

Original Research Article

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Assessment of Heavy Metals on Fortified Municipal Solid Waste Compost Treated Soils (Typic Ustropet) in Okra (*Abelmoschus esculentus* (L.) Moench) - Onion (*Allium cepa* L.) Cropping Sequence

V.S. Reddy Kiran Kalyan^{1*}, G. Sudha Narayani¹, A. Vijayprabhakar²
and Ch. Bhargavarami Reddy¹

¹Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, Tamilnadu, 641003, India

²Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamilnadu, 641003, India

*Corresponding author:

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From the experimental results emanated from first crop of okra, among the Municipal Solid Waste Compost (MSWC) treatments application of 100% Rec. NK + FMSWC with poultry manure 10% (9:1) at 5 t ha⁻¹ along with phosphorus (M₄P₁) recorded lowest Pb, Ni and Cd contents at harvest stage in soil which was on par with the treatment, 100% Rec. NK + FMSWC with SSP at 5 t ha⁻¹ along with phosphorus (M₇P₁) which was significantly lower than that of other treatments with FMSWC at higher doses. Onion crop was raised as succeeding crop to study the residual effect of municipal solid waste compost. From the experimental results, the application of 100% Rec. NK + FMSWC with poultry manure 10% (9:1) at 5 t ha⁻¹ with phosphorus (60 kg ha⁻¹) (M₄P₁) registered lowest heavy metal Pb, Ni and Cd contents in soil which was on par with the treatment, 100% Rec. NK + FMSWC with SSP at 5 t ha⁻¹ along with phosphorus (60 kg ha⁻¹) (M₇P₁) as compared to other treatments with FMSWC higher doses. With regard to heavy metals accumulation in soil, plant, fruit and bulb samples is below the permissible limits as prescribed by Indian standards (2013) and World Health Organization (2007).

Introduction

Application of organic manure is the most widely practiced technology for nutrient replenishment in soil. Before 1950, organic manure was the only source of plant nutrients and owing to high animal population, farm yard manure was the most common organic manure. During those days, cattle's account for 90 percent of total manure production. The proportion of cattle manure available for crop production decreased from 70 percent in

the early 1970s to 30 percent in the early 1990s. Although FYM is commonly used organic manure, it is not adequately available in the recent days due to decrease in cattle population. Hence, there is a strong need to identify suitable organic source alternative to FYM. Increasing population levels, booming economy, rapid urbanization and rise in community living standards have greatly accelerated the municipal solid waste

generation rate in developing countries (Minghua *et al.*, 2009). MSWC increased the aggregate stability of soil through the formation of cationic bridges thereby, improving the soil structure (Hernando *et al.*, 1989). Municipal solid waste also contains considerable concentrations of heavy metals such as As, Pb, Ni, Cd and Cr. With the light of above, the experiment was conducted with 10 different main plot treatments comprising three levels of fortified MSWC (5, 7.5 and 10 t ha⁻¹) and two subplot phosphorus levels (0, 100%) and along with control.

Materials and Methods

Municipal solid waste compost collected from the Municipal solid waste compost plant located at Vellalore, Coimbatore district which is being operated by United Phosphorus Ltd, Mumbai in collaboration with Coimbatore Corporation was fortified with poultry manure at 10% (9:1) and with single super phosphate at 50 kg per tonne. The fortified compost was heaped under aerobic condition for twenty one days and analyzed for its physico-chemical and chemical properties. The experimental field was ploughed thoroughly and levelled properly. Ridges and furrows were formed at 45 cm apart. Irrigation channels were formed separately for each row, so that manures and fertilizers will not be translocated from one plot to another. The plot size was 4 × 3 m (12 m²). The experiment was laid out in split plot design replicated thrice with the following main plot treatments: M₀ – Control, M₁ - 100% Rec. NK, M₂ - 100% Rec. NK + FYM 25 t ha⁻¹, M₃ - 100% Rec. NK + Unfortified MSWC at 5 t ha⁻¹, M₄ - 100% Rec. NK + PM Fortified MSWC at 5 t ha⁻¹, M₅ - 100% Rec. NK + PM Fortified MSWC at 7.5 t ha⁻¹, M₆ - 100% Rec. NK + PM Fortified MSWC at 10 t ha⁻¹, M₇ - 100% Rec. NK + SSP Fortified MSWC at 5 t ha⁻¹, M₈ - 100% Rec. NK + SSP Fortified MSWC at 7.5 t ha⁻¹ and M₉ - 100% Rec. NK +

SSP Fortified MSWC at 10 t ha⁻¹. The soil belongs to Irgur series (*Typic Ustropet*), loamy sand in texture, non-calcareous, slightly alkaline in reaction with low available nitrogen, high available phosphorus and high available potassium. The soil is sufficient in iron (2.91 mg kg⁻¹) and manganese (12.2 mg kg⁻¹), deficient in zinc (0.65 mg kg⁻¹) and copper (0.82 mg kg⁻¹) and with traces of heavy metals. Soil samples were collected at harvest stage of okra crop and vegetative, bulb initiation, bulb development and post harvest stages of onion crop, processed and analyzed for heavy metal concentration by using DTPA extractant method (Lindsay and Norvell, 1978).

Results and Discussion

From the experimental results, the available lead status of the experimental soil was 3.15 mg kg⁻¹. At harvest stage, the treatment which received 100% Rec. NK + FMSWC with poultry manure 10% (9:1) at 5 t ha⁻¹ along with phosphorus application (100 kg ha⁻¹) (M₄P₁) showed minimum value of available lead status (4.57 mg kg⁻¹) which was on par with the treatment, 100% Rec. NK+ FMSWC with SSP at 5 t ha⁻¹ along with phosphorus application (100 kg ha⁻¹) (M₇P₁) with the value of 4.64 mg kg⁻¹, as compared to other treatments with FMSWC at higher doses (Fig. 1). The interaction effect between the main plot and sub plot treatments was not significant. Application of MSWC fortified with poultry manure increased heavy metal concentration in soil but it ranged below the permissible limits. This might be due to the application of MSWC, which had sufficient nickel concentration and made available in the soil (Table 1).

Garcia Gil *et al.*, (2004) noticed that application of MSWC at 80 t ha⁻¹ vermicompost accumulated lead in soil which was below the critical limit (11.6 mg kg⁻¹). Madrid *et al.*, (2007) assessed the effect of MSWC on the

accumulation of heavy metals in a sandy soil and they identified that application of MSWC at 2.1 kg m⁻² registered maximum concentration of Pb (2.5 mg kg⁻¹) in soil with tomato as a test crop. Achiba *et al.*, (2009) proved that application of MSWC at 120 t ha⁻¹ recorded the highest concentration of lead in soil (97.1 mg kg⁻¹) with maize as test crop. Gharib (2014) studied the impacts of urban waste water and leachate on accumulation of iron (Fe), manganese (Mn), zinc (Zn), nickel (Ni) and cadmium in soil when barley (*Hordeum vulgare L*) was grown as test crop. The results showed that soil irrigated with 300 ml of waste water increased extractable heavy metals in soil and the concentrations of extractable Fe was 2.27 ppm.

The available nickel status of the experimental soil was 1.03 mg kg⁻¹. At harvest stage, the treatment which received 100% Rec. NK + FMSWC with poultry manure 10% (9:1) at 5 t ha⁻¹ along with phosphorus application (100 kg ha⁻¹) (M₄P₁) showed minimum value of available nickel status (3.57 mg kg⁻¹) which was on par with the treatment, 100% Rec. NK+ FMSWC with SSP at 5 t ha⁻¹ along with phosphorus application (M₇P₁) with the value of 3.48 mg kg⁻¹. The interaction effect between the main plot and sub plot treatments was not significant. Application of MSWC fortified with poultry manure increased heavy metal concentration in soil but it ranged below the permissible limits.

This is might be due to the application of MSWC, which had sufficient nickel and was made available in the soil. Albaladejo *et al.*, (2009) studied the effect of graded municipal solid waste compost and ungraded MSWC which included plastic bags, cans, pipes and e-waste on soil properties and they examined that application of ungraded MSWC at 25 kg m⁻² recorded maximum concentration of nickel (3.1 mg kg⁻¹) (Table 1).

Shulan Zhao *et al.*, (2012) assessed the effect of different particle size fractions of municipal solid waste compost on physical and chemical properties of soil and they reported that application of MSWC having the particle size 0.8 -0.4 mm registered maximum nickel concentration of 2.50 mg kg⁻¹. Kiayee (2013) investigated the effect of Municipal Waste Leachate (MWL) on soil chemical properties and accumulation of heavy metals in soil by growing wheat as test crop and proved that application of 300 t ha⁻¹ of MWL had registered highest available Ni in soil (0.38 mg kg⁻¹). Garcia Gil *et al.*, (2004) concluded that application of MSWC at 80 t ha⁻¹ registered maximum accumulation of Ni (13 mg kg⁻¹) in soil.

The available cadmium status of the experimental soil was 0.78 mg kg⁻¹. At harvest stage, the lowest available Cd content was recorded in treatment which received 100% Rec. NK+ FMSWC with poultry manure 10% (9:1) at 5 t ha⁻¹ along with phosphorus application (100 kg ha⁻¹) (M₄P₁) (1.38 mg kg⁻¹) followed by 100% Rec. NK + FMSWC with SSP at 5 t ha⁻¹ along with phosphorus application (100 kg ha⁻¹) (M₇P₁) with the value of 1.32 mg kg⁻¹ as compared to other treatments with FMSWC at higher doses. The interaction effect between the main plot and sub plot treatments was not significant. As the MSWC is a bin of all the heavy metals, a part or fraction may be available in the soil (Table 1).

Albaladejo *et al.*, (2009) showed that application of ungraded MSWC at 25 kg m⁻² registered maximum cadmium concentration in soil (1.6 mg kg⁻¹). The present results are also in accordance with the findings of Cherifa *et al.*, (2009) who revealed that application of MSWC at 80 Mg ha⁻¹ registered maximum cadmium concentration in soil (2.98 mg kg⁻¹). Achiba *et al.*, (2009) showed that application of MSWC at 120 t ha⁻¹ recorded the maximum concentration of

Cd (2.8 mg kg^{-1}) in soil. Kiayee (2013) investigated the effect of Municipal Waste Leachate (MWL) on accumulation of heavy metals in soil by growing wheat as a test crop and proved that application of 300 t ha^{-1} of MSL had registered highest available Cd in soil (0.06 ppm).

Available heavy metal concentration in soil was lower at harvest stage of onion compared to that of harvest stage of okra. This may be due to the low mobility of metal ions that forms stable links with organic matter. Also, heavy metal accumulation in soil or plant depends on the type of soil, pH, plant species and rates of compost application.

At harvest stage, application of 100 % Rec. NK + MSWC with poultry manure 10% (9:1) at 5 t ha^{-1} (M_4P_1) recorded lowest available lead (4.48 mg kg^{-1}) which was on par with the treatment, 100% Rec. NK+ FMSWC with SSP at 5 t ha^{-1} (M_7P_1) with the value of 4.31 mg kg^{-1} as compared to other treatments with FMSWC at higher doses (Fig. 2). The treatment (M_0) which received no manure and fertilizer rendered lowest value of 0.65 mg kg^{-1} . The results revealed that the interaction effect between the main plot and sub plot treatments was not significant. Available lead content decreased from vegetative stage to harvest stage due to the continuous uptake of plant. This might be due to application of organic amendments that contribute to metal immobilization through formation of stable complexes with OH or COOH groups on the solid surfaces of the organic polymers (Table 2).

Convertini *et al.*, (2004) studied that application of MSWC at 100 kg ha^{-1} recorded the highest Pb content (50 mg kg^{-1}) in soil under two crop rotations *viz.*, tomato- durum wheat and sunflower-durum wheat. Zhang *et al.*, (2006) observed the effect of MSWC on soil nutrient dynamics and crop nutrient

uptake by using barley (*Hordeum vulgare L.*) - wheat (*Triticum aestivum L.*) - canola (*Brassica rapa*) as cropping sequence and found that application of MSWC at 200 t ha^{-1} registered highest available lead content of 21.6 mg kg^{-1} in soil. According to Businelli *et al.*, (2009) metal mobilization is not an immediate process, but it involves various equilibrium that control their adsorption and desorption. This behaviour depends on soil characteristics like pH, organic matter, soil texture and climatic conditions. Topcuoglu (2016) studied the effect of long-term municipal solid waste compost application on soil metal bioavailability by cultivating cucumber crop for three years and found that application of MSWC at 100 t ha^{-1} increased Pb concentration in soil from 42.1 to 82.0 mg kg^{-1} .

Application of 100% Rec. NK + FMSWC with PM 10% (9:1) at 5 t ha^{-1} (M_4P_1) recorded the lowest available nickel at harvest stages with the values of 1.24 mg kg^{-1} respectively, which were on par with 100% Rec. NK + FMSWC with SSP at 5 t ha^{-1} (M_7P_1) (1.07 mg kg^{-1}) as compared to other treatments with FMSWC at higher doses (Fig. 2). The lowest values were recorded in control (M_0P_0) (0.31 mg kg^{-1}). The results revealed that the interaction effect between the main plot and sub plot treatments was not significant (Table 2).

Convertini *et al.*, (2004) investigated that application of MSWC at 100 kg ha^{-1} recorded the highest Ni content of 40 mg kg^{-1} in soil under sunflower-durum wheat crop rotation. Zhang *et al.*, (2006) observed the effect of MSWC on soil nutrient dynamics and crop nutrient uptake by using barley (*Hordeum vulgare L.*) - wheat (*Triticum aestivum L.*) - canola (*Brassica rapa*) as cropping sequence and found that application of MSWC at 200 t ha^{-1} registered highest available nickel content of 16.4 mg kg^{-1} in soil. The present findings are in line with Topcuoglu (2016) who

studied the effect of long-term municipal solid waste compost applications on heavy metal availability by using cucumber as a test crop for three consecutive years and found that application of MSWC at 100 t ha⁻¹ increased Ni concentrations from 15.9 to 30.0 mg kg⁻¹ in soil.

At harvest stage, the lowest content of available cadmium was recorded in the treatment with application of 100% Rec. NK + FMSWC with poultry manure 10% (9:1) at 10 t ha⁻¹ (M₄P₁) (0.75 mg kg⁻¹) as compared to other treatments with FMSWC at higher doses. The lowest value was recorded in control (M₀P₀) (0.12 mg kg⁻¹) (Fig. 2). The interaction

effect between the main plot and sub plot treatments was not significant. This might be due to alkaline pH of the soil that contributes to a decrease of heavy metal mobility by the formation of precipitates, by increasing the number of adsorption sites and decreasing the competition of H⁺ for adsorption and thereby increasing the metal stability with humic substances (Pigozzo *et al.*, 2006). Similar findings were reported by Convertini *et al.*, (2004) who observed that application of MSWC at 100 kg ha⁻¹ recorded the highest Cd content of 5.5 mg kg⁻¹ in soil under sunflower - durum wheat grown as crop rotation (Table 2).

Table.1 Effect of fortified municipal solid waste compost on available heavy metal content (mg kg⁻¹) in soil at harvest stages of okra

Treatments	Pb			Ni			Cd		
	P ₀	P ₁	Mean	P ₀	P ₁	Mean	P ₀	P ₁	Mean
M ₀	2.10	2.10	2.10	0.70	0.90	0.80	0.35	0.45	0.40
M ₁	2.09	2.09	2.09	0.90	0.96	0.93	0.52	0.53	0.53
M ₂	2.49	2.49	2.49	1.10	1.13	1.12	0.64	0.82	0.73
M ₃	3.60	3.60	3.60	3.32	3.49	3.41	0.78	0.89	0.84
M ₄	4.57	4.57	4.57	3.43	3.57	3.48	1.34	1.38	1.36
M ₅	7.50	7.50	7.50	4.54	4.57	4.56	2.40	2.35	2.37
M ₆	10.6	10.6	10.6	6.82	7.14	6.99	4.41	4.61	4.50
M ₇	4.64	4.64	4.64	3.21	3.48	3.36	1.21	1.32	1.27
M ₈	7.69	7.69	7.69	4.70	4.76	4.72	2.02	2.08	2.05
M ₉	10.5	10.5	10.5	6.91	6.97	6.94	4.12	4.22	4.17
Mean	5.58	5.57		3.56	3.69		1.78	1.85	
	SEd	CD (p=0.05)		SEd	CD (p=0.05)		SEd	CD (p=0.05)	
Main plot (M)	0.44	0.90		0.31	0.65		0.01	0.03	
Subplot (P)	0.25	NS		0.13	NS		0.03	NS	
M at P	0.73	NS		0.43	NS		0.03	NS	
P at M	0.81	NS		0.42	NS		0.03	NS	

Table.2 Effect of fortified municipal solid waste compost on available heavy metal content (mg kg⁻¹) in soil at harvest stage of onion

Treatments	Pb			Ni			Cd		
	P ₀	P ₁	Mean	P ₀	P ₁	Mean	P ₀	P ₁	Mean
M ₀	0.65	0.67	0.66	0.31	0.37	0.34	0.12	0.19	0.16
M ₁	0.58	0.53	0.56	0.32	0.45	0.39	0.21	0.32	0.27
M ₂	0.78	0.88	0.83	0.42	0.47	0.45	0.37	0.38	0.38
M ₃	0.98	1.36	1.17	1.03	1.01	1.02	0.51	0.51	0.51
M ₄	1.13	2.34	1.74	1.12	1.24	1.18	0.67	0.75	0.71
M ₅	4.19	4.24	4.22	1.75	2.19	1.97	0.77	0.76	0.77
M ₆	6.08	6.98	6.53	3.44	3.53	3.49	2.46	2.72	2.59
M ₇	1.45	1.44	1.45	0.98	1.07	1.03	0.34	0.53	0.44
M ₈	3.72	3.93	3.83	1.76	2.11	1.94	0.63	0.67	0.65
M ₉	5.68	5.76	5.72	3.64	3.79	3.72	2.14	2.20	2.17
Mean	2.52	2.81		1.48	1.62		0.82	0.90	
	SEd	CD (P= 0.05)		SEd	CD (P= 0.05)		SEd	CD (P= 0.05)	
Main plot (M)	0.16	0.70		0.08	0.37		0.12	0.53	
Subplot (P)	0.33	NS		0.24	NS		0.24	NS	
M at P	0.47	NS		0.33	NS		0.34	NS	
P at M	0.46	NS		0.34	NS		0.34	NS	

Fig.1 Effect of FMSWC on available heavy metal concentration in soil at harvest stage of okra

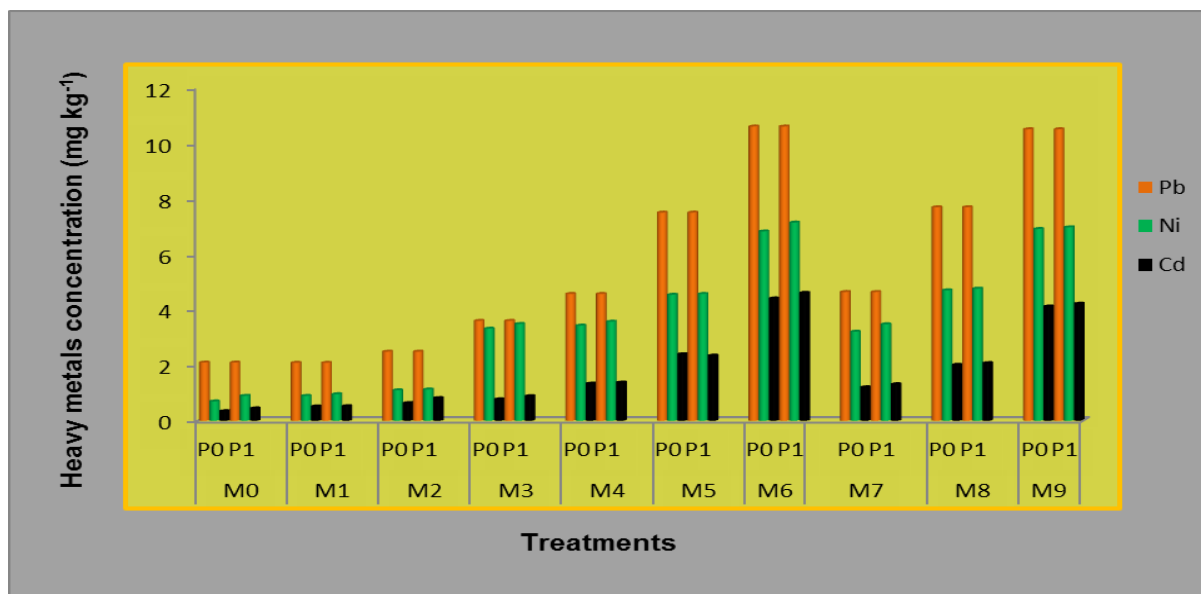
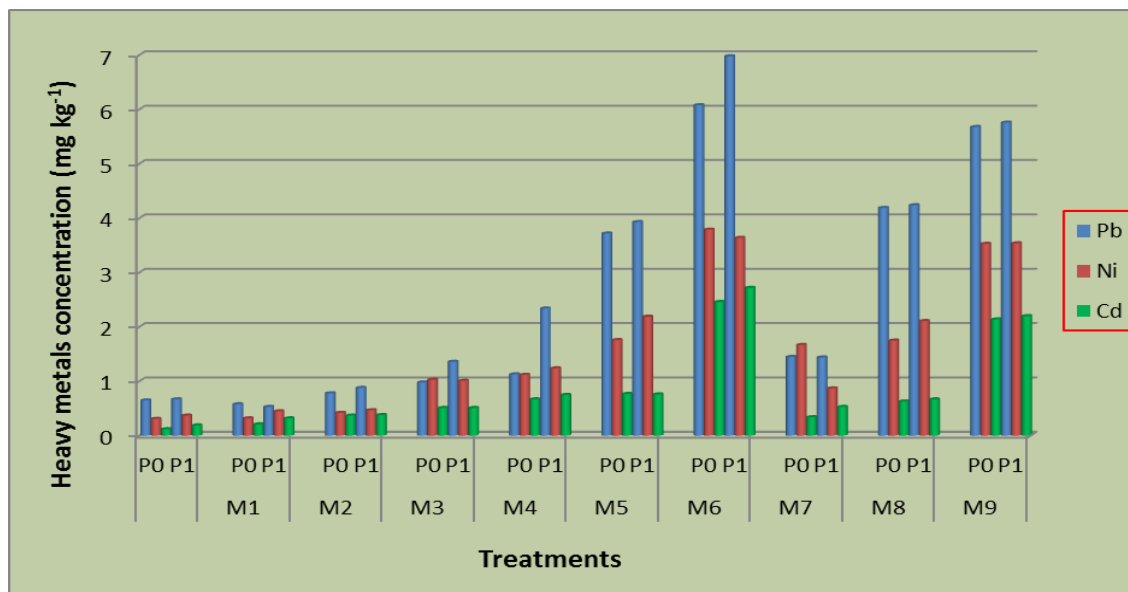


Fig.2 Effect of FMSWC on available heavy metal concentration in soil at harvest stage of onion



The present results are in line with the findings of Zhang *et al.*, (2006) who observed that application of MSWC at 200 t ha⁻¹ registered highest available cadmium 0.4 mg kg⁻¹ content in soil under barley (*Hordeum vulgare L.*) - wheat (*Triticum aestivum L.*) - canola (*Brassica rapa*) cropping sequence. Topcuoglu (2016) also reported the effect of long-term municipal solid waste compost applications on heavy metal availability in cucumber as a test crop for three consecutive years and found that application of MSWC at 100 t ha⁻¹ increased Ni concentration from 0.02 to 40.0 mg kg⁻¹ in soil.

In conclusion, heavy metals concentration in soil was below the permissible limit as prescribed by Indian Standards (2013) and World Health Organization (2007). Hence, MSWC can be effectively utilized as an alternative source of organic manure in the place of FYM along with 100 % recommended dose of fertilizers to obtain maximum fruit yield of okra and bulb yield of onion without environmental pollution.

Abbreviations: MSWC - Municipal Solid Waste Compost, Pb - Lead, Ni- Nickel, Cd- Cadmium and SSP- Single Super Phosphate .

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