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Nitrogen Contribution by Palm Oil Mill Effluent to Young Oil Palm (*Elaeis guineensis* Jacq.) as measured by ^{15}N Isotope Dilution Technique

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ABSTRAK

*Efluen kilang kelapa sawit (POME) merupakan sejenis bahan organik yang terhasil dari kilang memproses minyak sawit. Efluen tanpa rawatan merupakan satu bahan yang amat mencemarkan jika dilepaskan terus kedalam laluan air disebabkan oleh kandungan keperluan oksigen biologi dan kimia yang tinggi. Ianya mesti dirawat sebelum digunakan. Kandungan nutrien dalam POME telah dirawat adalah tinggi dan ianya boleh digunakan sebagai sumber baja untuk tanaman pertanian. Dua kajian di tapak semaian telah dijalankan dimana anakbenih kelapa sawit (*Elaies guineensis *Jacq.) telah ditanam dalam polibag mengandungi 8 kg tanah siri Selangor (Aeric Tropaquept) untuk menentukan subangan nitrogen oleh POME terhadap tumbesaran anakbenih kelapa sawit ditanam selama 40 minggu dengan menggunakan teknik pencairan isotop ^{15}N. Nitrogen dalam anak benih kelapa sawit yang disumbang oleh POME dikira mengikut kiraan Fried dan Dean (1952). Diantara 4.9-12.1 peratus dari jumlah nitrogen yang diberi sebagai POME dalam kedua-dua kajian telah diserap oleh anak kelapa sawit dalam masa 40 minggu. POME yang mengandungi jumlah pepejal yang tinggi menyumbang lebih banyak nitrogen kepada anakbenih kelapa sawit.*

ABSTRACT

*Palm oil mill effluent (POME) is an organic waste material produced at the oil palm mills. In its raw form, POME is highly polluting due to its high content of biological and chemical oxygen demand. It must be treated before being discharged into the waterways. But in view of its high nutrient content, it can be recycled to the soil as a fertilizer for agricultural crops. Two nursery trials were conducted using oil palm (*Elaeis guineensis *Jacq.) seedlings planted in polybags containing 8 kg Selangor series soil (Aeric Tropaquept) to evaluate the nitrogen contribution by POME applied to the soil. The trials were carried out for a period of 40 weeks using the nitrogen-15 isotope dilution technique. The nitrogen in the plants contributed by the POME at various times was calculated using the isotope dilution procedure described by Fried and Dean (1952). It was found that the amount of nitrogen contributed by POME in both the experiments ranged between 4.9 to 12.1 percent of the total nitrogen content of the POME applied. A higher N was utilized from POME that contained higher total solids.*

INTRODUCTION

Palm oil mill effluent (POME) is one of the major by-products of palm oil mills in Malaysia. Discharging raw oil palm waste material into waterways is a threat to the environment because of the high biochemical and chemical oxygen demand content (Yeow 1983). The Malaysian government has enforced the Environmental Quality Act which requires that raw POME be treated to an acceptable level before it is discharged. However, POME could be put into good use in view of its high nutrient value. Many research findings have shown that various types of waste materials are good sources of plant nutrients. Their application to land as fertilizer supplement for crops was found to be beneficial to crop performance and soil physical and chemical properties (Khaleel *et al.* 1981; Demuynck *et al.* 1984; Ghederim *et al.* 1985; Titloye *et al.* 1985).

Some studies have been carried out on utilization of POME and its effect on crop and soil properties (Chan *et al.* 1980; Koh and P'ng 1981;

Wood *et al.* 1981; Lim *et al.* 1983; Tan 1983; Lim 1987). However, little attention had been given to quantifying the amount of nutrients released by POME for plant uptake. Though POME contains other major plant nutrients, this study emphasises on nitrogen in view of its high composition in the effluent. The objective of this study is to quantify the amount of POME-nitrogen absorbed by oil palm seedlings with time.

MATERIALS AND METHODS

Two experiments were set up to evaluate the nitrogen release and uptake by oil palm seedlings from treated POME using the ^{15}N isotope dilution technique proposed by Fried and Dean (1952). The treated POME used in the experiments were obtained from the Golden Hope effluent treatment plant which employs a system of two-phase anaerobic contact process followed by an aerobic treatment of the anaerobic liquor using extended process and sedimentation (Whiting and Lim, 1981). The nutrient composition of the treated POME used in experiments 1 and 2 is shown in Table 1.

TABLE 1
Nutrient composition of treated POME used in the experiment

Experiment number	pH	Total solids (%)	Nutrients (mg kg^{-1}) N	P	K	Mg	Ca
1	7.8	3.64	2254	390	2952	932	687
2	8.2	7.66	4851	1619	3497	1949	1218

In experiment 1, 24 black ploythene bags, 30 cm x 30 cm, were filled with eight kg of Selangor series soil (Aeric Tropaquept) which was air-dried, ground and sieved through a 5 mm sieve. Another 24 black ploythene bags of the same size were filled with eight kg of the same soil thoroughly mixed with one litre of digested POME in each bag.

One two-month old oil palm seedling which was pre-germinated in a sand bed was planted into each of the polythene bags. The seeds attached to each of the seedlings were removed at planting. Five seedlings were randomly sampled and prepared for analysis for total N content at the beginning of the experiment. Two g of N as ammonium sulphate enriched with 5% atom excess (a.e) ^{15}N dissolved in 200 ml distilled water was applied to each of the four bags of the treated and untreated soil randomly at planting (time 0), 2 , 4 , 8 , 16 and 32 weeks after planting. At each time of application, those plants that did not receive labelled N were applied with the same amount of unlabelled N as ordinary ammonium sulphate. All the seedlings were also supplied with 1.14 g P as Triple superphosphate and 1.33 g K as Muriate of potash per plant at planting time.

The second experiment was set up in the same manner as the first experiment except that the chemical composition of treated POME used was different and the labelled ammonium sulphate used was with 10% ^{15}N atom excess. The same rates of N, P and K were used as in the first experiment. The chemical composition of the treated POME used in the two experiments is shown in Table 1. Though the POME used was derived from the same source, the nutrient composition varied quite markedly. This is mainly due to the solid content of POME, which varies with time and is attributed to the variation in retention time and discharged rates in the anaerobic digester system (Toh 1982).

The pH of the POME used in experiment 1 was 7.8, while for experiment 2, the pH was 8.2. Total solids content of POME used in experiment 1 was found to be 3.64% as compared to 7.66% in experiment 2. Poon (1982) had shown that total solids content was highly correlated with nutrient contents of the POME, especially N. The POME used in experiment 1 had lower nutrient content than in experiment 2.

The soil used in both the experiments (Selangor series - Aeric Tropaquept) had a pH in water of 4.7, organic matter 2.21%, total N of 0.18%, total P of 287 mg kg^{-1}, Bray-2 extractable P of 36.9 mg kg^{-1}, cation exchange capacity of 22.5 cmol(+)kg^{-1} soil, and exchangeable K, Ca and Mg of 0.48, 1.09 and 1.37 cmol(+) kg^{-1} soil respectively.

The oil palm seedlings (four replications per treatment) were arranged in a randomized complete block design and placed under a clear plastic covered shed. Each polybag was placed in a shallow basin to prevent leaching of nutrients during watering. All the excess water collected after watering was returned to the soil in the polybag. Watering was carried out twice daily. All the seedlings were allowed to grow for 40 w. They were then destructively sampled and separated into leaf, rachis, stem and roots. These were dried at 70°C and ground for analysis. Total ni-

trogen was determined using the Kjeldahl procedure (Bremner 1965) and ^{15}N analysis was made by mass spectrometry following Dumas dry combustion method for sample preparation (Fiedler and Procksch 1975 and Buresh *et al.* 1982)

The ^{15}N enrichment found in the tissues was corrected for the N already present in the seedlings at planting by using the formula of Jensen *et al.* (1985), where:

$$\text{atom \% } ^{15}\text{N excess}_{corr} = \frac{N \times \text{atom \% } ^{15}\text{N excess}}{N - N_{seedling}}$$

The average ^{15}N enrichment present in the oil palm seedlings at the end of the experiment was calculated using the formula :

$$\text{average \% }_{15}\text{N a.e} = \frac{(\%\ ^{15}\text{N a.e}_{leaf} \times N_{leaf}) + (\%^{15}\text{N a.e}_{rachis} \times N_{rachis}) + (\%^{15}\text{N a.e}_{stem} \times N_{stem}) + (\%^{15}\text{N a.e}_{root} \times N_{root})}{(N_{leaf} + N_{rachis} + N_{stem} + N_{root})}$$

The amount of nitrogen derived from POME was calculated using the formula:

$$\text{N from POME} = \left(1 - \frac{\%^{15}\text{N a.e POME treated plant}}{\%^{15}\text{N a.e non treated plant}}\right) \times \text{Total N in POME treated plant}$$

RESULTS AND DISCUSSION

Dry Matter Production

The leaf, rachis, stem and root dry matter production of oil palm seedlings grown in soil treated with POME was found to be significantly higher than that of seedlings grown in untreated soil in experiment 1. But the reverse was observed for the dry matter production in the oil palm seedlings in experiment 2 (Table 2). This may be due to the high ammonium-N released by the POME (Mohd Hashim 1990),and studies on other crops have shown that the excess amount of ammonium-N restricts vegetative growth of the crops (Warncke and Barber 1973; Zahari and Kho 1983). Visual observations made during the experimental period did not indicate any toxicity symptoms.

TABLE 2
The effect of POME on dry matter production of oil palm (g)

Treatments	Experiment 1					Experiment 2				
	Leaf	Rachis	Stem	Root	Total	Leaf	Rachis	Stem	Root	Total
	UNTREATED SOIL					**UNTREATED SOIL**				
0 week	24.80	10.80	21.73	14.58	71.91	45.93	29.95	50.68	34.98	161.54
2 weeks	30.45	15.25	25.63	16.30	87.63	53.50	38.15	54.00	34.43	180.08
4 weeks	25.80	12.93	19.83	15.08	73.64	50.08	31.35	49.68	33.08	164.19
8 weeks	34.10	17.63	30.50	19.30	101.53	46.25	29.53	36.68	29.58	142.04
16 weeks	27.47	13.67	21.30	15.17	77.71	46.93	31.95	48.68	32.00	159.56
32 weeks	29.15	12.95	23.20	15.48	80.78	42.88	29.80	52.80	33.15	158.63
	POME-TREATED SOIL					**POME-TREATED SOIL**				
0 week	42.08	27.26	39.35	25.08	138.76	40.85	21.85	38.20	27.18	128.08
2 weeks	42.97	24.83	38.10	26.07	131.97	40.20	25.18	43.83	32.48	141.69
4 weeks	37.68	24.15	36.40	26.30	124.53	38.00	19.08	35.35	27.23	119.66
8 weeks	43.07	30.30	36.77	25.87	136.01	38.65	21.03	40.58	25.33	125.59
16 weeks	41.07	25.40	43.47	25.13	135.07	36.90	21.13	36.30	25.33	119.66
32 weeks	53.27	38.93	54.63	31.20	178.03	41.40	19.90	36.30	26.87	124.47
LSD ±0.05	9.74	9.72	13.69	7.18	-	3.98	4.01	6.16	3.24	-

The N concentrations in the various parts of the oil palm seedlings (Table 3) were found to be similar in the seedlings planted in soils treated with POME and the untreated soils. These values were higher than the observations made by Hew and Toh (1972), in which N concentration in the leaf, rachis, stem and roots were 2.24%, 0.53%,1.46% and 1.02% respectively. This difference could be due to the different levels of soil fertility used in the trial. About 43-48% of the total N in the oil palm seedlings is channelled to the leaves. The total N obtained in experiment 1 was higher than in experiment 2 due to the lower dry matter yield in experiment 2 (Table 4).

The ^{15}N distribution in the different parts of the oil palm seedlings at different times of ^{15}N application showed that when the labelled fertilizer was applied at the beginning of the experiment, the highest enrichment was found in the leaf and root for both treated and untreated soil and that the enrichment was higher in the untreated soil compared to the POME treated soil.

TABLE 3
Nitrogen concentration (%) in POME-treated and untreated oil palm seedlings

Treatment	Experiment 1				Experiment 2			
	Leaf	Rachis	Stem	Root	Leaf	Rachis	Stem	Root
	UNTREATED SOIL				**UNTREATED SOIL**			
0 week	2.96	1.52	1.98	1.88	2.69	1.00	1.28	1.32
2 weeks	2.91	1.61	1.96	1.68	2.58	0.87	1.20	1.27
4 weeks	2.93	1.70	2.13	1.92	2.68	1.03	1.31	1.38
8 weeks	2.81	1.35	1.74	1.79	2.76	1.01	1.42	1.19
16 weeks	3.04	1.69	2.15	2.08	2.76	1.06	1.35	1.29
32 weeks	2.98	1.58	2.07	1.92	2.69	0.97	1.29	1.30
	POME-TREATED SOIL				**POME-TREATED SOIL**			
0 week	2.81	1.51	1.73	1.90	2.72	1.38	1.47	1.72
2 weeks	2.95	1.31	1.62	1.93	2.70	1.27	1.52	1.73
4 weeks	2.92	1.47	1.54	1.88	2.71	1.28	1.55	1.60
8 weeks	2.81	1.64	1.70	2.20	2.80	1.28	1.51	1.61
16 weeks	2.89	1.68	1.67	2.00	2.76	1.42	1.65	1.59
32 weeks	2.75	1.56	1.67	1.97	2.83	1.32	1.54	1.48

TABLE 4
Total nitrogen content (g) in POME-treated and untreated oil palm seedlings

Treatment	Experiment 1					Experiment 2				
	Leaf	Rachis	Stem	Root	Total	Leaf	Rachis	Stem	Root	Total
	UNTREATED SOIL					**UNTREATED SOIL**				
0 week	0.733	0.164	0.430	0.274	1.601	1.234	0.300	0.650	0.463	2.647
2 weeks	0.887	0.245	0.502	0.274	1.908	1.380	0.331	0.648	0.438	2.797
4 weeks	0.756	0.220	0.422	0.290	1.688	1.340	0.324	0.648	0.457	2.769
8 weeks	0.959	0.237	0.529	0.435	2.070	1.274	0.298	0.520	0.352	2.444
16 weeks	0.835	0.232	0.457	0.315	1.839	1.294	0.337	0.656	0.414	2.701
32 weeks	0.868	0.205	0.480	0.297	1.850	1.151	0.289	0.681	0.429	2.550
	POME-TREATED					**POME-TREATED SOIL**				
0 week	1.182	0.412	0.680	0.477	2.751	1.112	0.300	0.563	0.466	2.441
2 weeks	1.269	0.326	0.616	0.503	2.714	1.087	0.320	0.666	0.562	2.635
4 weeks	1.101	0.356	0.562	0.494	2.513	1.030	0.244	0.548	0.434	2.256
8 weeks	1.211	0.498	0.624	0.569	2.902	1.083	0.268	0.611	0.407	2.369
16 weeks	1.187	0.426	0.726	0.502	2.841	1.020	0.301	0.598	0.402	2.321
32 weeks	1.463	0.609	0.912	0.616	3.600	1.172	0.263	0.559	0.398	2.392
LSD ± 0.05	0.304	0.189	n.s	0.213	-	0.114	0.020	n.s	n.s	-

This was to be expected due to the dilution of the available nitrogen in the soil from the N released by POME. When the ^{15}N fertilizer was added at the 32nd week, the highest enrichment in the untreated soil was found in the leaves, while in the treated soil, it was found in the roots (Table 5 and 6).

Nitrogen Derived from POME

The amounts of N derived from POME in experiment 1 were highest in the first two weeks after planting and decreased with time. The highest amount of N utilized by the oil palm seedlings was found to be during the first two weeks. This

TABLE 5
Percent ^{15}N a.e in oil palm seedlings in experiment 1

Time of ^{15}N application	^{15}N atom excess (%) Leaf	Rachis	Stem	Root	Mean
			UNTREATED SOIL		
0 week	0.560	0.455	0.483	0.473	0.5222
2 weeks	0.545	0.542	0.583	0.494	0.5473
4 weeks	0.583	0.559	0.481	0.613	0.5625
8 weeks	0.604	0.604	0.583	0.610	0.5996
16 weeks	0.706	0.685	0.589	0.854	0.7005
32 weeks	0.814	0.745	0.685	0.713	0.7567
S.E	±0.128	±0.039	±0.113	±0.096	-
			POME TREATED SOIL		
0 week	0.535	0.370	0.338	0.603	0.4734
2 weeks	0.535	0.436	0.546	0.512	0.5213
4 weeks	0.532	0.409	0.547	0.572	0.5258
8 weeks	0.514	0.441	0.660	0.658	0.5611
16 weeks	0.630	0.743	0.721	0.603	0.6654
32 weeks	0.665	0.777	0.738	0.820	0.7290
S.E	±0.082	±0.104	±0.068	±0.073	-

TABLE 6
Percent ^{15}N a.e in oil palm seedlings in Experiment 2

Treatments	^{15}N atom excess (%) Leaf	Rachis	Stem	Root	Mean
				UNTREATED SOIL	
0 week	0.801	0.539	0.564	0.695	0.6946
2 weeks	0.814	0.677	0.617	0.548	0.7105
4 weeks	0.950	0.934	0.711	0.625	0.8386
8 weeks	1.127	0.959	0.893	0.665	0.9658
16 weeks	1.694	1.154	1.422	0.966	1.4490
32 weeks	2.219	1.568	1.821	1.151	1.8543
S.E	±0.153	±0.307	±0.215	±0.077	-
				POME TREATED SOIL	
0 week	0.553	0.705	0.699	0.665	0.6267
2 weeks	0.504	0.496	0.752	0.790	0.6271
4 weeks	0.505	0.679	0.738	0.713	0.6204
8 weeks	0.649	0.608	0.975	0.968	0.7833
16 weeks	1.029	0.888	1.302	1.246	1.118
32 weeks	1.314	1.643	2.120	1.915	1.6385
S.E	±0.166	±0.135	±0.233	±0.168	-

TABLE 7
Nitrogen derived from POME

Treatment	Experiment 1 N derived from POME (%)	(mg/plant)	Experiment 2 N derived from POME (%)	(mg/plant)
0 week	9.35	257.22	9.78	238.73
2 weeks	4.75	128.92	11.74	309.35
4 weeks	6.52	163.85	26.02	587.01
8 weeks	6.42	186.31	18.90	447.74
16 weeks	5.01	142.44	22.80	529.19
32 weeks	3.66	131.76	11.88	284.17
% Range in POME-N utilized over 40 weeks period		5.72 - 11.41		4.92 - 12.10

indicates that mineralization of POME was most active in the first two weeks after application. In experiment 2, the amount of N absorbed from mineralized N from POME was found to increase with time (Table 7). The difference found in experiment 1 and 2 was due to the amount of total solids present in the POME used. In experiment 1, the range in N contributed by 1.01 of POME was 128.92 - 257.22 mg N over a period of 40 w. Since the total N added from 1.01 POME was 2254 mg, between 5.72 - 11.41 percent of this nitrogen was taken up by the oil palm seedlings. In experiment 2, the percent ^{15}N a.e present in the different parts of the plants were higher than in experiment 1. This is due to the higher ^{15}N enrichment of the fertilizer used. The total amount of N released with time was also found to be higher due to the high total solids present in the POME used, as compared to experiment 1. The range in N contributed by 1.01 of POME in experiment 2 was 238.73 - 587.01 over a period of 40 w, and since the total N added in one litre of POME was 4851 mg at the beginning of the experiment, between 4.92 - 12.10 percent of this total N was utilized. These percentages were found to be about equal to the values obtained in earlier work conducted under field conditions where it was shown that 10% of ammonium sulphate and 8% of urea were utilized by young oil palms in a period of 3 m (Zaharah *et al.* 1987). Thus POME used in this experiment is a good source of nitrogen for oil palms and there is potential for it to be used as a source of nitrogen.

CONCLUSION

This study showed that when POME with low total solids content was applied to the oil palm seedlings, the highest N was absorbed by the oil palm seedlings during the first two weeks after application. But with a higher total solids content, the N absorbed increased up to 16 w after application. On the average about 4.9 - 12.1 percent of the total N content of the POME applied was utilized by the oil palm seedlings over a period of 40 w.

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