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Insert Formulation and Characterization of Empty Fruit Bunch Compost Formulation as Soilless Growing Media for Ornamentals

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One of the leading environmental effects of many systems in horticulture, such as soilless culture, is the generation of organic plant residues and substrate wastes. Nowadays, there is a higher demand for ecologically friendly and lower-cost substrates. There is high interest in assessing compost from agro-wastes that can be used as growing media. This study aimed to test for phytotoxicity effect and evaluate the chemical and physical properties of substrates formulated from oil palm empty fruit bunch (EFB) compost as the main component and EFB biochar, rice husk (RH) biochar, vermiculite, sewage sludge and cocopeat as additives. The components were formulated in different ratios forming 18 formulations, including controls. Experiments were conducted in stages. First was a germination assay phytotoxicity test using *Solanum lycopersicum* (Tomato) seeds, and nine formulations were shortlisted (highest germination rate and best root growth within incubation days). The selected formulations were then analyzed for physical and chemical characteristics. The final four formulations were selected for pot trial; 10VRM (10 % vermiculite + 90 % EFB compost), 10 EBC (10 % EFB biochar + 90 % EFB compost), 10SWS (10 % sewage sludge + 90 % EFB compost) and 10 RHB (10 % rice husk biochar + 90 % EFB compost). These four formulations are potentially used as growing media because they show a high germination rate (>90 %), low phytotoxicity (<5 %), pH near neutral and high amount of nutrient content. In the following study, the potting media that depicted the best growth and flowering qualities is formulation 10RHB for growing *Molineria latifolia* var. megacarpa. It produced the tallest plant height (34.99 cm), the most number of flowers (5.93 nos) and the highest number of leaves (5.3 nos), as well as the earliest day to flowering amongst treatments (31.4 d). *Rhodomyrtus tomentosa* planted in 10 EBC showed the best growth compared to the other three formulations tested, with the tallest plant height (63.35 cm), the most number of flowers (23.93 nos), the highest number of leaves (308.9 nos) and earliest day to flowering amongst treatments (70.6 d). The two best recommendations are 10RHB (90 % EFB Compost + 10 % rice-husk biochar), and 10 EBC (90 % EFB Compost + 10 % EFB biochar) to grow both ornamental landscape plants. EFB compost-based with biochar as additives are potential soilless media formulations that could be utilized as potting media compared to other soil-only based mixtures in the current ornamental industry.

1. Introduction

Agro waste refers to waste generated from plants and animals, such as plant fibres, leaves, hulls, and manures. In 2020, 72.8 billion MYR in exports of palm oil and items derived from palm oil were made by the country (Malaysian Palm Oil Council (MPOC), 2021). Palm oil makes up only 10 % of the entire biomass of the oil palm tree, which is thought to have 90 % biomass (Kurnia et al., 2016). Biomass from oil palms is the term used to describe agricultural waste products created by the oil palm business's replanting, pruning, and milling processes. The milling process in the oil palm processing mills, however, results in the production of oil palm shell (OPS), palm kernel shell (PKS), empty fruit bunch (EFB), and palm oil mill effluent (POME) (Khalil et al., 2016). Due to its dependence on land, the oil palm business is frequently linked to environmental issues. The

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annual output rate of total dry matter (TDM) is around 55 t/ha of land (Lim, 2017). A sizable amount of oil palm biomass waste is either burned or dumped into the fields, posing a serious environmental risk. Large-scale biomass waste production has increased worries about the sustainability and environmental effects of oil palm agriculture and processing, particularly in biodiversity loss, rainforest degradation, and air pollution (Liew et al., 2017). The industry must start caring about utilizing all resources from the oil palm in an optimal way while simultaneously limiting the environmental impact to improve the environmental performance of palm oil production.

Soilless substrates are used in horticulture for growing seedlings, plant propagation, vegetable production, and producing ornamental plants in pots. The ability of soilless cultivation to provide effective and extensive plant production is acknowledged on a global scale. Growing concern regarding the effects of several frequently used materials on the environment has prompted researchers to find and evaluate more environmentally friendly alternatives (Barret et al., 2016). Attention has been paid to renewable materials made from municipal, industrial, and agricultural waste streams. Unfortunately, very few have found effective and environmentally responsible materials for growing media to guarantee the growth and sustainable development of soilless farming. (Atiyeh et al., 2001).

Biochar has been combined with a few additives to provide additional nutrient sources for soil improvement and plant growth (Irshad et al., 2022). In the current study, organic fertilizer, compost, and microalgae were used as sources of nutrients that may be stored in biochar, and according to Colla and Rouphael (2020), the fertilizers that will be added to crops are known as "slow-release" fertilizers. According to Zaccardelli et al. (2006), compost can be an excellent substitute for soil in nursery peat-based potting mixes for seedling growth. This study aimed to assess the suitability of EFB compost together with additives as components in soilless growing media and to determine the best potential formulations to be used as soilless growing media for potted ornamentals.

2. Methods

2.1 Materials

EFB compost was assessed as the main agro-materials component. EFB compost was obtained from Dusun Durian Estate (Sime Darby Plantation), Banting, Selangor. The composting consisted of empty fruit bunch, POME sludge and decanter cake. The process took 90 d. There were five additives added, which are empty fruit bunch (EFB) biochar and rice husk biochar (RHB) obtained from UPM Biorefinery, vermiculite and cocopeat purchased from D'Syira Sdn. Bhd. and sewage sludge collected from Indah Water Consortium plant as amendments, including three controls (refer to Table 1).

Table 1: 15 formulations of EFB compost, including three controls

Codes of Formulations	Formulations		
10EBC	10 % EFB Biochar	+	90 % EFB Compost
20EBC	20 % EFB Biochar	+	80 % EFB Compost
30EBC	30 % EFB Biochar	+	70 % EFB Compost
10RHB	10 % RH Biochar	+	90 % EFB Compost
20RHB	20 % RH Biochar	+	80 % EFB Compost
30RHB	30 % RH Biochar	+	70 % EFB Compost
10SWS	10 % Sewage Sludge	+	90 % EFB Compost
20SWS	20 % Sewage Sludge	+	80 % EFB Compost
30SWS	30 % Sewage Sludge	+	70 % EFB Compost
10CCP	10 % Cocopeat	+	90 % EFB Compost
20CCP	20 % Cocopeat	+	80 % EFB Compost
30CCP	30 % Cocopeat	+	70 % EFB Compost
10VRM	10 % Vermiculite	+	90 % EFB Compost
20VRM	20 % Vermiculite	+	80 % EFB Compost
30VRM	30 % Vermiculite	+	70 % EFB Compost
100EFB	100 % EFB Compost		
100PTG	100 % PEATGRO (Commercial)		
CONTROL	Distilled Water		

2.2 Phytotoxicity test using germination assay

The first shortlisting method from the 18 formulations is through a germination essay. A germination assay was conducted using tomato (*Solanum lycopersicum*) seeds with a quick growth rate recommended for use as a phytotoxic indicator. Each formulation extracts (ten replicates for each sample) was prepared by shaking fresh samples with distilled water at a solid: water ratio = 1:10 (w/v) for 1 h. The suspensions were centrifuged, filtered and kept at 4 °C before the test. For the germination test, 5 mL of each extract was dispensed into a sterilized petri dish lined with filter paper. Twenty seeds of tomato were placed in one dish and replicated ten times, and the petri dish with seeds was incubated at 25 °C in the dark for three days. Distilled water, 100 % EFB compost and commercial soilless growing media (Peatgro) were used as the control. Treatments were evaluated by counting the number of germinated seeds after three days and measuring the root length (He et al., 2009). The germination index (GI) formula as presented in Eq(1) was used to determine the germination rate, and the best nine formulations based on GI were shortlisted.

$$\text{Germination Index} = \left\{\frac{\text{Number of Germinated Seed}}{\text{Days of first count}}\right\} + \cdots + \left\{\frac{\text{Number of Germinated Seed}}{\text{Days of final or last count}}\right\} \quad (1)$$

2.3 Chemical and Physical Characterization

The shortlisted nine formulations were analyzed for total organic carbon (TOC) by the dry combustion method at 540 °C for 4 h (Abad et al., 2002) and total N (TN) by Kjeldahl digestion (Bremmer and Mulvaney, 1982) and analyzed using Seal Auto Analyzer 3 High Resolution (Seal AA3 HR) (Seal Analytical, Wisconsin, USA)). pH were determined in a 1:5 (v/v) water extract using pH Meter. Dry ashing of plant tissue for the quantitative determination of the concentrations of calcium (Ca), iron (Fe), magnesium (Mg), phosphorus (P), potassium (K), and zinc (Zn) utilizing high-temperature dry oxidation of the organic matter (Baker et al., 1964) and dissolution of the ash with hydrochloric acid (HCl). Bock (1978) reported the best reviews on organic matter destruction. Digest analytic concentrations can be determined by atomic absorption spectroscopy (AAS) (Watson and Isaac, 1990). From this characterization, the four best formulations were selected. The result of dry-ashing and Total N is presented in Table 2.

2.4 Pot trial

Pot trials were conducted using the four selected formulated growing media and a control growing media. The growing media treatments were replicated four times and laid out in a randomized complete block design (RCBD). The experiment layout was conducted with the same treatments/ one plot was for *Molinera latifolia* var. megacarpa (Lemba) planting, and the other was for *Rhodomyrtus tomentosa* (kemunting).

2.5 Experimental design

There were a total number of 120 pots (5 formulations x 4 blocks x 6 experimental units) in each experiment for each species. *Molineria latifolia* var. megacarpa and *Rhodomyrtus tomentosa* were planted in 25.5 cm diameter plastic pots. The plastic pots had the same height, which was 35.5 cm. The pots were filled with formulated growing media treatments after the media were prepared in bulk according to ratio. The five treatments selected are 10VRM (10 % vermiculite plus 90 % EFB compost), 10EBC (10 % EFB biochar plus 90 % EFB compost), 10RHB (10 % rice husk biochar plus 90 % EFB compost), 10SWS (10 % sewage sludge plus 90 % EFB compost) as well as Control (50 % burnt rice husk plus 50 % coco peat). A field trial was carried out for six months.

3. Results and Discussion

3.1 Germination rate and root length

The germination test evaluates biowaste materials' compost maturity and phytotoxicity (Roe, 1997). This index has been proven to be a more sensitive parameter to illuminate both the low toxicity of growing media affecting root growth and the high toxicity affecting germination (Zuconni, 1981). Germination assay results showed that the germination rates using all the formulations are very high (77 % - 95 %), but there was a significant difference. The highest rate of germinated seeds is 20VRM (91.5 %), 30VRM (91.0 %), 10VRM (91.0 %) and 10CCP (90.5 %). The lowest rate of germinated seeds is 20SWS (77.0 %). Another critical aspect of this assay is measuring the root length to determine the best formulation that allows faster root growth. A root analyzer (WinRHIZO Root System Instrument, USA) calculated the overall root length and volume. This is vital to ensure cuttings and seedlings grow well in the selected formulations. 10VRM showed the highest root growth with a mean of total observation of 2.63 cm, followed by 20 EBC (2.55 cm), 30VRM (2.52 cm), and the lowest 30EBC (2.29 cm). There were no significant differences between root lengths for all formulations.

From both assay, germination test and root length, the nine best formulations were shortlisted according to the number of germinated seeds and root length. The 9 selected formulations which are 10VRM, 20VRM, 30VRM, 10EBC, 20EBC, 10CCP, 30CCP, 10RHB and 10SWS was characterised both physically and chemically.

3.2 Chemical and physical characteristics of the formulations

Table 2 shows the nine selected formulations' main chemical and physical properties. The pH values ranged from 5.3-7.7. The highest pH value was within the optimal pH range for growing media (5.2– 6.3; Bunt, 1988). Considering this value, all formulations were suitable to be used regarding acidity and alkalinity. TOC range is between 15.0 % – 23.9 %. Selected formulations analyzed had different TOC values, with highly significant differences between formulation means. Total nitrogen (TN) content ranged between 1.03 % and 1.85 %. No significant differences were found for TN formulation means. The C/N ratio varied between 10.1 and 19.3. According to Rosen et al. (1993), a C/N ratio between 15 and 20 is ideal for ready-to-use compost. Inbar et al. (1990) cautioned that the C/N ratio of compost is only one parameter by which maturity should be gauged, and specific chemical analyses are equally important.

Table 2: Selected formulation chemical and physical characteristics

	10VRM	20VRM	30VRM	10EBC	20EBC	10CCP	30CCP	10RHB	10SWS
N (%)	1.85a	1.03b	1.12b	1.38ab	1.25ab	1.18b	1.09b	1.34ab	1.46ab
P (%)	0.33c	0.33bc	0.32c	0.35bc	0.32c	0.28d	0.26d	0.37ab	0.39a
K (%)	1.09ab	1.08ab	1.15a	1.11a	0.99abc	0.79bcd	0.86abcd	0.74cd	0.67d
Ca (%)	0.13b	0.16ab	0.17ab	0.21a	0.10ab	0.19ab	0.17ab	0.21a	0.22a
Mg (%)	0.50a	0.44b	0.48ab	0.11c	0.09c	0.09c	0.08c	0.11c	0.09c
Fe (µg/g)	216.4ab	252.6a	234.8a	162.0bc	152.4c	153.5c	167.2bc	155.2bc	135.8c
Zn (µg/g)	156abc	150bcd	139cde	154bc	163ab	133de	129e	141cde	175a
Cu (µg/g)	83a	74a	67a	75a	74a	68a	74a	75a	78a
TOC (%)	16.5bc	15.0c	15.0c	22.9a	21.8a	19.8ab	20.9a	20.8ab	23.9a
C: N Ratio	10.1b	11.6b	13.8ab	16.6ab	17.5ab	16.7ab	19.3a	15.1ab	16.5ab
pH	7.2a	7.4a	7.7a	6.1b	5.7bc	5.3c	5.9b	6.1b	6.0b
Bulk density	0.67ab	0.56cd	0.62bc	0.52d	0.53d	0.36e	0.30e	0.30e	0.75a
Water holding capacity	33.5a	26.3b	29.9ab	32.7a	33.7a	26.4b	31.3ab	33.4a	32.7a

** TOC - total organic carbon **Within rows, means followed by the same lowercase letter do not differ significantly by LSD (0.05).

3.3 Pot Trial

Table 3 shows no significant difference in plant height, total leaf area and root length between treatments of *Molineria latifolia* var megacarpa planted in different media formulations. The other parameters depicted significant differences among treatments with the number of leaves per plant planted in rice husk biochar. Similarly, it goes to chlorophyll content, stomatal conductance and transpiration rate, stating that all physiological interaction of the plant is the best in RHB media. The enhancement of flowering in the particular media formulation is probably due to the composition of the biochar in line with the previous study by Zimmerman (2010), stating that agronomic benefits are mainly derived from the fertilizer value of biochar and its effects on the improvement of soil physical conditions, in particular, the soil water holding capacity and soil drainage characteristics, at the same time, enhancing the flowering and fruiting quality of the plants.

Table 3 also shows that there is a significant difference between treatments of media formulation. The only parameters that were not significant were the number of leaves per plant, number of flowers per plant, total leaf area and root length. The transpiration rate of *Rhodomyrtus tomentosa* was observed to be affected by the interaction between formulation treatments and potted test plants arranged in randomized complete block design. There is a significant difference in transpiration rate for each formulation. Transpiration rates were highest for test plants grown in EBC (1.41 mmol/m²/s), and the lowest was marked by SWS (0.83 mmol/m²/s). Transpiration rate (E) is positively correlated with stomata conductance. The highest stomata conductance is in the plants grown in the control formulation. It is dramatically higher than the rest of the formulations. Followed by plants grown in EBC formulation, RHB, and VRM, the lowest stomata conductance is by leaves of test plants grown in SWS formulations treatment effects on the plant gas exchange. Plant gas exchange measurements at the leaf level were performed with one plant per treatment. When the soil water supply was good, the stomatal conductance was high. Compared to the unaltered control, biochar appeared to lower transpiration, while leaf stomata were only visibly reduced with the highest biochar application (Kammann et al., 2011). Applying biochar to soil draws greater attention to sustainable soil quality improvement and carbon sequestration (Sohi, 2012). In the soil, biochar increases the capacity of the soil, holding water and nutrients holding capacity, reducing the need for fertilizers. The increase in N, P, and K content was also due to the presence of beneficial microbes inside the composts, as mentioned by Ramli et. al (2019). The dosage of biochar may also impact how the soil reacts during respiration. In previous research, increased soil CO_2 effluxes have been observed in ornamental plants with increasing biochar application rates (Mitchell et al., 2015). Many small and field tests reported increases in plant growth and crop productivity after mixing biochar with the soil (Jeffery et al., 2011), and contributing to better growth (shoot and stem elongation) of plants grown in media with the presence of biochar, in this study mainly, was EFB biochar.

Table 3: Effect on growth and flowering performance of Molineria latifolia var megacarpa and Rhodomyrtus tomentosa between different media formulations.

Parameters / Formulations	VRM	EBC	SWS	RHB	CONTROL
Molineria latifolia var megacarpa					
Plant Height (cm)	32.74^{b}	32.8^{b}	34.35^{ab}	35.26^{a}	33.91^{ab}
Leaves per plant (No)	4.83^{ab}	4.83^{ab}	4.40^{b}	5.30^{a}	5.08^{ab}
Flower per plant (No)	4.53^{a}	5.96^{a}	3.73^{a}	5.77^{a}	6.67^{a}
Chlorophyll content (mg/mg)	55.46^{a}	50.68^{a}	54^{a}	55.64^{a}	55.66^{a}
Stomatal Conductance (mmol/m²/s)	0.04^{b}	0.0553^{ab}	0.0956^{a}	0.102^{a}	0.035^{b}
Transpiration rate(mmol/m²/s)	0.545^{a}	0.613^{a}	0.217^{a}	0.881^{a}	0.548^{a}
Total leaf area (cm²)	5972^{a}	5851^{a}	5191^{a}	6353^{a}	5693^{a}
Root Length (mm)	1368.1^{a}	1277.8^{a}	1495.7^{a}	1519.7^{a}	1569.4^{a}
Rhodomyrtus tomentosa					
Plant Height (cm)	61.95^{ab}	63.71^{a}	61.82^{ab}	62.83^{a}	57.99^{b}
Leaves per plant (No)	291.4^{c}	314.77^{a}	301.00^{b}	274.03^{d}	311.458^{a}
Flower per plant (No)	17.13^{b}	22.2^{a}	20.7^{a}	15.37^{b}	16.38^{b}
Chlorophyll content (mg/mg)	53.42^{a}	53.9^{a}	53.16^{a}	50.61^{b}	53.79^{a}
Stomatal Conductance (mmol/m²/s)	0.0716^{ab}	0.1018^{ab}	0.0598^{b}	0.1008^{ab}	0.1384^{a}
Transpiration rate(mmol/m²/s)	1.34^{a}	1.41^{a}	0.83^{a}	1.21^{a}	1.59^{a}
Total leaf area (cm²)	6631^{a}	6903^{a}	6436^{a}	5461^{a}	6081^{a}
Root Length (mm)	1045.1^{a}	1264.7^{a}	1133.1^{a}	1054.8^{a}	1331.9^{a}

4. Conclusion

Generally, the effect of the formulated soilless media on the planting of the two local plants has shown positive growth and flowering performance under all selected formulations tested in the field. The test plants are hardy and robust, usually found primarily in secondary jungles. In this study, the plants were planted in container pots, and they showed good growth and development attributes through the six months of the study period, further proving that they can grow well in the formulated soilless media. In conclusion, after the selection was made based on a phytotoxicity test, chemical and physical characterizations, nutrient analysis, and a 6 mth pot trial, it can be concluded that the objective was achieved, which was to formulate suitable, lightweight soilless media using that is locally available and is a renewable resource. This was achieved with two best media formulation recommendations which are 90 % EFB Compost + 10 % rice-husk biochar (10 RHB) and 90 % EFB Compost + 10 % EFB biochar (10 EBC) to grow *Rhodomyrtus tomentosa* and *Molineria latifolia* var. Megacarpa respectively as ornamental landscape plants. The new combination of soilless media, which consists of biochar additives, is potentially a better media mixture than standard topsoil and other soil-based mixtures. It is recyclable, low-cost, readily available, sequestrates carbon in the soil, helping to mitigate climate change issues, is easy to handle, lightweight and produces uniform plant growth, making it a suitable medium for planting, particularly landscape plants.

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