



Land application of municipal compost in mountain ecosystem: Effects on growth, biomass and heavy metal uptake by vegetable crops

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Abstract

Disposal of municipal composts to agriculture can provide essential nutrients to the plants, whereas a rapid increase in human activities has contaminated municipal composts with many toxic heavy metals such as Cd, Pb, Ni, Hg, etc. Therefore, the present study was designed to assess the effects of municipal compost amended soil on growth performance and heavy metals (Cu, Zn, Cd, and Pb) accumulation especially in the edible parts of vegetable (bean; *Phaseolus vulgaris* L., palak; *Spinacia oleracea* L.) crops under mountain ecosystem. The tested vegetables were grown in soil amended with municipal composts produced in Kullu valley of Himachal Pradesh, India as 0%, 20%, 40%, and 60%. The results showed that Cu, Zn, Cd, and Pb concentrations in edible parts of both bean and spinach increased significantly ($p < 0.05$) with increasing application rates of municipal composts in soil. The accumulation of Cd and Pb was found higher in spinach as compared to the bean. A similar and an opposite trend were also recorded for Cu and Zn. The concentrations of all the heavy metals in both the tested crops grown on soil amended with municipal compost had exceeded their safe limit as described under PFA acts 1954. The results further showed that growth of both the bean and spinach measured in terms of numbers of leaves, heights, dry weight, and yield were found to be increased significantly with the increasing application rate of municipal compost. From the present study, it can be concluded that the application of municipal composts can improve crop yield but may not be a suitable option for disposal in mountain agriculture as it poses a serious risk to the safety of vegetable crops. The present study further suggests that the lower application rate i.e., <20% of municipal compost should be tested for agricultural use in the future.

Keywords: municipal composts, heavy metals, vegetables, mountain ecosystem, pot assay

Introduction

Rapid industrialization and urbanization have led to the addition of chemicals and harmful metals such as Cd, Zn, Cu, Pb, etc., into the environment which ultimately causes environmental pollution (Ghosh *et al.*, 2013) [15]. Besides that, the unprecedented increase in municipal solid waste generated, such as increasing use of plastic packaging with approximately 6000 tonnes per day in Southeast Asian countries, is due to the outbreak of the novel coronavirus disease in 2019, followed by the emergency lockdown and stay at home policy imposed in most countries by Haque *et al.* (2020) [19] and could be significantly more difficult, particularly in countries with poor municipal solid waste management (Sarkodie and Owusu 2020) [40]. Municipal solid waste generation is expected to reach 1.42 kg/capita/day by 2025 studied by Hoornweg and Bhada-Tata (2012) [20] and 2.6 billion metric tonnes by 2030 (Statista 2020) [47]. Due to the possibility of recycling important nutrients like organic matter, nitrogen, phosphorus, and other nutrients from solid wastes, there is an increase in the trend of using such wastes in agriculture. Solid waste composts are widely used in suburban agriculture and their repeated uses to increase the heavy metal

concentration in soil and consequently in the food chain (Singh and Agrawal, 2007, 2008, 2010) [44, 45, 43]. Municipal solid waste compost (MC) is prepared from the treatment of households, green wastes from gardens, industrial waste, hospital wastes, etc. MC when used in agricultural practices increases the soil fertility, microfauna, and heavy metal concentration in the soil (Singh and Agrawal, 2007; Carbonell *et al.*, 2011; Tafesse and Leta, 2019) [44, 8, 48]. The texture of the raw materials, particle size, kind of inoculum, moisture content, temperature, pH, aeration period, and heat insulation are all factors that influence the compost's features (Amaladoss *et al.*, 2020; Zhu *et al.*, 2021) [5, 54].

MC enhances the properties of soil like air circulation, water penetration, water retention, and soil porosity and also reduces the mobility of the heavy metal, etc. (Weber *et al.*, 2007; Jilani and Rashid, 2019; Zhao *et al.*, 2021) [50, 22, 53]. Tafesse and Leta (2019) [48] reported an increase in the yield of potato tubers grown in soil amended with MC. Heavy metals like Cd, Mn, Ni, Co, Pb, Zn, etc., have been reported in MC, and amended soil can be easily transferred to the food chain (Costa *et al.*, 1994; Mbarki *et al.*, 2008; Mohee and Soobhany, 2014; Fang *et al.*, 2016) [12, 27, 32, 14]. Long-term exposure of humans being

to Cd can affect the reproductive system, renal function, bone metabolism, and Pb inhibit the synthesis of hemoglobin, dysfunction of joints, cardiovascular, renal, and reproductive systems (Duruibe *et al.*, 2007) [13]. Arsenic toxicity affects the cardiovascular system and causes hypertension. Mg even in a very small amount causes insomnia, headache, affects kidneys and thyroid and high exposure to Hg causes even death (Chouhan *et al.*, 2015) [10]. At the current moment, the positive and negative impacts of MC on health, as well as the disposal activities that occur, are only poorly recognized. Positive characteristics of MC include its use as an energy source through the gasification process (Yang *et al.*, 2021) [51]. To limit municipal solid waste output, a major technological circular economy and sustainable development are required to slow the rate of resource depletion and develop alternative ways to meet future needs in many science and technology fields (Zhang *et al.*, 2022) [52].

There is scarce evidence on the effects of MC application on growth performance and heavy metal accumulation in vegetables grown under the mountain ecosystems. Therefore, the present study was carried out to assess the effects of different doses of MC amendments on growth performance, yield, and heavy metal accumulation in bean (*Phaseolus vulgaris* L.) and spinach (*Spinacia oleracea* L.) crops under mountain ecosystem.

Materials and Methods

Study area

The present study was carried out at nursery premises of G.B. Pant National Institute of Himalayan Environment, Himachal Regional Centre, Kullu, Himachal Pradesh (Latitude 31° 51. 941', longitude 077° 07. 565' and altitude 1132 m above sea level) during October 2017 to February 2018. The experimental period is characterized by cold and chilly weather with snowfall. The study site was adjacent to the national highway having medium to high vehicular traffic throughout the year. The Physico-chemical properties of the soil are given (Table 1).

Plant materials and experimental design

In the present study, two vegetable crops namely French bean (*Phaseolus vulgaris* L.) and spinach (*Spinacia oleracea* L.) were selected as they are frequently grown in the study areas for commercial and consumption purposes. Spinach is also an annual plant, green leafy vegetable and consumed to meet out the demand of Fe requirement. Tom *et al.* (2014) [49] and Alia *et al.* (2015) [2] reported that French bean and spinach respectively can accumulate high concentrations of heavy metals. Seeds of both the French bean and spinach were procured from the local seed store of Kullu Valley, Himachal Pradesh.

The experimental soil was collected from an agricultural/farmer's field and was mixed with a recommended dose of NPK and farmyard manure. Municipal solid waste composts (MSWC) used in the present study were obtained from Municipal Corporation, Kullu, Himachal Pradesh. The selected Physico-chemical properties of experimental soil and MSWC are given in Table 1. The prepared soil was separated into four group's i.e. T₀, T₁, T₂,

and T₃, the respective group was amended with MSWC @ 0%, 20%, 40%, and 60% respectively Ten earthen pots from each group soil were filled up and kept randomly under ambient condition for the stabilization. Two sets of four treatments were prepared, one for *P. vulgaris* and another for *S. oleracea*. Ten healthy seeds of each plant, *P. vulgaris*, and *S. oleracea* were sown at 2cm depth in five pots at equal distance in respective pots. After the seed germination, pots were regularly weeded and watered as and when required for maintaining the soil moisture during the whole period of the experiment.

Table 1: Selected Physico-chemical characteristics of soil and MC used in the present study

Properties		Garden soil	Municipal composts	Indian limits ^a
pH	Soil: Water	7.64±0.01	7.75±0.01	-
EC	mS cm ⁻¹	261±0.06	621±0.33	-
Organic carbon	%	0.56 ± 0.00	2.90 ± 0.02	-
Available P	mg/g dw	0.98 ± 0.00	1.42 ± 0.01	-
Na	mg/kg dw	180±0.03	146.67±1.76	-
K	mg/kg dw	3811±2.08	2808±1.33	-
Ca	mg/kg dw	600±0.33	709±0.01	-
Cu	mg/kg dw	0.83±0.42	148.63±0.72	135-270
Zn	mg/kg dw	6.33±0.22	113.12±0.30	300-600
Cd	mg/kg dw	1.33±0.08	2.00±0.14	3-6
Pb	mg/kg dw	7.43±0.09	86.17±1.17	250-500

Values are mean ± 1S.E. of three replicates. ^aAwasthi, 2000

Soil sampling and analysis

100g of soil samples from each treatment were collected in triplicates in polythene bags. The samples were brought back to the laboratory, air dried, crushed, and passed through a 2mm mesh size sieve, and were stored at room temperature for further analysis. The pH of soil and MSWC was measured in the suspension of soil and water in a 1:5 ratio (w/v) using a glass electrode attached to an ion analyzer (Eutech, 700). Standardization of pH meter was conducted by using buffer solution of pH4, 7, and 9.2. Electrical conductivity was measured in the same suspension using a conductivity meter (Eutech, 700). Nitrate nitrogen (NO₃-N) was estimated by the NO₃-N electrode with the help of the ion analyzer (WTW, pH/ion 340 i). Organic carbon (OC) content in the samples was determined by using a modified method of Walkley and Black's rapid titration (Allison 1986) [3]. The total nitrogen (TN) content was determined using the micro-Kjeldahl technique through the Gerhardt automatic analyzer (model KB8S, Kjeldatherm, Germany). The available P was extracted in sodium bicarbonate (NaHCO₃), and the content was quantified as per the method given by Olsen and Sommers (1982) [35]. Exchangeable bases (Na⁺, K⁺, and Ca²⁺) were extracted using a repeated leaching technique as described by Jackson (1958) [21] and were then determined infiltrates by using atomic absorption Spectrophotometry (model 2380, Perkin-Elmer, Inc., Norwalk, Conn.).

Plant sampling and analysis

For the determination of growth parameters, biomass, and yield of the test plants, French bean, and spinach, five plants

were randomly collected from each respective treatment at the time of maturity. The harvested plant samples were brought to the laboratory and washed carefully with the tap water for removing the adhered soil and dust particles. For the analysis of growth parameters, number of leaves, number of pods, and number of root nodules, root length, shoot length, pod length, and total length of the plant were measured manually. For biomass determination, plants were separated into roots and shoots and oven-dried at 80 °C till constant weight was obtained. Then the plant parts were separately weighed and biomass was calculated. For the total biomass of the plant, dry weights of root, stem, and leaves were added and were expressed as g plant⁻¹. The yield of both test plants was calculated as the fresh weight of shoot (spinach) and pods (French bean) per plant at the time of harvesting and also expressed as g plant^[1].

Heavy metal analysis in soil and plants

For heavy metal analysis, edible parts of French bean and spinach, the pods, and shoot, respectively were plucked from each respective treatment at maturity. Samples were collected in pre-washed polyethylene bags, brought to the laboratory washed with running tap water and processed. Edible portions of tested plants were chopped into small pieces by using a stainless-steel knife and were then oven-dried at 80°C till constant weight. The oven-dried samples were powdered or crushed using stainless steel blender and passed through a 2mm size sieve and stored at room temperature for the further analysis of heavy metals.

For digestion, 1g of dry powder of plant and soil were taken into 100ml beaker separately and 15ml of the tri-acid mixture (HNO₃: HClO₄: H₂SO₄ in 5:1:1 ratios) was added to the beaker. The mixture was then digested at 80°C on a hotplate till the solution became transparent or colorless (Allen *et al.*, 1986)^[4]. The digested samples were then filtered and the final volume was maintained to 25 ml using double distilled water. The filtrates were analyzed for concentrations of Cu, Zn, Cd, and Pb using an atomic absorption spectrophotometer (Model Analyst 800, Perkin-Elmer) fitted with a specific lamp of a particular metal. The measurements were made using a hollow cathode lamp of Cu, Zn, Cd, and Pb at wavelengths of 324.8, 213.9, 288.8, and 213.3nm respectively. The values of the detection limits for Cu, Zn, Cd, and Pb were 0.001, 0.008, 0.005, and 0.01 µg/ ml respectively. Standard solutions were frequently run to check the sensitivity of the instrument. Quality assurance and precautionary measures were also taken into consideration to avoid errors in methodology.

Transfer factor

To understand the mobility of heavy metals from soil to edible parts of tested plants under different levels of MC amendments, transfer factor (TF) was calculated using the following formula:

$$TF = \frac{\text{Concentration of metal in edible part of vegetable}}{\text{Concentration of metal in soil}}$$

Results and Discussion

Physico-chemical properties of soil and MC

The results of the physicochemical properties and heavy metal content in soil/MC and soil amended with MC are given in Tables 1 and 2, respectively.

The concentrations of heavy metals in locally produced municipal composts in Kullu valley were found higher than in the agricultural soil. Pb concentration in MC had exceeded the safe limit set for the agricultural soil (Awasthi 2000)^[7]. The results further showed that the application of MC had increased the pH, EC, nutrient (NPK), exchangeable Na, K, Ca, and heavy metal content in agricultural soil significantly (Table 2).

The increase in pH of amended soil may be ascribed to the formation of ammonia due to the decomposition of organic matter (Preethu *et al.*, 2007; Peyvast *et al.*, 2008)^[38, 37]. EC in the soil increases with the increasing application rate of MC in soil which varied from 217 mS/cm to 397 mS/cm (Table 2). Similar results were also reported by many researchers (Mishra *et al.*, 2005; Sharma *et al.*, 2008; Mishra *et al.*, 2009; Singh and Agrawal, 2010)^[28, 42, 30, 43]. The unamended soil had lower OC content than that those amended with MC (1.15% - 2.98%). Singh and Agrawal (2010)^[43] and Arthur *et al.* (2019)^[6] also found similar results i.e., increasing in the OC content in the soil with an increase of application of organic composts. Total N and P content in soil were found to increase from 2% to 4.98% and 20.44 mg/kg dw to 37.86 mg/kg dw, respectively with increasing application rates of MC (Singh and Agrawal, 2007; Kolodziej *et al.*, 2015; Sharma *et al.*, 2018)^[44, 25, 41]. An increase in the total N content in soil was ascribed to the amendment of organic composts as it contains high amounts of nutrients, organic carbon, inorganic nitrogen, and phosphorous (Liu *et al.*, 2017)^[26]. Mkhabela and Warman (2005)^[31] showed that the MC compost amended soil had higher total P content in the second year than in soil amended with fertilizers and a mixture of fertilizers. An increase in soil phosphorous solubility by the addition of urban waste compost in soil was also reported by Giusquiani *et al.* (1988)^[18].

In the present study, the mean concentration of available N and P were found to be increased with the increasing the concentration of municipal compost in soil which ranged between 14.28 mg/kg to 25.68 mg/kg and 0.18 mg/kg- 1.49 mg/kg, respectively (Table 2).

A Similar trend of available N and P content was also reported in the earlier studies (Mishra *et al.*, 2005; Singh and Agrawal, 2007; Giannakis *et al.*, 2015; Sharma *et al.*, 2018; Arthur *et al.*, 2019)^[28, 44, 17, 41, 6]. Exchangeable Na, K, and Ca content (mg/kg dw) were also found to be increased with the increasing MC amendment rate in soil and ranged between 113.25 - 173.66, 3025 - 4180, and 886.66-1160, respectively. Singh and Agrawal (2007 and 2010)^[44, 43] showed that the content of these ions increased with the increasing MC in soil. Ca content in soil affects the solubility of heavy metals by precipitating and forming insoluble heavy metal compounds (Khalid 1980)^[23].

Table 2: Selected Physico-chemical properties of soil amended with different doses of MC collected from Municipal Council, Kullu valley, north-western Indian Himalaya

Soil properties	MC (%)			
	0	20	40	60
pH (Soil: Water)	7.53 ^b ± 0.06	7.73 ^b ± 0.16	7.54 ^a ± 0.03	7.98 ^a ± 0.03
EC (mS cm ⁻¹)	217.08 ^d ± 0.02	221.90 ^c ± 0.23	289.82 ^b ± 0.17	397.75 ^a ± 0.18
Organic carbon (%)	1.15 ^d ± 0.51	1.97 ^c ± 0.05	2.28 ^b ± 1.03	2.98 ^a ± 0.54
Total N (mg/g dw)	2.08 ^d ± 0.35	3.33 ^c ± 0.11	3.81 ^b ± 0.05	4.88 ^a ± 0.98
Available N (mg/g dw)	14.24 ^d ± 0.10	20.24 ^c ± 0.05	21.60 ^b ± 0.14	25.58 ^a ± 0.85
Total P (mg/g dw)	20.49 ^d ± 0.05	28.58 ^c ± 0.94	34.66 ^b ± 0.13	37.52 ^a ± 0.16
Available P	0.19 ^c ± 0.02	1.20 ^b ± 0.02	1.44 ^a ± 0.04	1.53 ^a ± 0.09
Ex. Na (mg/g dw)	113.44 ^d ± 0.10	146.46 ^c ± 0.14	158.47 ^b ± 0.08	173.60 ^a ± 0.04
Ex. K (mg/g dw)	3026 ^d ± 0.22	3553.5 ^c ± 0.13	3577.5 ^b ± 0.13	4180 ^a ± 0.44
Ex. Ca (mg/g dw)	886.45 ^d ± 1.08	911.68 ^c ± 0.05	1021.6 ^b ± 0.09	1160.6 ^a ± 0.09
Cu (mg/g dw)	73.28 ^d ± 0.88	114.68 ^c ± 0.41	138.40 ^b ± 0.38	186.33 ^a ± 0.52
Zn (mg/g dw)	85.79 ^d ± 1.53	156.45 ^c ± 0.58	187.85 ^b ± 0.41	215.90 ^a ± 0.34
Cd (mg/g dw)	15.32 ^c ± 0.21	34.45 ^b ± 0.47	45.45 ^b ± 0.19	47.89 ^b ± 0.43
Pb (mg/g dw)	9.28 ^d ± 0.20	31.84 ^c ± 0.20	64.35 ^a ± 0.58	74.45 ^a ± 0.35

Values are mean ± SE of three replicates.

Values within a column adhered with different alphabets are statistically different at P<0.05 (Duncan's Multiple Range Test)

Table 3: Effects of soil amended with different doses of MC on number of leaves, height, biomass and yield attributes of *S. oleracea* and *P. vulgaris* under mountain ecosystem

Vegetables/ Characteristics	MC (%)			
	0	20	40	60
<i>S. oleracea</i>				
No. of leaves (per plant)	5.1 ^d ± 0.16	7.18 ^c ± 0.15	9.04 ^b ± 0.14	16.30 ^a ± 0.83
Plant height (cm/plant)	13.6 ^d ± 0.31	17.83 ^c ± 0.11	21.76 ^b ± 0.13	26.00 ^a ± 0.24
Total plant biomass (g/plant)	0.13 ^d ± 0.02	0.24 ^c ± 0.01	0.96 ^b ± 0.03	1.11 ^a ± 0.04
<i>P. vulgaris</i>				
No. of leaves (per plant)	14.0 ^d ± 0.21	18.07 ^c ± 0.11	24.07 ^b ± 0.17	34.01 ^a ± 0.15
Total plant height (cm/plants)	50.8 ^d ± 0.78	70.51 ^c ± 0.29	76.60 ^b ± 1.01	82.056 ^a ± 1.02
Total plant biomass	2.7 ^d ± 0.09	3.62 ^c ± 0.10	7.09 ^b ± 0.09	7.75 ^a ± 0.14
No. of pods (per plant)	40.9 ^d ± 0.14	46.10 ^c ± 0.22	75.65 ^b ± 0.14	85.78 ^a ± 0.13
Pod length (per plant)	9.16 ^d ± 0.77	10.72 ^c ± 0.19	11.27 ^b ± 0.15	12.02 ^a ± 0.16
Pod fw (g/plant)	7.13 ^d ± 0.11	11.05 ^c ± 0.11	25.09 ^b ± 0.22	28.12 ^b ± 0.20
Pod dw (g/plant)	0.81 ^b ± 0.04	1.13 ^b ± 0.15	2.14 ^a ± 0.12	2.28 ^a ± 0.16

Values are mean ± SE of three replicates. Values within a column adhered with different alphabets are statistically different at P<0.05 (Duncan's Multiple Range Test)

Growth performance of crops

The growth parameters of both the vegetables i.e., bean and spinach crops grown in soil amended with MC and unamended soils under the mountain ecosystem are given in (Tables 3). The growth of bean and spinach were found healthy i.e., no visible injury and infections were observed. Growth performance assessed in terms of numbers of leaves, length of root, shoot, total plant in both bean and spinach were found to be increased significantly (p<0.05) with the increase in the amount of MC application rate in soil. Numbers of

leaves in both the test plants, number of nodules, and pod characteristics such as number of pods, pod length, fresh and dry weight of pods in bean were also found to be increased significantly (p<0.05) with an increase of MC application rate in soil (Table 3).

Table 4: Results of two-way ANOVA test for selected parameters of *P. vulgaris* and *S. oleracea* grown in soil amended with different levels of MC under mountain ecosystem

Parameters	Vegetables	Treatment	Vegetables × Treatments
df	1	3	3
Number of leaves	1314 ^{***}	347.8 ^{***}	302.46 ^{**} *
Total plant biomass	511.6 ^{***}	528.48 ^{***}	233.25 ^{***}
Cu	1487 ^{***}	1183 ^{***}	122.9 ^{***}
Zn	118.9 ^{***}	870.41 ^{***}	50.98 ^{***}
Cd	179.6 ^{***}	199.2 ^{***}	146.39 ^{***}
Pb	212.5 ^{***}	269.0 ^{***}	118.22 ^{**}

Level of significance: *** = p<0.001; ** = p<0.01; * = p<0.05; ns = not significant

This increase in growth parameters might be because of the properties of MC as it is rich in plant nutrients and organic matters.

Mishra *et al.* (2005) [28] have shown that rice crops grown in MC amended soil elevates many of its growth parameters. Soil fertility is increased by using MC in addition to chemical fertilizers as it provides Ca, K, S and other nutrients in the soil (Christodoulous and Margarita, 1996; Aktar *et al.*, 2018) [11, 1]. Mishra *et al.* (2007) [29] showed that the addition of MC @ 200 kg/ha results in increased growth and yield of wheat crops.

The result of two-way ANOVA analysis also showed that the growth parameters like number of leaves, root and shoot fresh weight and dry weight, plant fresh and dry weight were significantly affected by both vegetable type and treatment of MC and their interactions (Table 4).

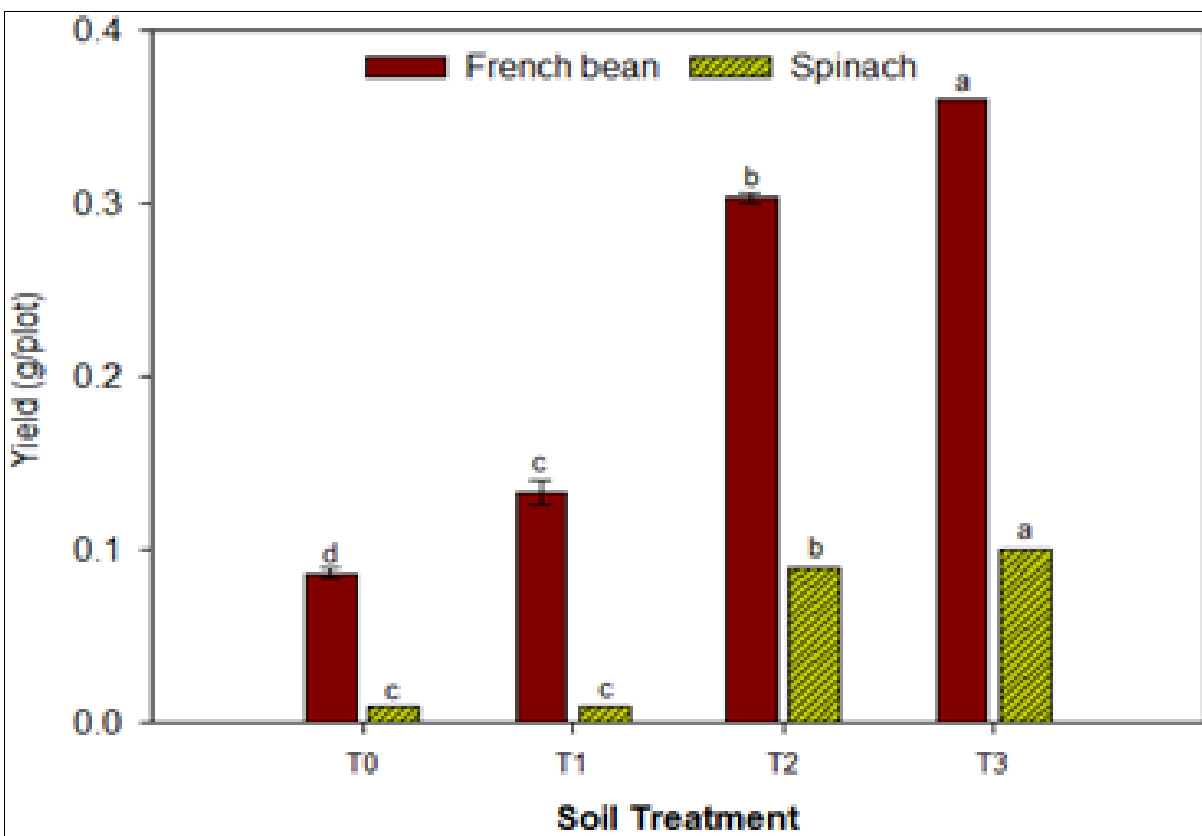


Fig 1: Economic yield of *P. vulgaris* and *S. oleracea* crops grown in soil amended with different doses of MC under mountain ecosystem. Bars are the mean \pm SE of three replicates. Bars adhered with different alphabets are statically significant at $p < 0.05$ (Duncan's Multiple Range Test), $T_0 = 0\%$, $T_1 = 20\%$, $T_2 = 40\%$ and $T_3 = 60\%$

Yield i.e., fresh weight of edible parts of bean and spinach (pod and shoot, respectively) was found to be increased significantly with the increasing the application rate of MC in soil (Fig. 1). The yield of both the test crops did not show much rise in plants grown in soil amended with 20% of MC as compared to those unamended soil. The increase in yield of beans in plants grown in soil amended with 20% MC showed an increase of 44% over unamended soil. On the other hand, no significant increase in the yield of spinach was observed (Fig. 1). Major rise in the yield of bean and spinach (800% and 233%, respectively) were seen in soil amended with 60% MC. The increase in yield of the test plants was due to the overall positive effects of MC on the soil properties (Murtaza *et al.*, 2019; Tafesse and Leta, 2019) [34, 48]. Ozores-Hampton *et al.* (1994) [36] showed that the growth and yield of squash and tomato plants were increased due to the MC application. Singh and Agrawal (2010) [43] also reported that there was an increase in the yield of rice with an increase in the amount of sewage sludge in the soil. Mishra *et al.* (2005) [28] showed that the yield of the rice crop was higher in MC amended soil as compared to control fields. The highest increase in the yield of both crops was seen in the soil amended with 60% MC. Other studies have also reported that anaerobically decomposed MC significantly increased the growth of wheat and rice plants (Murtaza *et al.*, 2019) [34].

Heavy metal concentration in MC amended soil

The concentration of Cu, Zn, Cd, and Pb in soil amended with MC and unamended soil is given in Table 2. The results showed that the concentrations of all the heavy metals in soil

were found to increase with the increase in the concentration of MC application rate. When the obtained values were compared with the National and International standards for heavy metal in soil, the concentration of Cu in soil exceeded the permissible limits in soil amended with MC @ 60%. The concentration of heavy metals in different parts of plants grown on soil contaminated with heavy metals due to long-term use of wastewater, municipal compost, sewage sludge was reported in the literature (Singh and Agrawal, 2007, 2010; Sandeep *et al.*, 2019; Khan *et al.*, 2020) [44, 43, 39, 24].

The concentrations of Zn and Pb in all the amended and unamended soil were found below the permissible limits of both the National and International standards.

While the concentration of Cd was found above the permissible limit set by National and International standards in all the soil either treated with MC or untreated (Table 2). Singh and Agrawal (2007) [44] reported that the concentration of heavy metals was higher in soil amended with sewage sludge than in unamended soil, the concentration of Cu, Zn, and Cd was higher in the soil amended with 40% of sewage sludge and concentration of Pb was higher even in soil amended with 20% of sewage sludge amendment.

A study by Carbonell *et al.* (2011) [8] from Spain found that the amendment of municipal solid waste compost increased the concentration of Cu, Zn, Cd, and Pb in soil. Heavy metal concentration in the soil also increased due to the amendment of MC (Cherif *et al.*, 2009) [9].

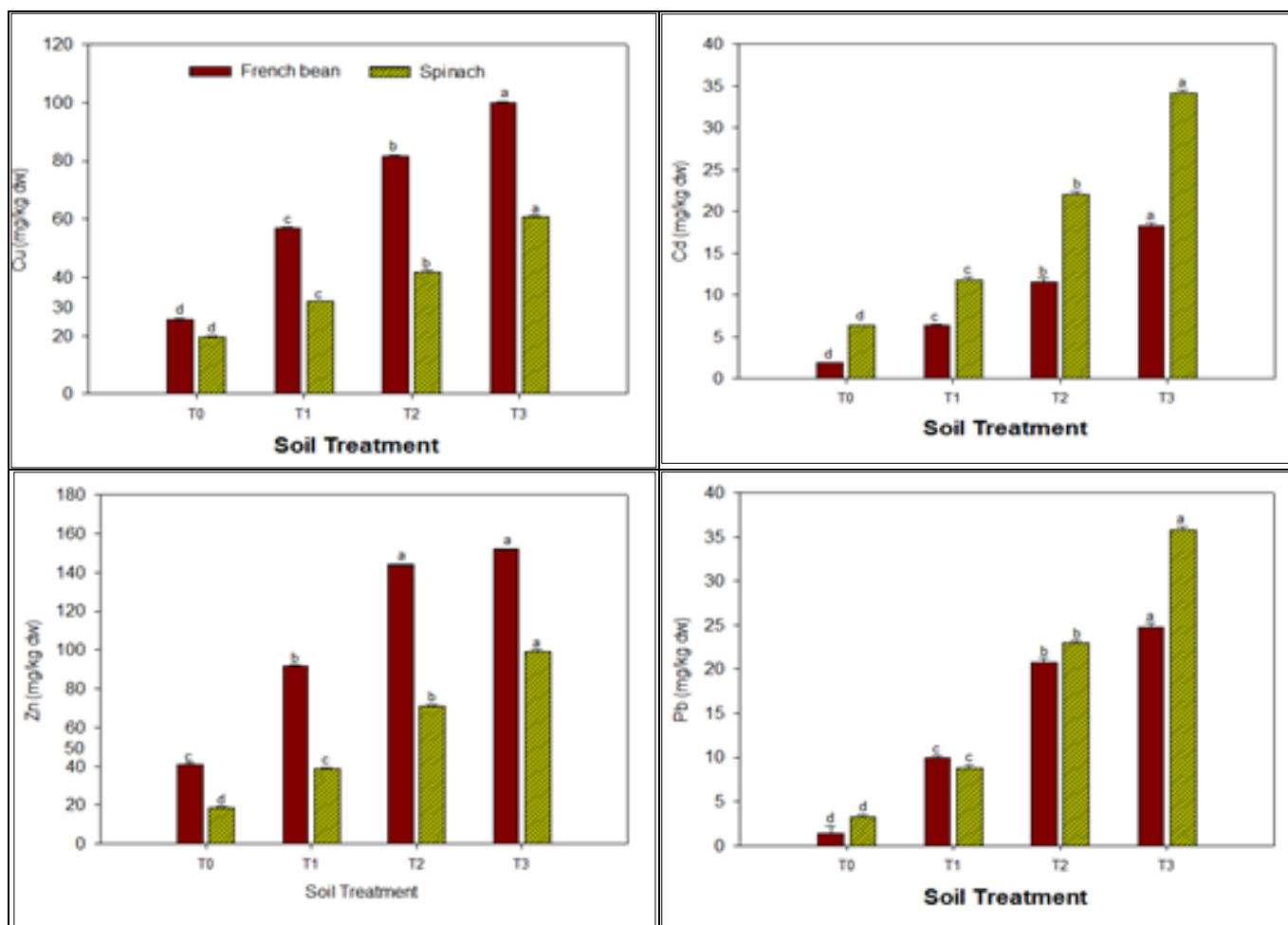


Fig 2: Heavy metal accumulation in edible parts of *P. vulgaris* and *S. oleracea* crops grown in soil amended with different doses of MC under mountain ecosystem. Bars are the mean \pm SE of three replicates. Bar adhered with different alphabets is statically significant at $p < 0.05$ (Duncan's Multiple Range Test). T₀ = 0%, T₁ = 20%, T₂ = 40% and T₃ = 60%

Heavy metal concentration in edible parts of tested crops

The concentration of heavy metal in edible parts of the bean (pods) and spinach (shoots) grown in soil amended with different concentrations of MC are shown in Fig. 2. The results showed that Cu and Zn tend to accumulate more in beans whereas Cd and Pb tend to accumulate more in spinach. The results further showed that the concentration of all the heavy metals in edible parts of the test vegetables increased significantly with increasing the application rate MC. The maximum concentration of Cu, Zn, Cd and Pb were found in edible parts of vegetables grown in soil amended with MC @ 60% i.e., 100.3 mg/kg dw, 155 mg/kg dw, 18.4 mg/kg dw and 25.2 mg/kg dw in bean and 61.3 mg/kg dw, 100.5 mg/kg dw, 34.2 mg/kg and 36.4 mg/kg dw in spinach, respectively (Fig.2). Heavy metals concentration was higher in municipal solid waste composts as compared to the soil which further increases their concentration in soil (Smith 2009) [46]. The concentration of Cu, Zn, Cd, and Pb gradually increased in seeds of mungbean with the increase in the concentration of sewage sludge in soil (Singh *et al.*, 2010; Carbonell *et al.*,

2011; Giannakis *et al.*, 2014) [43, 8, 16]. Cu concentration in fresh vegetables grown in soil amended with wastewater and sewage sludge exceeded the permissible standards and accumulated maximum to minimum in order as root > leaves > cobs > spathes > shoots > grains of maize plants (Muchuweti *et al.*, 2006; Carbonell *et al.*, 2011) [33, 8]. The result of two-way ANOVA showed that the concentration of Cu, Zn, Cd, and Pb were significantly affected by vegetable types, treatments, and interaction of vegetable types and treatment (Table 4).

Health risk associated with heavy metal accumulation in vegetables

When the concentration of Cu, Zn, Cd, and Pb in edible parts of tested vegetables were compared with permissible limits set by different agencies, except control and Zn in leaves of spinach grown on soil amended with 20% MC, the concentration of all the heavy metal in French bean and spinach grown in the municipal solid waste compost amended soil had exceeded both the Indian and European standards.

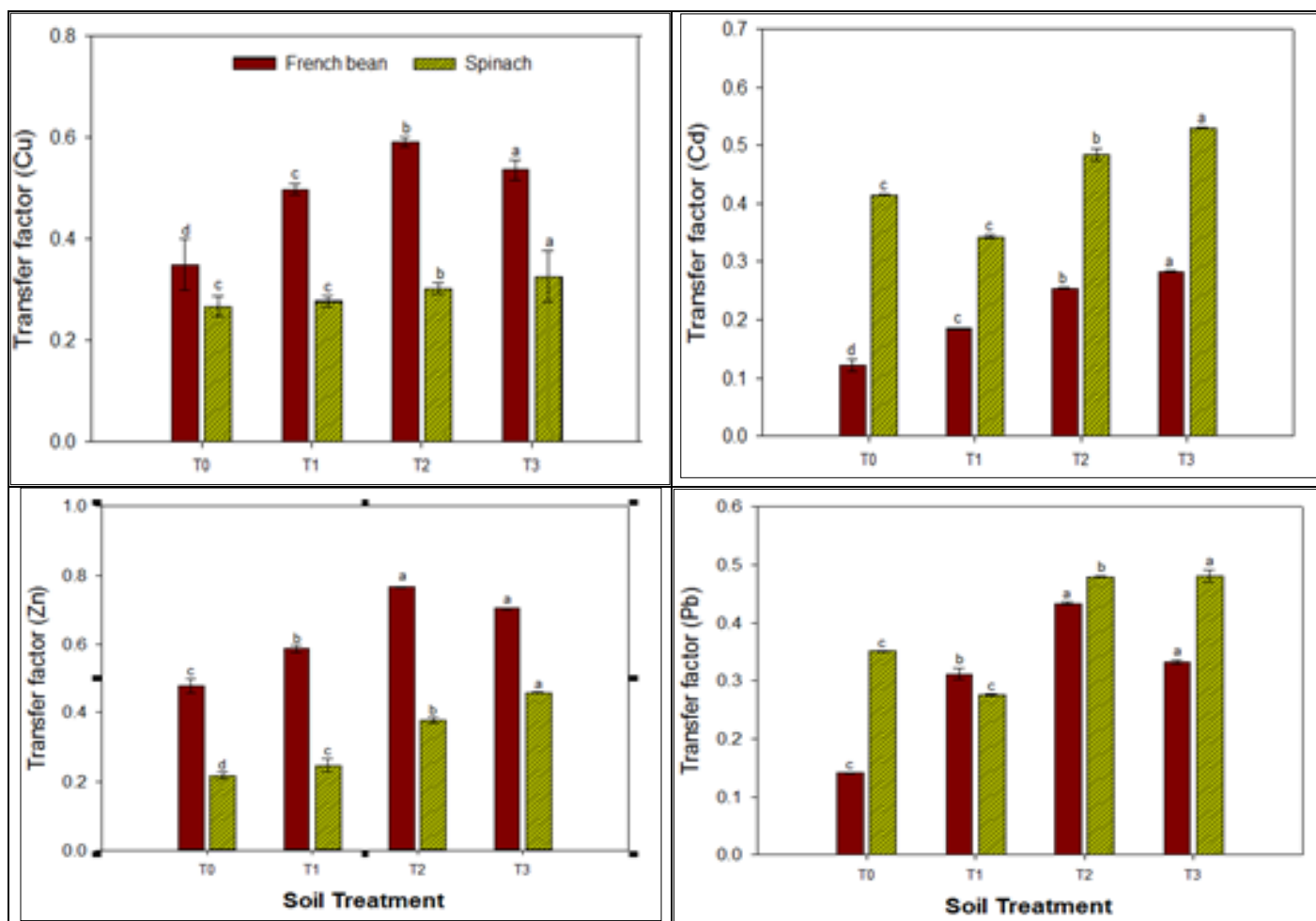


Fig 3: Heavy metal transfer from soil amended with different doses of MC to edible parts of *P. vulgaris* and *S. oleracea* crops under mountain ecosystem. Bars are the mean \pm SE of three replicates. Bars adhered with different alphabets are statically significant at $p < 0.05$ (Duncan's Multiple Range Test). T₀ = 0%, T₁ = 20%, T₂ = 40% and T₃ = 60%

The concentration of Pb and Cd in different parts of maize, beans, sugarcane, and tomato is grown in soil mixed with sewage sludge and wastewater in Zimbabwe had exceeded the European standards (Muchuweti *et al.*, 2006) [33]. The concentration of Cd in seeds of mung bean was found higher and above permissible level grown in soil amended with sewage sludge at 12 kg/m² rate in Varanasi, India (Singh *et al.*, 2010) [43]. The concentration of Pb was found more in spinach grown in soil amended with a mixture of sewage sludge and fly ash as compared to that of unamended soil (Sharma *et al.*, 2018) [41].

Heavy metal mobility in soil-plant system

The mobility of heavy metals from soil to the edible parts such as pods of beans and shoots of spinach under the mountain ecosystem was calculated as TF and is given in Fig.3. Transfer factor for Cu, Zn, Cd and Pb ranged from 0.35 to 0.59, 0.48 to 0.77, 0.12 to 0.28 and 0.14 to 0.43 in bean and from 0.27 to 0.33, 0.22 to 0.46, 0.34 to 0.53 and 0.28 to 0.48 in spinach grown on soil amended with MC. The TF values for Cu, Zn, and Pb in bean crops were found highest at the 40% MC application rate and for Cd @ 60% MC application rate. However, the highest TF value was recorded @ 60% MC

amendment for all the heavy metals. The transfer factor for all the heavy metals in all the treatments as well as for both test vegetables were found below a unit which indicates a lower uptake and accumulation rate of heavy metals in the test vegetables under the mountain ecosystem. The results indicate that the TF values for all the heavy metals were found very low and exposure of crops in soil amended with MC for a long time would not be safe for consumption.

Conclusion

From the above results and discussion, it is clear that the growth and yield of both the test plants i.e., bean and spinach increased significantly with increasing the application rate of municipal compost under the mountain ecosystem. On the other hand, the application of municipal compost had also increased the concentration of heavy metals in edible parts of the tested vegetables above the permissible limit even at the lowest application rate. Thus, the present study suggests that the application of municipal compost to agricultural areas of Kullu valley is not a suitable approach for its disposal. An alternative approach for the disposal of municipal compost may be worked out to reduce the toxic hazards of heavy metals to the local population of Kullu valley and mountain

ecosystems.

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