INFLUENCE OF MUNICIPAL SOLID WASTE COMPOST (MSWC) ON THE GROWTH AND YIELD OF GREEN GRAM (*VIGNA RADIATE* (L) WILCZEK), FENUGREEK (*TRIGONELLA FOENUM-GRAECUM* L.) AND ON SOIL QUALITY

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ABSTRACT

Pot culture experiments were carried out to study the effect of characterized municipal solid waste compost (MSWC) amendments (0, 50, 100, 250, 500, 750 and 1000 g) with garden soil (6 kg) on the growth and the yield of green gram (*Vigna radiata* (L) wilczek) and fenugreek (*Trigonella foenum-graecum* L.) as well as changes on soil quality. The growth and the yield of green gram and fenugreek were enhanced by MSWC application upto 500 g. Soil amended with > 500 g MSWC inhibited the plants biometric parameters neither with-significantly nor without-significantly suggest a possible toxic effects to both plants. No dosage effect was detected for total chlorophyll synthesized, except green gram grown in 1000 g of MSWC amendments. Compared with control, percentage of protein was increased significantly upto 250 g for green gram and 500 g for fenugreek. A significant reduction in percentage of carbohydrates was observed above 750 g of MSWC exposure for green gram and above 500 g for fenugreek. There was no specific trend and significant changes were observed in percentage of reducing sugars in both plants except green gram exposed to 50 g MSWC exposure. There was no significant difference in all plant yield parameters of both plants except fenugreek seed weight in 250 g MSWC amendment. Generally, chemical parameters of soil are improved by the addition of MSWC, after 90 d of experimental period.

Key words: Municipal solid waste compost; Pot culture; Soil quality; Microbial population; Plant yield

INTRODUCTION

Municipal solid waste (MSW) is a mixed waste from residential, commercial, institutional and industrial sources. Continuous application of MSW load has many effects on the air, water and soil as well as public health (Chatterjee, 2010). Incineration of MSW generally produces significant amounts of polluting flue gases, and also gives rise to toxic solid residues. Composting of MSW is an alternative to incineration and disposal in landfills (Alidadi *et al.,* 2005; Yaghmaeian *et al.,* 2005; Alidadi *et al.,* 2008).

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Agricultural lands amended with municipal solid waste compost (MSWC) can be a way to return the organic matter to soil and minimize the risk of environmental pollution. Various studies have demonstrated improvements in soil fertility using a variety of compost material (Parvaresh *et al.,* 2004; Parthasarathi *et al.,* 2008; Ogwueleka, 2009). The conclusions from the previous studies showed the benefits of using MSWC as an organic soil amendment may be seen in agricultural land, but compost should only be applied to soil after it has been characterized and shown to be safe (Fitzpatrick, 2001; Parvaresh, *et al.,* 2004; Yaghmaeian *et al.,* 2005; Moldes *et al.,* 2007; Ogwueleka, 2009). Various authors pointed out that the salinity (Siminis and Manios, 1990), the concentration of phytotoxic ions (Gouge and Sanderson, 1975), the low total porosity and the variability in MSWC properties (Vavrina, 1995), are limiting factors to this use.

Tirupur town is located 35 miles from Coimbatore, the Manchester of South India. According to the census of 2001 the population of Tirupur was 550,826. This larger population generates greater waste, which leads to pollution. The management of solid waste in Tirupur is done by bio-composting method, which was undertaken by a private sector. This was introduced in the year 2000 and it has 11 divisions for collecting solid waste from various parts of this city. Nearly 1-2 t d^{-1} of segregated organic waste is collected and composed aerobically in the composting unit.

The overall objective of the present study was to characterize and to evaluate MSWC from Tirupur, as a component of substrates for potted plant production, to assess the effects caused by application of MSWC's to soil and to evaluate the changes in soil properties. Further, mixture designs were used to evaluate the best combination of MSWC with soil for growth of greengram (*Vigna radiate* (L) wilczek) and fenugreek (*Trigonella foenum-graecum* L.) in pots.

MATERIALS AND METHODS

Collection and analysis of MSWC and soil

The soil used in this study was collected from agricultural land. Soil and MSWC (obtained from municipal solid waste recycling plant, Tirupur) used for the present study were analyzed for pH (1:2.5 soil water suspension), electrical conductivity (EC) (1:2.5 soil water suspension filtrate), total nitrogen (N), available phosphorous (P) (Jackson, 1973), potassium (K) (Toth and Prince, 1949), available iron (Fe), magnesium (Mg) (Lindsay and Norvell, 1978) and organic carbon (OC) (Walkley and Black, 1934) (Table 1). The concentration of Ca was determined by digestion with nitric acid, sulphuric acid, and perchloric acid and then analyzed by UV-VIS Spectrophotometer (Hitachi model UV-VIS U-3210). For all analyses, dried fresh MSWC and soil were sieved to <20 mm and homogenized. Soil used in this study was collected from garden land; shade dried for 3 d and was passed through a 2mm sieve. The soil characteristics were pH 7.3, 7.8% clay, 25% slit, 62.1% sand and 0.25% organic matter.

Experimental Design

The substrate for plant growing media (dry) were prepared by mixing different quantities [0 (T1), 50 (T2), 100 (T3), 250 (T4), 500 (T5), 750 (T6) and 1000 g (T7)] of MSWC with a fixed quantity of soil (6 kg). Six kilogram of soil alone served as the control. These amounts correspond to 16.5 to 330 t ha^{-1}. MSWC and soil mixture were placed in pots in completely randomized design. The seeds of green gram (*Vigna radiate* (L) wilczek) and fenugreek (*Trigonella foenum-graecuk* L) were procured from Tamil Nadu Agricultural University, Coimbatore were air-dried and stored at room temperature. Uniform size seeds of green gram and fenugreek were surface sterilized in 0.1% mercuric chloride solution for 5 minutes and washed thoroughly with distilled water to remove all the trace of mercuric chloride. Twelve seeds of green gram and 25 seeds of fenugreek were sown in each treatments (CMSW soil preparation) pot and control pots (soil alone) in triplicate upto 90 d of the test period. Regular watering was done during the course of study. Both the seeds were sown in same pots to study the influence of MSWC on mixed cultivation.

After 90 d, plants were carefully uprooted and removed from the pots, shaken free of soil in a manner to minimize the loss of nodules and washed with distilled water. The various below and above ground morphometric parameters such as root and shoot length, number of leaves, number of nodules, number of pods, number of seeds, weight of the seeds and plant dry biomass were recorded. Biochemical analyses like proteins (Lowry *et al*., 1951), total chlorophyll, carbohydrates and amino acid were estimated in leaves using the standard methods from the manual of biochemical methods (Sadasivam and Manickam, 1996) and reducing sugars using Somogyi, (1952) method. Soil samples were also collected individually from the pots and analyzed for pH, EC, organic carbon, C/N ratio, micro and macronutrients, proteins (Lowry *et al.,* 1951) and the activities of amylase, invertase, cellulase (Galystan, 1965) and reducing sugars (Somogyi, 1952) were determined. The enzyme activity was expressed in mg of glucose released per gram of soil on dry weight basis for 24 h of incubation. Further, soil samples were collected in sterile plastic bag from the bottom of the pots for enumeration of bacteria and fungi. Pour plate technique was employed to enumerate the microorganisms (bacteria and fungi). All the analyses were carried out in triplicate and means are given.

Statistical analysis

Analysis of variance was performed in the present study. The least significant differences (LSD) among mean values were calculated at $P < 0.05$ confidence level. Correlation analysis was performed to assess the nature of relationship between the MSWC amendments and selected soil parameters.

RESULT

Characteristics of MSWC and soil

The main chemical characteristics of garden soil and MSWC are listed in Table 1. High concentrations of pH, OC, total N, available P, calcium (Ca), Mg, Pb and Fe were detected in MSWC verses the garden soil. EC was marginally lower than soil. The low values for the carbon/nitrogen (C/N) ratio in MSWC were recorded.

Plants biometric parameters

In general, all the biometric parameters were increased upto 500 g (T5) of MSWC application further, decreased with increasing amendments in both plants. Further, significant reduction was observed in green gram grown above the MSWC application of 750 g (T6) for shoot length and number of leaves and 1000 g (T7) for root nodules. Root length and plant biomass also showed a decreasing trend in higher treatment concentrations of 750 g (T6) and 1000 g (T7) when compared to control, while that reduction was not significant (Fig. 1). In the case of fenugreek, significant reduction was observed above the treatments of 1000 g (T7) for shoot length and number of root nodules and 750 g (T6) for number of leaves, whereas there was no significant change in root length (Fig. 2).

Influence of increasing amount of MSWC on total chlorophyll, protein, amino acids, carbohydrates and reducing sugars of the plants green gram and fenugreek were given in Fig.3 and 4. No significant differences in the amount of total chlorophyll synthesized in relation to the applied MSWC amendments were noted, except green gram grown in 1000 g (T7) of MSWC exposure. However, the

Table 1: Characteristics of MSWC and soil used for the study

Characteristics	MSWC	Soil
pH	8.6	7.5
EC (mS/cm)	10.4	12.6
OC (%)	8.4	4.1
Total N (%)	0.51	0.07
Available P (%)	0.04	0.002
Available K (%)	1.2	0.12
Ca (%)	53	14
Mg (%)	2.1	1.6
Pb (μg/g)	200	0.03
Fe (%)	0.58	0.06
C/N	17	58

EC: electrical conductivity OC: organic carbon N: nitrogen P: phosphorus K: potassium Ca: calcium Mg: magnesium Pb: lead Fe: iron

Table 2: Influence of MSWC on soil parameters

Treatments	pH	EC (mS/cm)	OC (%)	N (%)	C/N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	7.7	0.2	3.4	0.08	44	0.005	0.03	15	2.3
T2	7.3	0.2	3.5	0.07	47	0.003	0.02	15	2.8
T3	7.2	0.3	5.5	0.08	65	0.007	0.04	10	2.0
T4	7.1	0.6	4.8	0.08	61	0.011	0.06	13	2.3
T5	7.5	0.7	5.0	0.08	60	0.013	0.39	15	3.0
T6	7.4	1.5	4.7	0.09	52	0.017	0.16	20	3.6
T7	7.4	1.9	5.5	0.10	54	0.022	0.16	23	3.5

EC: electrical conductivity OC: organic carbon N: nitrogen P: phosphorus K: potassium Ca: calcium Mg: magnesium

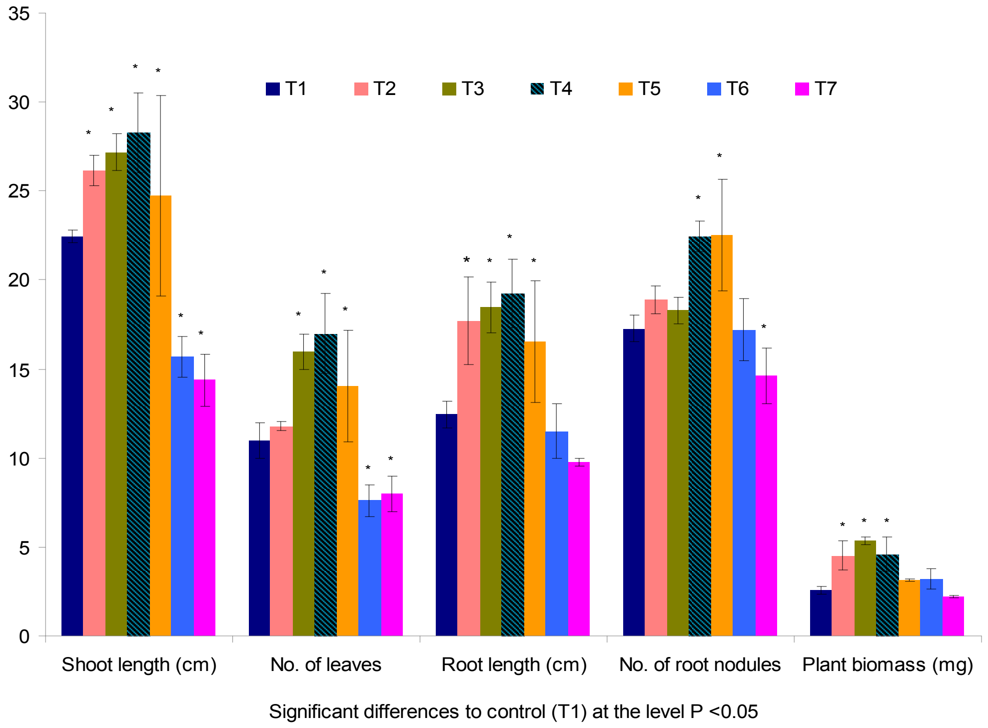

Fig. 1: Influence of increasing amount of MSWC on biomatrix parameters (shoot length, number of leaves, root length, number of root nodules and plant biomass) of the plant green gram

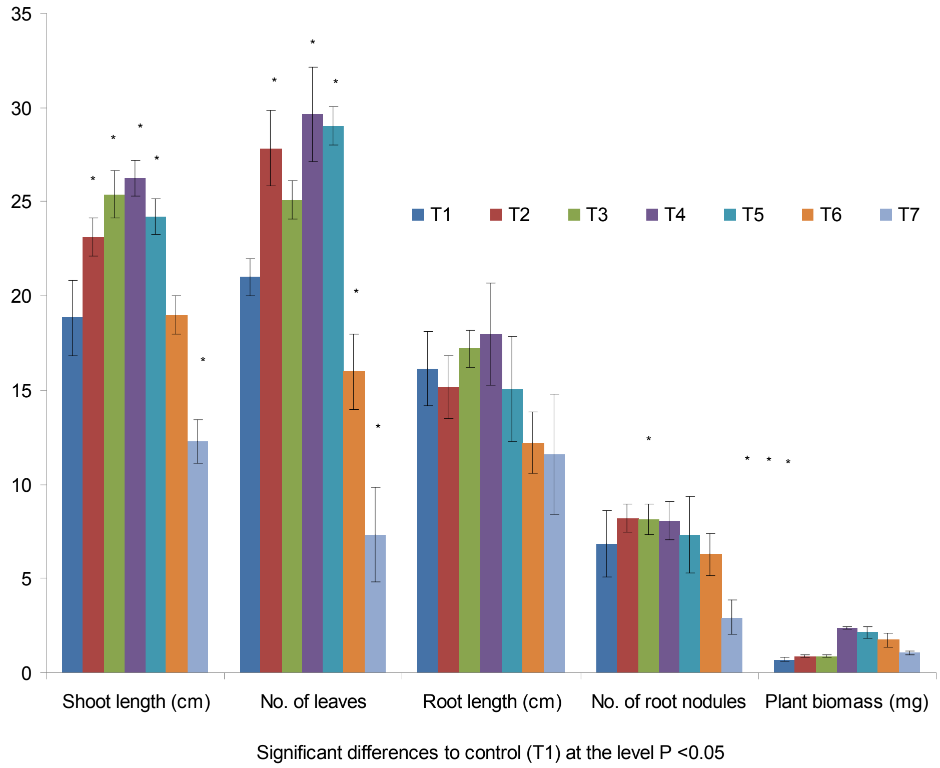

Fig. 2: Influence of increasing amount of MSWC on biomatrix parameters (shoot length, number of leaves, root length, number of root nodules and plant biomass) of the plant fenugreek

total chlorophyll was estimated <2 mg g^{-1} in all the treatments in both plant leaves. Percentage of protein content is showed that significantly increased with increasing amendments of MSWC upto 250 (T4) g for green gram. Further, the level retained as like as control. In the case of fenugreek percentage of protein content was increased with increasing amendments of MSWC upto 500 g (T5); however, this increase not significant when compared to the control except 500 g (T5) exposure. Percentage of amino acids in both the plant leaves were <3%. Green gram was grown in 100 (T3) and 250 g (T4) MSWC amendments showed that the percentage of amino acid content was significantly higher than the control. Further, it reduced with increasing addition of MSWC which was not significant. In contrast, a significant decrease was observed when fenugreek at higher treatments of 1000 g (T7) of MSWC. Compared with control, a significant reduction in percentage of carbohydrates was observed above 750 g (T6) of MSWC exposure for green gram and above 500 g (T5) for fenugreek. There was no specific trend and significant change was observed in percentage of reducing sugars when compared to the control in both plants except green gram exposed to 50 g (T2) MSWC exposure, which was significantly increased. The yield of both plants was estimated by counting the number of pods, number of seeds and weight of the seeds (Fig. 5). These results showed that there was no significant difference in yield parameters of both plants when compared to the respective control except fenugreek seed weight in 250 g (T4) MSWC amendment, which showed significantly higher value.

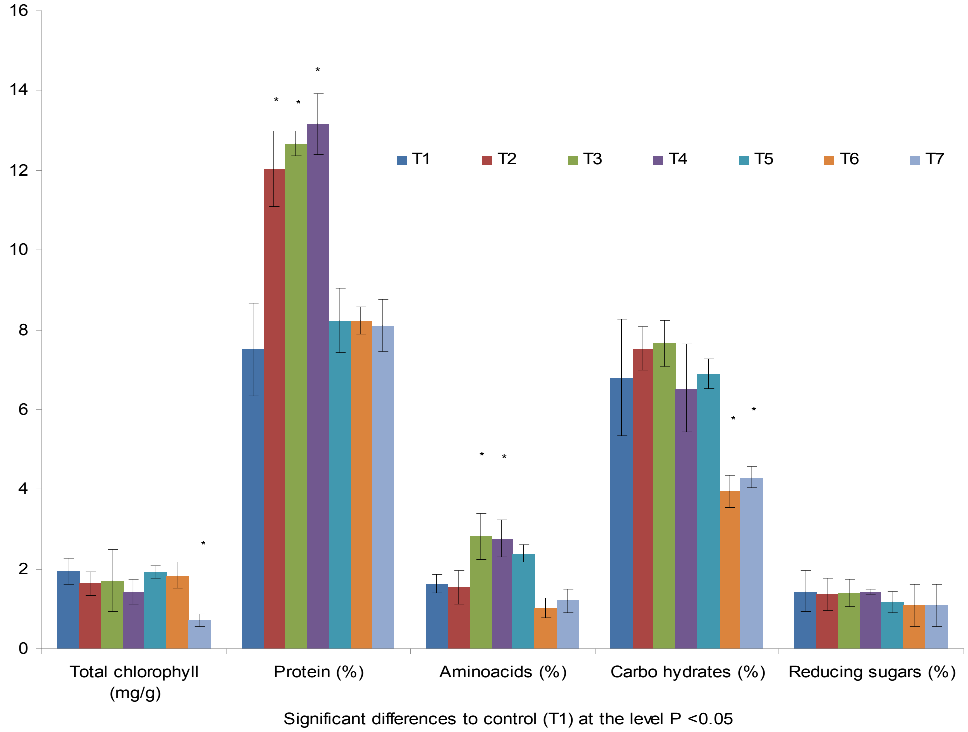

Fig. 3: Influence of increasing amount of MSWC on biomatrix parameters (total chlorophyll, protein, aminoacids, carbohydrates and reducing sugars) of the plant green gram

Soil properties

The characteristics of the soils amended with different quantities of MSWC were analysed after 90 d of the experiment and given in Table 2. By the end of the experiment, in all experimental plots (T1 to T7), soil pH values varied in the range of pH 7.1 to 7.5 and their differences were not significant, regardless of the amount of compost. Electrical conductivities were very high in MSWC and soil (10.36 and 12.6 mS cm^{-1}), however, at the end of the experimental period which gave a

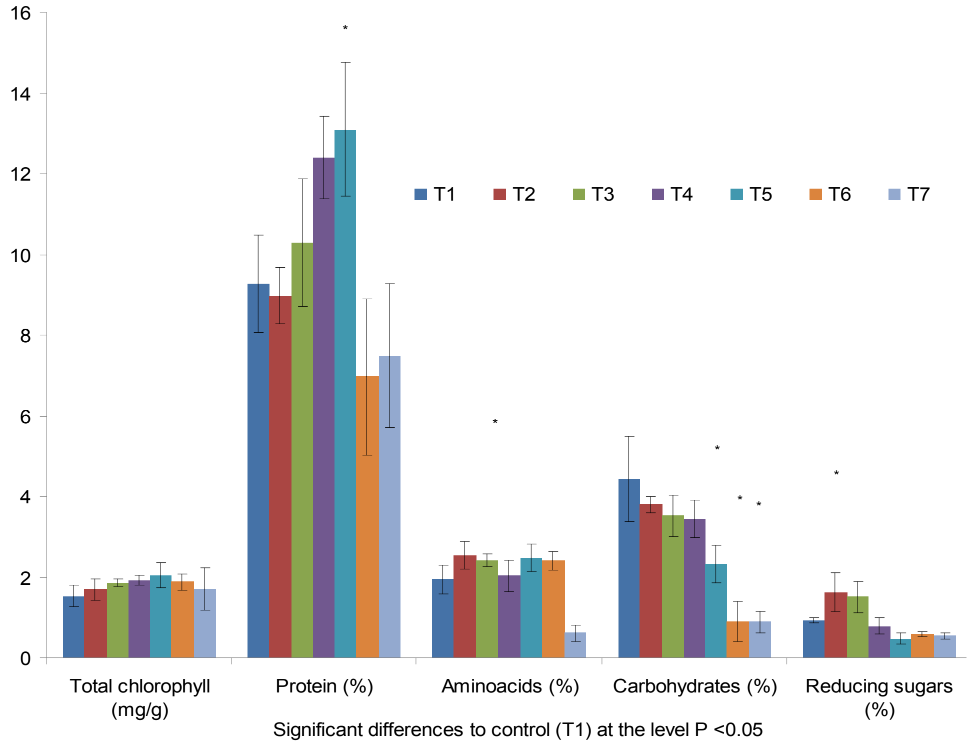

Fig. 4. Influence of increasing amount of MSWC on biomatrix parameters (total chlorophyll, protein, aminoacids, carbohydrates and reducing sugars) of the plant fenugreek

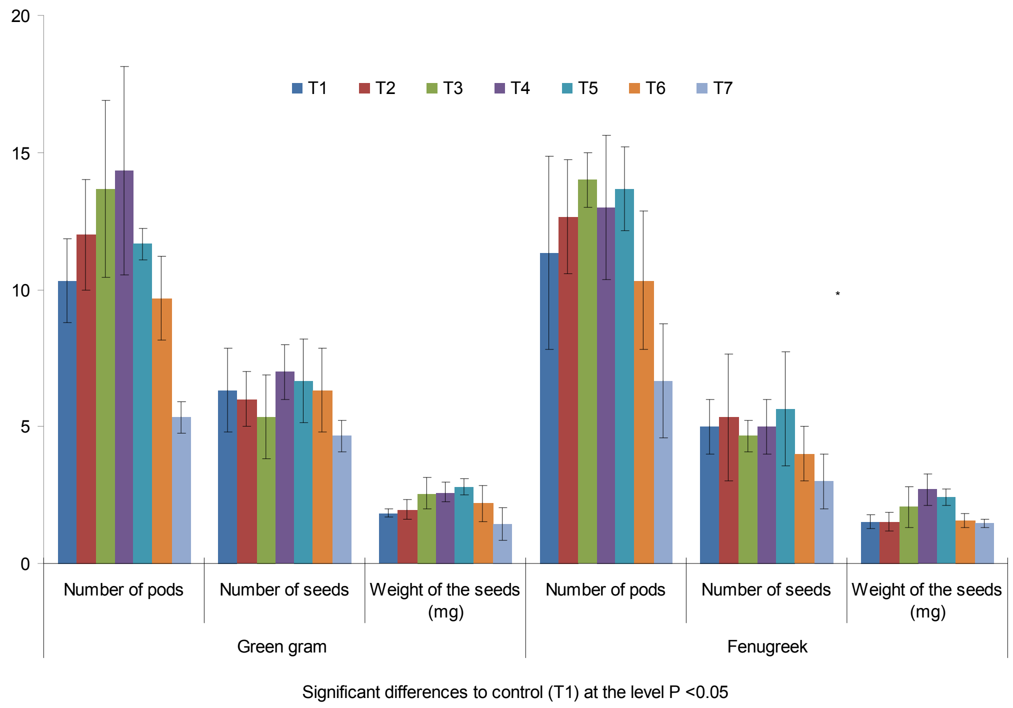

Fig. 5. Influence of increasing amount of MSWC on yield of green gram and fenugreek

relatively low value (<2 mS cm^{-1}). Further, EC was increased with increasing MSWC amendments. MSWC application positively affected soil OC content that increased from the initial value of 4.09% (Table 1) to 5.46, 4.79, 5.00, 4.65 and 5.46% in T3, T4, T5, T6 and T7 treatments (Table 2), respectively. However, significantly higher values of OC as compared with control (T1) were observed only in the treatments with medium and high rates of composts. Characteristics of soil and MSWC showed significant differences in total N were found (Table 1). Moreover, in the soil and MSWC mixed pots at the end of the experimental period of 90 d, N concentrations were at the same level as in the soil. High values of C/N ratio were observed at all experimental pots as well as control. In the present study, K content of soils ranged from 0.032 to 0.38%, Ca from 15% to 22.5% and Mg from 2.3% to 3.5%. The P contents of soils were less than 0.1%.

The effects of MSWC on activity of soil enzymes (amylase, invertase and cellulase) and enumeration of microbial biomass (bacterial and fungal populations) were tested after 90 d of the experiment and the results were shown in Fig. 6 and 7. As shown in Fig. 6, the invertase activity was increased significantly above 500 g MSWC application nevertheless; cellulose enzyme was decreased and significant at 1000 g (T7) of MSWC application. Amylase activity was significantly increased at 100 g (T3) of MSWC application further, remain its level same as control. Populations of fungi and bacteria in MSWC treatments were significantly higher than those in control treatments at 90 d after transplanting (Fig. 7). There was no significant

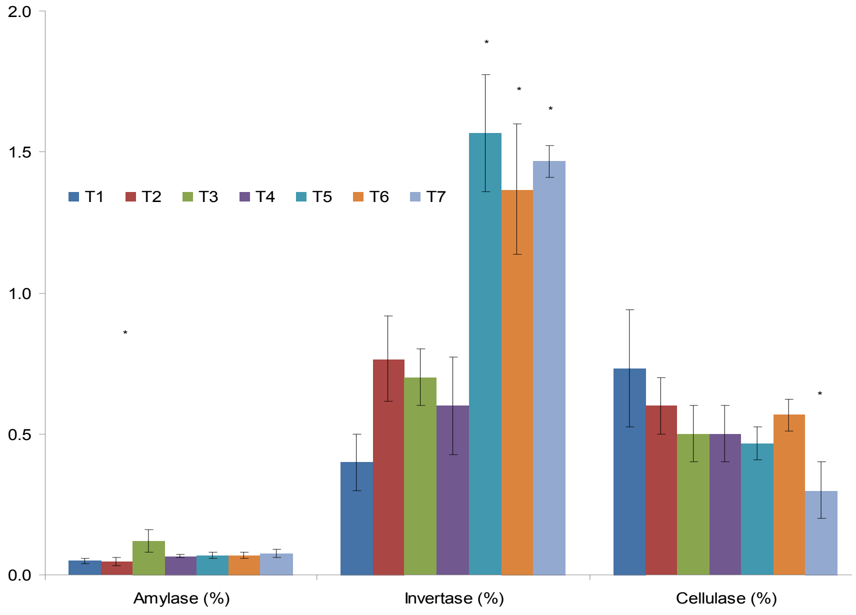

Fig. 6. Influence of increasing amount of MSWC on soil enzyme activity

Table 3: Correlation matrix between MSWC amendments, soil enzyme activities, selected soil parameters.

	Treatments	Amylase	Invertase	Protease	BP	FP	OC	pH
Amylase	.12							
Invertase	.86*	.10						
Protease	-.73	-.49	-.65					
BP	.80*	.38	.82*	-.68				
FP	.73	.58	.65	-.84*	.91**			
OC	.59	.81*	.53	-.84*	.74	.92**		
pH	.06	-.48	.14	.39	-.34	-.50	-.43	
EC	.98**	.07	.77*	-.67	.75	.68	.52	.05

* Significant at $P < 0.05$ **Significant at $P < 0.01$
BP – Bacterial population FP – Fungus population OC – organic carbon

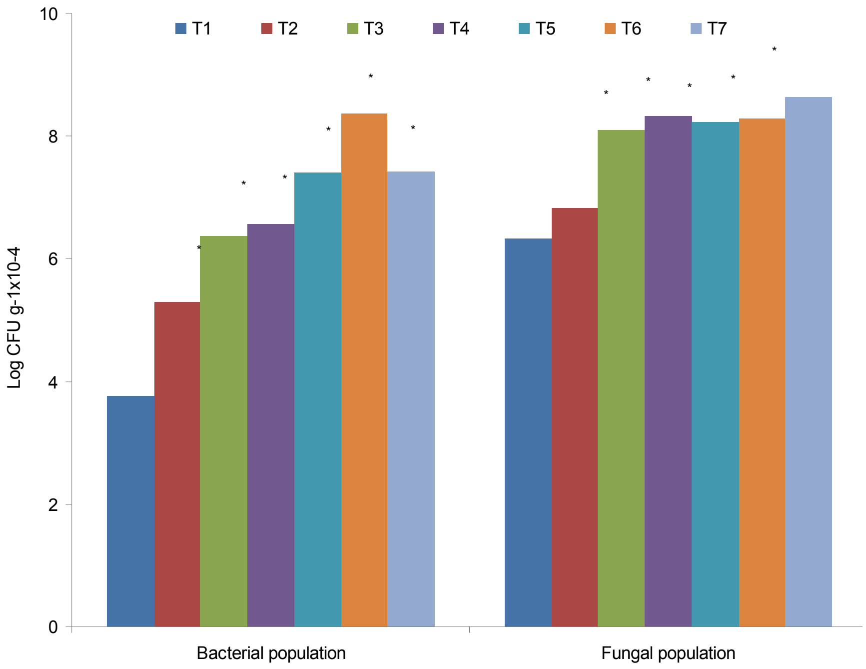

Fig. 7. Influence of increasing amount of MSWC on microbial population

difference between control (T1) and 100 g (T3) MSWC treatment for fungal populations; however T2 showed higher value than in control. Generally, microbial biomass was increase with increasing OC content of the soil.

Results from the correlation matrix indicated that significant positive relationship between soil MSWC amendments, invertase enzyme and EC (Table 3). Amylase had close correlation with OC and protease had close negative correlation with fungal population and organic carbon. However, pH did not have any statistically significant relationship with enzyme activities and MSWC amendments.

DISCUSSION

Until now the evaluation of compost quality has mainly been based on physico-chemical properties (Moldes *et al.,* 2007). For that purpose, the C/N ratio is widely used as an indicator of the maturity and stability of compost. Compost with a C/N ratio of less than 20 are ideal for plant production (Davidson *et al.,* 1994) and ratios above 30 may be toxic, causing plant death (Zucconi *et al.,* 1981). The low values recorded in the present study for the C/N ratio (<20) in MSWC suggest that compost was stable and mature. High values of pH and EC in the MSWC may be due to the presence of high concentrations of soluble salt. The characteristics of MSWC showed that a wide range of essential nutrients were found in the compost.

Compost as a soil amendment can have substantial 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). In the present study, both plants grew better in the lower MSWC amendments (≤500 g) than in the control. However, all biometric parameters decreased in the higher amendments (≥750) neither with-significantly nor without-significantly suggest a possible toxic effect to both plants. This is may be due to the excessive salt content of the MSWC (Alvarenga, *et al.,* 2007), the major factor limiting the use of certain composted wastes, because it generates phytotoxicity in some plants. Similar results are obtained by Simone and Taylor (2003) who observed inhibitory effect of tomatoes plant growth after application of MSWC. Noguera *et* *al.*, (2003) recommended low soluble salt levels (EC < 3.5 dS cm^{-1}) are preferable for potting compost. Low values indicate a lack of available salts, while high values indicate a large amount of soluble salts that may inhibit biological activity (Moldes *et al.,* 2007). The EC of MSWC and soil used in the present study was exceeding the limit recommended by Noguera *et al.,* (2003) for substrates. The present study soluble salts were initially very high (10.36 mS cm^{-1} for MSWC and 12.60 mS cm^{-1} for garden soil) and had decreased by almost 90% at the end of experiment. Initial EC values of soil (before experiment) was higher than final values (after the experiment), perhaps due to leaching of salts by watering and values were increased with increasing addition of MSWC. As demonstrated by Noguera *et al.,* (1997), the excess of soluble salts is easily and effectively leached from the material under customary irrigation regimes when used for ornamental plants like tomatoes, flowers, etc., in garden greenhouse. High value of C/N ratio at the end of 90 d experimental period indicate that nitrogen shortage in the soil, apparently caused by plant uptake, resulted in an appreciable increase of C/N ratio at the end of experiment, both in control plots, and in the plots amended with MSWC.

Nutrient contents (P, K, Ca and Mg) were higher in soil amended with MSWC than in original soil revealing that only MSWC can supply all nutrients necessary for plant growth. The experimental soil in this study was collected from agricultural land; typically contain more Mg (1.6%). The Mg content was increased from low (1.6%) to very high level (> 3.0) in soil amended with >500 g MSWC may be due to low nutrient uptake by small root system of the plant grown in T5, T6 and T7.

The results indicated that the level of microbial biomass was significantly (P <0.05) higher in the MSWC treatments when compared to control. Similar observations were recorded by Bhattacharyya *et al*., (2005), where they studied suitability of MSWC application to submerged rice paddies. Higher levels of microbial biomass in MSWC treated soil could be due to greater amounts of biogenic materials like mineralizable N, water soluble C and carbohydrate in MSWC (Bhattacharyya *et al.,* 2005). Tabatabai, (1994) was presumed that the source of enzyme in soil to be related to microbial biomass, plants and animals. The determination of specific factor, which is contributed to the total enzyme activity of soil, is difficult (Bhattacharyya *et al.,* 2005). The correlation matrix of the present study, however, indicated that enzyme activities of soil were related to microbial biomass. In the present study, microbial biomass (bacterial and fungus population) is positively correlated with invertase activity (r = 0.81, P <0.05) and MSWC amendments (r = 0.80, P <0.05). A positive correlation between enzyme activities and microbial biomass was noted earlier by Bhattacharyya *et al.,* (2005). In this study, the addition of MSWC increased the enzyme activities of soil especially invertase activity. This could have originated from the higher amounts of endoenzymes in the viable microbial populations and increased levels of accumulated enzymes in the soil matrix (Bhattacharyya *et al.,* 2005). The enzymes in the organics amended soils may also directly contribute to enzyme activities (Dick and Tabatabai, 1984).

The utilization of MSWC over a 90 d period improved the soil fertility. This experimental study shows that the efficiency of the municipal solid waste compost has a significantly higher yield at an optimum rate of 250g MSWC. Composted municipal solid waste has been used successfully to improve the physical and chemical properties of soils and also increase the growth of green gram (*Vigna radiate* (L) wilczek) and fenugreek (*Trigonella foenum-graecum* L.) upto 500 g MSWC amendments.

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