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The Efficacy of Palm Oil Mill Effluent as a Soil Ameliorant

J. SHAMSHUDDIN and H.A.H. SHARIFUDDIN
Department of Soil Science
Faculty of Agriculture
Universiti Pertanian Malaysia
43400 UPM Serdang, Selangor, Malaysia

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ABSTRAK

Satu kajian ladang telah dijalankan untuk menilai keberkesanan efluen kilang kelapa sawit (EKKS) sebagai pembaik tanah untuk pengeluaran jagung. EKKS telah diletakkan di dalam tanah Batang Merbau (Typic Kandiudult) pada kedalaman 0-30 cm sebelum jagung ditanam. Kacang tanah ditanam selepas jagung dituai. Kadar rawatan EKKS ialah 0, 5, 10, 20 dan 40 t ha^{-1}, dengan atau tanpa kehadiran 2 t batu kapur berdolomit ha^{-1}. Kalsium, Mg dan Al bertukar ganti, dan pH (0.01 M $CaCl_2$) di dalam tanah atas sebelum rawatan ialah masing-masing 0.36, 0.19, 1.50 $cmol_c$ kg^{-1} dan 4.1. Hasil tongkol basah tidak bertambah dengan kadar rawatan EKKS sehingga 10 t ha^{-1}; purata hasil ialah 1.7 t ha^{-1} dan menambahkan kadar rawatan EKKS kepada 20 dan 40 ha^{-1} mengakibatkan hasil basah > 2.2 t ha^{-1}. Kenaikan hasil disebabkan oleh kebaikan keadaan untuk pertumbuhan tanaman. Hasil tongkol basah kesemua kadar rawatan EKKS dengan kehadiran kapur ialah > 2.2 t ha^{-1}. Terdapat korelasi bererti diantara hasil jagung dengan Al dan Ca di dalam tanah. Purata hasil kacang tanah tanaman pertama ialah 3 t ha^{-1}. Tidak terdapat sebarang kolerasi diantara hasil kacang tanah dengan Al, Ca atau Mg bertukar ganti di dalam tanah.

ABSTRACT

A field experiment was conducted to assess the effectiveness of palm oil mill effluent (POME) as a soil ameliorant for the production of food crops. The POME was incorporated into the top 0-30 cm of Batang Merbau soil (Typic Kandiudult) prior to seeding with maize. Following maize, groundnut was grown. POME was applied at 0, 5, 10, 20 and 40 t ha^{-1}, both in the presence and absence of 2 t dolomitic limestone ha^{-1}. Exchangeable Ca, Mg and Al, and pH (0.01 M *$CaCl_2$) in the topsoil prior to application of the treatments were 0.36, 0.19, 1.50 $cmol_c$ kg^{-1} and 4.1, respectively. The average fresh cob yield of maize was 1.7 t ha^{-1}, and did not increase with application of POME at rates of up to 10 t ha^{-1}. Increasing the rate of POME to 20 and 40 t ha^{-1} resulted in fresh cob yield > 2.2 t ha^{-1}. The increase in yield was attributed to improvement in the soil conditions for plant growth. Fresh cob yields in the presence of lime were > 2.2 t ha^{-1} at all rates of application of POME. Maize yield was significantly correlated with the exchangeable Al and Ca in the soil. Average pod yield for the first crop of groundnut was 3 t ha^{-1}. Groundnut yield was not correlated with exchangeable Al, Ca or Mg in the soil.*

INTRODUCTION

Rubber, cocoa and palm oil, the main agricultural exports of Malaysia, are mainly grown on acid and highly weathered soils. These soils are classified as Ultisols and Oxisols and occupy about 72% of the land area of Malaysia (IBSRAM 1985). The clay fractions of the soils are dominated by variable-charge minerals such as kaolinite, goethite and gibbsite (Tessens and Shamshuddin 1983). Charges on the mineral surfaces depend on soil pH and/or ionic strength (Uehara and Gillman 1981) and are, therefore, affected by application of lime or organic matter.

During the early replanting phase of rubber and oil palm plantations, the interrow areas are sometimes used for cash crop production such as maize and groundnut. Low pH, high Al activity in the soil solution, and Ca and/or Mg

TABLE 1
Selected chemical and physical properties of the soil before treatment

Depth (cm)	pH (1:1) ($CaCl_2$)	Exchangeable Cations					Al Sat^n	Texture		
		Ca	Mg	K	Na	Al		Clay	Silt	Sand
		cmol$_c$ kg^{-1}					(%)	g kg^{-1}		
0-15	4.11	0.36	0.19	0.22	0.09	1.50	64	392	26	581
15-30	3.82	0.19	0.10	0.13	0.06	1.48	76	423	13	557
30-45	3.63	0.13	0.06	0.13	0.04	1.38	79	417	45	537

deficiency are major factors reducing the yields of the crops in these soils (Shamshuddin *et al.* 1991; Ismail *et al.* 1993). These constraints are also known to lower cocoa production on Ultisols and Oxisols in Malaysia. Liming the plough layer is a standard practice to overcome these problems, but Ca remains mainly in the zone of lime incorporation (Pavan *et al.* 1984; Gillman *et al.* 1989).

Malaysia produces large amounts of palm oil mill effluent (POME) annually (Chan *et al.* 1983); for every tonne of palm oil produced, about 3 tonnes of POME are generated. At the current rate of palm oil production (> 7 million tonnes in 1993) about 18 million tonnes of POME are produced annually as a processing waste product. POME is an organic-rich waste water with the capacity to detoxify Al when it is incorporated into acid soil (Shamshuddin *et al.* 1992a, b). The POME contains large amounts of plant nutrients, notably N (4.4%), P (1.0%), K (1.5%), Mg (1.0%) and Ca (1.3%) (Hishamuddin *et al.* 1985). Application of POME to the soil is known to increase soil pH which, in turn, reduces exchangeable Al in the soil (Shamshuddin *et al.* 1987) and is suitable for application to the soil in oil palm plantations. Since there is minimal groundwater pollution (Zin *et al.* 1983), POME can be used as an acid soil ameliorant for sustained food crop production. The objective of this study was to determine the effectiveness of POME to alleviate soil acidity for annual crop production.

MATERIALS AND METHODS

Experimental Procedures

A field experiment was established on Batang Merbau soil within a rubber replanting scheme at Kampung Jimah Baru, Port Dickson, Malaysia. The soil was a clayey, kaolinitic, isohyperthermic type (Typic Kandiudult) soil with 5^0 slope, low CEC and low pH (Table 1). Digested POME at 0, 5, 10, 20 and 40 t ha^{-1} with or without 2.0 t ground magnesium limestone (GML) ha^{-1} was incorporated into the soil to a depth of 30 cm. A randomized complete block design with four replications was adopted. The elemental composition of the POME is given in Table 2. The POME used in the experiment was obtained from an anaerobic ponding treatment system of a palm oil mill. The slurry effluent was then further treated in a flocculative pond to reduce the biochemical oxygen demand (BOD) to < 50 mg L^{-1}. At the time of application, the POME solid was moist, having a moisture content of about 50%. The GML used in the study contained 6.7% Mg and 18.5% Ca.

Maize (*Zea mays* var. Mas Madu) was planted 30 d after the treatments were applied; groundnut (*Arachis hypogaea* var. Matjam) was planted

TABLE 2
Elemental composition of the POME*

Major Element		Trace Element	
Element	Amount (%)	Element	Amount (mg kg^{-1})
N	2.20	Cu	72
P	0.96	Fe	2
Ca	0.64	Mn	296
K	0.93	Zn	122

* The POME contained 20% C_{org}. The chemical composition may vary from factory to factory, depending on the extraction process and the time of digestion.

TABLE 3
The pH and the chemical composition* of the topsoil solutions for selected treatments at the maize harvest

POME (t ha^{-1})	pH	Al	Ca	Mg	K	S	Ca/Al	Mg/Al
		μM						
0	4.73	108	1069	482	1262	311	9.9	4.5
20	5.10	77	1854	914	1566	773	24.1	11.9
40	4.55	72	1445	624	973	631	20.1	8.7
0+GML	5.20	16	938	992	528	717	58.6	620
20+GML	5.20	32	2016	1791	1012	820	63.0	60
40+GML	5.13	38	2142	1558	1415	1313	56.4	41
LSD (0.05)	0.87	109	1533	1194	739	685		

* As the soil solution P concentration was very low, the data are not presented in this table.

immediately after the maize harvest. Fertilizers at the rate of 120 kg N, 100 kg P and 150 kg K ha^{-1} for maize and 45 kg N, 28 kg P and 60 kg K ha^{-1} for groundnut were applied prior to the planting of each crop. A composite sample of five cores was taken from each of the experimental plots (6 x 6 m) before treatment and subsequent to the maize and groundnut harvests at depths of 0-15, 15-30, 30-45 and 45-60 cm. Maize and groundnut were harvested after 70 and 120 d, respectively.

Chemical Analysis

Soil

pH in 0.01 M $CaCl_2$ (w/v 1:1) and in H_2O (w/v 1:1) was determined after 1 h of intermittent shaking and overnight standing. Basic exchangeable cations were extracted by 1 M NH_4OAc buffered at pH7; Ca and Mg were determined by atomic absorption spectrophotometry; K and Na were determined by flame photometry. Aluminium was extracted by 1 M KCl and determined colorimetrically (Barnhisel and Bertsch 1982). Organic C_{org} was determined by the modified Mebius procedure (Nelson and Somners 1982). Particle-size analysis was carried out by the method of Day (1965).

Soil Solution

The air-dried soils (< 2 mm) from the experimental plots were rewetted at a matric suction of 10 kPa and incubated for 1 day (Menzies and Bell 1988). Soil solutions was extracted by centrifugation at 2000 rpm for 1 h and filtered through 0.45-m filter. pH and EC were determined immediately on 2 ml subsamples. The rest of the solutions were stored at 5°C for determination of Al, Ca, Mg, K, Na, Mn, Fe and S by inductively coupled plasma atomic emission spectroscopy. Only topsoil solutions of selected samples were analysed as the others were not expected to give any significant result, and hence, unable to contribute towards the attainment of the set objective.

RESULTS

Effects on Soil Solution

The topsoil solution pH at the harvest of maize (Table 3) and groundnut (Table 4) was not significantly affected by the POME and/or GML treatments, although it tended to be higher where lime was applied. In an earlier pot experiment, POME treatment was found to increase soil solution pH significantly (Shamshuddin *et al.* 1992b). The subsoil solution pH was not determined as a previous study by Ng (1994) showed that subsoil was not affected significantly by POME or GML treatment. The concentrations of Ca, Mg and S in the soil solutions were higher in the POME than in the no-POME control plots, with and without GML (Table 3). On the other hand, soil solution Al concentra-

TABLE 4
The pH and the chemical composition* of the topsoil solutions for selected treatments at the groundnut harvest

POME (t ha^{-1})	pH	Al	Ca	Mg	K	S	Ca/Al	Mg/Al
		μM						
0	4.37	52	548	250	785	279	10.5	4.8
20	5.03	50	1311	515	1161	510	26.2	10.3
40	4.55	75	810	366	958	409	10.8	4.9
0+GML	4.98	30	1009	655	954	577	33.6	21.8
20+GML	5.28	29	749	855	695	716	25.8	29.5
40+GML	4.88	31	1096	641	1003	540	35.4	20.7
LSD (0.05)	1.15	54	595	400	476	338		

* As the soil solution P concentration was very low; the data are not presented in this table.

tion tended to decrease with POME application in the absence of GML but increased in its presence. There was less change with solution pH and Al, Ca, Mg and S concentrations after groundnut harvest (Table 4).

Effects on Solid Phase

POME treatment alone did not significantly decrease the amount of exchangeable Al in the soil (Tables 5 and 6). On the contrary, a pot experiment indicated a significant reduction in exchangeable Al as a result of POME application (Shamshuddin *et al.* 1992a). However, when both POME and limestone were incorporated together into the soil, the minimum level of exchangeable Al was observed with 5 t POME ha^{-1} + GML at the maize harvest (Table 5). Exchangeable Ca and Mg were not significantly affected by POME application alone, but were increased in those treatments which received GML, which contains Ca and Mg.

Effects on Maize and Groundnut Yields

The fresh weight yield of maize cobs was < 2 t ha^{-1} at POME application rates < 10 t ha^{-1} (Table 5). The highest yield of 4.15 t ha^{-1} was obtained with application of 20 t POME ha^{-1}. The higher yield of maize in the 20 t POME ha^{-1} is attributable to the higher soil pH (Table 5). Yields > 3t ha^{-1} were also obtained when 20 and 40 t POME ha^{-1} were added together with 2 t GML ha^{-1}.

Treatment with 2 t GML ha^{-1} gave the highest groundnut yield of 4.16 t ha^{-1} (Table 6). However, this yield was not significantly different from the yield of the other treatments, except where 40 t POME ha^{-1} was applied. On average, the groundnut yield for the whole experiment was about 3 t ha^{-1}.

DISCUSSION

The soil pH ($CaCl_2$) and pH (H_2O) were correlated with the soil solution pH but the pH ($CaCl_2$) had the higher ($r = 0.69$) correlation and was selected to explain the variation in the maize and groundnut yields due to POME application (Tables 5 and 6). The soil solution pH was not used to explain the variation in yield as its value appeared to be unaffected by the POME and/or GML treatment.

In an earlier study, Shamshuddin *et al.* (1989) reported that critical soil pH values for groundnut and maize grown on Ultisols in Malaysia were 4.3 and 4.6, respectively. This means that a 90% relative maize yield was obtained when soil pH was around 4.6. Data in Table 5 show that the soil pH was in general < 4.6. Thus, it would appear that the pH condition was not conducive for maize.

The maize yield in the control treatment was 1.75 t ha^{-1}. However, maize yield was significantly increased by the application of 20 t POME ha^{-1} alone. The yield also increased to > 3 t ha^{-1}

TABLE 5
The pH, exchangeable Al, Ca and Mg in the topsoil, and maize yield (fresh cob weight)

POME (t ha^{-1})	pH ($CaCl_2$)	Exchangeable Cation			Yield (t ha^{-1})
		Al	Ca	Mg	
		cmol$_c$ kg^{-1}			
0 (T1)	4.09 ba	1.46 bdac	0.80 ba	0.29 b	1.75 b
5 (T2)	3.92 b	1.65 ba	0.55 ba	0.27 b	1.59 b
10 (T3)	3.88 b	1.79 a	0.32 b	0.30b	1.85 b
20 (T4)	4.40 ba	1.37 bdac	0.28 b	0.21b	4.15 a
40 (T5)	3.85 b	1.55 bac	0.49 ba	0.21 b	2.21 ba
0+GML (T6)	4.45 ba	0.62 ed	0.95 ba	0.69 ba	2.21 ba
5+GML (T7)	4.62 a	0.33 e	1.38 a	1.03 a	2.73 ba
10+GML (T8)	4.35 ba	0.95 ebdac	1.02 ba	0.73 ba	2.39 ba
20+GML (T9)	4.33 ba	0.78 edc	1.17 a	0.48 ba	3.35 ba
40+GML (T10)	4.37 ba	0.90 ebdc	1.32 a	0.81 ba	3.22 ba

TABLE 6
The pH, exchangeable Al, Ca and Mg in the topsoil, and groundnut yield (fresh pod weight)

Treatment	pH $CaCl_2$	Exchangeable Cations			Yield (t ha^{-1})
		Al	Ca	Mg	
		cmol$_c$ kg^{-1}			
T1	3.78 ba	1.42 ba	0.54 bc	0.22 c	2.97 ba
T2	3.83 ba	1.50 a	0.49 bc	0.19 c	2.74 ba
T3	3.62 b	1.64 a	0.40 c	0.17 c	3.51 ba
T4	4.07 a	1.16 ba	1.61 ba	0.65 ba	3.28 ba
T5	3.75 ba	1.65 a	0.35 bc	0.25 cb	2.55 b
T6	4.02 a	1.34 ba	0.82 bac	0.55 bac	4.16 a
T7	4.06 a	0.98 ba	1.13 bac	0.59 bac	3.23 ba
T8	3.71 ba	1.26 ba	0.75 bac	0.52 bac	3.10 ba
T9	3.89 ba	1.08 ba	1.42 ba	0.68 a	3.52 ba
T10	3.93 ba	0.74 b	1.71 a	0.70 a	3.36 ba

when the soil was treated with ⩾ 20 t POME together with 2 t GML ha^{-1}. The increase in yield, although not significant, was due in part to better soil conditions (lower Al) and/or increase in plant nutrient contents (Ca and Mg) of the soils as a result of the treatment (Tables 3 and 5). The POME used in the current experiment contained moderate amounts of N, P, K and Ca (Table 2).

Data in Table 6 also show that the soil pH at the groundnut harvest was about 4, and therefore, the pH condition in the soil was good enough for groundnut production. Thus, groundnut did not respond to the POME application. However, groundnut growth responded favourably to GML application alone, giving the highest yield of 4.16 t ha^{-1} when the soil was treated with 2 t GML ha^{-1}.

There was an indication that the maize yield increased with increasing soil solution Ca/Al concentration ratio, but this trend was not observed for the Mg/Al ratio (Tables 3 and 5). However, in the subsequent crop of groundnut, the yield was indicated to increase with increasing soil solution Ca/Al and Mg/Al concentrations ratios (Tables 4 and 6). As indicated in Table 3 and 5, maize yield appeared to increase with an increase in soil solution Mg concentration. This is consistent with the finding of an earlier study by Shamshuddin *et al.* (1991) where magnesium application was required to improve maize yield. The observed yield increase as a result of the POME and/or GML treatment for both crops was due to an increase in Ca, Mg and/or reduction in Al in the soil solution.

There was no significant correlation between the maize or groundnut yield and the exchangeable Al and Ca. However, when the 20 t POME ha^{-1} treatment was not taken into consideration in the regression analysis, the maize yield was significantly correlated with the exchangeable Al. The relationship is given by the equation:

$$Y = 3.31 - 0.84 \text{ Al}, \quad r = 0.69, P < 0.05.$$

Likewise, the maize yield (without the 20 t POME ha^{-1}) was significantly correlated with the exchangeable Ca. The relationship is given by this equation:

$$Y = 1.20 + 1.36 \text{ Ca}, \quad r= 0.79, p < 0.05$$

The above results showed that the maize yield was increased by reduction in the exchangeable Al and/or by increase in the exchangeable Ca. The reduction in exchangeable Al and the increase in the exchangeable Ca can be achieved by POME and/or GML application. There was also the possibility of the soil acidity being alleviated via complexation of Al by organic acids in the POME, as the POME used in the current study contained 20% C_{org} (Table 2). However, the maize or groundnut yield was not significantly correlated with Al or Ca concentration in the soil solution.

Maize yield appeared to be unaffected by the exchangeable Mg. This is contrary to the findings of Ismail *et al.* (1993) who observed in a pot experiment that relative top maize weight increased with increasing exchangeable Mg. More research is needed to prove conclusively the need of extra Mg by maize grown on acid soils to alleviate Al toxicity.

CONCLUSION

Palm oil mill effluent is available in large quantities in Malaysia. Due to its high plant nutrient content it can be used to ameliorate acid soil infertilities for maize production. Maize yield appears to increase with an increase in exchangeable Ca and/or decrease in exchangeable Al. However, these trends were not observed in the groundnut yield. In this study, the POME required to ameliorate acid soil infertilities for maize production was about 20 t ha^{-1}.

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REFERENCES

BARNHISEL, R. and P.M. BERTSCH. 1982. Aluminum. In *Methods of Soil Analysis* eds. A.L. Page, R.H. Miller and D.R. Keeney. 2nd edn. Part 2 pp. 275-300. Agronomy Monogr. 9. Madison: ASA and SSSA.

CHAN, K.W., T.C. P'NG and R. MOHD AMINUDDIN. 1983. Palm oil mill effluent utilization and its future research directions in the oil palm industry. In *Proceedings Seminar on Land Application of Palm Oil Mill and Rubber Factory Effluents,* eds. K.H. Lim, A.T. Bachik and Y.C. Poon. pp. 23-45. Kuala Lumpur: Malaysian Society of Soil Science.

DAY, P.R. 1965. Particle fractionation and particle analysis. In *Methods of Soil Analysis.* ed. C A Black. 1st edn. Part 2 pp. 545-567. Agronomy Monograph 9. Madison: ASA, Madison, USA.

GILLMAN, G.P., K.L. BRISTOW and M.J. HALLMAN. 1989. Leaching of applied calcium and potassium from an Oxisol in humid tropical Queensland. *Australian Journal of Soil Research* **27**: 183-198.

HISHAMUDDIN, M. J., S. ABDUL HALIM, H. ABDUL SAHAR and M. AHMAD SHAFIZI. 1985. *Perusahaan Kelapa Sawit Di Malaysia - Satu Panduan.* Kuala Lumpur: Palm Oil Research Institute.

IBSRAM. 1985. *Report of the Inaugural Workshop and Proposal for Implementation of the Acid Tropical Soils Management Network.* Bangkok: International Board for Soil Research and Management.

ISMAIL, H., J. SHAMSHUDDIN and S.R. SYED OMAR. 1993. Alleviation of soilacidity in Ultisol and Oxisol for corn growth. *Plant and Soil* **151**: 55-65.

MENZIES, N.W. and L.C. BELL. 1988. Evaluation of the influence of sample preparation and extraction technique on soil solution composition. *Australian Journal of Soil Research* **26**: 451-464.

NELSON, D.W. and L.E. SOMMERS. 1982. Total carbon, organic carbon and organic matter. In *Methods of Soil Analysis* eds. A.L. Page, R.H. Miller and D. R. Keeney. 2nd. edn. Part 2. pp. 539-579. Agronomy Monograph 9. Madison: ASA and SSSA.

NG, C.C. 1994. The effects of palm oil mill effluent on the characteristics of weathered soils. B. Agric. Sc. thesis, Faculty of Agriculture, UniversitiPertanian Malaysia.

PAVAN, M.A., F.T. BINGHAM and P.F. PRAAT. 1984. Redistribution of exchangeable calcium, magnesium, and aluminum following lime or gypsum applications to a Brazilian Oxisol. *Soil Science Society of America Journal* **48**: 33-38.

SHAMSHUDDIN, J., I. JAMILAH and A.M. MOKHTARUDDIN. 1987. Chemical changes in soils affected by application of palm oil mill effluent. *Pertanika* **10**: 41-47.

SHAMSHUDDIN, J., H.A.H. SHARIFUDDIN and Z. SHAMSHUDDIN. 1989. Reduction of aluminium toxicity through liming. *UPM Research News* **3(2)**: 2-3.

SHAMSHUDDIN, J., I. CHE FAUZIAH and H.A.H. SHARIFUDDIN. 1991. Effects of limestone and gypsum applications to a Malaysian Ultisol on soil solution composition and yields of maize and groundnut. *Plant and Soil* **134**: 45-52.

SHAMSHUDDIN, J., I. JAMILAH, H.A.H. SHARIFUDDIN and L.C. BELL. 1992a. Changes in solid phase properties of acid soils as affected by limestone, gypsum, palm oil mill effluent and rock phosphate applications. *Pertanika* **15**: 105-114.

SHAMSHUDDIN, J., I. JAMILAH, H.A.H. SHARIFUDDIN and L.C. BELL. 1992b. Limestone, gypsum, palm oil mill effluent and rock phosphate effects on soil solution properties of some Malaysian Ultisols and Oxisols. *Pertanika* **15**: 225-235.

TESSENS, E. and J. SHAMSHUDDIN. 1983. *Quantitative Relationship Between Mineralogy and Properties of Tropical Soils.* Serdang: Universiti Pertanian Malaysia Press.

UEHARA, G. and G.P. GILLMAN. 1981. *The Mineralogy, Chemistry, and Physics of Tropical Soils with Variable Charge Minerals.* Boulder: Westview Press.

ZIN, Z.Z., MOHD TAYEB DOLMAT, A.N. MA, K.H. YEOH and K.H. LIM. 1983. Monitoring and environment assessment - water quality. In *Proceedings Seminar on Land Application of Palm Oil Mill and Rubber Factory Effluents* eds. K.H. Lim, A.T. Bachik and Y.C. Poon. pp. 163-179. Kuala Lumpur: Malaysian Society of Soil Science.

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