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Efficacy evaluation of empty palm oil fruit bunch compost in improving soil characteristics, plant growth and disease suppression of tomato plants under tropical acid soil

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Abstract

Aim : Tomato is one of the most important crops worldwide as it is the second most important vegetable in the world after potato. A study was conducted to investigate the efficacy of empty fruit bunch (EFB) compost in improving soil characteristics, plant growth and disease suppression of tomato plants under tropical acid soil.

Methodology : Twelve tomato seedling cv MT-11 were transplanted on each planting bed. The growth of tomato plant was assessed based on plant height, leaf area, dry matter weight and incidence of bacterial wilt disease. Soil sampling was done at 45 and 60 day after transplanting (DAT) for physio-chemical and microbial properties.

Results : Applying EFB compost increased plant height, leaf area, dry matter accumulation, and suppressed development of bacterial wilt disease compared to using chicken manure. A higher disease reduction (16.7 %) occurred with 15 mg ha⁻¹ EFB compost, followed by 22.5 mg ha⁻¹ EFB compost (14.3 %), and 7.5 mg ha⁻¹ EFB compost (8.33 %).

Interpretation : Organic amendment in tomato cultivation affects soil properties, plant development and disease suppression. Application of EFB compost at 15 mg ha⁻¹ appeared as the best treatment soil amendment in tomato cultivation under tropical acidic soil condition.

Introduction

Tomato (*Lycopersicon esculentum*) is one of the most widely distributed vegetables grown in various cropping systems and locations throughout the world. Tomato is the main fruit vegetable for low-income oriented farmers, and a valuable cash crop in the tropics and subtropics. Tomato yield has declined during last few years due to intensive crop cultivation, gradual deficiency in soil organic matter, accumulation of phytotoxic substances and pests and diseases infestation (Pinheiro *et al.*, 2006). However, application of empty fruit bunch compost has reported significant increase in tomato yield, plant dry weight and biomass production (Mokhtari *et al.*, 2013) and has reduced total N fertilizer requirements (Cassman *et al.*, 1998).

Demand for organic fertilizer and interest of utilizing agricultural wastes and converting the wastes into value added fertilizers are increasing gradually for the conservation of natural resources, lessening the input cost of farmers as well as maintenance of environmental quality (Biradar and Biradar, 2015). The empty fruit bunch are organic residue that results after the fresh fruit bunches are harvested from the oil palm and is processed in the mill. About 22% of the fresh fruit bunch processed ends up as empty fruit bunch which is a good source of macro and micro nutrients. Normally, empty fruit bunch contains 30% dry matter, 2.5% oil, and 63% water and is a fibrous material. Even when it is piled up to more than 1.5 m in height, the bottom mass remains loose and porous, allowing air to pass freely through the pile. Therefore, EFB is considered suitable for the production of good quality compost (Good and Beatty, 2011; Mohammadi *et al.*, 2012).

Most of the soils in Malaysia are Ultisols and Oxisols and occupy about 72% of Peninsular Malaysia. These soils are highly leached, acidic deficient in nitrogen, and frequently contain toxic concentrations of available aluminium and manganese (Lal, 2000). Agricultural wastes have long been utilized to upgrade soil fertility and crop productivity in various ways (Marinari *et al.*, 2000; Zhai *et al.*, 2009). Soil organic matter and essential plant nutrients are added for plant growth (Yang *et al.*, 2004). Several studies have demonstrated that EFB compost can be applied to agricultural land as a substitute for chemical fertilizers and for soil conditioning (Thambirajah *et al.*, 1995; Yusri *et al.*, 1998; Zhai *et al.*, 2009; Noor Mohammad *et al.*, 2012). Research on field application of EFB compost for the understanding of crops response in acid tropical soils is lacking. Therefore, a field experiment was conducted to investigate the efficacy of EFB compost in improving soil characteristics, plant growth and disease suppression of tomato plants under tropical acid soil.

Materials and Methods

Experimental site and treatments : An experiment was carried out in Experimental Farm 10, Faculty of Agriculture, UPM Serdang from January–May 2014. The soil type was Munchong series

which was sandy clay loam, acidic, low in organic matter, and poor in macro nutrients. Land was prepared by clearing weeds and plowing twice, followed by the preparation of planting-bed. Each 1m × 3m planting-bed was separated by a distance of 1 m. There were four treatments of EFB compost rate: 0 mg ha⁻¹ EFB compost (Control), 7.5 mg ha⁻¹ EFB compost, 15.0 mg ha⁻¹ EFB compost, 22.5 mg ha⁻¹ EFB compost and 7.5 mg ha⁻¹ chicken manure. Chicken manure was used as farmers' standard. The experimental design used was as a randomized completely block design with three replications.

A 28-day-old empty fruit bunch compost supplemented with *Trichoderma* T24 and chicken manure with specific properties was used (Table 1). Seventy five kg empty fruit bunch and 30 kg chicken manure were mixed properly. The materials were then inoculated with 10.5 kg of *Trichoderma* T24 inoculum. A half of inoculums were added at beginning of composting process and the remaining was done after 18 days of composting when temperature in the heap decreased. The substrates were taken into 10 Styrofoam containers which contained 10kg of materials. The temperature of composting materials was monitored daily and the heaps were turned every other day for 28 days. Water was added to the heap, if the material moisture was lower than 60% (Kausar *et al.*, 2010; 2011).

Planting and crop management : The experimental units were planted with tomato cv. MT-11. Tomato seedlings were germinated and grown in polystyrene trays filled with potting mix. Ten days after sowing, tomato seedlings were transplanted into small planting bags (10 cm in diameter) and watered as needed with tap water. Twelve seedlings (30 day-old) per treatment were transplanted to the field in double rows 60 cm apart, at a distance of 50 cm in between rows, on each planting bed. All the plants were fertilized with NPK (12:12:17) @ 12.5 g plant⁻¹ as basal fertilizer (equal to 0.5 mg ha⁻¹). The whole plot was watered once in the morning and again in the late afternoon by means of a sprinkler system. Weed control was done manually.

Plant performances sampling and related data : The growth of tomato plant was studied based on plant height, leaf area, dry matter weight, and incidence of bacterial wilt disease. Plants were sampled 45 and 60 days after transplanting (DAT). The whole plants were uprooted and weighted. For measuring total leaf area, leaves were individually separated from the plant and total leaf area was determined using LI-3100 Leaf Area Meter. The samples were oven dried at 60 °C until constant weight was attained. After estimating dry weight, the samples were ground to a size less than 2.0 mm and used for determination of N, P, K, Ca and Mg uptake by plant.

Soil sampling and data collection : Soil sampling was done at 45 and 60 DAT. Soil was randomly collected from around the tomato plant at a depth of 15 cm using small auger. Part of soil sample was stored in a freezer at 4°C for determination of

bacteria, fungi and *Trichoderma* population, as well as $\text{NH}_4\text{-N/NO}_3\text{-N}$ content. While the remaining was air dried and sieved to a size less than 2.0 mm for chemical analysis.

Chemical analysis of soil : The pH was measured by following the method of Sharifuddin and Dynoodt (1981). Two g of soil was analyzed for total soil carbon using Total C method (computerized system model Leco CR-412), using infra-red absorption and 99.5% pure oxygen at 40 psi at 1500 °C for 60-120 sec nominal. Kjeldahl method was used to determine total N. Extractable $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ concentration were determined by the modified method of Keeney and Nelson (1982). Molybdenum blue method was used to determine extractable P using the method of Murphy and Riley (1962). Leaching method was adopted to determine exchangeable K, Ca, and Mg (Sharifuddin and Dynoodt, 1981).

Bacterial wilt disease incidence of tomato plant : The symptom of bacterial wilt disease caused by *Ralstoniasolanacearum* is characterized by sudden wilting of the foliage. Bacterial wilt was distinguished from the vascular disease caused by pathogens by suspending a clean section of diseased stem in clear water, when a white, milky stream of bacterial ooze would exude from the xylem elements in 3–5 min. The water would become completely milky in 10-15 min if the stem had been severely infected. Bacterial wilt disease incidence was counted based on the number of plant infected divided by the total number of plant.

Soil microbial population : Total bacteria, fungi and *Trichoderma* populations in soil were determined by total plate count technique.

Data analysis : The obtained data were analyzed using SAS package (SAS Institute Inc., 2001) for analysis of variance and mean comparisons by least significant difference.

Results and Discussion

Different rates of EFB compost evaluated in the present study varied in diverse traits. The study demonstrated that growth and disease suppression of tomato plant increased significantly in term of leaf area, dry matter accumulation, nutrients and bacterial disease infestation with the application of EFB compost or chicken manure. Among the treatments, 15.0 mg ha^{-1} EFB compost emerged as the most suitable compost rate for tomato cultivation. The same rate (7.5 mg ha^{-1}) of EFB compost showed comparatively higher performance in most of the studied parameters than that of chicken manure, indicating that EFB compost could be used successfully as soil conditioner for tomato cultivation.

Results showed that leaf area and plant dry weight of tomato at 60 DAT were significantly ($p \leq 0.05$) influenced by EFB compost and chicken manure. The highest significant leaf area (1854.30 cm^2) was found in plants treated with 22.5 mg ha^{-1} EFB

compost, which was 31% higher than control (1282.90 cm^2). It was noted that plants receiving 7.5 mg ha^{-1} EFB compost produced 15.46 % higher leaf area and 20.002 % higher dry matter than plants receiving of 7.5 mg ha^{-1} chicken manure (Table 2).

In the study, EFB compost enhanced plant growth, dry matter accumulation and disease suppression by improving soil physical, chemical and biological properties. Compost consist of humus which is a negatively charged colloidal particle that coagulates with cations and soil particles to form granular or crumb structures. Compost also contains peptides, amino acids, polysaccharides and phytohormones which are available for immediate uptake and absorption by plants (Parrado *et al.*, 2008; Killi and Kavdir, 2013). It improves different physico-chemical properties of soil such as buffering capacity, infiltration rate, prevents rapid changes in acidity or alkalinity, modifies color, and increases heat absorbing capacity that ultimately results in better plant growth and yield (Ouedraogo *et al.*, 2001; Kausar *et al.*, 2014). The coconut coir dust amended with oil palm frond compost provided optimum plant growth condition of cauliflower in a tropical humid soil throughout the growing period due to superiority in physiological traits such as stomatal conductance, photosynthesis rate and chlorophyll content in leaves and higher rate of nutrients uptake resulting maximum total dry mass production and economic yield (Erwan *et al.*, 2013). Use of EFB compost on *Brassica rapa* var. *parachinensis* gave higher yield (36.0 mg ha^{-1}) than conventional fertilizers which yielded 34.0 mg ha^{-1} (Chiew, 2004).

Observation on disease infestation showed that bacterial wilt disease incidence was 41.66 – 66.67 % and 83.33 – 100 % at 45 and 60 DAT, respectively. The ($p \leq 0.05$) highest significant disease suppression was found in plants treated with 15.0 mg ha^{-1} EFB compost both at 45 and 60 DAT, where disease suppression was 60 and 20 % higher than the plants receiving control treatment (Table 2).

Tomato variety MT11 used in the study was susceptible to bacterial wilt disease (MARDI, 1990) and most of the plants wilted after day 60. Bacterial wilt incidence of tomato plants indicates that the EFB compost was insufficient to suppress the disease, although lowest bacterial infestation was found in plants receiving 15.0 mg ha^{-1} EFB compost. The results of the present study were consistent with the findings of Wang *et al.* (1998) who stated that resistance may often break down or may not be expressed under certain environmental conditions and insufficient for use in heavily infested fields.

Nutrients uptake by tomato plants was significantly ($p \leq 0.05$) influenced by the application of EFB compost and chicken manure, except for potassium. Application of EFB compost and chicken manure increased the uptake of N, P, Ca and Mg. There was no significant difference among the three rates of EFB

Table 1 : Properties of microbial infused EFB compost and chicken manure

Parameter	EFB compost	Chicken manure
pH	8.05 ± 0.31	9.21 ± 0.58
Total carbon (%)	31.6 ± 0.44	28.27 ± 0.39
Total nitrogen (%)	1.76 ± 0.07	4.04 ± 0.07
C/N ratio	17.95 ± 0.18	6.99 ± 0.09
Electrical conductivity (mS cm ⁻¹)	2.37 ± 0.05	5.4 ± 0.26
P (%)	1.52 ± 0.05	2.15 ± 0.04
K (%)	1.65 ± 0.08	2.26 ± 0.15
Ca (%)	2.39 ± 0.13	2.17 ± 0.08
Mg (%)	1.02 ± 0.11	1.48 ± 0.06
Total fungi (log10 cfu g ⁻¹ compost)	9.32 ± 0.15	5.74 ± 0.04
Total bacteria (log10 cfu g ⁻¹ compost)	6.16 ± 0.14	6.56 ± 0.45
Total actinobacteria (log10 cfu g ⁻¹ compost)	5.38 ± 0.27	5.87 ± 0.21

Table 2 : Effect of EFB compost and chicken manure on growth at 60 DAT and incidence of bacterial wilt disease of tomato plant

Treatment (mg ha ⁻¹)	Plant height (cm)	Leaf area (cm ²)	Dry matter weight (g)	Bact. Wilt 45 DAT (%)	Bact. Wilt 60 DAT (%)
0.0 EFB (Control)	60.03 ^a	1282.90 ^c	22.00 ^c	66.67 ^a	100.00 ^a
7.5 EFB	63.40 ^a	1823.60 ^a	35.40 ^a	55.56 ^b	91.67 ^{ab}
15.0 EFB	65.93 ^a	1844.50 ^a	36.90 ^a	41.66 ^c	83.33 ^b
22.5 EFB	67.53 ^a	1854.30 ^a	38.37 ^a	47.22 ^c	85.66 ^b
7.5 CM	63.00 ^a	1579.30 ^b	29.49 ^b	55.55 ^b	100.00 ^a

Different letters in a column indicate significant difference at $P \leq 0.05$ by LSD; EFB= empty fruit bunches, CM= chicken manure, DAT= days after transplanting, Bact. Wilt= bacterial wilt disease

compost and chicken manure, except for Mg. The highest amount of Mg and K was found in plants receiving 15.0 mg ha⁻¹ EFB compost which was closely followed by 22.5 mg ha⁻¹ EFB compost, 7.5 mg ha⁻¹ EFB compost and 7.5 mg ha⁻¹ chicken manure, respectively (Table 3).

The increase in crop growth was reflected by nutrients uptake of tomato plants. It was found that N, P, K, Ca and Mg contents in tomato plant increased significantly with the applications of EFB compost. Organic molecules in EFB compost act as sites for cation exchange and increase adsorption and retention of nutrients in soil. Organic acids and humic fractions form compounds with phosphorus and zinc making them available to plants. Humic acid increases extractability of iron, manganese, zinc, and copper, but this extractability decreases gradually with time. These substances reduce aluminum toxicity but increase availability of iron and manganese by reducing their higher oxide forms to available forms (Kausar *et al.*, 2014).

Total carbon content in soil was significantly ($P \leq 0.05$) influenced by the application of EFB compost and chicken manure. Total carbon content increased with increasing the rate of EFB compost. At 60 DAP, the highest amount of total carbon was found in soil receiving 15.0 mg ha⁻¹ EFB compost. There was no significance difference between EFB compost and chicken

manure at the same rate (7.5 mg ha⁻¹) for total carbon. The total N content increased with increase in EFB compost rate. At the same rate (7.5 mg ha⁻¹), the effect of EFB compost on total N as compared to that of chicken manure was high (Table 4).

The highest amount of NH₄-N was found in soil treated with 22.5 mg ha⁻¹ EFB compost which was statistically at par with the soil receiving 15.0 mg ha⁻¹ EFB compost and 7.5 mg ha⁻¹ EFB compost. Application of EFB compost or chicken manure significantly ($P \leq 0.05$) increased the soil content of NO₃-N at 60 DAT. At the same rate, application of EFB compost significantly ($P \leq 0.05$) increased the soil content of NO₃-N as compared to chicken manure. The increase of EFB compost rate significantly ($P \leq 0.05$) increased the amount of extractable P. At both sampling dates, same rate (7.5 mg ha⁻¹) of EFB compost and chicken manure were statistically similar in terms of extractable P. EFB compost and chicken manure significantly influenced ($P \leq 0.05$) the amount of exchangeable K in soil. The amount of exchangeable K increased with increase of EFB compost rate. However, there was no significant difference in between 15.0 mg ha⁻¹ and 22.5 mg ha⁻¹ EFB compost rate. The amount of exchangeable K was higher in soil treated with 7.5 mg ha⁻¹ EFB compost than soil treated with same rate of chicken manure. Use of EFB compost significantly ($P \leq 0.05$) influenced the amount of exchangeable Ca in soil. The highest amount of exchangeable Ca

Table 3 : Effect of EFB compost and chicken manure on nutrient uptake of tomato plant at 60 DAT

Treatment (mg ha ⁻¹)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)
0.0 EFB (Control)	1.69 ^b	0.22 ^b	2.47 ^a	0.41 ^b	0.42 ^c
7.5 EFB	2.31 ^a	0.31 ^a	2.71 ^a	1.11 ^a	0.65 ^b
15.0 EFB	2.31 ^a	0.35 ^a	2.84 ^a	1.14 ^a	0.82 ^a
22.5 EFB	2.41 ^a	0.37 ^a	2.82 ^a	1.13 ^a	0.65 ^b
7.5 CM	2.28 ^a	0.32 ^a	2.68 ^a	1.25 ^a	0.63 ^b

Different letters in a column indicate significant difference at $P \leq 0.05$ by LSD; EFB= empty fruit bunches, CM= chicken manure, DAT= days after transplanting

Table 4 : Effect of EFB compost rate and chicken manure on chemical properties changes in experimental plot at 60 DAT

Treatment (mg ha ⁻¹)	Total carbon (%)	Total nitrogen (%)	NH ₄ -N (mg kg ⁻¹ soil)	NO ₃ -N (mg kg ⁻¹ soil)	Extractable P (ppm)	Exchangeable K (ppm)	Exchangeable Ca (g kg ⁻¹ soil)	Exchangeable Mg (g kg ⁻¹ soil)	Soil pH
0.0 EFB	1.06 c	0.77 c	12.51 b	15.19 d	112.53 d	135.63 c	0.30 d	0.08 d	5.85 b
7.5 EFB	1.37 ac	0.91 b	15.77 a	19.68 b	281.13 c	235.63 b	0.60 c	0.15 c	6.62 a
15.0 EFB	1.60 a	1.04 ab	15.85 a	22.26 a	414.83 b	318.70 a	1.08 a	0.28 a	6.79 a
22.5 EFB	1.45 ab	1.11 a	16.06 a	23.69 a	606.87 a	356.33 a	0.87 ab	0.24 ab	6.91 a
7.5 CM	1.08 bc	0.90 b	13.37 b	17.20 c	284.27 c	192.87 b	0.68 bc	0.19 bc	6.56 a

Different letters in a column indicate significant difference at $P \leq 0.05$ by LSD; EFB= empty fruit bunches, CM= chicken manure, DAT= days after transplanting

Table 5 : Effect of EFB compost rate and chicken manure on microbial population changes in experimental plot at 60 DAT

Treatments mg ha ⁻¹	Bacteria log 10 cfu g ⁻¹	Fungal log 10 cfu g ⁻¹	Trichoderma log 10 cfu g ⁻¹
0.0 EFB	8.34 c	5.05 c	2.96 d
7.5 EFB	8.62 b	5.17 b	3.65 b
15.0 EFB	8.66 b	5.21 b	3.68 b
22.5 EFB	8.96 a	5.40 a	3.92 a
7.5 CM	8.63 b	5.23 b	3.41 c

Different letters in a column indicate significant difference at $P \leq 0.05$ by LSD; EFB= empty fruit bunches, CM= chicken manure, DAT= days after transplanting

was found in soil receiving 15.0 mg ha⁻¹ EFB compost, closely followed by 22.5 mg ha⁻¹ EFB compost rate. There was a significant ($P \leq 0.05$) effect of EFB compost and chicken manure on exchangeable Mg content and pH in soil as compared to control (Table 4).

In the present study, it was found that the application of EFB compost increased the availability of primary nutrients (N, P, and K), as well as Ca and Mg in soil. The increase in nutrients was due to the presence of nutrients in EFB compost. According to Guo *et al.*, 2016, compost increases organic matter content, total N, available P, exchangeable K, available water content, and porosity of soil as compared to control. They also added that compost amended plots showed more root growth near the soil surface and top soil. Better structural condition of organic manure amended soil is associated with decreased bulk density and

increased porosity and hydraulic conductivity of soil (Guo *et al.*, 2016). The results of the study is consistent with the findings of Toumpeli *et al.* (2013) who stated that compost (156 mg ha⁻¹) prepared from *Phragmites australis* increased the availability of N, P, Ca and Mg concentrations, macro-aggregate stability and reduced clay dispersion in soil which enhanced tomato var. Santorini production in low input agriculture farming system.

Soil application of EFB compost and chicken manure increased soil pH (Alexander, 2001). Depending on the pH of compost and native soil, compost addition may raise or lower the soil pH. Addition of neutral or slightly alkaline compost to an acidic soil increase soil pH, if added in appropriate quantities. In the present study, pH of EFB compost was slightly alkaline (8.05). Soil pH is one of the most important characteristics that may influence other properties (Bedada *et al.*, 2016). It may affect the

solubility of mineral and therefore, it governs several soil processes. It influences soil chemical and biochemical reactions. Soil reaction may affect plant growth directly or indirectly because it affects the solubility and availability of plant nutrients. It influences plant growth by affecting the activity of beneficial microorganisms. The rise in pH can be partly attributed to accumulation of basic cations and subsequent neutralization of protons in the root by anions (mainly HCO_3^- and CO_3^{2-}), which accompany the cations in the water flow in the roots (Abujabbar et al., 2016).

Total bacterial, fungal and *Trichoderma* population in soil was found to be significantly ($P \leq 0.05$) affected by the application of EFB compost and chicken manure (Table 5). *Trichoderma* population was found to increase with the application of EFB compost. The use of EFB compost containing *Trichoderma* might increase *Trichoderma* population in soil. *Trichoderma* is well known for its involvement in decomposition of organic matter (Kausar et al., 2014). Apart from that, *Trichoderma* possess the ability to solubilize plant nutrients and exhibit plant-growth promoting activity (Altomare et al., 1999). Microbial infused rice straw compost carries microbial population which colonizes rhizosphere of plants protecting them from diseases by competing for nutrients and infection sites or by production of antifungal compounds that can improve plant growth (Compant et al., 2005; Kausar et al., 2014). In addition, compost helps microorganisms to produce gummy substances that build good soil structure. These polysaccharides of microbial metabolism improve aggregate stability and soil properties. Compost stimulates symbiotic association of different microorganisms and plays significant role in transferring certain nutrients from soil to plants (Russo and Perkins-Veazie, 2010). Microorganisms have the ability to convert nutritionally important elements from unavailable to available forms through biological processes and also inhibit phytopathogens in soil by increasing the beneficial microorganisms, metabolites, hormones, and nutrients (Vessey, 2003; Jilani et al., 2007).

In conclusion, the results of this experiment showed that EFB compost @ 15.0 mg ha^{-1} gave optimum plant growth, nutrient uptake and disease suppression, thus indicating its suitability for tomato cultivation under low input farming system.

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