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Effect of applying different ratios of compost made of municipal solid waste on the growth of *Zea mays* L. (Corn)

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Since composts are soil like amendments made from plant and animal remains, they are more important than inorganic fertilizer because they consist of relatively stable decomposed materials resulting from accelerated biological degradation of organic matter. However, little attention has been paid on the use of compost as bio-fertilizers to improve soil structure, fertility and consequently growth and productivity of plants among farmers in Sri Lanka mainly due to lack of awareness on the beneficial effects. Therefore, the present study focuses on obtaining baseline data set on the efficacy in terms of plant growth characteristics by using different soil compost ratios of different types of composts. Four different types of composts and three different soil compost ratios (1:0.5, 1:1 and 1:1.5) were used in this study. Results of the present study clearly indicated that different composts act differently on the growth parameters tested and showed a reasonable variation with different soil compost ratios indicating both positive and negative effects on plant growth and yield. The results showed that the best soil compost ratio that could be used to significantly improve the growth parameters of *Zea mays* is 1:1 followed by 1:0.5. From among the different MSW composts used in this study, the best performance was shown by Dikovita followed by Mihisaru Segregated. This study further highlighted that higher ratio (1:1.5 soil compost) of certain MSW composts was not desirable and showed a negative effect on plant height.

Key words: Aggregate stability, compost, nutrients, phytotoxicity, soil amendment, solid waste.

INTRODUCTION

Approximately, 76% of solid waste can be turned into compost. Municipal Solid Waste (MSW) is a permanent and inexpensive source of organic matter, when there is low organic matter in soil (Zakaria et al., 2014). A survey of MSW compost has reported that on average, 20% of the total C in MSW compost was organic C, 8% carbonate C, and 71% residual C which may have included organic C components (He et al., 1995). It can be also used as a suitable alternative to chemical fertilizers (Singh et al., 2007). Municipal solid waste is largely made-up of kitchen and yard waste, and its composting has been adopted by many municipalities

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(Otten, 2001). Compost is normally produced through the activity of aerobic (oxygen requiring) microorganisms. These microbes require oxygen, moisture, and nutrients in order to grow and multiply. MSW compost increases the aggregate stability of soil through the formation of cationic bridges thereby, improving the soil structure (Hernando et al., 1989). Various experiments have indicated that applications of compost improve plant health, yield and nutritional quality. Research conducted by Lima et al. (2004), demonstrated the beneficial action of compost on the physical and chemical properties of soil and on plant development. Ramadass and Palaniyandi concluded that the amount of nitrate nitrogen and ammonium nitrogen content were found significantly high in enriched compost applied soil (Ramadass and Palaniyandi, 2007). Pant et al. (2012) demonstrated that compost quality impacted on nutrient extraction efficiency, microbial activity, phytohormones and, total nutrient content of the extracts. They also reported that these differences in extract quality in turn influenced growth and tissue mineral nutrient content of pak choi.

Since composts are soil like amendment made from plant and animal remains, they are more important than inorganic fertilizer because they consist of relatively stable decomposed materials resulting from accelerated biological degradation of organic matter under controlled aerobic conditions (Storey et al., 1996). The advantages of compost fertilizer in crop production includes ready availability of nutrient materials, gradual release of nutrients without being wasted through leaching, increased soil drainage, aeration, water holding capacity, nutrient holding capacity. Further, compost application is very popular among farmers as an environmentally friendly fertilizer.

Compost has two main effects on soils, particularly on nutrient-poor soils. It replenishes soil organic matter and supplies plant nutrients (Sanchez-Monderoo et al., 2004). Organic matter plays a crucial role in improving physical, chemical and biological properties of soils. Soil structure can be improved by the binding between soil organic matter and clay particles via cation bridges and through stimulation of microbial activity and root growth (Farrell and Jones, 2009).

From a biological point of view, compost application to soil directly affects both diversity and size of microbial communities as well as enzyme activities, since most of the processes in soil are mediated by enzymes from microbial origin (Böhme et al., 2005). On the other hand, the improvement of soil micro-biota in turn influences plant growth by means of the presence of plant growth promoting substances and the increase of nutrient availability (Ros et al., 2006). Further, some organic materials like compost can increase crop yields due to improved soil through nutrient release during decomposition and mineralization (Otten, 2001). They may also improve soil physical properties such as moisture retention, bulk density and aeration. The positive effect on physico-chemical and biological properties of compost amendments promotes ideal conditions for plant growth and, in turn, improve yield. There are many studies that support this influence (Warman and Termeer, 2005). A wide diversity of raw materials have been used in these studies, although a combination of different wastes is recommended to prevent some detrimental properties of specific materials, which might hamper the composting process (Sánchez-Arias et al., 2008). However, compost quality is not the only factor to be considered for the success of the amendment. Soil properties also play an important role by making necessary adaptation of compost characteristics to the specific soil demands. Sometimes, these demands are better met not by means of improved physico-chemical or nutritional compost properties but through the action of microbial inoculants (Grandlic et al., 2009).

The assessment of compost influence on plant growth can be achieved through different parameters, among them yield, productivity, dry weight of plant, weight and number of fruits, length and weight of stem, shoot and root Carbon, N or P uptake capacity, etc (Warman and Termeer, 2005). Application of compost and bio-fertilizers to improve soil structure, fertility and consequently development and productivity of plants has received little attention either due to the non-availability of compost or non-awareness about the benefits of compost among farmers in Sri Lanka. Further, the production of compost especially at domestic level is significantly low due to the non-availability of suitable user friendly solid waste management methods and research data to prove the efficacy of this valuable resource.

In addition, very few studies have been conducted on the best soil compost ratio to be practised and to recommend under field conditions. As a result, there is a huge void about the awareness of practical application in terms of soil compost ratio and on the recommended doses of organic fertiliser. Therefore, the main aim of the present study is to give some base line data on the effectiveness of applying MSW compost on the vegetative growth of plants using *Zea mays* while making different mixes of locally available MSW compost. Presently, *Zea mays* is one of the fast growing and spreading cash crops in Sri Lanka.

Study area

The study was carried out in pot bags at Phorowatta, Mihisaru compositing facility of the western province waste management authority. The site was located about 35 km to the south of Colombo, the capital of Sri Lanka and is managed by the Western Province Waste Management Authority of Sri Lanka.

Table 1. Some physical and chemical properties of the composts used for this study *(Source: Western Province Waste Management Authority).*

Compost name	pH	EC(dS/m)	Moisture (%)	Org. C %	Total N %	P_2O_5 %	K_2O%	C:N
Agalawaththa	8.6	6.91	15	37.79	0.36	1.3	1.7	28.6
Mathugama	7.8	2.1	36	35.90	0.08	1.3	1.8	38.1
Mihisaru - Seg	8.3	5.25	21	52.26	1.77	1.4	1.7	29.5
Dikovita	7.3	2.6	36	28.17	1.22	1.4	0.6	23.1

Table 2. Effect of compost mixes on vegetative development of *Zea mays.*

Treatment WAP		Plant height (cm)			Stem girth (cm)			Number of leaves			Wet biomass (g)
		4	6	8	4	6	8	4	6	8	8
	1: 0.5	16.33[a]	59.67[a]	104.00[a]	3.67[a]	6.33[a]	7.00[a]	7.00[a]c	13.33[a]	16.00[a]	458.33[a]
AGL	1:1	17.00[a]	65.33[a]	109.33[a]	3.76[a]	7.33[a]	7.33[a]	6.33[a]	12.33[a]	15.33[a]	516.00[a]
	1:1.5	22.00[b]	83.69[a]	131.33[a]	5.00[b]	8.33[a]	7.33[a]	8.67c	15.33[a]	15.33[a]	449.33[a]
	1: 0.5	27.33[a]	91.33[a]	153.00.[a]	7.67[a]	10.0[a]	8.00[a]	9.67[a]	14.33[a]	17.67[a]	550.00[a]
DWT	1:1	27.00[a]	87.0[ab]	155.67[a]	6.50[a]	9.0[ab]	8.16[a]	10.33[a]	15.00[a]	17.33[a]	534.33[a]
	1:1.5	26.33[a]	75.00[b]	126.33[b]	6.33[a]	8.33[b]	7.83[a]	9.67[a]	14.33[a]	16.33[a]	458.33[a]
	1: 0.5	21.67[a]	67.00[a]	116.00[a]	5.33[a]	8.67[a]	8.33[a]	8.67[a]	14.00[a]	16.33[a]	463.33[a]
MI-S	1:1	17.67[a]	50.0[ab]	114.33[a]	5.00[a]	8.00[a]	7.67[a]	8.33[a]	14.33[a]	15.67[a]	516.67[a]
	1:1.5	13.33[a]	41.67[b]	97.30[b]	4.67[a]	7.67[a]	7.67[a]	7.33[a]	12.00[a]	15.33[a]	521.67[a]
	1: 0.5	16.33[a]	77.67[a]	136.00[a]	5.00[a]	9.33[a]	7.33[a]	8.67[a]	14.33[a]	16.67[a]	535.00[a]
MTG	1:1	16.67[a]	66.67[a]	124.67[a]	4.73[a]	9.00[a]	7.67[a]	7.67[a]	13.00[a]	16.67[a]	605.00[a]
	1:1.5	16.33[a]	69.00[a]	124.67[a]	4.67[a]	8.67[a]	8.16[a]	8.76[a]	14.00[a]	17.00[a]	561.67[a]

Means represented by the same letter along column are not significantly different.

METHODOLOGY

Four locally available MSW compost varieties (Dikovita, Mathugama, Mihisaru Segregated and Agalawatta) which had been prepared by aerobic oxidation using windrow composting technique were used for this study. The plant pots were filled using three soil compost mixes (1:0.5, 1:1 and 1:1.5). Four seeds of *Zea mays* were planted per pot but thinned down to have one seedling per pot two weeks after planting to give ten (10) plant pots per trial. Data on growth parameters (Plant height, stem girth, number of leaves and wet biomass) were recorded at 4, 6 and 8 weeks after planting (WAP).

Data collected were averaged over the two trials before being subjected to statistical analysis of variance and significant means were compared using Duncans Multiple Range Test (DnMRT) at $p<0.05$ confident level.

RESULTS AND DISCUSSION

From the results of the physical and chemical analysis of the soil used for the trial (Table 1), it is obvious that the fertility status of the soil is inherently low, according to the nutrient rating for soil fertility classes in Nigeria (Obigbesan, 2001) and this implies that cropping the soil without the use of soil amendments will not be economical. Variation in nutrient composition of different composts used in this study was similar to those reported by Adebayo et al. (2011) working with organic amendment and its effect on early growth of *Moringa oleifera*. They observed higher nutrient concentrations in compost prepared with the same type of animal droppings but different plant residues, the nutrient composition was in the order *Tithonia diversifolia* compost > *Chromonela odorata* compost > *Celosia cristata* compost.

Effects of different soil compost ratios on the vegetative growth of *Z. mays*

When Agalawaththa (AGL) compost is considered, significant increase in plant height had been recorded for 1: 1.5 ratio of soil and compost only at the 4WAP and no significant difference has been recorded for any other ratios at 6 and 8 WAP (Table 2). However for Dikovita (DWT) and Mihisaru Seg (Mi-S) composts, significant increase in plant height has been observed for 1:1.5 ratio both at 4 and 8 WAP. No significant increase in plant height was recorded for any soil compost ratio at any WAP for any MSW compost except AGL used in this study (Figure 1).

According to the results of the present study (Figures 1 to 4), compost as a soil amendment can have

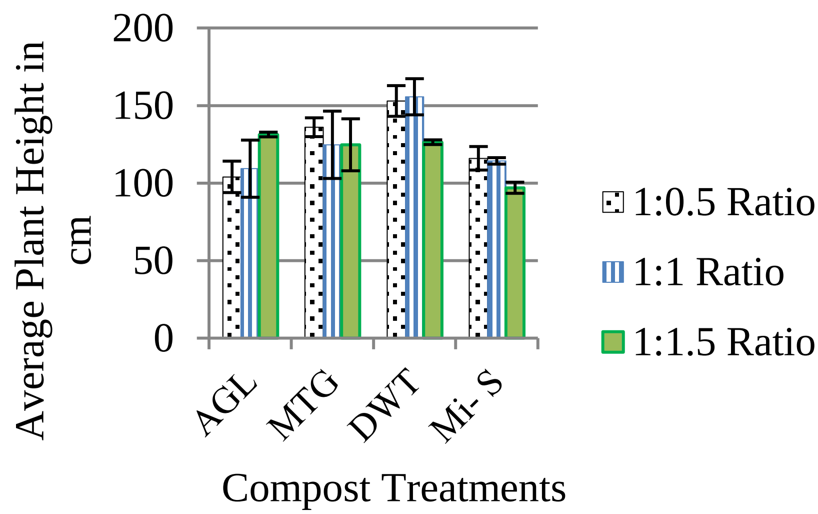

Figure 1. Effect of different MSW compost on plant height at different soil compost ratios at 8 WAP.

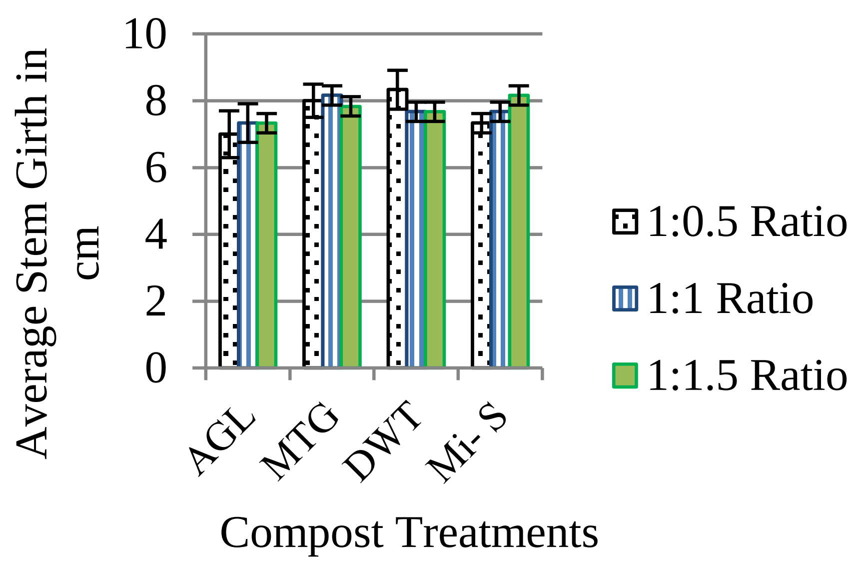

Figure 2. Effect of different MSW compost on stem girth at different soil compost ratios at 8 WAP.

considerable effects on plant growth and yield. However, results were not always positive and can vary depending on rates, compost maturity and available N (Cisar and Snyder, 1992). The results of this study confirm that the significantly beneficial treatment to improve the plant height is 1:1.5 soil AGL compost ratios for the growth of *Z. Mays* at 4 WAP and for Mihisaru Seg and Dikovita at 6 and 8 WAP (Table 3).

These results are consistent with the result of Lima et al. (2004) who concluded that the urban waste application contributes to increase the growth of Corn (*Z. mays*) plants. These results obviously endorse the fact that the compost quality varies with the raw material used, maturity and the method by which those composts were made as reported by Pant et al. (2012). However no significant increase of growth parameters was recorded at 6 or 8 WAP for any compost. This could be due to the non-availability of easily available nutrients by 6 and 8 weeks confirming the use of all available nutrients by the 4^{th} week. When physico-chemical parameters of the composts used in this study are considered, Mihisaru seg had the optimum C:N ratio to have the maximum performance. Since the pH and moisture recorded are not favourable for good microbial growth, no significant

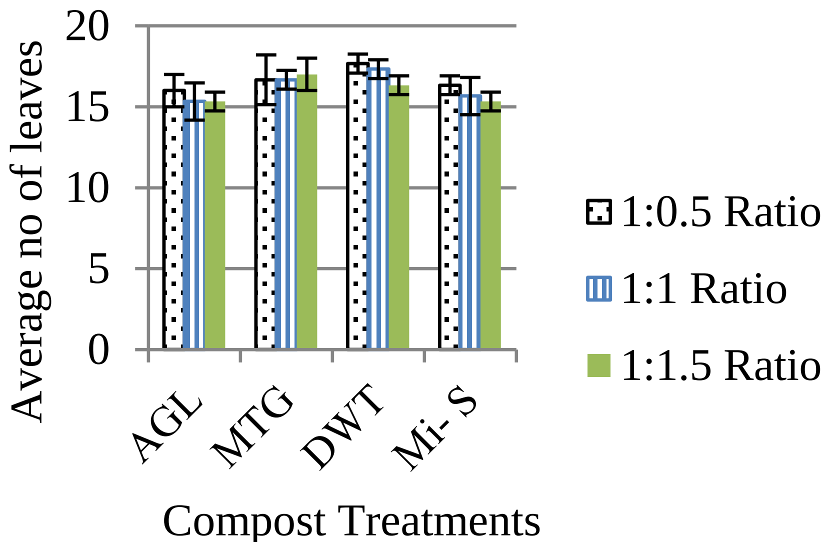

Figure 3. Effect of different MSW compost on no. of leaves at different soil compost ratios at 8 WAP.

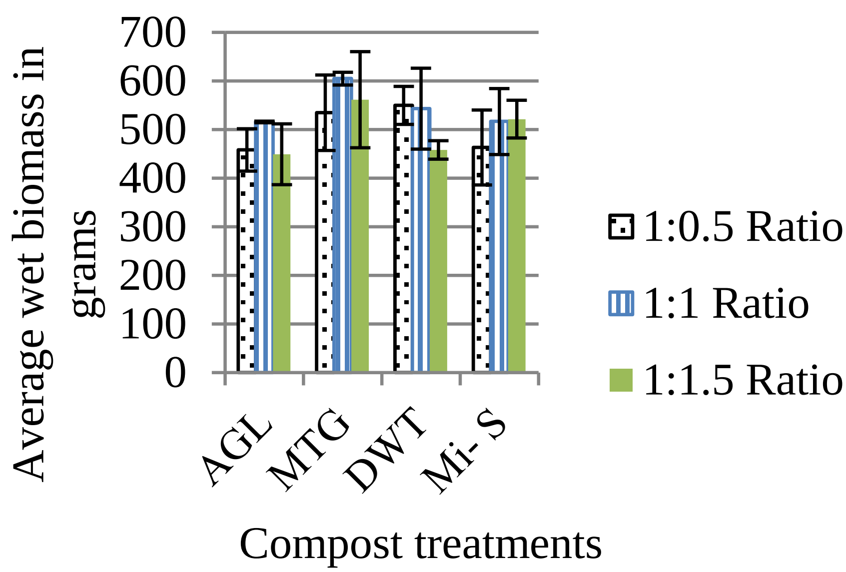

Figure 4. Effect of different MSW compost on wet biomass at different soil compost ratios at 8 WAP.

difference for any of the growth parameters at any soil compost ratio was recorded for Mihisaru seg compost.

When all the growth parameters are considered, results of this study confirmed that DWT performed well in all soil compost ratios suggesting the ability to provide suitable conditions for optimum growth at 8 WAP. Composts with a C/N ratio of less than 20 are ideal for plant production and ratios above 30 may be toxic, causing plant death because it generates phytotoxicity in some plants as reported by Zucconi et al. (1981). These findings further endorse the best performance of Dikovita MSW with all favourable physico chemical properties and C:N ratio of 23.1. Ribeiro et al. (2007) found that the addition of 10 to 20% MSW compost, increased growth and yield of *Geranium.* Furthermore, application rates of 30 and 60 Mg ha^{-1} of MSW compost increased the aggregate stability of soil through the formation of cationic bridges thereby, improving the soil structure (Perucci, 1990). Improved plant height after compost addition is related to increases of biomass N, C, and S (Pant et al., 2012). Application of 2.5, 10, 20, and 40 Mg ha^{-1} MSW compost increased soil microbial

Table 3. Effect of different compost types on vegetative development of *Zea mays* at 1:0.5, 1:1 and 1:1.5 soil compost ratios.

Treatment		Plant height (cm)			Stem girth (cm)			Number of leaves			Wet biomass (g)
WAP		4	6	8	4	6	8	4	6	8	8
	AGL	16.33^{a}	59.67^{a}	104.00^{a}	3.67^{a}	6.33^{a}	7.00^{a}	7.00^{a}	13.33^{a}	16.00^{a}	458.33^{a}
1: 0.5	MTG	16.33^{a}	77.67^{a}	136.00^{b}	5.00^{a}	9.33^{a}	7.33^{a}	8.67^{a}	14.33^{a}	16.67^{a}	535.00^{a}
	DKV	27.33^{b}	91.33^{b}	153.00^{b}	7.67^{b}	10.0^{b}	8.00^{b}	9.67^{b}	14.33^{a}	17.67^{a}	550.00^{a}
	MI-S	21.67^{a}	67.00^{a}	116.00^{a}	5.33^{a}	8.67^{a}	8.33^{a}	8.67^{a}	14.00^{a}	16.33^{a}	463.33^{a}
	AGL	17.00^{a}	65.33^{a}	109.33^{a}	3.76^{a}	7.33^{a}	7.33^{a}	6.33^{a}	12.33^{a}	15.33^{a}	516.00^{a}
1:1	MTG	16.67^{a}	66.67^{a}	124.67^{a}	4.73^{a}	9.00^{a}	7.67^{a}	7.67^{a}	13.00^{a}	16.67^{a}	605.00^{a}
	DKV	27.00^{a}	87.00^{a}	155.67^{b}	6.50^{a}	9.00^{a}	8.16^{a}	10.33^{a}	15.00^{a}	17.30^{a}	534.33^{a}
	MI-S	17.67^{a}	50.00^{a}	114.33^{a}	5.00^{a}	8.00^{a}	7.67^{a}	8.33^{a}	14.33^{a}	15.67^{a}	516.67^{a}
	AGL	22.00^{a}	83.69^{a}	131.33^{a}	5.00^{a}	8.33^{a}	7.33^{a}	8.67^{a}	15.33^{a}	15.33^{a}	449.33^{a}
1:1.5	MTG	16.33^{a}	69.00^{a}	124.67^{a}	4.67^{a}	8.67^{a}	8.16^{a}	8.76^{a}	14.00^{a}	17.00^{a}	561.67^{a}
	DKV	26.33^{a}	75.00^{a}	126.33^{a}	6.33^{a}	8.33^{a}	7.83^{b}	9.67^{a}	14.33^{a}	16.33^{a}	458.33^{a}
	MI-S	13.33^{a}	41.67^{b}	97.30^{b}	4.67^{a}	7.67^{a}	7.67^{b}	7.33^{a}	12.00^{a}	15.33^{a}	521.67^{a}

Means represented by same letter along column are not significantly different.

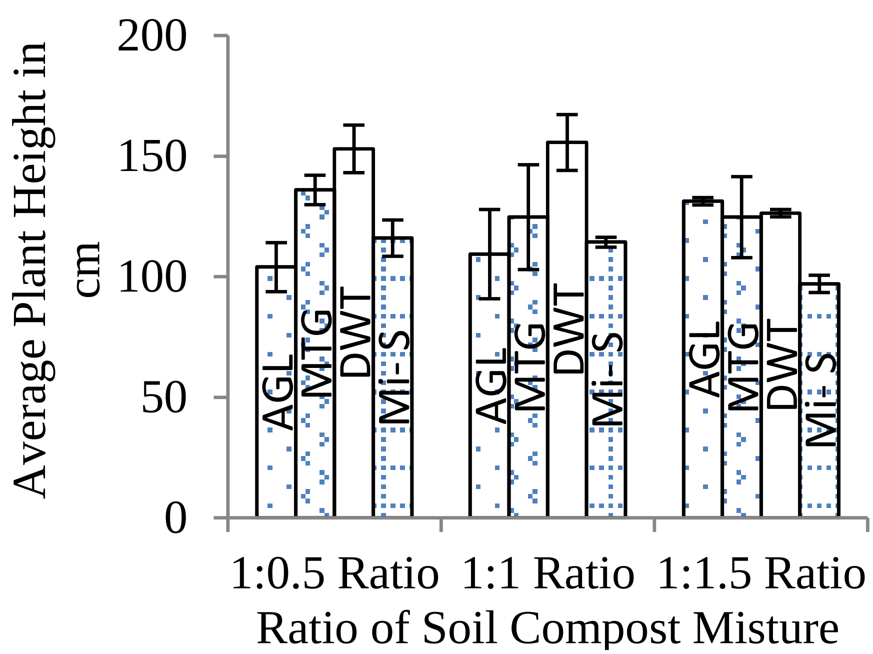

Figure 5. Effect of different MSW compost on plant height at different soil compost ratios at 8 WAP.

biomass C and soil respiration when compared to a control (Bhattacharyya et al., 2003).

When wet biomass at 8 WAP is considered, Mathugama (MTG) showed remarkably higher values than the other composts at all ratios. This could be attributed to the highest C:N ratio of MTG compared to all other MSW composts used. This clearly establishes the fact that C:N ratio could be the most important factor for enhanced vegetative growth as reported by Zheng (2009).

Effect of different compost types on the vegetative development of *Z. mays* at a constant ratio of soil compost mix

The results of the study carried out to identify the effect of different composts on the growth of *Z. mays* are given in Table 3. As per the results, it is clear that all vegetative growth (plant height, stem girth, number of leaves) results for Dikovita (DKV) compost at 1:0.5 ratio performed significantly better at all weeks after planting than the

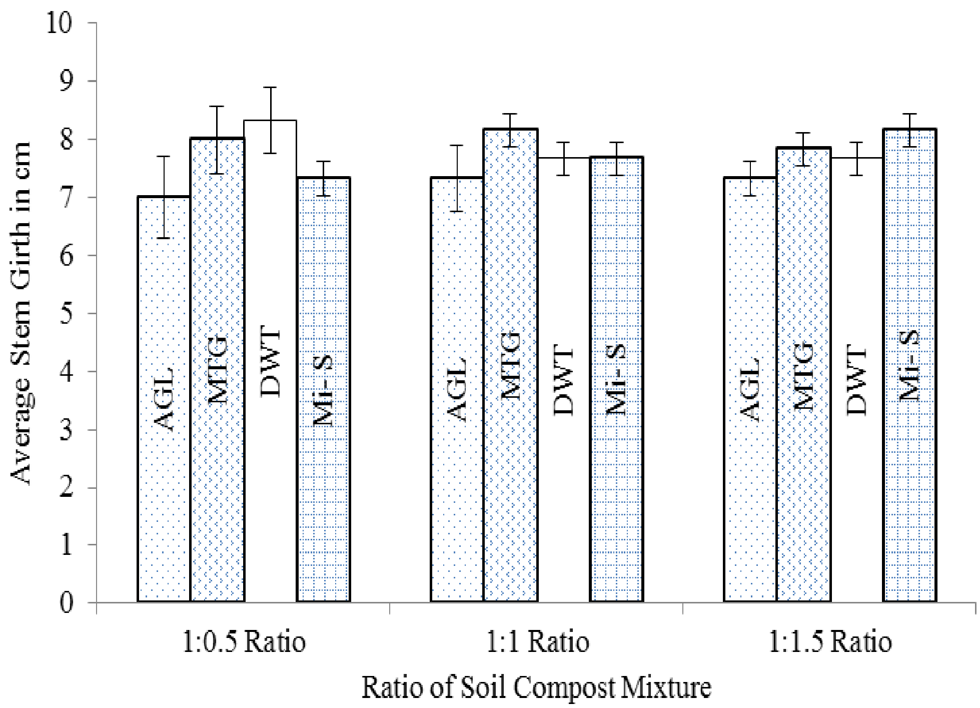

Figure 6. Effect of different MSW compost on stem girth at different soil compost ratios at 8 WAP.

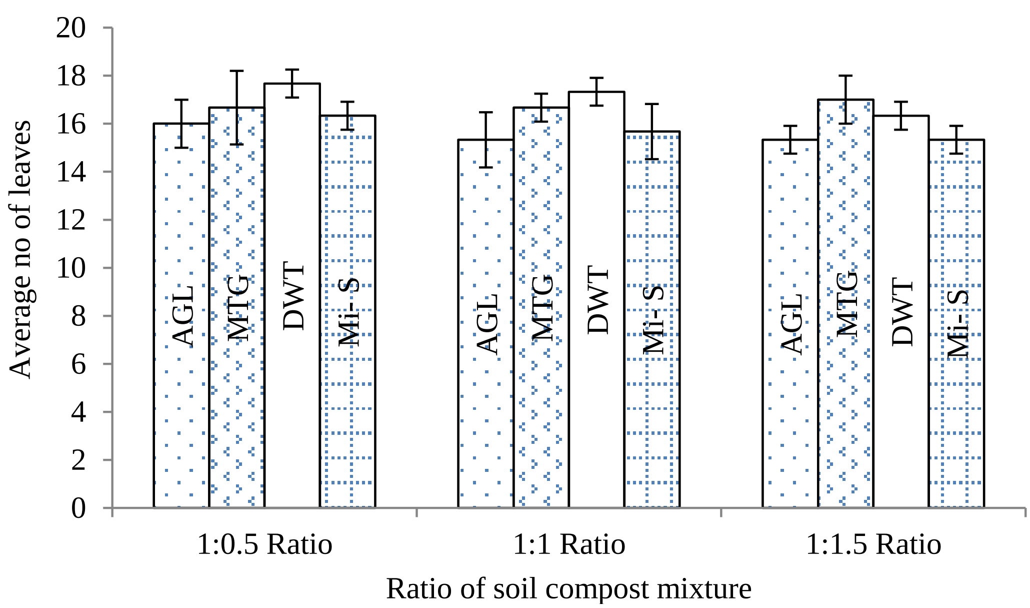

Figure 7. Effect of different MSW compost on the number of leaves at different soil compost ratios at 8 W AP.

other composts (Figures 5, 6, 7). No significant difference was observed for any other soil compost ratio for any type of compost for any growth parameter except for DKW at 1:1 and 1:1.5 ratio at 6 and 8 WAP. However, no significant differences among four compost types were observed for wet biomass at any soil compost ratio (Figure 8).

Even though Zheljazkov and Warman (2004), reported that the addition of municipal solid waste compost to agricultural soils has beneficial effects on crop

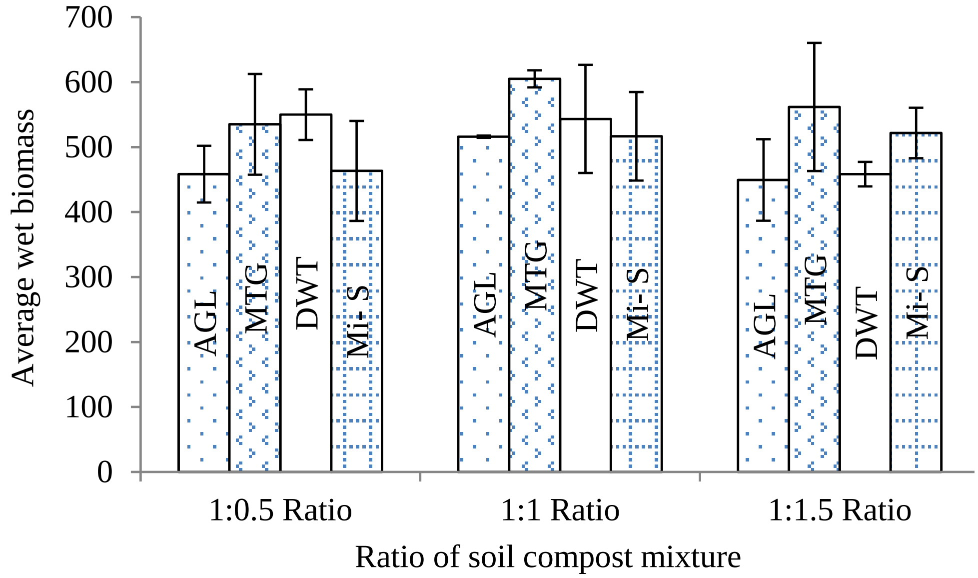

Figure 8. Effect of different MSW compost on wet biomass at different soil compost ratios at 8 WAP.

development and yields by improving soil physical and biological properties, failure to obtain significant difference for increased compost addition by way of higher ratios in this study could be attributed to the non-availability of nutrients and not having suitable properties in the compost used as reported by Alvarenga et al. (2007). It is further reported that compost generally have greater residual effect on subsequent crops than inorganic nutrient sources due to slow release of their nutrients over time. This could also be one reason why significant growth increase was not detected at 8 WAP during this study. Further, at 1:1.5 soil compost ratio, Mihisaru seg showed significantly low plant height at 6 and 8 WAP and also stem girth at 8 WAP. These strange results could be due to the excessive salt content in municipal solid waste as reported by Alvarenga et al. (2007). This observation could be further proved by the recorded high EC in the Mihisaru seg compost.

Results indicated that average plant height of *Z. mays* (Corn) were significantly ($P < 0.05$) influenced by the compost treatments (Table 3). Corn plants treated with Dikovita (DWT) compost had the significantly highest plant height and stem girth at 1:0.5 compost ratio at all WAP. However, significantly low plant height was reported when plants are treated with 1:1.5 soil:compost ratio. This could again be due to the salt toxicity or phytotoxicity as reported earlier. From among all composts tested, Dikovita performed significantly well compared to the rest of the composts in all mixes (Figure 1).

Brinton (2000) reported that composts having C:N ratio less than 20 would prevent nutrient immobilization or N starvation in the soil (Brinton, 2000). On the other hand, C:N ratio higher than 30:1 will cause microorganisms to be immobilized (that is, consume and make unavailable for plant uptake) in soil. Having a C:N ratio of 23.1 for DWT could be the main reason for significantly better action of both plant height and stem girth as evidenced by Brinton (2000). However, number of leaves and wet biomass did not show any significant difference among the different MSW composts used in this study at any given soil compost ratio. Even though this observation issomewhat extraordinary and unexplainable, some sort of growth disturbance with respect to the number of leaves is indicated. This may be attributed to either to phytotoxicity or salt intolerance as reported by many researchers previously.

Conclusions

Overall this study revealed how differently the organic fertilizers from different sources influence *Z. mays* plant growth. From among the different MSW compost used in this study, Dikovita compost was more beneficial than all other composts at 1:1 soil compost ratio at 4 WAP when vegetative variables analysis of number of leaves, stem girth and plant height are considered. Therefore, it can be concluded that the best soil compost ratio that could be used to improve the growth parameters of *Z. mays* significantly is 1:1 followed by 1:0.5. This study further highlighted that higher ratio (1:1.5 soil compost ratio) of certain MSW composts is not desirable and showed a negative effect on plant height. No significant increase or decrease in wet biomass over the different soil compost ratios was observed in this study signalling the need of further investigations on the quality and the production process of compost.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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