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Enhancement of growth and yield of Maize (*Zea mays* L.) using co-compost pellets with biochar

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Abstract— Waste generation and complexity is increasing due to urbanization and absence of proper solid waste management system in developing countries. Co-composted organic fractions of Municipal Solid Waste (MSW) with Dewatered Fecal Sludge (DFS) has a high potential to use as an agricultural resource in Sri Lanka. Oil palm Empty Fruit Bunches (EFB) has become a rising environmental and economic problem and it is a potential source for biochar feedstock. This study was focused on utilization of EFB as a biochar in amending sandy loam soil and evaluating performance of maize (Zea mays L.) fertilized with co-compost pellets (CCP). The experiment was carried out at the Sustainable Agriculture Research and Development Centre, Makandura. The growth and yield characteristics of maize plants were used to assess the effect of pelletized forms of different CCP. Randomized completely block design with four blocks and seven treatments namely MSW+DFS CCP with 30% available Nitrogen (T2) and 100% available Nitrogen (T3), MSW+DFS+biochar CCP with 30% available Nitrogen (T4) and 100% available Nitrogen (T5), MSW+DFS+Mineral enriched CCP (T6) and MSW+DFS+Biochar+Mineral enriched CCP (T7) were compared with mineral fertilizer recommendation by Department of Agriculture (DOA) of Sri Lanka (T1) as control. Significantly higher yield could be obtained under stress weather conditions with T2 against the control. The yield was increased by 22% over current mineral fertilizer recommendation of DOA. It could be concluded that harvest of 4.5 to 6.3 tons ha-1 could be achieved by amending soil with 42 tons ha-1 of MSW+DFS CCP with 30% available Nitrogen.

Keywords— Biochar, Co-compost, Pellets, Zea mays L.

Introduction

Waste generation is increasing due to the population growth and urbanization in Sri Lanka. It has been reported that around 6,400 tons of Municipal Solid Waste (MSW) is generated daily whereas waste collection is only about 3,740 tons day^{-1} (Anon, 2020a). MSW compost is produced in 120 compost sites island-wide under the Pilisaru project (Anon, 2008).

The term, MSW usually applies to a heterogeneous collection of wastes produced in urban areas. Improperly managed solid waste poses a risk to human health and the environment, including contamination of water, attracting insects and rodents and increasing flooding due to blockage of drainage canals or gullies. In addition, it may result in safety hazards from fires or explosions and also increases greenhouse gas (GHG) emissions, which contribute to climate change (Karunarathne, 2015).

Biochar is a carbon-rich material obtained from thermochemical conversion of biomass in an oxygen limited environment (Trupiano et al., 2017). Biochar enhances soil properties in many ways such as by holding carbon and making soils more fertile by means of reduced nitrogen leaching into the ground water, reduced nitrous oxide emissions, and increased cation-exchange capacity, as well as by increased pH, increased water retention and increased number of beneficial soil microbes (Anon, 2020b).

Oil palm plantations currently spread in Southern part of the country. Planted area has reached to 4,719 ha by 2012 (Anon, 2012) and production mills generate a large amount of solid wastes such as extracted oil palm fibers, palm shells, palm stone and empty fruit bunches (EFB). Most of these wastes, including EFBs, are dumped in the mill area due to high production rate associated with limited utilization and application. The utilization of oil palm EFBs as biochar feedstock is a way of managing the waste problem. The presctise may decrease the emission of methane (CH_4) and nitrous oxide (N_2O) from the degradation of EFBs (Shariff et al.,2014).

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 MSW. DFS has carbon (C), nitrogen (N), phosphorus (P) and potassium (K) as well as micronutrients while biodegradable MSW is rich in organic carbon and show good bulking properties. By combining two, the benefits of each can be used to optimize the process and the product (Anon, 2019c).

Urea is the most widely used N source in the world which represents 21% of total fertilizer N. Granular urea has note worthy characteristics, including less tendency to stick and cake than NH_4NH_3, no risk of explosion, and less corrosiveness towards handling and application equipment. Substantial savings in handling, storage, transportation, and application costs are possible because of urea's high N content (Havlinet al., 2014).

Maize (Zea mays L.) is the second most important cereal crop grown in Sri Lanka. It is widely used in food and feed industries and consumed as green cobs (Malaviarachchi et al., 2007) as well. There are number of traditional and hybrid Maiz varieties which have been recommended for Sri Lankan conditions as Bhadra, Ruwan, Aruna, Muthu, MI Hybrid Maize 01, MI Hybrid Maize 02 (Anon, 2013). MI Hybrid Maize 02 has cylindrical shape pod. The average yield is 5.5 - 6.5 t h^{-1} (Anon, 2019d).

Therefore, this study focussed on the impact on plant growth, yield quality and quantity when co-compost is added as a 100% organic, and in combinations with mineral fertilizer. The general objectives are the determination of optimum application rate of co-compost for maize cultivation using MI/M/Hybrid 02 and the possibility of using EFB as biochar, DFS and MSW in organic cultivations that can minimize environmental issues and public health.

Methodology and Experimental design

Experimental Site

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 ^{0}C and 20.8 ^{0}C respectively. Soil type is sandy loamy which consists of alluvial soil as a top layer.

Tested Fertilizer Combination

Seven types of fertilizer combinations were used for the experiment as given in Table 1. 100% available N in T_2 and T_4 signifies the assumption that all N added is absorbed into the plant. In T_3 and T_5 30% available N signifies the assumption that 30% of added N is absorbed into the plant.

Preparation of Biochar

Oil palm empty fruit bunches (EFB) wereused as a feedstock biochar was made using a pyrolyzer (Pushpakumara et al., 2016).

Preparation of Co-Compost pellets

Co-composting of dewatered fecal sludge , municipal solid waste and biochar weredone at the Kurunagala municipal council compost station operating under the Pilisaru project. Pellets were produced by using pellatizer machine (Grauetal., 2017).

Crop Establishment and Maintenance

Co-compost pellets were applied two weeks before seed sowing. Amount of co-compost necessary for the soil amendment (per plot) was calculated according to its percentage of nitrogen. Co-compost requirement of maize (per plot) was calculated using the urea requirement (325 kg ha^{-1}) of maize as recommended by DOA (Anon, 2019d).

Table 1. Tested fertilizer combination

Code	Treatment	Basal dressing kg/ha			Top dressing kg/ha		
		Urea	TSP	MOP	Urea	TSP	MOP
T_1	Mineral fertilizer	162.5	50	25	162.5	50	25
T_2	FS-MSW-pellet 100% available N	12650					
T_3	FS-MSW-pellet 30% available N	42133					
T_4	FS-MSW-Biochar-pellet 100% available N	13599					
T_5	FS-MSW-Biochar-pellet 30% available N	45366					
T_6	FS-MSW-Mineral-Pellet	1875					
T_7	FS-MSW-Biochar-Mineral-Pellet	1875					

T_1- Mineral fertilizer(control), T_2- Fecal sludge + Municipal Solid Waste Compost Pellets 100% available Nitrogen, T_3- Fecal sludge + Municipal Solid Waste Compost Pellets 30% available Nitrogen, T_4- Fecal sludge + Biochar+ Municipal Solid Waste Compost Pellets 100% available Nitrogen, T_5- Fecal sludge + Biochar+ Municipal Solid Waste Compost Pellets 30% available Nitrogen, T_6- Fecal sludge + Mineral fertilizer +Municipal Solid Waste Compost Pellets, T_7- Fecal sludge + Biochar+ Mineral fertilizer +Municipal Solid Waste Compost Pellets.

Co-compost pellets were applied only as a basal dressing, while mineral fertilizer were applied as both basal and top dressing. Mineral fertilizer basal dressing was applied two days before seed sowing in the field. Top dressing was applied four weeks after seed sowing. Earthing up was carried out four weeks after seed sowing. Manual weeding, pest and disease control and other cultural practices were performed according to DOA recommendation. Thinning out was carried out three weeks after seed germination leaving one well grown, vigorous, healthy and uniform seedling per planting hole.

Experimental Design

Seven treatments were arranged in a Randomized Completely Block Design (RCBD) with four blocks.

Data Recording

Following vegetative and reproductive data were collected from six randomly selected plants from each treatment from each block.

Vegetative Parameters

Plant height, blade length (7th leaf), chlorophyll content (SPAD), leaf area and fresh weight of the rootswere taken as vegetative parameters.

Plant height was measured from soil surface to tip of the fully emerged leaf sheath from four randomly selected plants and data were recorded two weeks after the seed sowing and continued within two weeks interval.

Blade length was measured from end of leaf sheath to tip of the leaf from two randomly selected plants and data were recorded one month after seeds sowing.

Chlorophyll content was measured from the middle part of the fully emerged leaves by using SPAD-502 Plus (Konica Minolta) chlorophyll meter and data were recorded two weeks after the seeds sowing and continued once in two weeks.

Leaf area and fresh weight of the roots were measured at harvesting (50 days after seeds sowing) from one randomly selected plant and data were recorded.

Yield Parameters

Pod diameter, pod length, number of pods and yield were taken as yield parameters.

Pod diameter was measured by using Vernier caliper from two randomly selected plants and data were recorded 20 days after pod emergence.

Pod length was measured from two randomly selected plants and data were recorded 20 days after the pod emergence.

Number of pods were counted at 75 days after the seed sowing.

Predicted grain yield was taken at harvesting. One randomly selected pod and number of seeds were recorded for each treatment 25 days after the pod emergence. Total number of seeds per plot was calculated using number of pods per plot. Predicted grain yield was calculated using the weight of 1000 seeds (241.9 g) and the plot size of 4.64 m^2.

Statistical Analysis

Data were analysed by analysis of variance using SAS Statistical software (version 9.4).

Results and Discussion

Vegetative Parameters

Mean values of quantitative vegetative parameters are given in Table 2. The highest plant height was recorded with T_2 while the lowest was recorded with T_6. Even though the highest plant height was demonstrated by addition of MSW co-compost (T_2), addition of mineral fertilizer into FS-MSW co-compost (T_6) tend to lower the plant height according to the results of T_6 and T_1 (mineral + pellet is significantly lower than the control). This may be due to the stress conditions prevailed during the research period.

Table 3. Mean values of quantitative yield parameters

T	Yield ($g\ m^{-2}$)	Pod diameter (cm)	Pod length (cm)
T_1	443.94^{b}	4.18^{bc}	26.19^{a}
T_2	501.97^{ab}	4.25^{bc}	24.94^{a}
T_3	542.42^{a}	4.78^{a}	27.13^{a}
T_4	417.43^{bc}	4.33^{b}	25.50^{a}
T_5	468.81^{ab}	4.76^{a}	27.31^{a}
T_6	232.49^{e}	4.25^{bc}	26.50^{a}
T_7	323.28^{d}	4.00^{c}	25.50^{a}
p	0.0001	0.0012	0.1024

T-Treatment, T_1- Mineral fertilizer, T_2- Fecal sludge + Municipal Solid Waste Compost Pellets 100% available Nitrogen, T_3- Fecal sludge + Municipal Solid Waste Compost Pellets 30% available Nitrogen, T_4- Fecal sludge + Biochar+ Municipal Solid Waste Compost Pellets 100% available Nitrogen, T_5- Fecal sludge + Biochar+ Municipal Solid Waste Compost Pellets 30% available Nitrogen, T_6- Fecal sludge + Mineral fertilizer +Municipal Solid Waste Compost Pellets, T_7- Fecal sludge + Biochar+ Mineral fertilizer +Municipal Solid Waste Compost Pellets, p-significant probability value

The highest mean value (Table 2) of the leaf bade length was recorded with T_2 while the lowest was recorded with T_7. However $T_2$and T_3had no significantdifference. Even though the leaf bade length growth was increased by the addition of MSW co-compost in T_2 and T_3, addition of mineral fertilizer+biochar into MSW co-compost (T_7) tend to lower the leaf bade length. It was found that T_7 andT_6 have no difference with T_1. This may be also due to the stress conditions prevailed during the research period that can reduce the effect of mineral ferti

Table 2. Mean values of quantitative and vegetative parameters

Treatment	Plant height (cm)	Leaf blade length (cm)	Chlorophyll content (SPAD)	Leaf area (cm^2)	Root fresh mass (g)
T_1	98.59^{e}	41.86^{c}	51.68^{ab}	13619.5^{a}	131.75^{b}
T_2	136.50^{a}	53.61^{a}	43.36^{e}	13063.7^{a}	137.25^{b}
T_3	132.42^{ab}	50.60^{ab}	53.41^{a}	13809.0^{a}	184.75^{a}
T_4	116.76^{cd}	47.48^{b}	45.32^{de}	16116.7^{a}	148.75^{ab}
T_5	122.25^{bc}	47.45^{b}	53.13^{a}	16032.0^{a}	156.25^{ab}
T_6	82.75^{f}	41.60^{c}	48.07^{bcd}	15671.3^{a}	184.00^{a}
T_7	95.66^{e}	41.23^{c}	46.55^{cd}	11647.3^{a}	125.00^{b}
P	<0.0001	<0.0001	0.0025	0.1212	0.0437

T_1- Mineral fertilizer, T_2- Fecal sludge + Municipal Solid Waste Compost Pellets 100% available Nitrogen, T_3- Fecal sludge + Municipal Solid Waste Compost Pellets 30% available Nitrogen, T_4- Fecal sludge + Biochar+ Municipal Solid Waste Compost Pellets 100% available Nitrogen, T_5- Fecal sludge + Biochar+ Municipal Solid Waste Compost Pellets 30% available Nitrogen, T_6- Fecal sludge + Mineral fertilizer +Municipal Solid Waste Compost Pellets, T_7- Fecal sludge + Biochar+ Mineral fertilizer +Municipal Solid Waste Compost Pellets, p-significant probability value

The highest mean value (Table 2) of the chlorophyll content (SPAD) was recorded with T_3 while the lowest was recorded with T_2. Even though the highest Chlorophyll content was demonstrated by MSW co-compost 30% available nitrogen (T_3), addition of MSW co-compost 100% available nitrogen (T_2) tended to lower the chlorophyll content. However T_5 was not significantly different with T_3 probably due to the addition of excess amount of nitrogen than the requirement of the plant. Further results indicated that addition of mineral fertilizer to MSW co-compost pellet tended to lower the chlorophyll content. Leaf area among all treatments was unchanged (Table 2).

The highest mean value (Table 2) of the root fresh mass was recorded with T_3 while the lowest was recorded with T_7. However T_3 and T_6 was not significantly different. Even though root fresh mass was increased by addition of MSW co-compost and MSW co-compost + mineral fertilizer (T_3, T_6), addition of mineralfertilizer + biocharinto MSW co-compost (T_7) lowered the root fresh mass. This may also be due to the stress conditions prevailed during the research period and cultivation under irrigation water.

Yield Parameters

Mean values of quantitative yield parameters are given in Table 3. Pod lengths were not different among all treatments suggesting no effect of the treatments.

The highest mean value (Table 3) of the pod diameter was recorded with T_3 while the lowest was recorded with T_7. Even though the highest pod diameter was achieved by MSW co-compost (T_3), addition of mineral fertilizer + biochar into MSW co-compost (T_7) tended to lower the pod diameter according to the results. However T_1, T_6 and T_2 were not significantly different with T_7. This may also be due to the stress conditions prevailed during the research period as observed with plant height and blade length.

Mean values (Table 2) of the highest predicted yield was recorded with T_3 while the lowest was recorded with T_6. Even though the highest predicted yield was demonstrated by addition of MSW co-compost (T_3), addition of mineral fertilizer into MSW co-compost (T_6) lowered the predicted yield. Mineral fertilizer with MSW co-compost (T_6) was not significantly different with mineral fertilizer with MSW co-compost treatments (T_7). This may also be due to the stress conditions prevailed during the research period and cultivation under irrigation water. (Malaviarachchi et al., 2007)

The results show significant treatment effect in both vegetative and yield parameters. Mineral fertilizer and mineral fertilizer with MSW co-compost had lower values for vegetative and yield parameters. The FS-MSW pellets 30% available Nitrogen fertilizer (T_3) showed significantly better performance than mineral fertilizer recommendation of DOA (5.1 to 6.2 t ha^{-1}). However, under the study conditions (irrigated water and average day time temperature of 33 ^{0}C) the yield recorded with mineral fertilizer recommendation was 4.0 to 5.2 t ha^{-1}.

Conclusions

When the co-compost is used as a fertilizer with maize, optimum yield could be obtained with the application of excess amount of co-compost. FS-MSW pellets with 30% available Nitrogen could increase the yield by 22% over current mineral fertilizer recommendation of DOA. FS-Biochar-MSW pellets with 30 % available Nitrogen also increased the yield by 6 % over the current mineral fertilizer recommendation. However co-compost with biochar showed lower yield than co-compost. A better understanding of the behavior of co-compost pellets and biochar can be obtained by conducting the same trial under normal rain fed conditions in same soil.

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