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Research Paper

Comparative efficiency of different fungal species in composting Municipal Solid Waste collected from Alwarkurichi Town Panchayat, Tamil Nadu

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ABSTRACT

The fungal strains were isolated from the soil samples collected from Kodaikanal forest and it was inoculated with the Municipal Solid Waste collected from Alwarkurichi Town panchayat. The isolated fungal strains are *Aspergillus* species I, *Aspergillus* species II, *Mucor* species, *Penicillium* species I, *Penicillium* species II and *Trichoderma* species. During the decomposition process, there were gradual increase in pH, electrical conductivity, total nitrogen, total phosphorus and total potassium. There was continuous increase in bacterial and fungal population up to middle of the composting period and attainment of fairly stable bacterial and fungal count in the final product of decomposition. The actinomycetes population increased continuously and reached stable count at the end of decomposition. The micronutrient content showed a steady increase from the beginning to the end. The heavy metal concentration has decreased during the period of composting. The significant changes ($P<0.05$) were observed in all the parameters. While comparing the efficiency of different fungal strains employed for bio-degradation of MSW, it has been found that the fungus *Mucor* species played a vital role to bring bio-degradation of MSW, when compared to other fungal strains. All the physico-chemical and biological parameters exhibited significant ($P<0.05$) changes in accordance with number of days of decomposition in all the treatments.

Key words: MSW, *Mucor* sp., *Penicillium* sp., Actinomycetes population, bio-composition.

INTRODUCTION

The per-capita generation of MSW vary from one country to another country. The per capita generation of municipal refuse in the United States is approximately 2 kg per person per day. The average rate can be lower than 0.5 kg per person per day in some developing countries (Jerry, 2003). There are 104 big cities and 295 small cities in India which are generating about 1, 88,500 tonnes of MSW per day. In Tamil Nadu, there are 12 Municipal corporations including Corporation of Chennai and 127 municipalities. The per day generation of MSW in Tamil Nadu is about 10,870 tonnes excluding the garbage generated from the Corporation of Chennai (Reckoner, 2008). The term composting, or aerobic biological treatment, is used to define bio-degradation under controlled aerobic conditions. The process of composting is used for the stabilization of wastewater solids in order to use the product as a solid amendment or mulch in landscaping, horticulture and agriculture (EPA, 2000). The collection and recycling of solid waste has several environmental benefits such as strong reduction of waste, preserving landfill space (Consonni et al., 2005), destruction of organic contaminants, such as halogenated hydrocarbons (Buekens and Cen, 2011), immobilization of inorganic contaminants (Samaras et al., 2010), utilization of recyclables from the thermal residues (CEWEP, 2011). Thermo-chemical treatment process is an important element of a sustainable united system for municipal solid waste Management, (MSW) (Psomopoulos et al., 2009).

This research work is an initiative to find out a suitable solution for overcoming the persistent problem of mishandling of MSW. The handling and management of Municipal Solid Waste is a great concern all over the world and attracted the attention of environmentalists, scientists, beaurocrates, rulers and NGOs. The ill effects of MSW in the way of emission of noxious gases, floating in the atmosphere, degradation of land and underground water, pollution of water bodies, etc, are increasing day by day. Hence, it is an urgent necessity to find out a suitable mechanism for the effective handling, Eco-friendly management and scientific disposal of MSW. The main focus of this research work was to isolate and identify the fungal strains and to conduct the study of decomposition of MSW with the identified fungal strains and to observe the physico-chemical and biological parameters from the initiation to the end of decomposition process. This study was undertaken with a basic objective to find out an effective method for the scientific handling and eco-friendly management of MSW by converting MSW into valuable quality bio-manure with a view to reduce the environmental degradation and to bring sustainability. The major objective of this research is to find a suitable and efficient fungal strain to be used for the biodegradation of MSW with a view to to set up a scientific and Eco-friendly model for the handling and management of MSW. The identification of a suitable fungal strain for making a model for efficient and Eco-friendly handling of MSW will enable the society to handle, and dispose the mounting garbage scientifically and preserve our universe from environmental degradation.

MATERIALS AND METHODS

Study site

The study was conducted at Sri Paramakalyani Centre of Excellence in Environmental Science, Manonmaniam Sundaranar University, Alwarkurichi in Tirunelveli District, Tamil Nadu, India. The forest soil from Kodaikanal (10° 13'58.08" North, 77° 31'02.40" East, elevation 1929 m) was collected and isolated the fungal strains from this soil. Fungal strains were introduced directly into the raw garbage collected from Alwarkurichi Town panchayat (10° 47'07.30" North, 77° 22'49.29" East, elevation 102 m). The map showing the location of collection of soil sample for the isolation of fungal strains and the experimental location are marked in Figure 1a and b. The longitudes of these locations are also plotted, in the map using Global Positioning System (GPS) GARMIN (etrex).

Isolation and identification of fungal strains

The forest soil samples were collected in a container using spatula aseptically, the container was properly sealed, labelled and brought to the laboratory. Then the samples were heated at 80°C for 15 min for the destruction of vegetative cells other than fungal strains. A 1 g soil sample was taken and mixed with 100 ml of distilled water, treated this as 10^{-2} dilution blank, shaked vigorously and serial dilution blanks of 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} were prepared and transferred to the sterile Petri dishes. The plates were incubated at 27°C temperature for 3-5 days. The selective media of Martin's Rose Bengal agar (Pramer and Schmidt, 1966) was used for the isolation of fungi. The isolated fungal strains were identified using the Lactophenol cotton blue slide mount method.

Physico-chemical parameters

The methods used for the observation of various physic-chemical to be rectified parameters as pH and EC, temperature, total carbon, total nitrogen (Bremner, 1965), total phosphorus and total potassium (Jackson, 1973). In addition, the population of bacteria, fungi and actinomycetes were counted using the standard methods. On completion of 60 days of decomposition, compost samples were drawn and analysed at Tamil Nadu Agricultural University, Coimbatore.

Treatments

The treatments were designed in Completely Randomized Design method. The treatments were T_1 – Treatment 1-100 kg of MSW (Control), T_2 – Treatment 2-100 kg MSW+ *Aspergillus* species I, T_3 – Treatment 3-100 kg MSW+ *Aspergillus* species II, T_4 – Treatment 4-100 kg MSW+ *Mucor* species, T_5 – Treatment 5-100 kg MSW+ *Penicillium* species I, T_6 – Treatment 6-100 kg MSW+ *Penicillium* species II and T_7 – Treatment 7-100 kg MSW+ *Trichoderma* species. The experimental observations were made from all these six treatments from 0 day to 60th day at an internal of 15 days.

Statistical analysis

All the experiments were conducted in triplicates and tabulated the mean values. The obtained data from the analysis of the compost were analysed using Completely Randomized Design (CRD) as suggested by Panse and Sukhatme (1967), to find out the best treatment. The critical difference was worked out at five per cent probability level. The statistical analysis of all the data has been done using Microsoft excell 2007 and data were analyzed through ANOVA to determine significance of differences (0.05 and 0.01 levels).

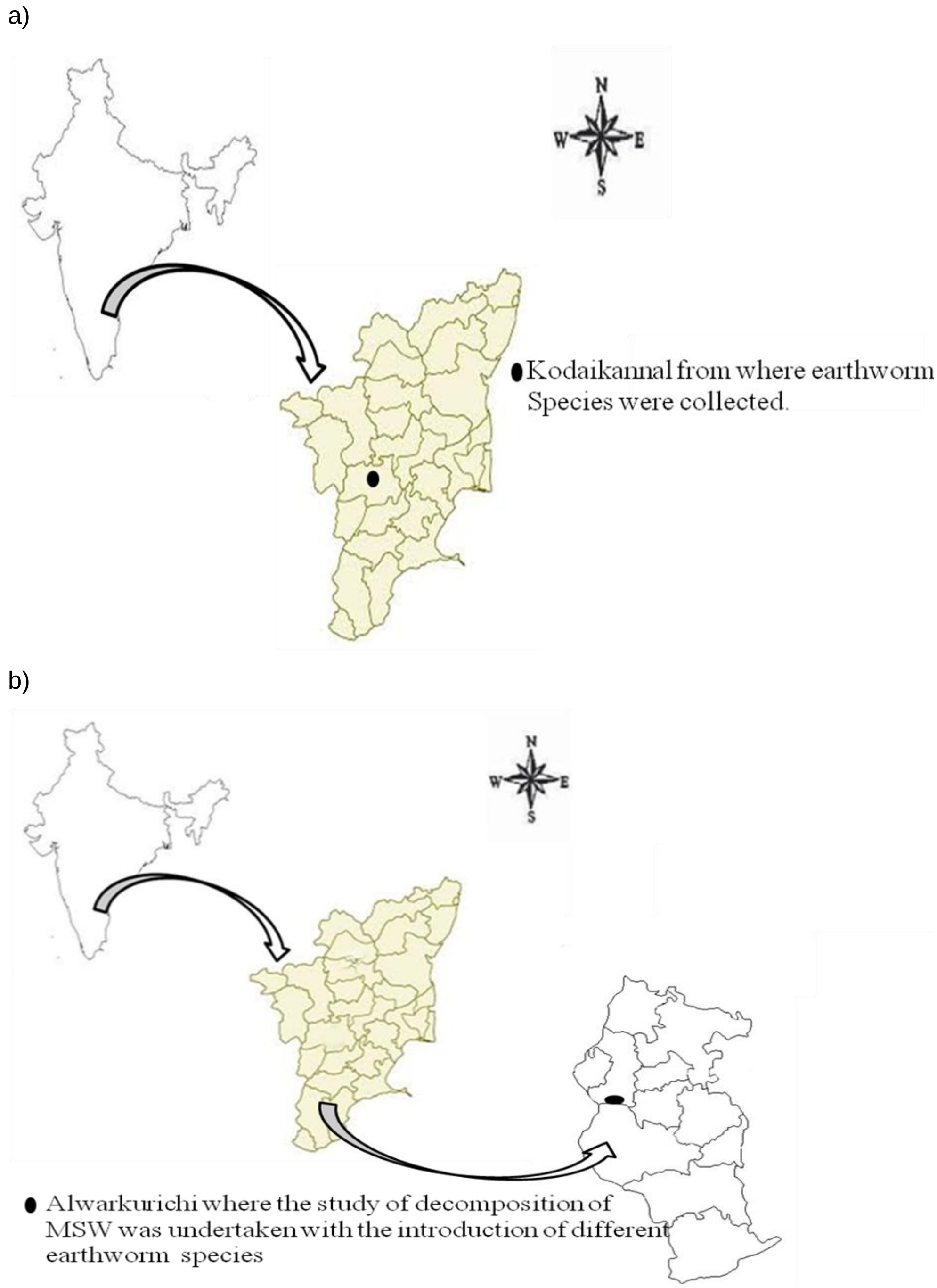

Figure 1. (a). Kodaikannal forest- place of soil sample collection. (b). Alwarkurichi-study site.

RESULTS AND DISCUSSION

Identification of fungal strains

The fungal strains were identifies as *Aspergillus* species I, *Aspergillus* species II, *Mucor* species, *Penicillium* species I, *Penicillium* species II and *Trichoderma* species. All the fungal strains were identified in different biochemical tests and confirmed with Bergeys manual of bacteriology.

Effect of pH, electrical conductivity and temperature during composting by fungal strains

The pH had been measured for all the seven treatments by taking samples at regular intervals. The pH in all the seven

Table 1. Effect of pH, EC and temperature during composting by fungal strains.

Treatments	pH		EC ((dsm-1)		Temperature (0C)	
	0th day	60th day	0th day	60th day	0th day	60th day
T_1	6.32*	7.90	1.55	2.85	35	39
T_2	6.50	8.20	1.50	3.45	36	37
T_3	6.25	7.65	1.60	3.80	37	37
T_4	6.40	7.80	1.55	2.95	35	38
T_5	6.30	8.25	1.60	3.80	37	36
T_6	6.25	8.02	1.50	3.12	38	37
T_7	6.20	7.90	1.55	3.90	37	38

*Values are expressed as mean.

treatments at the initiation of composting was found to be acidic and it ranged between 6.20 and 6.50. The highest pH 6.50 was observed from the treatment T_2 and recorded lowest pH of 6.20 from the treatment of T_7. The pH values were significantly ($P<0.05$) increased with number of days of decomposition in all the treatments. When the soil was applied with leachate of municipal solid waste pH was found to be 8.2, 8.1, 7.9 and 7.6 on 20th, 40th and 60th day and control, respectively (Soheil et al., 2012). The early mesophilic stages record a decrease in pH (acidic) and an increase in temperature and later stages record decrease in temperature and with corresponding increase in pH (Gray and Biddle stone 1985; Gray et al., 1971), Cardenas and Wang, 1980 reported that, the pH descends slightly to values of about 5 at the beginning of composting and rises as the material gradually decomposes and finally staying between 7 and 8. On examination of pH changes during composting and possession of stable pH by the matured compost in all the seven treatments, it could be inferred that the result of this study is agreeable with the findings of Gray and Biddlestone (1985) and Gray et al. (1971), Cardenas and Wang (1980).

The EC is the measure of a solution's ability to carry electrical charges that is the measure of a soluble salt content of the compost. The salt content of compost is due to the presence of Na, Cl_2, K, NO_3^-, SO_4^- and NH_4^- ions (Brinton, 2003). The samples had been drawn at frequent intervals from all the seven treatments and observed for EC values. It was found that EC was low during the initial stages of decomposition, continued to be increased and reached stable values on attaining compost maturity. Campbell et al. (1997), reported that the EC of compost samples varied from 2.40 to 3.90 dSm^{-1} in 50 to 60 days of old compost. The lowest EC 1.50 dSm^{-1} shown by T_2 and T_6 and highest EC 1.60 dSm^{-1} by T_3 and T_5 at the initiation of study and the matured compost from the treatment T_7 had shown highest 39 dSm^{-1} EC. In this study also EC continued to be increased from the beginning of composting to the end in all the seven treatments and it was statistically significant ($p>0.05$) within the treatments. While examining the EC values of all the seven treatments with the statement of Campell et al. (1997), it could be inferred that the EC values hold by the composts in all the seven treatments were within the recommended limits and the compost from all these seven treatments could be used as organic manure in agriculture production. The EC from soil samples treated with compost leachate were recorded as 0.48, 3.8, 6.4 and 14.4 dSm^{-1} on, 20th, 40th, 60th day and control respectively (Soheil et al., 2012). The E.C. values of this study were found to be in accordance with the findings of Soheil et al. (2012).

The highest temperature 38°C was recorded from the treatment T_6 and recorded the lowest temperature 35°C from the treatments T_1 and T_4 at the beginning of study. The temperature in all the seven treatments increased with increase of days of incubation and reached maximum temperature on 45th day. The temperature started declining towards the end of the composting period and reached fairly stable temperature on completion of decomposition. The treatment T_1 recorded highest 39°C temperature and T_5 recorded lowest 36°C temperature on completion of decomposition (Table 1).

Effect of total carbon, total nitrogen, total phosphorus during composting by fungal strains

The lowest carbon content 24.90% was measured from the sample of treatment T_3 and the sample from the treatment T_7 was measured with the highest 25.75% carbon content at the beginning of this study. Among the seven treatments taken up for this study, the compost samples from the treatment T_3 was recorded with lowest 12.40% carbon content followed 12.50% by the treatment T_2 and observed highest 13.80% carbon content in the compost of the treatment T_5. Mondini et al. (2003) investigated that the decrease of organic carbon content shows the decomposition of waste by microbial population. A part of the carbon is transferred into CO_2 and the remaining carbon is assimilated by the microbes during the decomposition process (Cabrera et al., 2005). The observed carbon values indicate that the results of this study have

Table 2. Effect of total carbon, total nitrogen and total phosphorus during composting by fungal strains.

Treatments	Total carbon (%)		Total nitrogen (%)		Total phosphorus (%)	
	0^{th} day	60^{th} day	0^{th} day	60^{th} day	0^{th} day	60^{th} day
T_1	25.10*	13.00	0.39	0.55	0.12	0.28
T_2	25.00	12.50	0.40	0.68	0.11	0.28
T_3	24.90	12.40	0.38	0.52	0.12	0.35
T_4	25.50	12.75	0.42	0.73	0.13	0.30
T_5	25.50	13.80	0.41	0.60	0.13	0.39
T_6	25.20	12.90	0.43	0.75	0.12	0.29
T_7	25.75	13.30	0.40	0.70	0.11	0.25

*Values are expressed as mean.

Table 3. Effect of C:N ratio and total potassium during composting by fungal strains.

Treatments	C:N ratio		Potassium (%)	
	0^{th} day	60^{th} day	0^{th} day	60^{th} day
T_1	64.36*	23.64	0.23	0.45
T_2	62.50	16.91	0.26	0.45
T_3	65.53	23.85	0.22	0.40
T_4	60.71	15.85	0.23	0.44
T_5	62.20	23.00	0.25	0.44
T_6	58.60	17.20	0.25	0.43
T_7	64.38	19.00	0.21	0.45

*Values are expressed as mean.

relevance with the findings of Mondini et al. *(*2003) and Cabrera et al. (2005).

The nitrogen concentration set a continuous ascend on progress of decomposition and observed stable values on maturation and it was significantly ($P<0.05$) increased. The sample from the treatment T_3 was observed with lowest 0.38% nitrogen content and T_6 with highest 0.43 nitrogen content at the beginning of study and the treatment T_6 recorded highest 0.75% and T_3 recorded lowest 0.52 nitrogen content on completion of decomposition (Table 2). The increase of nitrogen content in all the seven treatments taken up for this study might be attributed to the mineralization of organic matter, decrease of substrate carbon and movement of labile pool nitrogen in to available pool during the bio-degradation of MSW. Metting (1993) reported that the enhancement in the concentration of nutrients with time was due to mineralization of native carbon accompanied by a reduction in the total volume of the wastes. Bermal et al. (1998) had investigated that the rise in nitrogen level during maturation phase could possibility be due to concentration effect caused by strong degradation of labile organic carbon compounds which reduces the weight of composting materials. The recorded nitrogen values in this research are agreeable with the findings of Metting (1993) and Bermal et al. (1998).

The concentration of phosphorus in the MSW was lowest 0.11% for the treatment T_2 and T_7 at the beginning of the experiment. The phosphorus concentration had been steadily increasing with the progress of composting and attained stable concentration in all the seven treatments on completion of decomposition (60^{th} day). The analysis of samples collected from the matured compost in all the seven treatments had shown a highest concentration 0.35% of phosphorus by the treatment T_5. The treatment T_7 was measured with lowest phosphorus content 0.25% (Table 2). The increase in concentration during composting in all the treatments might have been caused by the mineralization and breakdown of complex organic compounds and release of phosphorus in the soluble form. The macro and micro nutrients were increased during composting due to the loss of carbon contents as CO_2 (Gaur, 1982). The total phosphorus content gradually increased during composting process and water solubility of phosphorus decreases with humification, so that phosphorus solubility during the decomposition was subjected to further immobilization (Elango et al., 2009). When the findings of this study was compared with the report of Gaur (1982) and Elango et al. (2009), it could be seen the similarity among these findings.

Effect of total potassium, and C:N ratio during composting by fungal strains

The C:N ratio was high during the initial stages and the treatment T_3 recorded the highest 65.53 C:N ratio and the

Table 4. Effect of microbial population by fungal strains.

Treatments	Bacterial population(-x10^5)		Fungal population (-x10^2)		Actinomycetes population (-x10^3)	
	0^{th} day	60^{th} day	0^{th} day	60^{th} day	0^{th} day	60^{th} day
T_1	9.00*	12.00	7.00	9.00	5.00	9.00
T_2	10.00	13.00	6.00	8.00	4.00	8.00
T_3	9.00	11.00	8.00	11.00	6.00	9.00
T_4	8.00	12.00	6.00	7.00	5.00	8.00
T_5	10.00	14.00	7.00	10.00	5.00	9.00
T_6	11.00	16.00	7.00	9.00	7.00	10.00
T_7	9.00	13.00	5.00	8.00	3.00	7.00

*Values are expressed as mean.

treatment T_6 was observed with the lowest 58.60 C:N ratio. The C:N ratio was inversely proportional to time and reached fairly stable value on completion of bio-degradation of MSW. The calculated values of C:N ratio for the compost samples from all the seven treatments revealed that the highest 23.64 C:N ratio (Table 3) was observed from the treatment T_1 and recorded lowest 15.85 C:N ratio from the treatment T_4 (Table 3). The increase in concentration of 'N' and decrease in concentration of 'C' with time contributes for the decline of C:N ratio in all the seven treatments. The C:N ratio significantly and statistically decreased ($P<0.05$) with time. Mathur (1991) reported that proper composting results in conservation of nitrogen and transformation of carbon in the wastes to CO_2 and humic substances. He had also reported that the ideal C:N ratio of manure compost is 10 to 20. It was reported by Sadasivam and Manickam (1996) that C:N ratio narrows down as nitrogen remains in the system, while some of the carbon is released as CO_2. While examining the above two findings with the C:N ratio values of this study, it could be inferred that the carbon and nitrogen transformations took place during the decomposition of MSW in all the seven treatments in accordance with their findings. The comparison of favourable C:N ratio for a matured compost reported by Mathur (1991), with the C:N ratio of compost samples all these treatments. The possession of ideal C:N ratio by the treatments T_2 - 16.91, T_4 - 15.85, T_6 - 17.20 and T_7 -19.00 indicates compost maturity and good fertility status and suitability of its application as bio-manure.

The potassium concentration had been increasing continuously in case of all the seven treatments of MSW with different fungal strains and attained fairly constant values in the matured compost. The highest 0.45% concentration of potassium was observed from the treatments T_1, T_2 and T_7 followed 0.44% by the treatments T_4 and T_5. The lowest 0.40% potassium concentration was measured from the treatment T_3. Potassium is an element having higher solubility and its concentration had been increased continuously during the course of decomposition and attained stable concentration in the matured compost of all the treatments. The continuous increase in concentration of potassium might be attributed by mineralization of organic compounds, loss of carbon as CO_2 and assimilation of carbon by the microbes. Metting (1993), reported that the enhancement in the concentration of nutrients with time was due to mineralisation of native carbon accompanied by a reduction in the total volume of wastes. Gallando- Lara et al. (1987), investigated that potassium increased during the period of composting. The observations made in this study on mineralization of potassium in MSW during decomposition with different fungal strains were on par with the findings of the Melting (1993) and Gallando- Lara et al. (1987).

Effect of fungal strains on microbial population during composting

The bacterial population was enumerated periodically during composting. The bacterial population was minimum at the initiation of composting in all the seven treatments and set a steady increase up to 30^{th} day, when the bacterial population was highest in all the seven treatments. The bacterial population was maintained at higher level from 30^{th} day to 45^{th} day. The survival and multiplication of bacteria would be difficult under the condition of high temperature and starving conditions (low C: N ratio). The bacterial population was highest 11.00×10^5 CFU/g in the treatment T_6 and lowest 8.00×10^5 CFU/g in the treatment T_4 at the beginning of composting. The other treatments namely T_1 T_3, T_5 and T_7 could maintain a population in between those two. The matured compost sample from the treatment T_6 was enumerated with highest 16.00×10^5 CFU/g bacterial count followed 14.00×10^5 CFU/g by the treatment T_5 and the lowest 11.00×10^5 CFU/g bacterial count was recorded from the compost sample of the treatment T_3 (Table 4). Fang and Wong (2000) reported

Table 5. Effect of micro nutrients by fungal strains.

Treatments	Micro nutrients (mg/kg)							
	Copper (Cu)		Zinc (Zn)		Manganese (Mn)		Iron (Fe)	
	0th day	60th day	0th day	60th day	0th day	60th day	0th day	60th day
T_1	4.10*	5.30	9.50	11.30	1.90	2.90	8.10	9.35
T_2	3.75	4.50	8.00	9.12	2.75	3.20	4.80	6.50
T_3	2.00	2.90	10.10	12.10	1.75	2.85	6.00	7.30
T_4	4.75	6.20	11.75	13.50	1.80	2.45	4.50	5.95
T_5	4.25	5.40	10.50	12.50	2.90	3.85	4.75	6.20
T_6	4.00	5.38	12.25	13.80	3.50	4.56	6.10	7.35
T_7	3.50	4.60	13.00	14.50	3.30	4.15	7.00	8.20

*Values are expressed as mean.

that decrease of microbial diversity in the composting mass could be due to high temperature. Bharadwaj (1999), reported that organic matter decomposition is a dynamic process by the activities of a succession of microbial population. The low bacterial population in all the seven treatments at the beginning and their continuous increase upto 30th day of decomposition and maintenance of high bacterial population from 30 to 45 day could be attributed to the findings of Fang and Wrong (2000) and Bharadwaj (1999). There was a significant change of bacterial count at $P<0.05$ level.

The fungal population had been almost same in all the treatments at the initiation of composting and it varied from 5.00×10^2 CFU/g inT_7 to 8.00×10^2 CFU/g in treatments T_3 . The highest (11.00×10^4 CFU/g) fungal population had been observed from the samples of matured compost on completion of decomposition in treatment T_3 and lowest 7.00×10^2 CFU/g fungal count was enumerated from the treatment T_4 . The thermophilic fungi would have dominated during the initial stage of composting and the other biodegradable fungi might have dominated during the later stages and brought about breakdown of complex organic compounds and mineralization. Barton (1979) reported that between 50 and 60°C thermophilic bacteria and fungi dominate along with actinomycetes and decompose the cellulose, hemicelluloses, proteins and fats to low molecular compounds such as glucose, amino acids and fatty acids. The existence of fungal populations in all the seven treatments and rate of decomposition were agreeable with the findings of Barton (1979).

The actinomycetes population in the raw compost was low in all the seven treatments at the initiation of composting. There was a steady and gradual increase of actinomycetes population from the beginning to the end of decomposition process in case of all the seven treatments and reached maximum population on 60th day. The actinomycetes population was highest in all the seven treatments on 60th day. The treatment T_6 was counted with highest 10×10^4 CFU/g actinomycetes count and T_2 and T_4 with lowest 8×10^4 CFU/g actinomycetes count in the samples of compost collected on 60th day. The micronutrients concentration had been gradually and steadily increasing during the composting period and attained maximum and stable concentration in the finely decomposed compost. The heavy metal concentration set a decline right from the beginning of decomposition and attained stable concentration at the end of decomposition (Table 5). The heavy metal concentration in the end product, compost is well within the limit of prescribed Indian standards (Table 6) and hence, the compost obtained in this study can be utilised for economic crop production.

Conclusion

The observation of various physico-chemical and biological characteristics during the process of composting and nutrient value and other characteristics of the final product of MSW decomposition, that is, compost, revealed that the fungal strain *Mucor* sp., played a prominent role when compared to the other fungal strains employed in this study. Hence, it is reported that the *Mucor* sp., is highly efficient in bringing decomposition of MSW and maintaining favourable physico-chemical and biological characteristics in the compost to make its suitability as valuable organic manure in sustainable crop production. Since, handling, management and disposal of MSW poses a lot of problems even it is a threat to the environment, we are under pressure to identify suitable method/model to handle the MSW scientifically. The observation of various characteristics such as pH, EC, nutrient status, microbial count, micro nutrient concentration and heavy metal concentration in this study, it could be inferred that the decomposition of MSW with the inoculation of fungal strain is highly effective in bringing decomposition which will enable for the Eco-friendly disposal of MSW. Moreover, the fungal strain *Mucor* sp., is comparatively more efficient in

Table 6. Effect of heavy metals by fungal strains.

Treatments	Heavy metals (mg/kg)							
	Lead (Pb)		Cadmium(Cd)		Chromium (Cr)		Nikel (Ni)	
	0th day	60th day	0th day	60th day	0th day	60th day	0th day	60th day
T_1	40.25*	38.65	3.20	2.90	25.75	23.80	33.00	31.00
T_2	55.75	53.00	2.75	2.45	38.20	35.00	25.20	23.00
T_3	62.30	61.00	3.50	3.10	32.75	29.00	35.10	34.60
T_4	47.50	46.50	3.75	3.40	43.60	41.50	31.75	29.50
T_5	61.00	58.90	3.75	3.20	35.75	33.50	32.82	31.50
T_6	52.73	50.20	4.20	3.80	38.62	35.00	24.75	23.50
T_7	47.83	46.50	3.75	3.50	43.71	41.00	24.75	23.00

Values are expressed as mean.

the decomposition process rather than the other fungal species employed in this study. Hence, it can be concluded this study with the findings to use the fungal strain *Mucor* sp., for the effective management, Eco-friendly disposal and scientific handling of MSW.

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