required for the manufacture of inorganic fertilizers. The studies were continued to monitor the soil nutrient dynamics and palm growth performance with different residue management practices at different time periods.

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