

Effect of Oil Palm Sludge on Soil Properties and Growth of Oil Palm Seedlings, *Elaeis guineensis*

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ABSTRACT. Experiments were conducted in a greenhouse to examine the effects of palm oil sludge (POS) on soil physical properties, kinetics and dynamics of N-mineralization, and N-uptake efficiency of oil palm seedlings. The 15% (w/w) POS-soil mixture promoted good growth of oil palm seedlings due to its beneficial effect on physical properties and nutritional aspects. Incorporation of more than 15% POS however, resulted in detrimental effects such as leaf and root senescence of oil palm seedlings. Scanning Electron Micrographs (SEM) showed that at lower rates (10-15% POS), sludge tended to bind soil particles resulting in a strong soil structure. Root volume measurements showed that 15% sludge amendment was the most favourable treatment. Studies on reduction of organic carbon and changes in C:N ratios in different sludge treatments revealed that POS decomposed rapidly with near complete decomposition within one month. The results of N mineralization kinetics showed that 15% POS amended soil with 0.01% urea (0.94% N) gave the highest mineralization potential and the lowest rate constant. The results of N-inflow of oil palm seedlings at different ratios of urea treated 15% POS revealed that the 0.01% urea (0.94% N) treated 15% POS gave the maximum N-inflow ($171.5 \mu\text{g ml}^{-1} \text{ root day}^{-1}$) after 105 days. The higher urea (>0.01%) treatments decreased the N-inflow and root development of oil palm seedlings. The data on net assimilation rate (NAR) also showed that the 0.01% urea amended POS resulted in the highest NAR which ultimately enhanced growth and development of oil palm seedlings.

INTRODUCTION

Palm oil sludge (POS) is predominantly colloidal in nature and contains higher N and other organic and inorganic solids. However it is a waste material in oil palm industries in Malaysia (Teoh *et al.*, 1986). Hence, POS

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could be the solution to the problems which arises from chemical fertilizer application. Addition of POS would further improve soil conditions due to reduced fertilizer loss (by leaching, denitrification and volatilization), particularly N, while increasing the nutrient retention power of the soil.

Newbould (1989) noted that organic carbon and total mineralizable N may decrease over time with increased chemical fertilizer input. Hornby *et al.*, (1986) reported that heavy doses of fertilizer incorporated with sewage sludge, for example, could retard microbial processes involved in N mineralization. Therefore, selection of optimal proportion of POS and inorganic fertilizer is essential in order to increase mineralizable N in the soil. Available soil-N can be estimated by predicting kinetic parameters such as mineralization potential and rate constants (Talpez *et al.*, 1981).

In addition to the dynamics of nitrogen turnover in POS-amended soils, knowledge on nutrient absorption and N assimilation by plants is needed for efficient use of N fertilizer in agriculture (Newbould, 1989). Experimental results of uptake efficiency can also be used to understand crop growth responses to management and placement of fertilizer (Soon, 1988). However, very little information is available with regard to POS decomposition, N dynamics in POS-urea treated soil, N-uptake (N-inflow) and assimilation characteristics by oil palm. Moreover, it is important to examine the physical effects of sludge application to soil at the micro level, using specialized techniques such as Scanning Electron Microscopy (SEM). SEM, for example, has been used successfully by numerous researchers over the years for elucidation of soil structural properties (Chen *et al.*, 1980; Daniel, 1982; Davey, 1978; Glauser *et al.*, 1988; Power and Skidmore, 1984).

The objective of this study was to evaluate the effects of POS and POS-urea treatments on soil properties (sandy loam) and their influence on growth and development of oil palm seedlings.

MATERIALS AND METHODS

Palm oil sludge and soil

A sandy loam top soil was collected from the premises of Universiti Sains Malaysia and air-dried to pass through a 2-mm sieve. POS was obtained from a oil palm mill, Malpom Industries Bhd in Seberang Perai,

Penang, and dried at 60 C for 3 days. After drying, the sludge was ground to pass through a 1-mm sieve. The ground sludge (23% moisture content; 2.6% N; 30% C and 5.6 pH) was mixed with the sandy loam soil to obtain various sludge-soil mixtures (3 to 35% POS).

Root growth and POS decomposition

Oil palm seedlings (2.5-month old; 10 cm height) were planted in black polyethylene bags (20 x 20 cm) at rates of 10, 15, 40, and 75% (w/w) sludge-soil mixtures. Three replicates were used for each treatment. Seedlings were irrigated to field capacity of the sandy loam soil (Michael, 1978). An unamended sandy loam soil was used as control. For 2-month old seedlings, a similar trial was conducted under green house conditions to compare the 15% POS mixture with Malaysian nursery fertilizer mixture, recommended by Turner and Gillbanks (1974). A completely randomized block design was used with three replicates. This experiment was repeated.

POS decomposition studies were also conducted in a similar manner and involved additions of 3, 4, 5, 10, 15, 20, 25 and 35% sludge to the soil, followed by moistening sludge-soil mixtures with a fine spray of distilled water and thorough mixing. Moisture contents of the samples were maintained at WHC (26% moisture content) of sandy loam soil. The moisture level was adjusted gravimetrically with distilled water every third day during the experimental period (Michael, 1978). Scanning Electron Microscopic (SEM) procedure was followed to examine the surface of the aggregates after decomposition study as described by Davey (1978).

Nitrogen dynamics and inflow (uptake efficiency) studies

The treatments were (15% POS with different rates of urea (0.05, 0.03, 0.02 and 0.01% of dry weight of the POS soil mixture). The urea rates were equivalent to 7.2, 5, 3 and 2 g of urea with 15 kg of soil, respectively. Leaching and incubation studies were done as described by Standford and Smith (1972). The experiment was conducted for up to 17 weeks and linear least square method was used to estimate kinetic parameters such as mineralization potential, N_0 ; rate constant (K), and half time, ($t_{1/2}$).

Similar treatments were used for 6-month old oil palm seedlings for N-inflow studies. The shoot of each seedling was used to estimate the total

N content and root volume of each seedling was used to predict the N-inflow. The method proposed by Soon (1988) was followed to predict N-inflow of oil palm seedlings based on root volume. A digital planimeter (KP-90 N) was used to measure the leaf surface area of oil palm seedlings and net assimilation rate was calculated based on leaf surface area (Hunt, 1978). Completely randomized block design was used with three replicates for each treatment.

Analytical method and measurements

Available N was determined by using semimicro-Kjeldahl method (Bremnar, 1965). Root volume of oil palm seedlings was measured using the water displacement method (Leonard *et al.*, 1964). The method was calibrated using a micro-pipette for precision and accuracy. Roots of oil palm seedlings were separated from soil with the help of running tap water pressurized through 1-mm diameter glass tube. Live roots were distinguished from dead roots by colour and turgidity.

RESULTS AND DISCUSSION

Physical effect of POS and POS decomposition

After 2-months of decomposition, the effect of POS application on major physical properties such as water holding capacity (WHC), bulk density (BD), aggregate stability (AS%), and mean weight diameter (wet and dry sieving method) and aggregate size distribution indicated that the 15% POS amendment promote good growth of oil palm seedlings (3.5-month). The SEM study also revealed that 15% POS amendment gave strong soil structure which can reduce erodibility and conserve soil moisture (Vidhana Arachchi and Yahya, 1993).

Results of the aerobic decomposition trial under laboratory conditions (30 C \pm 1 C) during a 2-month period using different rates of POS amendment revealed that decreases in organic carbon, loss on ignition and C:N ratios were faster during the first month. Larry (1987) also found that, the total carbon mineralized increased significantly with increasing rates of paper mill sludge application. The results indicate that, POS underwent rapid decomposition during first month of incorporation into the soil. This is due

to POS having low C:N ratio compared to other organic materials such as coir dust and saw dust.

N-dynamics

Table 1 reveals that, net cumulative mineralized N increased with enhanced rates of sludge addition. Net cumulative mineralized N of the control however, was greater than rates of sludge addition of 3 to 10%. As the C:N ratio of sandy loam soil used in this experiment was about 10; this low value would tend to promote N mineralization. Coppola (1983) reported that, although nitrification rates varied from soil to soil, sandy loam soils tend to show high rates of N mineralization. The low values of cumulative mineralized N at low rates of POS application (<10%) compared to the control could be due to factors such as N immobilization, volatilization of ammonia and denitrification. POS at 15, 20, 25 and 35% resulted in more cumulative N mineralized than the control.

Table 1. Cumulative mineralized nitrogen [$\text{NH}_4^+ + \text{NO}_3^- + \text{NO}_2^-$; ug/g] in palm oil sludge amended soil after 4-week period.

| Sludge% | Decomposition time - Weeks | | | | | | |
|----------|-------------------------------------|-------|--------|--------|--------|--------|--------|
| | 0 | 1 | 2 | 3 | 4 | 6 | 8 |
| | Cumulative inorganic nitrogen, ug/g | | | | | | |
| 0% POS | 56.3 | 99.2 | 162.9 | 203.4 | 249.4 | 285.8 | 344.9 |
| 3% POS | 64.9 | 102.9 | 149.5 | 159.5 | 175.7 | 179.7 | 206.3 |
| 4% POS | 66.5 | 77.9 | 97.3 | 116.3 | 136.6 | 153.4 | 180.0 |
| 5% POS | 53.2 | 71.1 | 95.2 | 113.2 | 134.9 | 154.5 | 168.5 |
| 10% POS | 84.3 | 117.2 | 164.8 | 211.3 | 246.3 | 274.3 | 298.1 |
| 15% POS | 83.6 | 133.6 | 190.2 | 246.2 | 284.2 | 312.2 | 343.0 |
| 20% POS | 109.3 | 165.0 | 230.4 | 287.4 | 331.4 | 367.8 | 411.2 |
| 25% POS | 105.5 | 174.2 | 255.0 | 323.0 | 373.7 | 417.1 | 482.9 |
| 35% POS | 129.7 | 212.6 | 316.8 | 405.8 | 466.9 | 557.9 | 760.9 |
| 100% POS | 300.0 | 607.0 | 1006.4 | 1306.4 | 1522.4 | 1936.8 | 2514.8 |

Data on kinetic parameters such as mineralization potential, rate constant and half time revealed that high rates of urea incorporation with POS retarded mineralization (Table 2). Hornby *et al.*, (1986) reported that, sewage sludge with high rates of NH_4NO_3 addition was detrimental to N mineralization in sewage sludge-amended soil. Experimental results showed that the 15% POS with 0.01% urea treatment gave the highest N_0 ($7250 \pm 1280 \mu\text{g N/g}$) of soil, lowest K ($0.009 \pm 0.002 \text{ week}^{-1}$) and the highest $t_{1/2}$ (75 ± 14 weeks) compared to other treatments.

Table 2. Estimated kinetic parameters, mineralization potential (N_0), rate constant (K), half time ($t_{1/2}$) of N-mineralization rates, net assimilation rate (NAR) and N-inflow in the 15% POS, 15% sludge with urea amended soil, after 17-week period.

| Treatment | N_0 $\mu\text{g N g}^{-1}$ soil | K Week^{-1} | $t_{1/2}$ Weeks | N-inflow for 105 days $\mu\text{g N ml}^{-1}\text{day}^{-1}$ | NAR $\text{mg cm}^{-2}\text{week}^{-1}$ |
|-------------------------------|---|-------------------------|--------------------|--|--|
| 15% POS | 615.8 ± 52 | 0.059 ± 0.008 | 12 ± 1.6 | 3.8 | -0.123 |
| 15% POS with 0.05% urea | 3886.0 ± 72 | 0.028 ± 0.000 | 30 ± 0.0 | 55.6 | 0.340 |
| 15% POS with 0.03% urea | 6557.0 ± 307 | 0.011 ± 0.001 | 65 ± 2.8 | 21.3 | 0.458 |
| 15% POS with 0.01% urea | 7252.0 ± 282 | 0.009 ± 0.002 | 75 ± 14 | 172.0 | 0.460 |
| Sandy loam soil | 92.0 ± 2.4 | 0.275 ± 0.07 | 3 ± 0.6 | | -0.021 |

Effect of POS on root proliferation and uptake efficiency

Effects of POS on growth and development of oil palm seedlings are presented in Table 3. The 75% and 40% sludge treatments resulted in plant death within 1-month of the study. The 15% sludge treatment resulted in death of about 17% of the primary roots of 3.5-month old seedlings. Teoh *et al.*, (1986) reported that high rates of sludge amendment was detrimental to plant growth. However, the 15% sludge treated seedlings showed better vigour compared to the other treatments. Dry weights of roots, root tips and shoots were also higher in the 15% POS treated seedlings.

Table 3. Effect of sludge application on growth and development of oil palm seedlings, after a 1-month period.

| Sludge Treatment (%) | | | | | |
|---------------------------|----------|---------|----------|-----------------|-----------------|
| Parameter | 0 | 10 | 15 | 40 ^a | 75 ^a |
| Root Dry weight (mg) | 923±86 | 687±40 | 982±25 | 140±21 | 341±26 |
| Shoot Dry weight (mg) | 2730±113 | 1935±61 | 3357±151 | 2001±39 | 1435±90 |
| No. of root tips | 1505±483 | 1215±97 | 1660±112 | 870±44 | 900±46 |
| No. of primary roots | 5±2 | 5±0 | 6±2 | 5±1 | 5±1 |
| No. of dead primary roots | 0 | 0 | 1±0 | 3±1.7 | 3±1 |
| Dead primary roots (%) | 0 | 0 | 16.7 | 60 | 60 |

a - Dead plants

Comparison of fertilizer addition with 15% POS (Figure 1) revealed that root volume was higher in the fertilizer treatments compared to the 15% POS treatment and the control up to 6 weeks. Thereafter, root volume in

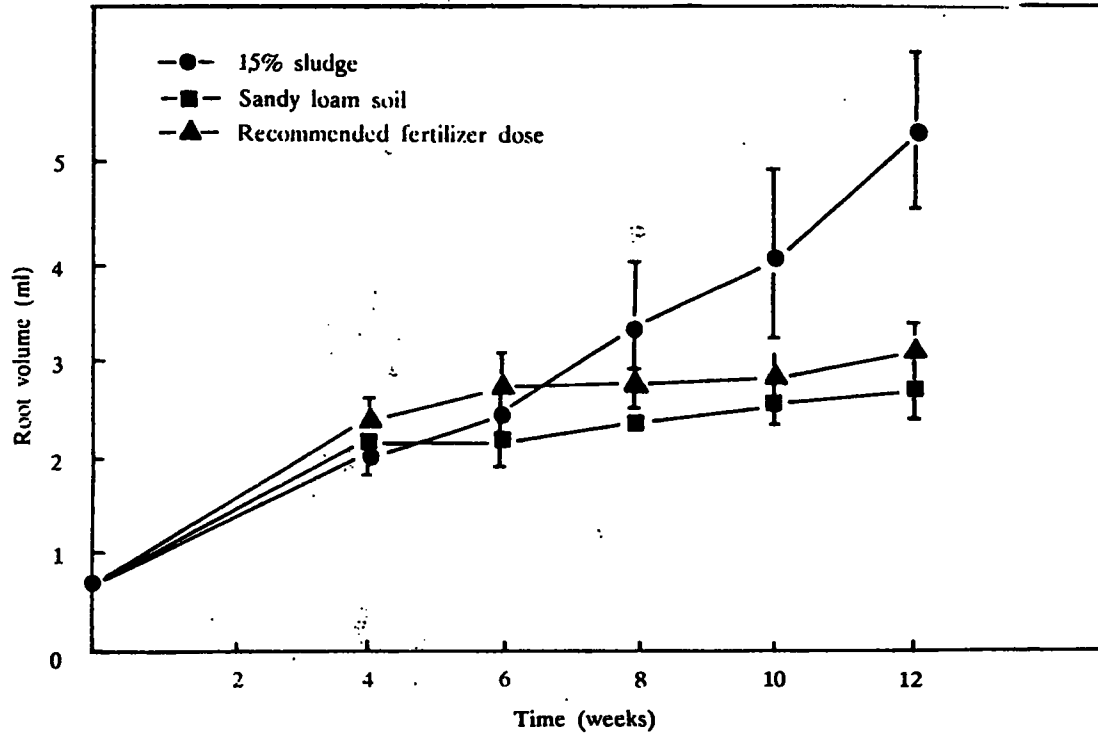


Figure 1. Effect of sludge and fertilizer treated soil on root volume of oil palm seedlings.

15% POS amended soil increased more rapidly than in the fertilizer treatment. Better growth observed during the early stages in fertilizer treatment could be due to the ready supply of nutrients in the medium. The supply of nutrients in the 15% POS amendment was probably delayed and this could be the reason for the late development of root system. Decomposition studies also indicated improvements in physical and chemical properties in sludge amended soil only after one month.

Total root volume of oil palm seedlings was significantly higher in 15% POS amended treatment than in fertilizer treatment after 3 months. The latter did not show any significant difference with respect to the control.

During the first 2-months, the highest shoot dry weight was observed for the fertilizer treatment (Figure 2). Thereafter, the highest growth was obtained in the 15% POS treatment. The initial slower release of nutrient and delayed soil physical improvements in 15% POS amended soil would explain the slow growth of shoot and roots during the early stage. The highest dry weight of whole plant (shoot and root) was observed with the 15% POS treatment after 3 months. Pairwise comparison indicated that the total dry weight of oil palm seedlings was significantly higher in 15% POS amended soil than in the fertilizer treatment. Lim *et al.*, (1983) found that 10% of POS (at 50% moisture content) supplemented with 20% chemical fertilizer gave better performance than 100% chemical fertilizer alone. Oil palm seedlings grown in the soil without POS showed N-deficiency symptom due to its low available mineralizable N, after a 2-month period.

The application of 15% POS with 0.01% urea gave the optimal mineralizable N for maximum uptake efficiency (N-inflow) of oil palm seedlings (Table 2). The maximum uptake efficiency at 105 days from planting date was $172 \text{ N } \mu\text{g ml}^{-1} \text{ day}^{-1}$.

Results of POS decomposition, N-dynamics and efficiency of N absorption (N uptake efficiency) showed that the 15% POS with 0.01% urea was the best combination for optimum of growth and development of oil palm seedlings. The data on net assimilation rate (NAR) also showed that the same treatment resulted in the highest NAR ($0.458 \text{ mg cm}^{-2} \text{ week}^{-1}$) which ultimately caused enhanced growth and development of oil palm seedlings.

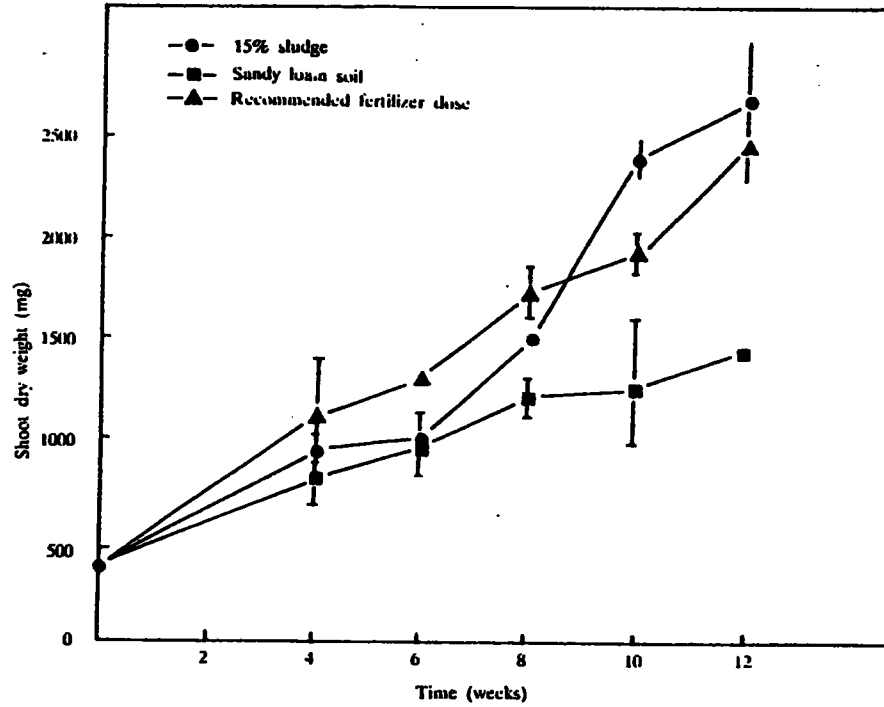


Figure 2. Effect of sludge and fertilizer treated soil on shoot growth of oil palm seedlings.

CONCLUSION

The optimum rate of POS addition during the nursery stage of oil palm seedlings is 15% (w/w). This rate enhances the physical and chemical properties of soil. When 15% POS was supplemented with 0.01% urea, it promoted better growth and development of oil palm seedlings without any detrimental effect.

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