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Editors
Wan Rasidah Kadir
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Organized by:
FGV
44. Soil microbial population of healthy and Ganoderma boninense infected (mounded and unmounded) Palms (Elaeis guineensis)  
Goh Yit Kheng, Chen Kah Yuong, Tung Hun Jiat, Goh You Keng, Wong Wei Chee, Chen Zi Yan and Goh Kah Joo

45. Formulation and characterization of EFB composts as soilless growing media for ornamentals  
Sarah B., L.A. Thohirah and A.B. Rosenani

46. Nitrohumic acids (NHA) based compound fertilizer effects on the rate of nutrient release and ammonia volatilization in soil tests  
Muhammad Syuhren A., Z.Z. Norztana and M.N. Mohd Hisham

47. Co-application of red gypsum and organic materials on sweet corn (Zea mays, L.) growth  
Nazira A., C.I. Fauziah, S.D. Zauyah and I. Roslan

48. Carbon dioxide evolution in soil amended with raw and composted recycled paper mill sludge  
Rosazlin A., I. Che Fauziah, K. Wan Rasidah and A.B. Rosenani

49. Production of rice foundation seed MR253 for marginal and acidic soil  
Azzami A. M. M., F. A. R. Muhamad Naim and M. Nor Akhya

50. Clay mineralogy and exchangeable potassium on soil formed on granite of Cameron Highland  
Nurfazrina R., J. Hamdan and A.W. Samsuri

51. The effect of organic and chemical fertilizers on growth, quality and phytochemical contents of kangkung (Ipomoea aquatica)  
Ahmad S. H., M. Humam, M. Azwadi and A.B. Rosenani

52. Carbon stocks and fluxes in a tropical lowland and montane forest  

53. Characterization of flavonoids in oil palm root exudates  
Walidah N.A., O. Radziah and S. Kamaruzzaman

54. Evaluation of control release fertilizer NPK for rice  
Khanif Y.M. and Ayuni Nurani

55. Nutrient uptake by vegetables crops under organic compost fertilization  
Norzi a Z. Z., I. Illani Zurainah, M. Haryati, M. Zulkefi and M. Theeba

viii
CARBON DIOXIDE EVOLUTION IN SOIL AMENDED WITH RAW AND
COMPOSTED RECYCLED PAPER MILL SLUDGE

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INTRODUCTION

Recycled paper mill sludge (RPMS) is a secondary sludge waste from pulp and paper industries generated from the final stage of papermaking after the biological treatment. Recycled paper mill sludge is an active organic material and has potential benefits to supply nutrients for crops growth. Reported trials stated encouraging plant growth and demonstrated the effect of sludge in improving soil fertility and nutrient properties, as well as soil physical properties (Phillips et al. 1997). Organic matter application is known to influence many soil functions and represents the largest reservoir of C. Land applications of organic materials have been extensively practiced in sustainable and low input agriculture. Apart from replenishing the soil organic matter, these organic materials also supply nutrients on slow release basis. The variable range of C compounds in the organic materials could affect the rate of decomposition. The use of C from the recycled paper mill sludge, as an energy source during the decomposition results in production of CO₂. The increase in the amount of CO₂ evolved from the soil, when recycled paper mill sludge decomposed, can be seen as an indicator of the rate of C mineralization. Therefore this study was carried out to determine the carbon dioxide evolution in soil amended with raw and composted recycled paper mill sludge after 90 days incubation.

MATERIALS AND METHODS

Soils, raw RPMS and RPMS compost

Raw RPMS from the biological treatment pond was collected from the United Paper Mill in Selangor, Malaysia. Meanwhile, RPMS compost comprises raw RPMS mixed with EFB fibres at 1:1 ratio (v/v) (Rosazlin et al. 2011). This material was air-dried, pulverized and sieved through a 1.0-mm sieve before used. The soil used in this study was the Bungor series (clayey, kaolinitic, isohyperthermic, Typic Paleudult) and data for chemical and physical characterizations, replicated three times, are shown in Table 1.
### Table 1: Chemical properties of soil, raw RPMS and RPMS compost used in the study (on a dry weight basis)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Soil</th>
<th>Raw RPMS</th>
<th>RPMS compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.89</td>
<td>7.84</td>
<td>7.18</td>
</tr>
<tr>
<td>EC, dS m⁻¹</td>
<td>n.d</td>
<td>3.08</td>
<td>4.84</td>
</tr>
<tr>
<td>Total N, %</td>
<td>1.77</td>
<td>4.05</td>
<td>2.68</td>
</tr>
<tr>
<td>Total C, %</td>
<td>16.60</td>
<td>33.67</td>
<td>52.52</td>
</tr>
<tr>
<td>CEC, cmol(+i) kg⁻¹</td>
<td>6.86</td>
<td>28.07</td>
<td>28.61</td>
</tr>
<tr>
<td>P, %</td>
<td>n.d</td>
<td>0.78</td>
<td>0.71</td>
</tr>
<tr>
<td>K, %</td>
<td>n.d</td>
<td>0.42</td>
<td>0.69</td>
</tr>
<tr>
<td>Ca, %</td>
<td>n.d</td>
<td>0.53</td>
<td>0.47</td>
</tr>
<tr>
<td>Mg, %</td>
<td>n.d</td>
<td>0.45</td>
<td>0.29</td>
</tr>
</tbody>
</table>

n.d- not detectable

### Determination of CO₂ production

This study was conducted in the Soil and Plant Analytical Laboratory, Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia. The topsoil (0 – 15 cm) used in this incubation study was obtained from the field experimental site. The soil was air dried, crushed and sieved through a 2-mm sieve. Rates of application of RPMS compost and raw RPMS in the laboratory experiment were equivalent to the field experiment. A completely randomized design (CRD) with four replications was used to test the following treatments; T1 – control (soil only), T2 – 300 kg N ha⁻¹ of composted RPMS and T3 – 300 kg N ha⁻¹ of raw RPMS and blank (without soil). Measurement of CO₂ was carried out according to the method described by Van De Werf and Verstraete (1987). This was to observe the amount of labile C decomposed by microorganism. Briefly, the CO₂ production was measured by incubating 100 g soil in 1L kilner jar homogenously mixed with specified treatments, with the water holding capacity adjusted to 60-70% using distilled water. Ten ml of 0.5 M KOH was placed inside the kilner jar. The JAR was covered to prevent evaporation and incubated at ambient temperature of 28°C in a dark room without mold growth. The amount of CO₂ produced was calculated by the difference between titration volume of KOH from sample containing the soil and the titration volume of a control (without soil), titrated with 0.5M HCl after incubation. Soils were sampled for three months (0, 1, 3, 5, 7, 11, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84 and 91 days after treatment).

### RESULTS AND DISCUSSION

**CO₂ Production**

The application of raw and RPMS compost resulted in decreased CO₂ productions with increasing incubation time (Figure 1). Organic C in soil organic matter is also the energy source for the metabolism of soil microorganisms. The decomposition rates of organic amendments, or turnover efficiency, is sometimes measured as a function of C mineralization, or the transformation of organic C to CO₂ during microbial respiration (Zibilske 1987). Overall, application of RPMS compost to the soil led to the highest decomposition, followed by raw RPMS and control, parallel to high total C content as
shown in Table 1. There was significant effect of application of raw and RPMS compost compared to the control throughout the incubation period. However, there was no significant difference between raw and RPMS compost within 90 days of incubation. Similar patterns of decomposition were observed for both treated soils. The decreased trends were observed from days 1 to 5 and from but days 5 to 7 and days 14 to 28 shows active phases of organic C release which is due to the effect of the addition of raw and RPMS compost. The slow phase occurred from day 42 onwards until 90 days of incubation. Microbial decomposition was active in the 1st 5 days which indicate the active C pool was decomposed within that time period.

![Graph](image)

Figure 1: CO$_2$ production in the soil applied with RPMS compost and raw compost within 90 days incubation in the laboratory

**Cumulative CO$_2$ Production**

The trend for cumulative CO$_2$ production from raw and RPMS compost addition to the soils showed an exponential increased with time in the 90 days of incubation under the laboratory condition (Figure 2). The total cumulative amount of CO$_2$ produced by RPMS compost, raw RPMS and the control were 140, 294, 267 mg/100g of soil, respectively. This was seen as a rapid increase during the initial stages of incubation, followed by a slower and relatively linear release. The amount of CO$_2$ released differed significantly between the soil treated with paper mill sludge and the control. The rates of CO$_2$ release from soil treated with raw and RPMS compost was almost doubled than the control treatment. On the first day of incubation, the cumulative CO$_2$ release from soil treated with raw and RPMS compost were at a similar level which resulted in no significant difference between treatments. This is an indication that the raw RPMS treatment had gone through partial decomposition, plus the much lower total C than the RPMS compost. There was a declining trend in soil respiration (measured as CO$_2$ production) along the studied period in all treatments, especially in the amended soils. This indicates a high activity of the soil microbial biomass from the beginning of the incubation period but
diminished when the energy rich substrate decayed. Consequently, the accumulated CO\textsubscript{2} patterns showed a greater increase during incubation study, which takes a flatter shape towards the end, especially in treated soils.

![Graph showing CO\textsubscript{2} production](image)

**Figure 2:** Cumulative CO\textsubscript{2} production in the soil applied with RPMS compost and raw compost within 90 days incubation in the laboratory

**CONCLUSION**

The effect of incubation time on CO\textsubscript{2} production after application of raw and RPMS compost showed that CO\textsubscript{2} production decreased with increasing incubation time. Meanwhile, the cumulative CO\textsubscript{2} production in the soil increased exponentially with time in 90 days incubation. Generally, application of RPMS compost to the soil led to the highest decomposition, followed by raw RPMS and control.

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**REFERENCES**

