Annex III

Effect of Municipal Solid Waste and Fecal sludge Co-compost Pellet and Powder Forms with Bio Char and Urea on Vegetative Growth of Maize (*Zea mays* L.)

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ABSTRACT

Sri Lanka is facing a severe problem of Municipal Solid Waste (MSW) and Fecal sludge (FS) disposal in urban areas. Co-compost preparation with MSW and FS is considered to be one of the most technically appropriate methods of managing this condition. Present study was conducted to investigate the effect of Municipal Solid Waste Fecal Sludge Co-compost, bio char and urea in pellet and powder forms in comparison to inorganic fertilizers on vegetative growth of maize (*Zea mays*). The maize variety MI/M/Hybrid 2 was tested with eight treatments and a control. Following fertilizer treatments, T_1-Mineral fertilizer, T_2-100% MSW-FS Co-compost pellet,T_3-100 % MSW-FS Co-compost powder,T_4-92.9% MSW-FS Co-compost + 7.1% Bio-char pellet,T_5-92.9% MSW-FS Co-compost + 7.1% Bio-char powder,T_6-84.8% MSW-FS Co-compost + 15.2% urea pellet,T_7-84.8% MSW-FS Co-compost + 15.2% urea pellet,T_8-77.68 % MSW-FS Co-compost + 15.2% urea + bio-char 7.2% pellet,T_9-77.68% MSW-FS Co-compost + 15.2% urea + bio-char 7.2% powder were applied as treatments. All measured parameters were significantly different among treatments. T_5-92.9% MSW-FS Co-compost + 7.1% Bio-char powder showed a higher vegetative growth in maize.

KEYWORDS: Bio-char, Co-Compost, Maize, Municipal solid waste

INTRODUCTION

Zea mays, corn or maize, is an annual grass in the Poaceae (Grass family) that originated in Central America and is widely grown throughout the world. It had the highest production in the cereal industry with 817 million tons been produced in 2009 (Anon, 2017c), for use in both the food and feed industry. Maize is utilized for production of over 500 different products and by products worldwide (Anon, 2017a). It has a large number of cultivars with different maturity periods and with different tolerance levels to environmental conditions and can be grown on a wide variety of soils such as well drained, deep, silt loams with adequate organic matter are most suitable. Maize has a higher leafy mass and higher vegetative growth within a shorter period of time than other mono-culture crops. It is in calories and a good source of vitamin B6. In Sri Lanka during 2015/2016 *maha* season, the extent of maize cultivation was 57,090 ha and the production was 207,070 metric tons. (Anon, 2017b).

Municipal Solid waste (MSW) is a serious issue in Sri Lanka and disposal of solid waste has become a serious environmental and socioeconomic issue. The waste generation has been increased due to the development, population growth, rapid urbanization, migration and accompanying changes in the consumption pattern and industrialization (Hikkaduwa *et al.*, 2015). In Sri Lanka around 3,424 metric tons of MSW is collected daily (Anon, 2012). In urban, suburban and provincial areas solid waste disposal sites are considered as major breeding sites of mosquitoes, rodents and other disease transmitters that affect human population's health (Salam, 2010). It causes pollution of surface and subsurface water bodies due to leachate contamination, air pollution from emissions of spontaneous combustion in dumps and adverse impacts on fauna and flora (Anon., 2010).

As a solution, compost manufacturing is done using more than one feedstock. One of the common urban and suburban waste, Fecal

Sludge (FS) that consist of moisture and relatively higher nitrogen content, and biodegradable municipal solid waste that is high in organic carbon and good bulking properties can be combined together to obtain the benefits of each and to improve the efficiency and productivity of manufacturing process and the quality of product (Anon., 2017d).

Bio-char is a carbon-rich material obtained from thermochemical conversion (slow, intermediate, and fast pyrolysis or gasification) of biomass in an oxygen-limited environment (Trupiano *et al*., 2017). It is a means of managing waste as the mass from crop residues, weeds, surplus biomass, grasses, excess forest litter, animal manure, municipal waste, *etc*. can be used for conversion into bio char (Anon., 2015). Bio-char has been described as a possible tool for soil fertility improvement, toxic element adsorption, climate change mitigation and microbial activities improvement (Trupiano *et al*., 2017).

Urea is the most widely used Nitrogen (N) source in the world which represents 21% of total nitrogen fertilizer. Granular urea has noteworthy characteristics, including less tendency to stick and cake than NH_4NO_3, no risk of explosion, and less corrosive to handling and application equipment. Substantial savings in handling, storage, transportation, and application costs are possible because of urea's high N content (Havlin *et al*., 2014). Nitrogen is the most important plant nutrient, responsible for shoot and leaf growth. That is necessary for chlorophyll synthesis and as a part of the chlorophyll molecule and involved in photosynthesis. Nitrogen is a component of vitamins and energy systems in plants. It is also an essential component of amino acids, which form plant proteins (Gupta, 2003).

Maize requires nitrogen in large quantities and nitrogen deficiency is the most common nutritional problem of maize plants. Therefore, this study was carried out with the objective of studying the suitability of MSW-FS Co-compost application on the maize variety MI/M/Hybrid 02. The growth response of maize to MSW-FS Co-compost pellet and powder form with bio char and urea were studied.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the Center of Excellence for Organic Agriculture, Department of Agriculture (DOA), Makandura, Gonawila (NWP), Sri Lanka from July to September 2017. It is situated in IL_{1a} agro ecological zone where daily average maximum and minimum temperatures were 35.6 ^{0}C, and 20.8 ^{0}C, respectively. The soil type is sandy loamy which consists of alluvial soil as a top layer.

Preparation of Biochar

Two different sized metal barrels were used (the bigger being 3,750 L volume with 86.36 cm diameter and 160.02 cm height, smaller one being 1,450 L volume with 55.88 cm diameter and 147.32 cm height). Refused oil palm empty fruit bunches (EFT) were loaded into the smaller barrel and it was placed within the large barrel. Dry hardwood was placed in the space between the two barrel and set fire for 3 h (> 300 ^{0}C). After complete pyrolysis process it was left to cool overnight.

Compost Preparation

Municipal solid waste with FS Co compost produced by Kurunegala municipal council was used in the experiment. Pellets were produced by using pellatization machine. Nitrogen enrichment was done by adding urea into the compost. Amounts of applied compost to pots were calculated according to its percentage of nitrogen. Urea or nitrogen requirement of maize plant was considered as 325 kg/ha (Anon, 2017a).

Poly Bag Preparation

Black colour polythene was used to make 45.72 cm height and 35.56 cm width poly bags. Top soil from field was sieved by 5 mm mesh and filled into poly bags with equal volume.

Field Layout

Eighty one poly bags for experimental plants and 40 poly bags as guard plants were arranged in 30×60 cm spacing. The treatments were arranged in a Latin Square design with nine treatments and nine replicates.

Treatments

Two formulation types *i.e.* powder and pellet form of co-compost and inorganic

Table 1.Treatments used in the experiment

Treatment	Description	Fertilizer g/plant				
		MSW-FS	Biochar	Urea	TSP	MOP
T_1	Mineral fertilizer			6.50	2	1
T_2	100 % MSW-FS Co-compost pellet	254.24				
T_3	100 % MSW-FS Co-compost powder	254.24				
T_4	92.9 % MSW-FS Co-compost + 7.1% Bio-char pellet	254.24	19.43			
T_5	92.9 % MSW-FS Co-compost + 7.1% Bio-char powder	254.24	19.43			
T_6	84.8 % MSW-FS Co-compost + 15.2 % Urea pellet	31.80		5.70		
T_7	84.8 % MSW-FS Co-compost + 15.2 % Urea powder	31.80		5.70		
T_8	77.68 % MSW-FS Co-compost + 15.2 % Urea + Bio-char 7.2% pellet	29.13	2.67	5.70		
T_9	77.68 % MSW-FS Co-compost + 15.2 % Urea + Bio-char 7.2% powder	29.13	2.67	5.70		

TSP-Triple super phosphate, MOP- Muriate of potash, MSW-FS - Municipal Solid Waste Fecal Sludge fertilizer as recommended by DOA for field conditions were used as treatments. Application rates of the treatments were decided according to nitrogen requirement of the maize plant (3 g/ plant-325 kg/ha) and nitrogen content in the treatment.

Crop Establishment and Maintenance

Poly bags filled with medium were kept for two days and the seeds of maize variety MI/M/Hybrid 02, soaked overnight, were sown at the rate of 2 seeds per bag. Thinning out was done at fourteen days after sowing to keep one seedling per poly bag. Basal dressing of inorganic fertilizers was applied two days before sowing. Irrigation, weeding and other cultural practices were done according to DOA recommendation.

Data Recording

Vegetative Parameters

Plant height (cm) was measured from the base of the plant to the collar of the flag leaf, starting from 2 Weeks After Sowing (WAS) at two weeks interval. Final height of plants was measured (cm) from the base of the plant to where tassel branching begins. Number of leaves was determined by counting all unfolded leaves including yellowish and dead leaves at two weeks interval. Length of 7^{th} leaf was measured from the base of the leaf to the tip. Data were recorded till 8 WAS. Soil Plant Analysis Development (SPAD) value (chlorophyll) was recorded using a SPAD meter (Konica Minolta) at vegetative and booting stages. SPAD value was taken as average from the fully expanded four mature leaves. Stem diameter was measured at base of the plant at booting stage using a vernier caliper.

Soil pH

Soil pH was measured at initial, vegetative and booting stages using 1:1 water_method. Soil samples were taken at 20 cm depth using an auger.

Statistical Analysis

Plant height, leaf blade length (7^{th} leaf), stem diameter and soil pH were statistically analyzed by General Linear Model (GLM) procedure and the number of Leaves was statistically analyzed by Wilcoxon scores (Rank sums) using SAS statistical package (version 9.4).

RESULTS AND DISCUSSION

Plant Height

Statistical analysis of mean values of height showed a significant difference among treatments. T_5 recorded highest value while the lowest value was recorded by T_9 at 2 WAS and 4 WAS. T_7 showed the lowest value in 6 WAS, 8 WAS, 10 WAS. Nitrogen is one of the most important nutrients required for plant vegetative growth indicated by height (John *et al*., 2014). Urea added treatments T_1, T_6 and T_7 had significantly higher values than all treatments except at 2 WAS and 4 WAS which may be attributed to the quick release of nitrogen provided by urea (Table 2). In T_8 and T_9, that cannot be observed due to the retention of Nitrogen by bio-char. However during later part of the experiment, T_1, T_6, T_7, T_8 and T_9 had significantly lower height than other treatments due to the depletion Nitrogen quickly. T_2, T_3, T_4, T_5 treatments with co-compost gradually release Nitrogen; and therefore, showed overall higher value of height.

Number of Leaves

Number of leaves were significantly different among treatments. T_5 recorded highest value while lower values were recorded by T_2, T_8, T_9 and T_7 in 2 WAS, 4 WAS, 6 WAS, and in 8 WAS respectively. T_2 and T_4 showed significantly lower number of leaves than T_3 and T_5 (Table 3). T_3 and T_5 contained MSW- FS

Table 2. Effect of different combinations of Co-compost, Bio-char and Urea on plant height

Treatment	Plant Height (cm)				
	2 WAS	4 WAS	6 WAS	8 WAS	10 WAS
T_1	4.61^{cd}	9.38^{b}	14.94^{c}	35.44^{c}	91.78^{bcd}
T_2	4.70^{cd}	9.11^{cb}	24.55^{b}	62.77^{b}	116.89^{ab}
T_3	6.16^{a}	17.33^{a}	29.33^{a}	95.16^{a}	117.00^{ab}
T_4	4.62^{cd}	9.55^{b}	28.22^{ab}	67.33^{b}	117.33^{a}
T_5	6.30^{a}	17.33^{a}	31.00^{a}	96.33^{a}	117.33^{a}
T_6	5.01^{cb}	8.88^{cb}	15.66^{c}	32.88^{cd}	96.22^{abc}
T_7	5.41^{b}	8.66^{cbd}	11.88^{c}	23.66^{d}	68.44^{d}
T_8	4.35^{d}	7.11^{d}	14.33^{c}	30.11^{cd}	95.00^{abc}
T_9	4.34^{d}	6.66^{d}	12.22^{c}	25.22^{cd}	73.56^{cd}

Means in a column with the same letters are not significantly different at the 0.05 probability level WAS-weeks after sowing co-compost in powder form. Hence, they release nutrients faster than T_2 and T_4 resulting in faster growth and higher number of leaves. T_2 showed a significantly lower value than T_4 and T_3 had a significantly lower value than T_5 which indicate the higher nutrients retention capacity of bio-char in pellet and powder forms of MSW-FS co-compost.

Table 3. Effect of different combinations of Co-compost, Bio-char and Urea on the number of leaves

Treatment	Number of Leaves			
	2 WAS	4 WAS	6 WAS	8 WAS
T_1	35.94	34.00	28.67	38.00
T_2	26.50	40.72	49.94	41.11
T_3	60.72	67.48	64.28	66.94
T_4	32.33	39.56	49.00	45.44
T_5	64.77	68.44	65.00	72.72
T_6	40.44	27.83	36.00	37.39
T_7	38.67	38.16	36.00	16.33
T_8	29.16	22.00	23.44	29.17
T_9	40.44	30.50	14.67	24.89

Means in a column with the 0.05 probability level WAS-weeks after sowing

Leaf Length (7th leaf)

Leaf length was significantly different among treatments and T_5 recorded the highest value while the lowest value was recorded by T_9. According to mean values of T_2 and T_3, there was a significant difference that can be attributed to faster release of nutrients by powder form than pellet form (Table 4).

Stem Diameter

Maize plants stem diameter was significantly different among treatments. T_5 and T_3 recorded highest value and T_9 recorded lowest value. T_1, T_6, T_7, T_8 and T_9 had no significant differences with T_4 (Table 4). T_3 and T_5 provide nutrients to the plants from FS-MSW co-compost in powder from regularly than T_4, T_6 and T_8. T_7 with urea may have released nitrogen rapidly which may not be efficiently absorbed by the maize plants.

Soil Plant Analysis Development (SPAD) Value

Value of SPAD indicates chlorophyll contents of plants. Significant differences in SPAD value among treatments were observed at vegetative and booting stages. At vegetative stage, highest SPAD value was recorded in T_5, while the lowest value was in T_1. At booting stage, T_2 showed the highest SPAD value while T_7 showed the lowest value (Table 4). Chlorophyll content in the leaf tissue differs with age of plant, species and growing season (Tari *et al*., 2013). In both T_2 and T_5 all macro and micro nutrients were provided by FS-MSW co-compost while T_5 has bio-char in powder form. Pellet form of T_2 may have higher capacity to retain and gradually release the nutrients that is important for chlorophyll production. (Trupiano *et al*., 2017).

Soil pH

Initial pH value of the soil used for this research work was 4.1. At 4 WAS and 8 WAS, soil pH was significantly different among treatments. T_5 recorded highest value at 4 WAS and 8 WAS, whereas T_9 and T_7 recorded lowest values at 4 WAS and 8 WAS respectively. (Table 4). Accordingly, it is possible to state that application of MSW co-compost had improved pH value of the medium to reach near to optimum range for maize plant that is 5.8-6.5 (Anon, 2017e)

CONCLUSIONS

Results revealed that MSW-FS co-compost was having superior effect on vegetative growth of maize plants. Treatments with MSW-FS co-compost powder form had a significant effect on growth parameters of maize plants when compared to the pellet form. A Pellet formation of bio-char had significant effect on growth parameters of maize plants compared to non-bio-char treatments. MSW-FS co-compost powder with bio-char in powder form can be suggested as the most suitable fertilizer type for cultivation.

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Table 4.Effect of treatments on leaf length, stem diameter, Soil Plant Analysis Development (SPAD) Value and soil pH value

Treatment	Leaf Length (cm)	Stem diameter (cm)	4 WAS	8 WAS	4 WAS	8 WAS
			Chlorophyll (SPAD)	Chlorophyll (SPAD)	pH	pH
T_1	35.33[d]	0.60[c]	27.57[d]	35.00[bcd]	4.09[c]	4.32[b]
T_2	52.33[c]	1.22[b]	33.66[bc]	40.19[a]	4.14[bc]	4.64[c]
T_3	63.67[ab]	1.79[a]	42.93[a]	37.94[abc]	4.25[b]	4.96[b]
T_4	54.00[bc]	1.41[b]	36.31[b]	39.79[a]	4.22[b]	4.73[c]
T_5	66.33[a]	1.88[a]	44.40[a]	38.80[ab]	4.58[a]	5.15[a]
T_6	36.00[d]	0.68[c]	32.14[bcd]	35.88[abcd]	4.04[c]	4.14[e]
T_7	32.11[d]	0.52[c]	29.46[cd]	29.05[e]	4.09[c]	4.12[e]
T_8	33.22[d]	0.62[c]	31.11[cd]	33.23[cde]	4.07[c]	4.42[d]
T_9	26.33[d]	0.44[c]	29.74[cd]	33.12[de]	4.05[c]	4.37[d]

Means in a column with the same letters are not significantly different at the 0.05 probability level. WAS -weeks after sowing

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