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Soil rehabilitation potential of co-compost pellets made from Municipal Solid Waste and Dewatered Faecal Sludge as feedstock

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Introduction

Sri Lanka is a tropical island with a total land area of about 6.5 million hectares. Based on the present estimated population of 21 million, the per capita availability of arable land reduced to about 0.15 ha, indicating heavy pressure on agricultural lands (Nayakekorale et al., 2001). The population has been expanding rapidly and the demand from various users have set up pressures on the land, and inevitably resulted in the misuse and degradation of land in many areas which is a serious problem in Sri Lanka (Anon, 2002). Net decrease in available plant nutrients and organic matter content in the soil defined as soil fertility declining is 61% of the total agricultural land in Sri Lanka (Anon, 2002). Ecological recovery of soil fertility can be achieved through balanced application of organic matter and chemical fertilizers. Organic amendments increase soil organic matter content and offer many benefits over time. Compost and biochar are commonly recommended as organic amendments.

Management of liquid and solid waste has emerged as a critical problem in the larger urban areas and around industrial sites in Sri Lanka. Composting is considered as a suitable solution to solid waste management, especially in the context of developing countries where perishable waste is the main fraction (50-80%) in the public waste collection (Cofie et al., 2016). Co-composting is the controlled aerobic degradation of organic materials, using more than one feedstock such as Dewatered Faecal Sludge (DFS) and organic fractions of Municipal Solid Waste (MSW). DFS has carbon (C), nitrogen (N), phosphorus (P) and potassium (K) as well as micronutrients while biodegradable MSW is high in organic carbon and has good bulking properties.

Pelletization is a possibility to add value to sieved co-compost by increasing product density and enhancing other features of compost (Alemi et al., 2010). This technology can be used to enhance the co-compost pellet quality by adding different additives such as biochar or mineral fertilizer. Biochar is a carbon rich solid material obtained from thermochemical conversion of biomass in an oxygen limited environment. It can provide many benefits which contribute to soil fertility with long lasting effects such as increase soil pH, water holding capacity, and contribute Cation Exchange Capacity (CEC) (Mao et al., 2012). In this research, empty fruit brunches (EFB) of oil palm (*Elaeis guineensis)* were processed into biochar.

This study was carried out with the specific objective of evaluating the soil rehabilitation potential of co-compost pellets made from MSW and DFS as the feedstock.

Material and Methods

Preparation of Compost and Co-Compost

The co-composting process was done at waste management center at Sundarapola, adjacent to the Kurunegala Municipal Council (KMC). Prior to composting, feedstock with different properties were separated and co-compost piles were made with MSW (70%) and DFS (30%) and were added after mixing together to make the co-compost piles. Trapezoidal windrow type co-compost piles were prepared with $18m^3$ volume and feedstock amount in one pile was 10 tons. Temperature and moisture content of each pile were measured daily in three central points using probe thermometer and 30 cm depth using compost moisture meter respectively. Pile turning and watering were done according to the temperature and moisture values. Weekly sampling was done and stored in the freezer for chemical analysis during the process. After maturation, compost was sieved through 5mm mesh size according to Sri Lanka standards.

Preparation of Biochar

Oil palm empty fruit bunches were used as a feedstock and biochar was made using a pyrolyzer (Pushpakumara et al., 2016). One pyrolysis process completed in 3-5 hrs and $0.37m^3$ dry materials were needed as feedstock per production cycle. It was left to cool overnight after pyrolysis.

Preparation of Co-Compost pellets

Sieved co-compost powder was used to produce pellets according to the treatment combinations. Before pelletization, the feedstock mixture was prepared using sieved biochar and urea. 15% of Biochar was added and mixed with total feedstock volume. Prepared mixture was inserted into the pelletizing machine manually at a controlled speed (Grau et al., 2017). Produced pellets were sun dried from four to six hours and were stored in poly sack bags.

Experimental Site

Resulted co-compost pellets were used in maize (*Zea mays* L.) variety MI Hybrid Maize 02 cultivation and seven treatments were arranged in a Randomized Complete Block Design (RCBD) with four blocks. The experiment was carried out at the Center of Excellence for Organic Agriculture, Makandura, Gonawila (NWP), Sri Lanka. It is situated in IL1a agro ecological zone where maximum and minimum temperatures were 35.6^0C and 20.8^0C respectively. Soil type is sandy loamy which consists of alluvial soil as a top layer.

Tested Fertilizer Combination

Seven types of treatments were used for the experiment as given in Table 1. 100% available nitrogen in T2 and T4 signifies the assumption that all nitrogen added is absorbed into the plant. In T3 and T5 30% available nitrogen signifies the assumption that 30% of added nitrogen is absorbed into the plant.

Table 1. Tested fertilizer combination

Code	Treatment		Application Rate kg/ha		
			Urea	TSP	MOP
T_1	Mineral fertilizer (Control)	*Basal dressing*	162.5	50	25
		Top dressing	162.5	50	25
T_2	DFS+MSW Co-compost pellet 100% available Nitrogen			12650	
T_3	DFS+MSW Co-compost pellet 30% available Nitrogen			42133	
T_4	DFS+MSW+Biochar Co-compost pellet 100% available Nitrogen			13599	
T_5	DFS+MSW+Biochar Co-compost pellet 30% available Nitrogen			45366	
T_6	DFS+MSW+Mineral Co-compost Pellet			1875	
T_7	DFS+MSW+Biochar+Mineral Co-compost Pellet			1875	

Soil sampling

Soil samples were collected from 30cm depths initially and at monthly intervals. Total nitrogen (%), available phosphorus, available potassium were determined by the methods described in SLS 645. pH and EC were determined using 1:5 water solution method described in ISO 10390(2007). Organic Carbon Content was determined by Walkey Black method described in SLS 1246:2003. Soil microbial biomass and activities were measured as biological properties of soil using Soda lime method (Koerner et al., 2011).

Statistical Analysis

Analysis of variance was used to analyze the data using SAS Statistical software (version 9.4).

Results and Discussion

Temperature changes co-compost production

Temperature changes in co-compost piles with time is shown Figure 1. This was different from normal composting process most probably due to the difference in feedstock. Average highest temperature was recorded as 57^{o}C.

pH and EC changes during co-compost process

pH value was fluctuated starting from 6.6 and finally increased up to 7.7. EC was increased from 6.4 to 7.3.

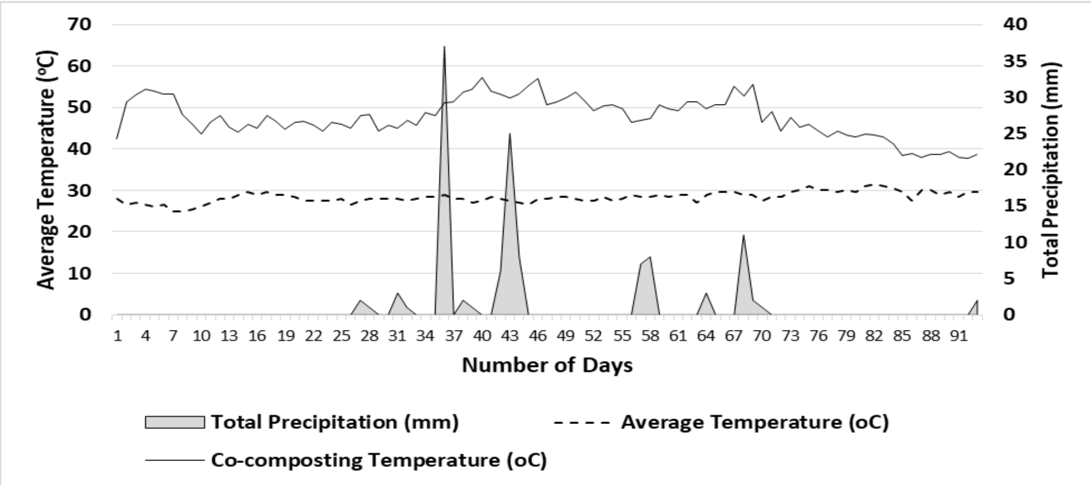

Figure 1: Temperature changes during co-compost production (ºC), Average environment temperature (ºC), total Precipitation (mm)

N, P, K composition during Co-composting

Composition of the Nitrogen, Phosphorus, and Potassium were changed with the time. Initial nitrogen value was 1.04% by mass and finally it was recorded as 1.27% by mass. Phosphorus changed from 0.65 to 0.86% by mass. Potassium value was increased from 0.56 to 0.65% by mass (Figure 2).

Organic Carbon and Organic Matter composition during Co-composting

Organic carbon and Organic matter content were increased from 6.24 and 12.29 to 7.90 to 15.80 % respectively by mass with the increase in compost age (Figure 3).

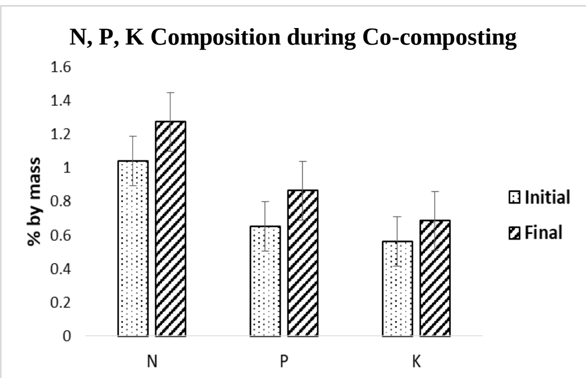

Figure 2: N, P, K composition during Co-composting

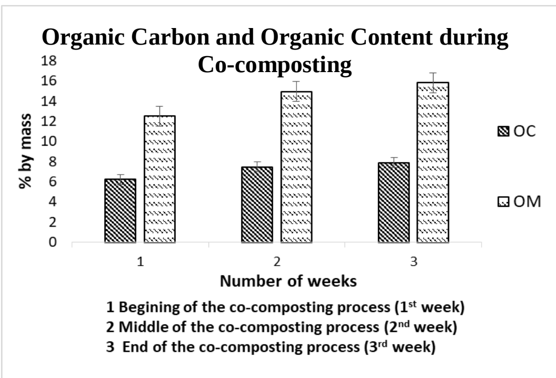

Figure 3: Organic Carbon and Organic Matter composition during Co-composting

Soil chemical properties during the tested period

There was a significant difference in pH values between control treatment (mineral fertilizer) and MWS-DFS co-compost treatments. T4 recorded the highest pH value (5.69812) while control treatment showed the lowest pH and EC when compared to the other treatments (Table 2).

Table 2. Comparison of chemical parameters with SLSI standards

Code	pH	EC	OC	N	P	K
T1	5.23125^{bc}	51.167^{e}	1.15813^{bc}	0.65813^{bc}	13.0475^{ab}	54.216^{b}
T2	5.21250^{bcd}	51.982^{e}	1.11000^{cd}	0.63125^{c}	7.9194^{d}	18.856^{e}
T3	5.15063^{cde}	73.687^{b}	1.14625^{bc}	0.48938^{e}	14.7819^{a}	65.641^{a}
T4	5.69812^{a}	82.121^{d}	1.32188^{a}	0.69375^{ab}	12.2431^{b}	40.174^{c}
T5	5.30250^{b}	82.596^{a}	1.24938^{b}	0.50000^{de}	14.6656^{a}	39.433^{c}
T6	5.10437^{ed}	68.598^{c}	1.01000^{d}	0.70438^{a}	7.3738^{d}	19.235^{e}
T7	5.07125^{e}	59.044^{d}	1.19063^{bc}	0.53688^{d}	9.9519^{c}	35.195^{c}
CV	3.343531	7.599238	13.75751	9.509556	23.44547	22.98164

Note: Means in a column with the same letters are not significantly different at the 0.05 probability level. cv-coefficient of Variance, p-significant probability value

The treatments with DFS-MSW-Biochar pellets (T_4 and T_5) had the highest pH and EC values, suggesting that biochar amendments have the ability to improve soil chemical properties such as cation exchange capacity (CEC) and electron conductivity (EC) in soil. There was a significant difference in soil organic carbon among the treatments. In DFS-MSW-Biochar pellet 100% available N treatment had significantly highest OC value by mass (1.32188%) when compared to the other treatments. This may be due to the ability of biochar to act as a carbon sequester. DFS-MSW-mineral pellet 100% available N (T_6) treatment recorded significantly highest N values by mass (0.70438%) when compared to the other treatments. DFS-MSW-pellet 30% available N treatment (T_3) recorded the significantly highest Phosphorous and potassium values.

T_2 and T_6 recorded the lowest P and K values and they were not significantly different from each other. Soil microbial activity was not significantly changed with the application of co-compost suggesting that soil microbial population had no considerable increase during this period. According to most of the published literature, factors critical to soil microbial activity are soil moisture availability, temperature, and availability of nutrients and organic energy sources (Koerner et al., 2011*)*. The stress conditions prevailed during the research period may have critically affected to the microbial activity in the soil.

Conclusions and Outlook

These results conclude that co-compost helps to improve soil pH, EC, organic carbon, Phosphorous and Potassium with compared to the mineral fertilizer application. Hence, co-compost produced from MSW and DFS can potentially be used in soil rehabilitation while co-compost enriched with biochar act as a soil amendment. A better understanding of the behavior of co-compost pellets and biochar with other field crops can be obtained by conducting continuous crop rotation in the same trial under normal rain fed conditions. Further, analysis of plant available nutrients are needed.

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