Pertanika J. Trop. Agric. Sci. **20(2/3)**: 91-99(1997) ISSN: 0126-6128

The Phytotoxic Effects of Palm Oil Dry Solids on Plant Growth

O. RADZIAH, H. AZIZAH and A.R. ZAHARAH
Department of Soil Science
Faculty of Agriculture
Universiti Putra Malaysia
43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

Keywords: palm oil mill effluent (POME), palm oil dry solids (PODS), phytotoxicity, decomposition, bioassay, sandy tailing soil

ABSTRAK

Kajian di rumahkaca dan di makmal bertujuan mengkaji kefitotoksikan pepejal kering kelapa sawit (PODS) terhadap pertumbuhan sayuran dan kesan penguraian terhadap kefitotoksikan. PODS mentah dan reput pada kadar 0, 1, 3, 6, 9, 15 dan 21% (b/b) digaul ke dalam tanah pasir bekas lombong dan ditanam dengan anak benih tomato dan bayam. Sampel PODS mentah dieramkan pada suhu 30°C selama 0, 1, 2, 3, 4, 6 dan 8 minggu dan ekstrak akueus setiap sampel dibiocerakinkan untuk mengesan perencatan pertumbuhan akar tomato. Keputusan kajian rumahkaca menunjukkan pertumbuhan tomato dan bayam dipengaruhi oleh jenis (mentah atau reput) dan kadar PODS yang digunakan. Tumbesaran kedua-dua sayuran terencat dengan pemberian > 1% PODS mentah. Sebaliknya, pemberian 1 - 21% PODS reput meningkatkan tumbesaran tanaman dengan penghasilan bahan kering maksimum pada paras 6%. Pada paras ini, berat kering pucuk tomato dan bayam meningkat 7 dan 178 kali berturutan, manakala berat kering akar meningkat 1.6 dan 62 kali berturutan berbanding tanaman pada PODS mentah. Kandungan N, P dan K tanah serta pH dan konduktiviti elektrik tanah juga meningkat dengan peningkatan paras PODS. Kajian pengeraman menunjukkan kesan fitotoksik PODS mentah berkurangan apabila PODS telah mereput > 4 minggu.

ABSTRACT

Glasshouse and laboratory experiments were conducted to evaluate the phytotoxicity of palm oil dry solids (PODS) on growth of vegetables and the effect of decomposition on the reduction of PODS phytotoxicity. Raw and decomposed PODS was applied to sandy tailing soil at the levels of 0, 1, 3, 6, 9, 15 and 21% (w/w) and planted with tomato and spinach seedlings. Samples of raw PODS were incubated at 30°C for 1, 2, 3, 4, 6 and 8 weeks and the aqueous extract of each sample was bioassayed for growth inhibition of tomato radicles. Results from the glasshouse experiment showed that growth of tomato and spinach was strongly affected by the type (raw or decomposed) and amount of PODS applied. Growth of both plants was inhibited by application of >1% raw PODS. In contrast, application of 1- 21% decomposed PODS increased plant growth, with maximum dry matter production at 6% level. At this level, shoot dry weights of tomato and spinach increased 7 and 178 times, respectively, while root dry weights increased 1.6 and 62 times, respectively, compared to plants in raw PODS. Soil N, P and K contents, pH and electrical conductivity also increased with increase in PODS levels. The incubation study showed that the phytotoxicity of raw PODS was reduced when PODS was decomposed for > 4 weeks.

INTRODUCTION

Palm oil mill effluent (POME) contributes a large proportion of the agricultural waste in Malaysia. If not treated correctly, this waste can cause environmental pollution. As a step to minimizing this problem, POME is currently being utilized in agriculture as organic fertilizer. Application of POME to soil has been shown to increase the growth of oil palm and other crops (Lim *et al.* 1984). However, application of high levels of raw POME to soil can adversely affect growth of plants. Direct application of such effluent was observed to reduce growth of oil palm seedlings (Mohd Nazeeb *et al.* 1984) and

the production of oil palm fresh fruit bunch (FFB) (Chan *et al.* 1981). Application of undecomposed POME to sandy tailings also reduced the growth of mustard greens (Zulkifli and Rosmin 1990). The inhibitory effect of raw POME on plant growth has been associated with the presence of lipid and some volatile substances, which indirectly inhibit the development of plant's roots (Lim 1986). This inhibitory effect is however only temporary, since the toxic compounds are rapidly decomposed and eliminated from the soil.

The inhibitory effects of POME on plant growth are similar to the phytotoxicity exhibited by other types of crop residues (Rice 1984). Inhibition of plant growth has been closely associated with the presence of phenolic substances. These toxic substances could be leached out in high amounts from the organic residues into the soil or produced by microorganisms during residue decomposition. The degree of inhibition from these compounds depends on the type of organic residue and the sensitivity of the plant root system (Zucconi and de Bertoldi 1987). Phytotoxicity has been found to be maximum at the early stage of residue decomposition and it disappears with prolonged decomposition (Guenzi *et al.* 1967; Kimber 1973).

Several types of POME generated in palm oil mills are being utilized as organic fertilizer One of the commonly used types is the decanter dried sludge. This is the solids remaining after the decanter sludge has been dried to a constant weight at 105°C in the mill and is referred to as palm oil dry solids (PODS) (Zakaria and Hassan 1993). It is usually applied to soil a few weeks before seeding or transplanting. This material may also contain water-soluble compounds which are phytotoxic to plant growth. Continuous application of the raw PODS can result in accumulation of these toxic compounds in soils. Although inhibition of plant growth with the application of raw palm oil mill effluent has been frequently observed, only a few studies have been conducted on this phenomenon. It is therefore of great importance to assess the phytotoxicity of PODS, quantify the amount of PODS to be applied and determine the degree of its decomposition, in order to utilize the effluent as an organic fertilizer. The experiments conducted aimed to determine the phytotoxic effect of raw and decomposed PODS on growth of two types of vegetables, and to evaluate the effect of decomposition period on the growth of tomato radicles.

MATERIALS AND METHODS

Effect of Raw and Decomposed PODS on Plant Growth

Raw PODS was collected from the Rantau Palm Oil Mill, Negeri Sembilan. It was a dried material containing 8% moisture and granular in shape, with size range 2-5 mm. The material was kept in plastic bags and stored in a cold room (8°C) before use.

Decomposed PODS was prepared by placing the raw effluent in dark plastic bags, moistening with (100%) distilled water and leaving to decompose aerobically in the glasshouse for 6 months at temperatures of 28-35°C. The material was turned over every month and the moisture content was maintained throughout the incubation period. The decomposed PODS was then air-dried, ground and sieved (2-mm mesh). The chemical properties of raw and decomposed PODS are shown in Table 1.

TABLE 1
Chemical characteristics of palm oil dry solids

	Raw	Decomposed
C (%)	19.43	14.40
N (%)	1.44	2.31
P (%)	0.32	0.35
K (%)	1.32	1.75
Ca (%)	1.46	2.36
Mg (%)	0.32	0.81
Lipid (%)	12.0	0
pH(1:5 in H_2O)	5.0	6.7

Soil Preparation and Treatments

Sandy tailing soil used in the study was collected from ex-mining land located at Universiti Putra Malaysia, Serdang. The infertile soil contained 89.7% sand, 7.5% silt and 1.7% clay, pH 6.3 (1:2.5 in H_2O), 1.4 g kg^{-1} organic carbon, 0.01 g kg^{-1} P, 0.01 cmol (+) K kg^{-1} soil and traces of total N. The soil was air-dried and passed through a 2-mm sieve. The soil was subsequently used to fill (1 kg/pot) 60 undrained pots with top diameter 19 cm and height of 15 cm.

The sandy soil was then treated with different levels of raw and decomposed PODS. The levels of PODS used were: 0, 1, 3, 6, 12, 15, and 21% (w/w air-dried basis). The treated soil was mixed thoroughly and watered to field capacity.

The two test plants used were tomato (*Lycopersicum esculentum*) and spinach (*Amaranthus viridis*). Tomato and spinach seeds were germinated on sandy soil for one month, after which two uniform seedlings from each plant species were transplanted to the respective pots. The experiments were laid out as a randomized complete block design (RCBD) with four replications per treatment. All the plants were watered to field capacity daily and harvested 30 days after transplanting (DAT). At harvest, plant shoots were cut 1 cm above ground level. The roots were freed from the soil and washed clean of adhering soil particles with tap water. Both shoots and roots were oven-dried at 60°C to constant weights and their dry weights were recorded.

Soil in each pot was sampled, air-dried and analysed for total N using the microkjeldahl procedure (Bremner 1965), exchangeable P using the method of Bray and Kurtz (1945), exchangeable K using the method of Singh and Ratnasingam (1970), soil pH (1:2.5 in H_2O) using pH meter and soil electrical conductivity (EC) (1:2.5; in H_2O) using the portable EC meter.

Effects of PODS Decomposition Period on Growth of Tomato Radicle

Incubation study. One hundred grams of raw PODS were placed in separate 500-ml conical flasks. The contents were moistened with 100 ml distilled water and incubated at room temperature (28-30°C) for 0, 1, 2, 3, 4, 5, 6 and 8 weeks. At the end of each sampling period, 10 g PODS from each flask was mixed with 100 ml distilled water and vigorously shaken on a rotary shaker for 6 hours. The suspension was left to settle in a cold room (8°C) for 30 min. The suspension was then decanted into a clean tube and centrifuged at 1000 (rpm) for 1 h. The clear brown supernatant was vacuum-filtered through Whatman No. 2 filter paper and the filtrate was subsequently bioassayed to assess its phytotoxicity.

Bioassay technique and seed selection. Several seeds, *viz* rice, mungbean, cucumber, spinach and tomato were tested for their sensitivity to the inhibitory compounds present in PODS extract (Table 2). The degree of inhibitory effect of the aqueous extract was evaluated by measuring the length of radicles in treated versus control. Tomato seed was found to be most sensitive to the bioassay tests conducted. This seed was easy to handle and consistent in response to PODS extract. Tomato seed was subsequently used in further bioassay tests conducted.

TABLE 2
Growth of seedling radicles in PODS extract

Seedlings	Radicle length (mm)	
	Distilled H_2O (control)	PODS extract
Tomato	61.9	10.8
Spinach	37.6	19.2
Mungbean	51.6	30.9
Cucumber	43.8	65.2
Rice	49.4	54.3

One gram of tomato seeds (400 seeds) were successively washed 5 times with sterilized distilled water. Initially, the seeds were sterilized in 0.1% NaOCl. However, this was discontinued as 0.1% NaOCl concentration was found to inhibit seed germination. The seeds were then germinated in glass petri dish lined with Whatman No.1 filter paper and kept in the dark at 30°C for 48 h. Uniformly germinated seeds with radicle length of about 1 mm were then used in the bioassay.

One millilitre of the PODS extract was pipetted into sterile glass petri dishes (90 x 10 mm) lined with double layer Whatman No.1 filter paper. Two millilitres of distilled water were added to make up a total of 3 ml solution per dish. The control dish was only given 3 ml sterilized distilled water. Ten pregerminated seeds were then placed at equidistant points in the dish. A similar procedure was used to determine the effect of lipids (oils and fats) extracted from PODS on growth of tomato radicles. The lipids were extracted earlier from PODS (raw and decomposed for 4 weeks). Five milligrams of the lipids were dissolved in 5 ml chloroform to form a concentration of 1 mg ml^{-1}. One millilitre of the solution was then placed in sterilized petri dishes as described previously. The chloroform in the dish was allowed to evaporate overnight, before 3 ml of sterilized distilled water was added to the dish. The control dish was given 1 ml chloroform which evaporated off overnight, before adding 3 ml of water. Ten pregerminated seeds were then placed at equidistant points in the dish. The bioassay was replicated three times.

All the petri dishes were then incubated in the dark at 30°C. Radicle growth was determined

by measuring the length of the radicles three days after incubation. The presence of inhibitory compounds in the treatment was indicated by stunted radicle length as compared to the normal radicle in control. The radicle growth in PODS extract was then expressed as the percentage of radicle growth in control (distilled water).

PODS analysis. The lipid content in PODS was determined by fluxing 10 g PODS with 100 ml petroleum ether for 2 h using the Buchi Sohxlet fat extractor. The percentage of lipid was calculated from the weight of dried residue in the collecting dish. The pH and electrical conductivity (EC) of the PODS extract (1:10; PODS: water (w:v)) were also determined. All data obtained were subjected to the analysis of variance using the SAS (1987) procedures.

RESULTS

Effect of Raw and Decomposed PODS on Plant Growth

Shoot and root dry weights. Results showed that shoot and root dry weights of tomato and spinach were significantly ($P \leq 0.01$) affected by the type (raw or decomposed) and amount of PODS applied (*Fig. 1A, B*). In general, application of decomposed PODS significantly increased both the dry weight of shoots and roots of both plants compared to raw PODS. Plant growth was also affected by the level of PODS applied. Maximum growth of tomato and spinach obtained in soils with an application of 6% decomposed PODS. At this level, the dry weight of tomato shoots and roots increased by 7 and 1.6 times, respectively, compared to plants in raw PODS. Spinach shoots and roots increased by 178 and 62 times respectively, in decomposed PODS compared to those in raw PODS.

Application of decomposed PODS at levels > 6%, however, decreased the growth of both plants. Shoot dry weight of tomato decreased by 43% when the level of decomposed PODS was increased from 6 to 9% (*Fig. 1A*). Shoot dry weight of spinach decreased by 50% when given 15% PODS (*Fig. 1B*). Similarly, the root growth of both plants was also reduced with the application of > 6% decomposed PODS.

Soil nutrients. Application of both types of PODS significantly ($P \leq 0.01$) affected N, P and K

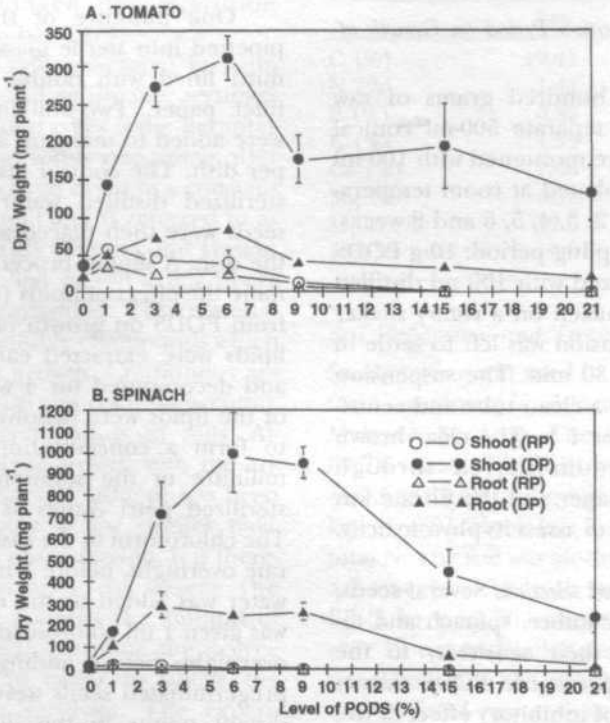

Fig 1. Effect of raw (RP) and decomposed PODS (DP) on dry weight of shoots and roots of tomato (A) and spinach (B) (Means ± Standard error)

contents of the sandy soil cultivated with tomato and spinach. In general, the soil N, P and K increased with increase in the level of PODS. Total N and available P were higher in soils treated with decomposed than with raw PODS (Table 3A, B). This was true for all levels of PODS applied. The available K in soil did not differ significantly between treatments with raw or decomposed PODS.

Soil pH and electrical conductivity (EC) were significantly ($P \leq 0.01$) influenced by the type and level of PODS applied (Table 4A, B). In general, the soil pH increased with increase in the levels of PODS applied. The pH was slightly higher in soil treated with decomposed PODS than soil treated with raw PODS. The EC, which measures the total soluble salts in soil, also increased with increase in PODS level. At ≤ 9% level, EC value in soils treated with raw PODS increased to > 5.5 mS cm^{-1} and to > 7.0 mS cm^{-1} with decomposed PODS.

Effect of PODS Decomposition Period on Growth of Tomato Radicles

Growth of tomato radicle. The results showed that the period of PODS decomposition significantly ($P \leq 0.01$) affected radicle length of tomato seedlings (*Fig. 2*). The percentage of radicle growth for tomato seedlings increased with decomposition period. Growth of the radicle was severely inhibited at weeks 0 and 1 with 30 and 18.7% inhibition, respectively, compared to the control. The tomato radicle was stunted and severely browned, indicating necrosis of the root cells resulting from the effect of growth inhibitors. Toxicity of PODS was found to decline rapidly after 2 weeks of incubation, resulting in rapid increase in growth of radicles up to 84.1% four weeks after PODS decomposition.

The bioassay results also showed that growth of tomato radicles was inhibited by the presence of high amounts of lipids in PODS, and the inhibition was reduced with PODS decomposi-

TABLE 3
Nutrient content of sandy tailings under (A) tomato and (B) spinach

(A) Tomato

Level of PODS (%)	N (g kg^{-1})		P (mg kg^{-1})		K (cmol(+)kg^{-1})	
	Raw	Decomposed	Raw	Decomposed	Raw	Decomposed
0	0.55	0.55	13.27	13.27	0.02	0.02
1	0.33	0.60	19.61	28.17	0.30	0.32
3	0.38	0.73	41.04	52.75	0.82	0.70
6	0.63	1.03	76.15	105.47	1.36	1.32
9	1.98	1.23	100.67	136.16	1.72	1.68
15	1.33	2.38	151.19	211.85	2.43	2.43
21	2.73	3.40	255.69	295.96	3.26	2.81
LSD (0.05)	0.08	0.58	17.93	15.57	2.57	0.34

(B) Spinach

Level of PODS (%)	N (g kg^{-1})		P (mg kg^{-1})		K (cmol(+)kg^{-1})	
	Raw	Decomposed	Raw	Decomposed	Raw	Decomposed
0	0.40	0.40	11.62	11.62	0.02	0.02
1	0.60	0.80	17.30	17.62	0.03	0.32
3	0.60	0.80	42.75	40.94	0.80	0.70
6	0.80	1.10	71.00	81.06	1.30	1.40
9	0.90	1.19	101.28	121.13	1.10	1.85
15	1.00	2.40	151.61	211.60	2.40	2.18
21	2.10	3.60	251.95	294.39	2.70	2.90
LSD (0.05)	0.12	0.16	16.79	10.13	0.33	0.53

TABLE 4
pH and EC of sandy tailings under (A) tomato and (B) spinach

(A) Tomato

Level of PODS (%)	pH		EC (mS cm^{-1})	
	Raw	Decomposed	Raw	Decomposed
0	5.8	5.8	0	0
1	6.2	6.5	1.0	1.0
3	6.3	6.8	2.8	2.5
6	6.3	7.1	3.3	2.8
9	6.1	7.2	5.5	7.0
15	6.1	7.3	7.3	10.0
21	6.0	7.3	11.3	16.0
LSD (0.05)	NS	0.1	0.3	1.0

(B) Spinach

Level of PODS (%)	pH		EC (mS cm^{-1})	
	Raw	Decomposed	Raw	Decomposed
0	5.8	5.7	0	0
1	6.6	6.9	1.0	1.0
3	6.9	6.9	2.3	2.3
6	7.0	7.1	3.3	2.7
9	7.0	7.0	5.7	7.0
15	7.0	7.1	7.7	9.0
21	0.2	7.2	10.0	16.3
LSD (0.05)	0.2	0.2	0.5	1.5

NS - not significant at $P \leq 0.05$

tion (Table 5). It was observed that the lipid content in PODS was reduced from 10.1% to 0.4% after 4 weeks of decomposition. The radicle growth was subsequently observed to increase from 78.7% at week 0 to 88.2% at week 4.

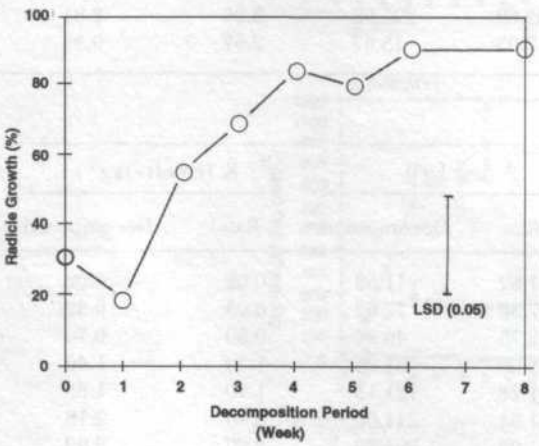

Fig 2. Effect of decomposition period of PODS on growth of tomato radicles

Changes in lipid, pH and EC of PODS. Decomposition of PODS was found to significantly ($P \leq 0.01$) influence the lipid content and pH, but not the electrical conductivity (EC) of PODS (Table 6). The lipid content in PODS decreased rapidly with increase in decomposition time. The lipid content was reduced by 96% after 4 weeks of incubation. The decrease in lipid content paralleled the increase in radicle growth of tomato seedlings as observed in Table 5. The pH of PODS extract increased significantly ($P \leq 0.01$) with increase in decomposition time. The pH increased from 5.0 at week 0 to 7.3 at week 4

TABLE 5
Effect of lipid on growth of tomato radicles

Decomposition period (week)	Lipid content in PODS (%)	Radicle (% of control)
0	10.1	78.7
4	0.4	88.2

TABLE 6
Lipid content, pH and EC of PODS extract as affected by decomposition period

Decomposition period (week)	Lipid content (%)	pH	Electrical conductivity (mS cm^{-1})
0	10.1	5.0	3.9
1	7.3	5.6	3.4
2	2.8	5.6	3.4
3	1.1	6.3	3.6
4	0.4	7.3	3.8
5	0.2	7.4	3.5
6	0.1	7.5	3.5
8	0.1	7.6	3.6
LSD (0.05)	1.9	0.4	NS

NS - not significant at $P \leq 0.05$

and remained almost constant thereafter. The EC of PODS remained almost constant (3.4 - 3.9 mS cm^{-1}) throughout the decomposition periods.

DISCUSSION

Results from the present study indicated the strong influence of PODS on growth of vegetable seedlings. Application of sandy tailing soil with raw PODS inhibited plant growth. Both tomato and spinach plants exhibited little shoot and root growth. In contrast, application of decomposed PODS benefited plant growth in sandy soil. Maximum plant growth was observed in soil treated with 6% decomposed PODS. At this level, growth of shoots and roots of tomato in decomposed PODS was higher than growth in raw PODS. There were differences in the plant's sensitivity to PODS. Spinach was more sensitive to the toxic compounds present in raw PODS then tomato.

Severe reduction in plant growth in soil treated with raw PODS strongly indicates the presence of soluble toxic compounds. The inhibition in plant growth was similar to that observed by earlier studies using other types of crop residues. Growth of wheat and oat seedlings was inhibited when grown in extract of wheat residue (Kimber 1973). Residues of wheat, barley and bluegrass were also inhibitory to wheat seedlings (Cochran *et al.* 1997). Isolation of the compounds revealed that phenolic compounds, especially the free phenolic acids, were responsible for causing plant growth inhibition (Kuwatsuka and Shindo 1973; Lodhi *et al.* 1987; Wójcik-Wojtkowiak *et al.* 1990).

The phytotoxic effect has also been shown to differ with plant types, the amount of toxins present and the amount of roots in contact with the toxic compound (Zucconi and de Bertoldi 1987). The toxins have often been found to affect the growth of the root system more severely than the vegetative parts. In the present study, development of plant roots in the raw PODS was severely retarded with the roots becoming dark brown, indicating death of the root cells. This effect was probably due to the presence of the toxic compounds. Poor root growth would then lead to poor development of the entire plant. Although the presence of high concentrations of nutrients could also give similar toxicity to plant root system (Reuter and Robison 1986), such effect was however not observed in soils given the decomposed PODS.

The results obtained do not illustrate clearly the relationship between plant toxicity and excessive availability of soil nutrients and pH. It was observed that soil N, P and K increased with increase in levels of either raw or decomposed PODS (Table 4). Application of 6% decomposed PODS was the optimum level for plant growth. In contrast, application of the same level of raw PODS inhibited growth, even though the nutrient contents in the soil were similar to those present in soil treated with decomposed PODS. This strongly suggested that plant growth inhibition could be due to other factors. Zucconi and de Bertoldi (1987) had earlier shown that plant growth could be inhibited by the phytotoxin, even in the presence of nutrients. The inhibitory effect could not be related to the soil pH as there was no extreme change in the pH with PODS application. The addition of 6% raw PODS to soil resulted in soil pH of 6.3-6.9, i.e. a soil pH which is considered normal for most plants (Table 4A, B) as compared to pH 7.1 for soils applied with 6% decomposed PODS. Application of high amounts (> 6%) of either raw or decomposed PODS resulted in increase in soil soluble salts measured as the electrical conductivity (EC), which could cause some problems to plant growth. Most plants have been shown to be adversely affected by salt content of > 8 mS cm^{-1} (Mengel and Kirby 1982). Differences in salt concentration will lead to differences in the osmotic pressure around the root cells and will subsequently inhibit the physiological activities of the plant, thus hindering uptake of water by the root cells (Wild 1988). The de-

composition period of PODS did not significantly affect the EC value. This probably indicates that the soluble salts would be an unlikely factor causing growth inhibition in tomato radicles as observed at weeks 0-1 after PODS decomposition. Inhibition of plant growth on soil applied with high doses of raw palm oil mill effluent could also result in waterlogging, which reduces the soil aeration (Chan *et al.* 1981).

Results from the bioassay study showed a rapid decrease in the degree of phytotoxicity as the decomposition period increased. The growth of tomato radicles in the first week of decomposition was severely inhibited, with only an 18.7% growth as compared to control. A prolonged decomposition period of 4 weeks resulted in reduced inhibition and a subsequent radicle growth increment of 84.1% (*Fig. 2*). The water-soluble toxic compounds could be the factor involved in the inhibition of radicle growth. The toxic compounds could rapidly be leached out from PODS immediately after it was mixed with water. This probably caused the radicle inhibition observed at week 0. A slight increase in toxicity after one week of decomposition was probably due to the presence of toxins produced through microbial metabolism of PODS. Several species of bacteria, fungi and actinomycetes have been isolated from other types of POME decomposing in soil (Palaniappan *et al.* 1984; Radziah 1994). These groups of microorganisms could also be responsible for producing the phytotoxic effects observed in raw PODS. However, the phytotoxic effect is temporary as the toxic compounds are rapidly decomposed by microorganisms. There are other microbial communities which metabolize toxins such as phenolic acids as their source of carbon and energy for growth (Blum and Shafer 1988). Such reduction in phytotoxicity of PODS was evident when PODS was allowed to decompose for > 4 weeks.

Apart from the soluble compounds, the lipid (oils and fats) component in PODS extract was also found to inhibit growth of tomato radicles (Table 5). Results obtained showed that crude lipid extract from raw PODS caused a 21.3% growth inhibition. This resultant effect could have intensified the overall phytotoxicity of PODS. However, the toxicity decreased with increase in decomposition period. Earlier studies have indicated that lipids in PODS were responsible for inhibiting root growth of some vegetables (Zulkifli and Rosmin 1990). The presence of fatty acids which are the glyceride components of the oils and fats in oil palm (Azis and Tan 1990) could be inhibitory to radicle growth. Braids and Miller (1975) have shown that a number of short chain fatty acids inhibited growth of wheat roots. However, these fatty acids have also been proven to be rapidly decomposed by soil microorganisms (MouCawi *et al.* 1981).

Decomposition of PODS was found to be beneficial to growth of plants, especially on sandy tailing soil. Application of 6% decomposed PODS to soils tremendously increased growth of spinach and tomato. The absence of phytotoxicity in decomposed PODS can probably be attributed to the breakdown of the toxins by soil microorganisms. The identity of the toxic compound and the significant role of these microorganisms in breaking down the inhibitory compounds present in the PODS need further study.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Universiti Putra Malaysia and Ministry of Science, Technology and Environment of Malaysia for the financial and technical support (Project Number IRPA 1-07-05-048).

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(Received 4 April 1997)
(Accepted 6 December 1997)