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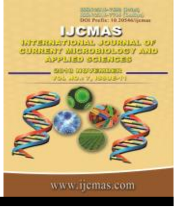

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Application of Enzyme Industrial Waste-Municipal Solid Waste Composts: Residual Effect on Physico-Chemical Properties of Soil

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ABSTRACT

Keywords

Compost, Industrial Wastes, Municipal Solid Waste, Residual effect, Soil properties

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The residual effect on soil properties on application of composts made out of composting enzyme industrial wastes and municipal solid wastes namely MEES compost (multiple effect evaporator salts + municipal solid waste) and primary sludge (PS) compost (Primary sludge + municipal solid waste) were evaluated in this study. Application of composts recorded a marginal increase in soil pH towards harvest (6.70 and 6.68 in treatment T_8 (50% N through MEES + 50 % N through FYM and T_7 (PS compost @ 10 t ha^{-1}) respectively) in comparison to the initial pH and a higher organic carbon content of 0.56 and 0.57 per cent at 30 DAS and 0.52 and 0.53 in T_6 (MEES Compost @10 t ha^{-1}) and T_7 (PS Compost @ 10 t ha^{-1}) respectively after the harvest of cowpea which was grown as the residual crop. A positive residual effect was evident in compost treatments with an increased status of available major and micro nutrients.

Introduction

Soil organic matter plays an important role in maintaining soil fertility and supply of plant nutrients. Application of organic residues to soil aims at improving the soil physical, chemical and biological properties which are in direct relation with the soil organic matter content. The rising interest in organic methods of farming brings in more usage of organic grade municipal solid waste compost considering their positive effects on soil properties (Iglesias-Jimenez and Alvarez, 1993).

The municipal solid waste composts are rich source of nutrients. Final mature municipal solid waste compost recorded a pH of 7.13, EC of 7.7 dS m^{-1}, total P 13.87 %, K- 0.6-1.7 % and Na- 0.086 % (Shyamala and Belagali, 2012). Municipal solid waste compost from Bangalore on characterization revealed a pH of 8.19, EC 0.58 $mScm^{-1}$, 26.61 % C, 1.13 % N, 2.92 % P and C: N ratio of 23.55 (Manju *et al.*, 2013).

Organic residues *viz.* composts, influence soil properties by exhibiting a residual effect on their application (Eghball *et al.*, 2004).

Application of municipal solid waste compost resulted in an improvement in soil physical properties like total porosity, field water capacity, plant available water and chemical properties like increased organic carbon, available P, K and Mg contents in soil exhibiting a better residual effect (Weber *et al.*, 2007). Three years after the application of composted biosolids improved several chemical and biological soil properties such as organic C (SOC), humified C fractions (THS-C), water soluble C (DOC), total nitrogen (Nk), basal respiration (CO_2-E), and potential nitrogen mineralization (PMN) (Ana *et al.*, 2012).

The composts, in general, possess a carryover effect, indicating the need to evaluate their residual effect in soil. Residual effect of application of composts on soil chemical properties evaluated in a study resulted in a 104 per cent increase in soil organic matter, 173 percent in available phosphorus, 17.4 per cent of exchangeable Ca (Demelash *et al.*, 2014). Here, this field experiment was conducted with the objective to evaluate residual impact on soil properties on application of enzyme industrial waste-municipal solid waste composts.

Material and Methods

The field experiment to evaluate the residual effect of enzyme industrial waste-municipal solid waste composts on physico-chemical properties of soil was carried out in a sandy loam soil located near Nelamangala, Bangalore in the Eastern Dry Zone (Zone 5) of Karnataka. Two composts made out of composting enzyme industrial waste-municipal solid wastes *viz.* MEES compost (multiple effect evaporator salts + municipal solid waste) and primary sludge (PS) compost (Primary sludge + municipal solid waste) and fertilizers were used in this experiment to know the effect on soil properties.

Experimental details

Wastes from enzyme industry were mixed with municipal solid waste and composting was carried out which resulted in two composts of improved nutrient status. These composts are referred to as MEES compost (multiple effect evaporator salts + municipal solid waste) and primary sludge (PS) compost (Primary sludge + municipal solid waste) in this study. These composts were evaluated for their residual effects on soil properties after the harvest of cowpea which was grown as the residual crop following the main crop which was maize. The field experiment consisted of nine treatments replicated thrice in a Randomised Complete Block Design. The treatments were applied only to the first crop maize and the treatment details for the first crop included T_1: Package of Practices (100 % NPK + FYM @ 10 t ha^{-1}), T_2: 100 % NPK + FYM @ 5 t ha^{-1}, T_3: 50% N through MEES compost + 50 % N through urea + P and K, without FYM, T_4: 50% N through PS compost + 50 % N through urea + P and K, without FYM, T_5: FYM @ 10 t ha^{-1}, T_6:MEES compost @ 10 t ha^{-1}, T_7:PS compost @ 10 t ha^{-1}, T_8: 50% N through MEES + 50 % N through FYM, T_9: 50% N through PS + 50 % N through FYM.

Based on the nitrogen concentration in composts and the recommendation to the first crop (maize), the application rates of composts were calculated. The composts were characterized and were found to be rich sources of nutrients. MEES compost recorded 2.28, 0.46 and 1.94 and PS compost recorded 1.93, 3.29 and 0.81 per cent N, P and K respectively. The nitrogen needs were met from the compost as well as the nitrogenous fertilizers applied. This experiment was carried out in the same field without disturbing the lay out using cowpea as the test crop. Cowpea (var. AV 5) was raised on residual nutrients left over in soil after harvest of first crop maize. During this experiment, fertilizer or manure was not added. The growth of cowpea was determined at 30 days after sowing (DAS), 60 DAS and at harvest. The soil samples were drawn during these periods and analyzed in the laboratory by following the standard procedures to understand the changes in soil properties. Soil pH and EC were determined by potentiometric and conductometric method respectively (Jackson, 1973), organic carbon by wet oxidation method (Walkley and Black, 1934), available nitrogen by alkaline permanganate method (Subbaiah and Asija, 1956), available phosphorus by Bray's method (Bray & Kurtz, 1945), potassium by neutral normal ammonium acetate extraction method, exchangeable Ca and Mg by Complexometric titration / versenate method, sulphur by turbidimetric method (Jackson, 1973) and DTPA extractable micronutrients by atomic absorption spectrophotometry (Lindsay and Norwell, 1978).

Statistical analysis

Fisher's method was adopted for analysis of variances and interpretation of the data. The level of significance used in 't' test was P=0.05 (Panse and Sukhathme, 1967).

Results and Discussion

Residual effect of enzyme industry biosolid composts on soil properties

pH, EC and organic carbon

The data pertaining to the residual effect of enzyme industry biosolid composts on pH, EC and organic carbon in soil at 30, 60 days after sowing (DAS) and at harvest of cowpea are indicated in Table 1.

There was no significant difference in soil pH at 30, 60 DAS and at harvest. In comparison to the initial pH, there was a marginal increase in soil pH on application of biosolid composts. Maximum pH of 6.70 was observed in treatment T_8 (50% N through MEES + 50 % N through FYM) which was on par with treatment T_7 (PS compost @ 10 t ha^{-1}) which recorded a pH of 6.68 at harvest. This observation is in accordance with the findings by Mkhabela and Warman (2005) who described increased soil pH when compost was used. This increase may be due to the mineralization of carbon and the subsequent production of hydroxyl ions.

Electrical conductivity also increased in comparison to the initial EC. At harvest, higher EC of 0.26 dS m^{-1} was recorded in treatment T_8 (50 % N through MEES + 50% N through FYM) and lower EC of 0.03 dS m^{-1} was recorded in treatment T_2 (100 % NPK + FYM @ 5 t ha^{-1}). Electrical conductivity of soil ranged from 0.06 dS m^{-1} in treatment T_1 (100 % NPK + FYM @ 10 t ha^{-1}) to 0.20 dS m^{-1} in treatment T_9 (50 % N through PS + 50% N through FYM) at 30 DAS. The treatments T_8 (50 % N through MEES + 50 % N through FYM) and T_9 (50 % N through PS + 50 % N through FYM) exhibited an increase in soil EC towards harvest and recorded 0.26 and 0.14 dS m^{-1} respectively. These results are in agreement with that of Iglesias-Jimanez and Alvarez (1993), who reported that MSW composts applied at rates ranging from 40-120 Mg ha^{-1} were seen to proportionally increase the EC of soils to which they were applied.

An increase in soil organic carbon content in comparison to the initial value was observed in all the treatments. Organic carbon content of soil did not vary significantly, though it recorded a decreasing trend from 30 DAS to harvest with progress in the growth of crop. Higher organic carbon content of 0.59 per cent in soil was recorded in treatment T_9 (50 % N through PS + 50 % N through FYM) at 30 DAS. This may be due to the increased amount of organic matter applied in these treatments. The treatments T_6 (MEES Compost @10 t ha^{-1}) and T_7 (PS Compost @ 10 t ha^{-1}) recorded higher organic carbon content of 0.56 and 0.57 per cent at 30 DAS and 0.52 and 0.53 at harvest respectively. This may be attributed to the higher levels of organic matter addition in these plots in the form of compost application. Civeira (2010) and Vaca *et al.*, (2011) reported similar results. Montemurro *et al.*, (2006) reported an increase in soil organic matter content with the application of MSW compost.

Major nutrients content of soil

The data pertaining to the residual effect of enzyme industry biosolid composts on available N, P_2O_5 and K_2O contents of soil at 30, 60 DAS and at harvest of cowpea are presented in Table 2.

Residual available nitrogen content of soil was not significant at 30, 60 DAS and at harvest (Table 2). Higher levels of available nitrogen (166.35 kg ha^{-1}) was observed in treatment T_1 (100 % NPK + FYM @ 10 t ha^{-1}) at 30 DAS. This may be due to the initial high status of available N in that treatment. Lower nitrogen content was observed in the soils with treatment T_5 (FYM@ 10 t ha^{-1}) at 30 DAS. However, an increase in available nitrogen content was observed in all the treatments except T_1 (100% NPK + FYM @ 10 t ha^{-1}) and T_2 (100% NPK + FYM @ 5 t ha^{-1}). At harvest, treatment T_3 (50 % N through MEES compost + 50 % N through urea, PK without FYM) recorded maximum nitrogen content and this was on par with T_4 (50 % N through PS compost + 50 % N through urea, PK without FYM). The increase in soil N status may be due to the release of N from composts.

Mineralization of organic matter in added composts leads to slow releasing of nutrients in particular N. Since there was no addition of fertilizers in the compost amended treatments T_6 (MEES Compost @10 t ha^{-1}) and T_7 (PS Compost @ 10 t ha^{-1}), the source of plant available forms of N was the organic source. The same levels of N found in the treatments T_1 (100 % NPK + FYM @ 10 t ha^{-1}) and treatments T_6 (MEES Compost @10 t ha^{-1}) and T_7 (PS Compost @ 10 t ha^{-1}) indicate undoubtedly that all N applied in mineral form was either taken up by plants or possibly leached from the soil during the growing season. The soil amended with composts still contained considerable amounts of N present in non-mineralized OM. Similar findings have been reported by Soumare *et al.*, (2003a) and Weber *et al.*, (2007).

Available phosphorus content of the soil varied significantly at 30DAS but not at 60 DAS and at harvest (Table 2). Available phosphorus was maximum (84.80 kg ha^{-1}) in treatment T_1 (100 % NPK + FYM @ 10 t ha^{-1}) at 30 DAS. Lower P content of 50.65 kg ha^{-1} was recorded in treatment T_5 (FYM @ 10 t ha^{-1}) at harvest. Phosphorus content of the soil decreased from 30 DAS to harvest in treatments T_1 (100 % NPK + FYM @ 10 t ha^{-1}), T_2 (100 % NPK + FYM @ 5 t ha^{-1}), T_3 (50 % N through MEES compost + 50 % N through urea, PK without FYM) and T_4 (50 % N through PS compost + 50 % N through urea, PK without FYM), whereas it increased in all the other treatments. The increase was observed in soils treated with composts, FYM and organic wastes. This may be attributed to the release of P from composts and wastes as a result of mineralization (Sharma *et al.*, 2013). These results are in conformity with the findings of Tognetti *et al.*, (2008) who summarised from their study that co-composting municipal organic waste with biosolids increased product degradability and nutrient release capacity which was evident from an increased extractable P. A similar increase was noticed in case of application of MSW compost. Soil P availability increased with addition of MSW compost, soil P retention decreased with increasing compost application because of competition between organic ligands and phosphate for sites on metallic oxides as well as the formation of phosphohumic complexes which can increase P mobility (Giusquiani *et al.*, 1988). Soumare *et al.*, (2003b) reported that the application of MSW compost improved the soil organic matter, total N, available P and K content.

Similar was the trend observed in case of available potassium content in soil (Table 2). Higher levels of available potassium 310.25, 299.17 and 290.12 kg ha^{-1} were recorded in treatment T$_1$ (100 % NPK + FYM @ 10 t ha^{-1}) at 30, 60 DAS and at harvest respectively. Available potassium content of soil varied significantly at 30 DAS and at harvest. At harvest maximum potassium content was observed in treatment T$_1$ (100 % NPK + FYM @ 10 t ha^{-1}) followed by treatment T$_7$ (PS compost @ 10 t ha^{-1}). High values of available K$_2$O may be ascribed to the release of K from organic sources.

These results are in accordance with the findings by Giusquiani *et al.*, (1988) who reported that soil K concentrations increased even when very low rates of MSW composts were used and Soumare *et al.*, (2003b) who reported that the application of MSW compost improved soil available K in the soil. Weber *et al.*, (2007) observed a large increase in the available K on application of MSW composts, during the entire period of the experiment.

Table.1 Residual effect of enzyme industry biosolid composts on pH, EC and organic carbon content of soil at 30 DAS, 60 DAS and at harvest of cowpea

Treatments	**pH**			**EC (dS m^{-1})**			**OC (%)**		
	30DAS	**60DAS**	**At harvest**	**30DAS**	**60DAS**	**At harvest**	**30DAS**	**60DAS**	**At harvest**
T$_1$	6.03	6.00	6.00	0.06	0.05	0.05	0.52	0.49	0.47
T$_2$	6.20	6.09	6.00	0.07	0.06	0.03	0.54	0.52	0.50
T$_3$	6.30	6.28	6.10	0.12	0.11	0.09	0.54	0.52	0.50
T$_4$	6.30	6.28	6.24	0.08	0.08	0.06	0.48	0.46	0.45
T$_5$	6.10	6.07	6.02	0.07	0.07	0.06	0.44	0.42	0.40
T$_6$	6.19	6.09	6.04	0.17	0.16	0.14	0.56	0.54	0.52
T$_7$	6.89	6.96	6.68	0.08	0.08	0.07	0.57	0.55	0.53
T$_8$	6.72	6.03	6.70	0.20	0.28	0.26	0.58	0.50	0.52
T$_9$	7.10	6.74	6.43	0.10	0.12	0.14	0.59	0.53	0.49
Sem±	0.26	0.25	0.30	0.03	0.03	0.01	0.06	0.08	0.07
C.D. at 5%	NS	NS	NS	0.08	0.09	0.04	NS	NS	NS

T$_1$: POP (100 % NPK + FYM @10t ha^{-1})
T$_2$: 100 % NPK+ FYM @ 5 t ha^{-1}
T$_3$: 50% N through MEES compost + 50 % N through urea, PK without FYM
T$_4$: 50% N through PS compost+ 50 % N through urea, PK without FYM
T$_5$: FYM@ 10 t ha^{-1}
T$_6$: MEES compost @ 10 t ha^{-1}
T$_7$: PS compost @ 10 t ha^{-1}
T$_8$: 50 % N through MEES + 50 % N through FYM
T$_9$: 50 % N through PS + 50 % N through FYM

Table.2 Residual effect of enzyme industry biosolid composts on major nutrients content of soil at 30 DAS, 60 DAS and at harvest of cowpea

Treatments	**Available N**			**Available P_2O_5**			**Available K_2O**		
	kg ha^{-1}								
	30DAS	**60DAS**	**At harvest**	**30DAS**	**60DAS**	**At harvest**	**30DAS**	**60DAS**	**At harvest**
T_1	166.35	155.25	150.86	84.80	80.80	72.45	310.25	299.17	290.12
T_2	160.18	150.90	140.10	74.32	69.26	65.21	292.42	284.67	271.32
T_3	155.25	168.94	174.72	65.21	62.16	59.36	281.83	273.52	257.21
T_4	145.10	150.03	156.45	80.12	79.68	75.26	270.50	262.43	248.12
T_5	125.38	130.71	135.87	40.17	43.99	50.65	224.13	231.57	243.17
T_6	145.77	150.90	155.09	59.75	62.06	63.19	253.81	264.36	266.75
T_7	135.31	142.98	150.62	65.81	70.87	75.59	248.65	253.35	274.93
T_8	130.71	136.03	141.51	60.18	62.69	66.30	232.08	241.89	257.18
T_9	130.00	133.02	140.40	51.01	56.50	65.50	230.93	243.68	252.01
Sem±	18.20	18.77	23.83	8.70	10.07	6.92	15.82	40.36	7.97
C.D. at 5%	NS	NS	NS	26.08	NS	NS	47.42	NS	23.90

T_1: POP (100 % NPK + FYM @10t ha^{-1})
T_2: 100 % NPK+ FYM @ 5 t ha^{-1}
T_3: 50% N through MEES compost + 50 % N through urea, PK without FYM
T_4: 50% N through PS compost+ 50 % N through urea, PK without FYM
T_5: FYM@ 10 t ha^{-1}
T_6: MEES compost @ 10 t ha^{-1}
T_7: PS compost @10 t ha^{-1}
T_8: 50 % N through MEES + 50 % N through FYM
T_9: 50 % N through PS + 50 % N through FYM

Table.3 Residual effect of enzyme industry biosolid composts on secondary nutrients content of soil at 30 DAS, 60 DAS and at harvest of cowpea

Treatments	Exchangeable Ca			Exchangeable Mg			Available S		
	cmol (+) kg^{-1}						mg kg^{-1}		
	30DAS	60DAS	At harvest	30DAS	60DAS	At harvest	30DAS	60DAS	At harvest
T_1	4.10	3.23	2.99	1.40	1.36	1.33	15.72	15.31	11.75
T_2	3.74	3.11	2.82	1.20	0.92	0.86	12.34	10.68	10.36
T_3	3.46	3.34	2.93	1.76	1.68	1.50	16.24	13.77	12.74
T_4	3.40	3.03	2.82	1.84	1.57	1.43	12.59	11.28	10.92
T_5	2.71	3.06	3.12	0.83	1.14	1.25	12.23	11.20	10.81
T_6	2.75	2.93	3.00	2.31	2.72	2.81	19.19	16.95	16.33
T_7	2.42	3.00	3.34	2.16	2.31	2.55	16.09	13.53	12.69
T_8	2.52	2.93	3.41	1.44	1.50	1.82	17.01	14.38	13.53
T_9	2.36	2.67	3.74	1.40	1.48	1.68	17.85	15.84	15.31
Sem±	0.54	0.35	0.26	0.50	0.39	0.91	4.33	2.70	1.61
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

T_1: POP (100 % NPK + FYM @10t ha^{-1})
T_2: 100 % NPK+ FYM @ 5 t ha^{-1}
T_3: 50% N through MEES compost + 50 % N through urea, PK without FYM
T_4: 50% N through PS compost+ 50 % N through urea, PK without FYM
T_5: FYM@ 10 t ha^{-1}
T_6: MEES compost @ 10 t ha^{-1}
T_7: PS compost @ 10 t ha^{-1}
T_8: 50 % N through MEES + 50 % N through FYM
T_9: 50 % N through PS + 50 % N through FYM

Table.4 Residual effect of enzyme industry biosolid composts on DTPA extractable micronutrients content of soil at 30 DAS, 60 DAS and at harvest of cowpea

Treatments	**Fe**			**Mn**			**Zn**			**Cu**		
	(mg kg^{-1})											
	30 DAS	**60 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**At harvest**
T_1	20.51	19.30	14.24	13.24	12.41	10.34	7.72	4.14	4.03	1.04	0.99	0.91
T_2	19.74	17.60	12.99	19.60	11.30	10.89	7.95	4.36	3.30	1.03	0.94	0.83
T_3	23.09	24.04	17.74	12.59	13.29	12.22	10.23	8.44	3.70	1.19	1.16	1.08
T_4	21.67	24.04	17.74	13.31	15.72	10.55	9.30	8.30	7.38	1.12	1.08	1.04
T_5	21.09	16.09	11.87	12.81	10.66	8.94	6.26	3.58	3.45	1.02	1.01	0.98
T_6	37.81	34.68	31.26	16.45	18.19	12.96	16.34	14.20	13.52	1.48	1.32	1.27
T_7	29.34	31.49	23.24	21.02	18.21	14.91	13.91	13.35	9.14	1.40	1.30	1.23
T_8	28.12	22.84	16.86	24.46	15.92	12.03	12.95	10.95	7.99	1.34	1.23	1.13
T_9	24.41	19.36	14.29	13.45	15.13	12.62	13.15	8.23	7.11	1.25	1.17	1.08
Sem±	6.69	3.25	4.17	5.47	3.50	1.96	2.74	2.93	0.95	0.19	0.20	0.16
C.D. at 5%	NS	9.75	NS	NS	NS	NS	NS	NS	2.86	NS	NS	NS

T_1: POP (100 % NPK + FYM @10t ha^{-1})
T_2: 100 % NPK+ FYM @ 5 t ha^{-1}
T_3: 50% N through MEES compost + 50 % N through urea, PK without FYM
T_4: 50% N through PS compost+ 50 % N through urea, PK without FYM
T_5: FYM@ 10 t ha^{-1}
T_6: MEES compost @ 10 t ha^{-1}
T_7: PS compost @10 t ha^{-1}
T_8: 50 % N through MEES + 50 % N through FYM
T_9: 50 % N through PS + 50 % N through FYM

Secondary nutrients content of soil

The data indicating the residual effect of enzyme industry biosolid composts on status of exchangeable Ca, exchangeable Mg and available S in soil at 30, 60 DAS and at harvest of cowpea are provided in Table 3.

Higher Ca content of 3.74 cmol (p+) kg^{-1} was recorded in treatment T_9 (50 % N through PS + 50% N through FYM) followed by 3.41cmol (p+) kg^{-1} in treatment T_8 (50 % N through MEES + 50% N through FYM). There were no significant differences between the treatments. However, the organic matter addition had increased the exchangeable Ca in post-harvest soil compared to other treatments. Shanmugam (2005) observed that repeated applications of compost for three consecutive years progressively increased soil Ca concentrations compared to fertilizer treatments. Municipal solid waste compost has been reported to increase total and extractable soil Ca concentrations (Warman *et al.*, 2004; Zheljazkov and Warman, 2004).

Magnesium content also followed the same trend. Higher Mg content of 2.81 cmol(p+) kg^{-1}was observed in the soil which received treatment T_6 (MEES Compost @ 10 t ha^{-1}) and this was on par with treatment T_7 (PS compost @ 10 t ha^{-1}) which recorded 2.55 cmol(+) kg^{-1} at harvest. Similar increase in soil Mg content with the application of municipal solid waste compost was also reported by Bhargavi (2001) and Weber *et al.*, (2007).

The available sulphur content of soil recorded higher values in organic treatments over initial sulphur contents of soil. Higher S content of 16.33 mg kg^{-1}was observed in treatment T_6 (MEES Compost @ 10 t ha^{-1}) followed by15.31 mg kg^{-1} in treatment T_9 (50 % N through PS + 50 % N through FYM) at harvest. This increase in available sulphur may be due to the release of organic bound sulphur and native sulphur through mineralisation process. Kadalli (1999) reported that treatments with composts increased the S content significantly. The sulphur content of soil decreased with time. This is in accordance with the study by Zhang *et al.,* (2006) who reported similar results on application of MSW compost. Municipal solid waste compost increased soil S concentrations, but levels decreased with time. This may be perhaps due to downward movement of the element in the soil profile.

DTPA extractable micronutrients content of soil

The data on the residual effect of enzyme industry biosolid composts on DTPA extractable micronutrients content of soil at 30, 60 DAS and at harvest are furnished in Table 4.

The content of all micronutrients followed similar trend as that of secondary nutrients in soil. The micronutrients content of residual soil after harvest of cowpea were higher in compost treatments when compared to that of treatment T_1 (100 % NPK + FYM @ 10 t ha^{-1}) and T_2 (100 % NPK + FYM @ 5 t ha^{-1}). The increase in micronutrients availability could be attributed to the release of organically bound micro nutrients through mineralization. Further, the increase in availability may also be due to the action of organic compounds by which they may form soluble complex with micronutrients and help in increasing their availability.

Iron content of soil ranged from 11.87 mg kg^{-1} in treatment T_5 (FYM @ 10 t ha^{-1}) to 31.26 mg kg^{-1} in treatment T_6 (MEES compost @ 10 t ha^{-1}) at harvest. Treatment T_7 (PS compost @ 10 t ha^{-1}) recorded 23.24 mg kg^{-1} of iron in the residual soil. In a study, significant increase in available soil Fe was reported with increase in application rate (Maftoun *et al.,* 2004). Soumare *et al.*, (2003b) reported an increase in Fe, Mn, Zn and Cu concentration in soils treated with compost. Manganese content in the soil ranged from 12.59 mg kg^{-1} in treatment T_3 (50% N through MEES compost + 50 % N through urea + P and K) to 24.46 mg kg^{-1} in treatment T_8 (50 % N through MEES + 50 % N through FYM) at 30 DAS. Soil Mn content was non-significant at harvest which ranged from 8.94 mg kg^{-1} in treatment T_5 (FYM @ 10 t ha^{-1}) to 14.91 mgkg^{-1}in T_7 (PS compost @ 10 t ha^{-1}). Total soil Mn concentrations tended to increase on addition of MSW composts (Giusquiani *et al.,* 1988). Kadalli (1999) reported a significant increase in the micronutrient status of soils applied with enriched composts.

Available zinc showed non-significant variation at 30 and 60 DAS. At 30 DAS it varied from 6.26 mg kg^{-1} in treatment T_5 (FYM @ 10 t ha^{-1}) to 16.34 mg kg^{-1} in treatment T_6 (MEES compost @ 10 t ha^{-1}). At harvest, zinc status ranged from 3.30 mg kg^{-1} in T_2 (100 % NPK + FYM @ 5 t ha^{-1}) to 13.52 mg kg^{-1} in T_6 (MEES compost @ 10 t ha^{-1}) treatment. The treatment T_7 (PS compost @ 10 t ha^{-1}) recorded 9.14 mg kg^{-1} of zinc in the residual soil. On application of MSW compost, an increase in the total soil Zn concentration was observed when compared to unamended control (Gallardo-Lara *et al.*, 1980; Giusquiani *et al.*, 1988). At harvest, Cu varied from 0.91 mg kg^{-1} in treatment T_1 (100 % NPK + FYM @ 10 t ha^{-1}) to 1.27 mg kg^{-1} in treatment T_6 (MEES compost @ 10 t ha^{-1}) which was non-significant. This is in accordance with the findings by Sebastio *et al.,* (2000) and Zhang *et al.,* (2006) who reported a significant increase in the soil Cu concentrations when amended with MSW compost in an acidic sandy soil.

The application of enzyme industrial waste – municipal solid waste composts resulted in a positive residual effect on soil physico-chemical properties as evident by the improved nutrient status of the soil. Even after the harvest of the residual crop, the soil recorded increased levels of pH, EC and available nutrients indicating the release of nutrients from the composts as a result of solubilization and mineralization emphasizing the strong carry over effect. Municipal solid waste, which is the carbon source in composting process, could be a source of potentially toxic or hazardous heavy metals, the presence of which in soil on application of these composts needs a major research further. The residual status of heavy metal concentration in the soil on application of these enzyme industrial waste – municipal solid waste composts needs to be evaluated to understand the possibilities of heavy metal contamination from the municipal solid waste. Hence, further research must be carried out before recommending these composts as a component in agriculture.

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