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ORIGINAL RESEARCH

Effects of municipal waste compost and nitrogen fertilizer on growth and mineral composition of tomato

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Abstract
Purpose Since simultaneous use of organic and mineral fertilizers on the basis of their chemical compositions can lead to better plant growth and soil fertility, the roles of municipal waste compost (MWC) and nitrogen (N) fertilizer on growth and mineral composition of tomato and some soil properties were evaluated under greenhouse condition.
Methods Treatments involved four MWC rates (0, 1, 2, and 4% on the basis of soil dry weight) and four N levels (0, 50, 100, and 200 mg kg^{-1} soil). Red cloud variety of tomato was sown in treated soils and 9 weeks later dried plant shoots and soil sub-samples were subjected to analysis.
Results Combined use of MWC and N led to better growth of tomato than sole application of either MWC or N fertilizer. Plant concentration and/or uptake of nitrogen, phosphorus, zinc, copper, iron, and manganese were increased by both MWC and N. The beneficial effect of MWC on nutrients uptake was more pronounced with N addition. Plant and soil concentrations of cadmium and lead were under the detection limit of atomic absorption spectrophotometer. Soluble salts, organic matter, sodium, chloride and DTPA-extractable zinc, copper, iron, and manganese in the soil were effectively increased with addition of MWC.
Conclusions Due to high soil pH and calcium carbonate equivalent (CCE) values of the calcareous soil, MWC heavy metals had no hazardous effect on tomato and even played a nutritional role. The most important problem raised from MWC application was the accumulation of soluble salts in the soil which must be monitored when making repeated application of MWC over an extended period of time.

Keywords Municipal waste compost · Nitrogen · Alkaline condition · Tomato · Heavy metals · Soil properties

Introduction

Generally, most agricultural soils of Iran have low content of organic matter (OM) and suffer from poor physical conditions (Havaee et al. 2014). On the other hand, daily production of large quantities of solid organic wastes causes serious disposal problems, environmental pollution, and possible health risks. Using a good strategy such as composting process, solid wastes can be converted into useful products for improvement of soils properties (Hashemimajd et al. 2004; Sohrabi Yourtchi et al. 2013). Soil disposal of municipal waste compost (MWC) is an attractive practical procedure reducing the waste disposal problems in large cities. Compost can be considered as a valuable source of nitrogen (N), phosphorous (P), essential trace elements, and OM that well improves soil physical properties and plant nutritional status (Bertoldi et al. 1996; Zinati et al. 2004; Kabirinejad and Hoodaji 2012). The two major drawbacks encountered from application of compost to soils are the accumulation of an excess amount of soluble salts in treated soils and the potential toxicity of certain trace elements to plants (Maftoun et al. 2004).

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Trace amounts of some elements such as copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) are essential micronutrients for plants, animals and microorganisms, but when applied in excessive amounts they may depress plant growth and reduce the quality of food materials (Petruzzelli 1996).

The uptake of trace elements from soil by higher plants depends on a variety of intrinsic soil factors such as soil pH (Basta and Tabatabai 1992), soil type (Eriksson 1989), OM content (McGrath et al. 1988), and composition of soil solution (Bingham et al. 1979). Some of these factors can be easily changed by addition of various materials to soil. Fertilizer application is a significant external factor that can affect the uptake of trace elements under certain circumstances. One of the most important elements in plant nutrition is N and many researchers have investigated the influence of N fertilizers on trace elements uptake for a long time. N fertilizers with acidifying potentiality have the capacity to decrease soil pH and increase the trace elements uptake by plants. Since decrease in soil pH by N fertilizers during the plant cultivation is mainly due to ammonium (NH_4^+) uptake by plants and nitrification by microorganisms, fertilizers containing NH_4^+ salts are potentially acidifying and can affect the trace elements uptake by plants (Ohtani et al. 2007). Parvizi et al. (2004) investigated the effect of N and Mn on growth, nutrient concentration and chlorophyll meter readings in wheat under greenhouse condition. Their results showed that applied N levels (0, 50,100, 200, and 400 mg kg^{-1} soil as NH_4NO_3) increased dry matter yield and the concentration of N, Mn, Fe, Zn, and Cu in plant shoot. Karimian and Ahangar (1998) reported that N reduced the antagonistic effect of phosphorus on Zn and increased plant Zn concentration. They concluded that such positive effect of N was probably due to the enhancing effect of N on root volume and growth. Rodriguez-Ortiz et al. (2006) showed that increase of ammonium nitrate application to soil (50,100, and 150 mg N kg^{-1} soil) significantly increased the aboveground accumulation of cadmium (Cd) and lead (Pb) in tobacco during a 50-day experimental period. Eriksson (1990) reported that Cd availability in two soils was increased after the application of acidifying N fertilizers.

From the other point of view, simultaneous use of organic and mineral fertilizers based on their chemical composition can lead to the improvement of plant yield and the fertility of soil. Most existing studies show positive effects of the combined application of organic amendments and mineral fertilizers on soil fertility by improvement of water and nutrient-holding capacity of the soil, minimizing the leaching losses and maximizing the efficiency of applied nutrient (Amusan et al. 2011; Chivenge et al. 2011). Apart from enhancing crop yield, the practice has a greater beneficial residual effect than the sole use of mineral fertilizer or organic materials (Cela et al. 2011; Demelash et al. 2014).

Since there is limited information on combined use of organic and mineral fertilizers, especially with respect to their adverse or beneficial impacts under alkaline/calcareous conditions of soils in Iran, the present study was initiated to (1) evaluate the combined effects of several rates of MWC and N levels on the growth and mineral composition of greenhouse tomato and (2) determine their impacts on some selected soil properties.

Methods

A bulk sample was collected from surface horizon (0–20 cm) of a fine, mixed (calcareous), mesic Typic Calcixerpts soil that was homogenized by plowing. Prior to analysis and potting, the soil was air dried, crushed and passed through a 2-mm sieve. Some physical and chemical characteristics of the soil sample are shown in Table 1. Municipal waste compost (MWC) was obtained from Isfahan Compost Company, air dried, and passed through a 2-mm sieve. Compost analysis was done by standard methods. Elements total concentration was measured as explained below for plant samples and cation and anion concentrations were measured by the procedure suggested by U.S. Salinity Laboratory Staff (1954). Some analytical

Table 1 Physical and chemical properties of the soil

Soil property	Quantity
Sand (%)	10
Silt (%)	46
Clay (%)	44
Texture	Silty clay
OM (%)	1.02
CCE (%)	31
EC (dSm^{-1})	0.24
CEC (cmol c kg^{-1})	21
pH (saturated paste)	8.0
Total N (%)	0.07
NaHCO3-extractable P (mg kg^{-1})	18.5
DTPA-extractable Fe (mg kg^{-1})	2.2
DTPA-extractable Mn (mg kg^{-1})	4.2
DTPA-extractable Zn (mg kg^{-1})	0.72
DTPA-extractable Cu (mg kg^{-1})	1.5

OM organic matter, *CCE* calcium carbonate equivalent, *EC* electrical conductivity, *CEC* cation exchange capacity, *DTPA* diethylene triamine pentaacetic acid properties of the MWC are presented in Table 2. Treatments consisted of four levels of MWC (0, 1, 2, and 4% on the basis of soil dry weight) and four N rates (0, 50, 100, and 200 mg kg^{-1} soil as urea) arranged in a factorial manner into a completely randomized design with three replications. Pots were filled with 2 kg of air-dried soil, thoroughly mixed with uniform amount of phosphorous (20 mg kg^{-1} soil as KH_2PO_4), appropriate amounts of MWC and half of the nitrogen treatments. Ten seeds of tomato (*Lycopersicon esculentum* L.), Red cloud var., were sown in each pot and seedlings were thinned to three, two weeks after emergence. Two weeks later, another half of N levels was added to pots. During the course of the experiment, pots were irrigated with distilled water to keep soil moisture content near the field capacity. Plants were harvested after 9 weeks, dried at 65 °C for 24 h and weighed. The ground plant samples were dry-ashed at 550 °C and analyzed for P by colorimetric method and Fe, Mn, Zn, Cu, Cd, and Pb by atomic absorption spectrophotometer. Total N was determined by a micro-Kjeldahl method. At the end of experiment, soil sub-samples were taken from each pot and analyzed for pH in saturated paste, OM (Jackson 1958), NO_3–N (Bremner and Keeney 1965), and DTPA-extractable Fe, Mn, Zn, Cu, Cd, and Pb (Lindsay and Norvell 1978). Furthermore electrical conductivity (ECe), sodium (Na), and chloride (Cl) concentration were determined in the saturation extract (U.S. Salinity Laboratory Staff 1954). The data were subjected to statistical analysis of variance (ANOVA) and the Least Significant Difference Test (LSD) was also performed to identify the homogenous sets of data.

Table 2 Analytical properties of the MWC

Property	Quantity
EC (dSm^{-1}) in 1:5 compost:water	12
pH (1:5 compost:water)	6.9
pH (1:5 compost:calcium chloride)	6.7
Total N (%)	1.25
OM (%)	18.9
C:N	15:1
Total P (mg kg^{-1})	810
Total Fe (mg kg^{-1})	4175
Total Mn (mg kg^{-1})	240
Total Zn (mg kg^{-1})	349
Total Cu (mg kg^{-1})	230
Total Cd (mg kg^{-1})	2.8
Total Pb (mg kg^{-1})	128
Cations concentration in saturated extract (me L^{-1})	
$Ca^{2+} + Mg^{2+}$	31
Na^{+}	54.3
K^{+}	59.0
Anions concentration in saturated extract (me L^{-1})	
$HCO_3^- + CO_3^-$	22.3
SO_4^{2-}	20.0
Cl^{-}	56.3

EC electrical conductivity, *OM* organic matter

Results and discussion

Growth and mineral composition of tomato plants

F values and level of significance from ANOVA on studied plant traits are shown in Table 3. A consistent increase in the plant dry matter was observed by raising the levels of the applied MWC (Table 4). This may be due to increase in soil OM, improvement of soil physical and chemical properties and, therefore, better plant nutritional status after MWC usage. Hu and Barker (2004) assessed agricultural-waste compost, sewage compost and yard waste for their capacity to support tomato growth. Based on vegetative growth, the agricultural-waste compost led to the highest growth while the yard waste caused the least. Generally, increase in nutrient content of the media improved the growth of tomato. In a 3-year study, Maynard (1995) observed that annual additions of MWC significantly increased the yield of field-grown tomato. He indicated that enhancement in soil OM and necessary plant nutrients are responsible for increase in tomato yield.

The effect of applied N on plant growth was found to be dependent on MWC rate (Table 4). In MWC rates of 0 and 1%, plant dry weight increased as the level of applied N reached to 50 mg kg^{-1} soil but further addition of N reduced the growth of tomato. However, in other MWC rates, plant dry weight was only decreased when applied N reached 200 mg kg^{-1} soil. These results show that N can be more efficient in growth improvement when it is applied in combination with MWC. Although there is no precise explanation for the growth reduction of tomato in the highest level of applied N, it can probably be attributed to ammonium toxicity which resulted from N volatilization in the alkaline condition of soil under study. Evidences show that among different plant species tomato is highly sensitive to N volatilization and thus it is used as an index plant for the studies in which the toxicity of ammonium from N volatilization is evaluated (Adams 1986). Volatilization of N occurs when large amount of ammonium fertilizers are added to alkaline soils. This process is highly related to soil pH and is frequently noted in soil pH higher than 7.5 (Mills et al. 1974; Mattos et al. 2003; Wang et al. 2004). Schuman and Mills (1996) assessed the toxicity caused by ammonium volatilization in buffered sand mediums. Results showed that the most severe injuries in tomato plants occurred when the pH of medium reached to highest

Table 3 Analysis of variance (mean square) and *F* test for studied plant traits

Source of variance	DF	Dry matter	Nutrients concentration					
			N	P	Fe	Mn	Zn	Cu
MWC	3	40.1**	0.09^{ns}	383,199**	67.6^{ns}	7763**	4567**	108**
N	3	34.4**	9.7**	1,750,197**	148^{ns}	4074**	50.9*	0.95^{ns}
MWC × N	9	2.36^{ns}	0.08^{ns}	1512^{ns}	164^{ns}	230^{ns}	40.5*	3.03^{ns}
Error	32	1.69	0.08	700	192	313	15.7	4.05

*, ** and ^{ns} are significant at 5, 1% probability level and non-significant, respectively

Table 4 Effect of MWC and N application on plant dry matter, N and P concentration in tomato shoot

MWC rates (%)	Applied N (mg kg^{-1} soil)				Mean
	0	50	100	200	
Dry matter (g pot^{-1})					
0	5.41	9.92	7.31	5.86	7.12
1	6.91	11.4	10.5	8.00	9.19
2	8.47	11.9	12.3	9.99	10.7
4	10.6	11.6	13.07	9.57	11.2
Mean	7.84	11.2	10.8	8.35	
LSD 0.05	Main effects: 0.99		Interactions: 1.98		
N concentration (%)					
0	0.93	1.51	2.87	2.77	2.02
1	0.92	1.55	2.53	3.16	2.04
2	1.07	1.66	2.46	3.01	2.05
4	1.26	1.85	2.64	3.1	2.21
Mean	1.26	1.85	2.64	3.10	
LSD 0.05	Main effects: 0.19		Interactions: 0.38		
P concentration (mg kg^{-1})					
0	3092	1817	2050	1804	2191
1	2575	1529	1458	1842	1851
2	2175	1667	1533	1750	1782
4	2200	1850	1833	1933	1954
Mean	2512	1716	1719	1832	
LSD 0.05	Main effects: 194		Interactions: 388		

amount of pH (8.6). Since the soil under study was calcareous in nature, N volatilization under such circumstances was not unexpected.

Additions of N to the soil increased N concentration in plant shoot (Table 4). Although at all levels of the applied N, the effect of MWC on shoot N concentrations was not significant (Table 4), enhancement in MWC additions increased N uptake by tomato plant from 140 to 246 mg per pot (nutrients uptake data have not been shown but can be calculated using nutrients concentration and plant dry weight). This can probably be attributed to low C:N ratio of MWC. Applied MWC had a suitable C:N ratio (15:1) (Table 2) which could lead to the net mineralization of N in soil. Maftoun et al. (2004) reported that consumption of MWC and poultry manure with low C:N ratios (12.8 and 7.6, respectively) significantly increased the concentration of N in spinach plants. Similar results were also reported by Lehrsch and Kincaid (2007) in field-grown corn. In contrast to the stated achievements, Giannakis et al. (2014) found an inhibition of plant growth with increasing dose of municipal solid waste compost in greenhouse-grown lettuce and tomato. Growth inhibition was associated with a sharp decrease in soil NO_3–N content. Their findings provided evidences that N immobilization and/or decreased N mineralization were responsible for inhibited growth by constraining N availability.

Increasing MWC application reduced the concentration of phosphorous (P) in plant shoot (Table 4). Since P uptake was enhanced by MWC additions from 14.9 to 21.7 mg per pot, the decrease in shoot P concentration can be related to a dilution effect. Successive application of urban waste compost to a calcareous soil increased organic and inorganic P concentrations in soil and caused higher P uptake by ryegrass and three other horticultural plants (Carbera et al. 1991). Chattopadhyay et al. (1992) indicated that organic acids and mineral phosphorous obtained from compost decomposition can simultaneously increase phosphorous availability in soil. The effect of N on plant phosphorous was in part similar to the influence of MWC. In general, N application up to 100 mg kg^{-1} soil decreased P concentration in tomato shoot whereas the highest N rate significantly increased it. Judging on P uptake data (not showed), the initial reduction in P concentration can be due to a dilution effect while the final increase can be assigned to growth reduction which resulted from the highest N level rather than the enhanced P uptake.

The effect of MWC and N application on Fe, Mn, Zn and Cu concentration in tomato shoot has been presented in Table 5. Results showed that MWC did not significantly affect shoot Fe concentration but effectively increased the total uptake of Fe as the level of MWC reached 4% in all applied N levels. Increase of plant Fe uptake by MWC application may be due to both higher growth of tomato and the production of chelating agents via MWC decomposition. These chelating agents can enhance availability of Fe and other micronutrients in soil and consequently

Table 5 Effect of MWC and N application on Fe, Mn, Cu and Zn concentration in tomato shoot

MWC rates (%)	Applied N (mg kg^{-1} soil)				Mean
	0	50	100	200	
Fe concentration (mg kg^{-1})					
0	64	68	60	64	64
1	60	62	65	57	61
2	59	50	55	75	60
4	57	57	72	73	64
Mean	60	59	63	67	
LSD 0.05	Main effects: 4.6		Interactions: 9.2		
Mn concentration (mg kg^{-1})					
0	84	113	136	143	119
1	50	60	93	98	75
2	53	59	74	83	67
4	52	62	66	77	64
Mean	59	73	92	100	
LSD 0.05	Main effects: 6.2		Interactions: 12.3		
Cu concentration (mg kg^{-1})					
0	10	8.1	9.9	8.4	9.1
1	11.7	11.3	11.5	12.3	11.7
2	12.9	13.4	13.2	14.4	13.5
4	14.4	17.6	16.3	16.7	16.2
Mean	12.3	12.6	12.7	12.9	
LSD 0.05	Main effects: 1.3		Interactions: 2.6		
Zn concentration (mg kg^{-1})					
0	17	11	13	13	13
1	27	25	30	28	27
2	32	38	38	41	37
4	51	62	65	62	60
Mean	32	34	36	36	
LSD 0.05	Main effects: 3.4		Interactions: 6.7		

improve their uptake by plant. Paulrage and Ramulu (1994) indicated that application of 20 t ha^{-1} of urban sewage sludge to a sandy-clay soil enhanced the DTPA-extractable Fe, Mn, Zn, and Cu in the soil and also improved their total uptake by tomato plants. Even though the effect of N application on shoot Fe concentration was not significant, the mean total uptake of Fe increased by 46% when the level of applied N reached 100 mg kg^{-1} soil. Addition of 200 mg N kg^{-1} soil decreased Fe uptake by tomato mainly due to the reduction of dry weight production in this treatment. In general, the increasing effect of MWC on total Fe uptake was more pronounced due to N addition. Ranjkesh (2015) reported that co-consuming of N fertilizer and compost accelerated the plant uptake of Fe by two different cultivars of wheat. Mean Mn concentration in the tomato aerial part significantly decreased with increasing MWC rates. Since MWC had no significant effect on total Mn uptake by tomato (it changed from 839 to 715 µg per pot which was not significant), the reduction in Mn concentration may be due to dilution effect. Increase of N levels from 0 to 200 mg kg^{-1} soil increased mean Mn concentration by 69% in tomato shoot (Table 4). Macfie and Taylor (1989) stated that ammonium-bearing fertilizers can increase Mn uptake by plants especially due to reduction of soil pH. In another study (Goldberg et al. 1983), the influence of N on the enhancement of Mn concentration in barley shoot was attributed to the dissolution of insoluble Mn by chemical compounds secreted by roots and also to the stimulation of root growth and better contact with soil. Soil application of MWC notably raised mean Cu concentration in tomato shoot (Table 5). As the level of MWC changed from 0 to 4% mean, Cu concentration and its total uptake increased by 78 and 184%, respectively. In spite of the fact that N application had no significant effect on Cu concentration (Table 5), Cu total uptake was significantly affected by N application. The highest Cu uptake was observed in 50 mg N kg^{-1} soil but there was no significant difference between 50 and 100 mg N kg^{-1} soil. Singh and Swarup (1982) studied the copper nutrition of wheat in relation to nitrogen and phosphorous fertilization. The effect of nitrogen on the enhancement of Cu uptake was attributed to the reduction of soil pH, increase in Cu solubility, enhancement in root volume and development and finally root secretion of chelating agents with the capacity to increase Cu availability in soil. MWC had the most significant influence on Zn concentration in tomato shoot and also the associated uptake of this element by plant. Mean Zn concentration and total uptake were, respectively, increased by 362 and 638% as the level of MWC changed from 0 to 4%. This suggests that the availability of Zn in MWC was the highest in comparison with the other micronutrients including Fe, Mn, and Cu. On the other hand, MWC contains soluble forms of Zn which remains bioavailable in the soil and consequently leads to considerable uptake of Zn by plant. It has been demonstrated (Han and Banin 1999; Kabata-Pendias and Pendias 2001) that metal's nature is a key factor affecting metal speciation and plant bioavailability in soil. For instance, addition of similar amounts of trace elements to soil may cause their different uptake by plant. In fact, the plant bioavailability of each trace element depends on its reaction with various soil components and the chemical behavior of that element in soil. Rajaie et al. (2008) reported that different distribution behavior of Cd and Ni in similar circumstances in different soils is partly related to their nature. Therefore, in the present study, the higher bioavailability of Zn for tomato plant can be also due to its special chemical behavior in the soil.

Raising N application from 0 to 200 mg kg^{-1} soil increased mean Zn concentration by 12.5% in tomato shoot (Table 5). The addition of N up to 100 mg kg^{-1} soil also increased total Zn uptake by 57%. Further increase in N application reduced Zn uptake by plant. The effect of MWC on plant concentration and uptake of Zn was dependent on the level of applied N. For instance, in the absence of MWC, increase in N application from 0 to 200 mg kg^{-1} soil reduced Zn concentration and its total uptake by plant. In contrast to 4% of MWC, the same enhancement in N level significantly increased the plant responses just mentioned.

In all plant samples, the concentration of Cd and Pb were under the detection limit of atomic absorption spectrophotometer. This can be due to low concentration of these elements in MWC (Table 2) and the high pH and retention capacity of the calcareous soil under study. Rajaie et al. (2006) evaluated the chemical forms of cadmium in two calcareous soil textural classes as affected by application of cadmium-enriched compost and incubation time. Results showed that large proportion of added Cd was converted to carbonate fraction and approximately stayed the same throughout the course of the experiment. Dixon et al. (1995) showed that the concentration of Pb and Cd in spinach plant grown on a compost-enriched soil decreased and/or was unaffected by compost treatments. They believed that this might be due to an increase in soil pH following the compost addition, low Pb and Cd concentration in the material and strong metal-binding capacity of the biosolid.

Chemical properties of the soil

F values and level of significance from ANOVA on soil chemical properties are shown in Table 6. Soil pH did not show any significant change with both MWC and N application (data no shown). This can be attributed to high CCE (calcium carbonate equivalent) and considerable buffering capacity of the soil under study. In addition, in all soil samples, DTPA-extractable Cd and Pb were under the detection limit of atomic absorption spectrophotometer. In control treatments, DTPA-extractable Fe, Mn, Zn and Cu were higher as compared to the beginning status of the soil (Tables 1, 7). Although there is no precise explanation for this event, it may be attributed to plant exudates secreted by roots in treatments suffered from trace elements deficiency which can lead to increase of these elements availability in the soil. This hypothesis is consistent with the findings reported by Lopez-Millan et al. (2009) in tomato. Except soil NO_3^- concentration which showed a significant decrease with MWC application; other selected soil chemical characteristics were markedly increased as the level of MWC reached 4% (Tables 7, 8). For instance, as compared with control, mean values of OM, DTPA-extractable Fe, Mn, Zn, Cu, Ece, Na, and Cl concentration in soil were, respectively, increased by 64, 84, 47, 388, 100, 970, 321, and 662% in the highest rate of MWC application (Tables 7, 8). The observed change in soil chemical characteristics is consistent with results reported by others (Bevacqua and Mellano 1994; Khoshgoftarmanesh and Kalbasi 2002; Maftoun et al. 2004). The influence of N fertilization was only significant for soil salinity and the concentration of NO_3^- and Cl in the soil (Tables 6, 8). Generally, the soil chemical properties just mentioned were significantly enhanced with increments in N addition (Table 8). In the present study, the enhancing effect of N on soil salinity was more pronounced in the absence of MWC. For instance, without MWC application, addition of 200 mg N kg^{-1} soil increased ECe by 434% when compared to control, whereas with 4% of MWC and the same N rate, the increase was only 32% (Table 8). This observation can be attributed to the improved growth of tomato associated with increments in MWC addition. On the other hand, greater growth of tomato led to higher absorption of NO_3^- and other existent elements which in consequence made a reduction in soil salinity. Despite the fact that tomato is moderately sensitive to salt stress, no adverse effect on plant growth was observed with the increase in soil salinity (Tables 4, 8). The apparent tolerance of this crop to salinity in our study may be due to

Table 6 Analysis of variance (mean square) and *F* test for soil chemical properties

Source of variance	DF	OM	Na	DTPA-extractable trace elements				EC	NO_3	Cl
				Fe	Mn	Zn	Cu			
MWC	3	0.87**	107**	29.3**	41**	97**	6.73**	18.0**	362**	240**
N	3	0.01^{ns}	0.17^{ns}	0.38^{ns}	3.6^{ns}	0.80^{ns}	0.018^{ns}	4.26**	22,863**	13.2**
MWC × N	9	0.01^{ns}	0.34^{ns}	0.29^{ns}	1.31^{ns}	0.35^{ns}	0.007^{ns}	0.011**	165*	4.11**
Error	32	0.01	0.28	0.56	1.73	0.52	0.008	0.007	59	0.75

*, ** and ^{ns} are significant at 5, 1% probability level and non-significant, respectively

Table 7 Effect of MWC on some soil properties including soil organic matter (OM) and concentration of Na, Fe, Mn, Zn, and Cu (each figure is the mean of 12 observations)

MWC rates (%)	OM (%)	Na (me L^{-1}) in saturated paste	DTPA-extractable trace elements (mg kg^{-1})			
			Fe	Mn	Zn	Cu
0	1.01	0.71	4.4	9.1	1.22	1.76
1	1.21	2.1	5.5	10.0	2.48	2.21
2	1.30	3.9	6.2	10.9	4.03	2.52
4	1.66	7.6	8.1	13.4	5.96	3.52
LSD 0.05	0.14	0.42	0.79	1.5	0.50	0.30

Table 8 Effect of MWC and N application on soil salinity and concentration of NO_3^- and Cl in the soil

MWC rates (%)	Applied N (mg kg^{-1} soil)				Mean
	0	50	100	200	
EC (dSm^{-1})					
0	0.35	0.46	0.79	1.87	0.87
1	0.97	1.32	1.42	2.78	1.63
2	2.13	2.53	2.48	3.23	2.60
4	3.27	3.47	3.73	4.32	3.67
Mean	1.62	1.94	2.11	3.05	
LSD 0.05	Main effects: 0.23		Interactions: 0.47		
NO_3 (mg kg^{-1})					
0	5	3	21	115	36
1	4	5	10	92	28
2	6	3	6	79	23
4	5	5	7	89	26
Mean	5	4	11	94	
LSD 0.05	Main effects: 3.9		Interactions: 7.8		
Cl (me L^{-1}) in saturated paste					
0	1.6	1.6	1.7	1.7	1.6
1	3.5	4.2	4.5	6.9	4.8
2	6.2	8.5	8.3	7.5	7.6
4	9.2	13.7	11.5	14.2	12.2
Mean	5.1	7.0	6.5	7.6	
LSD 0.05	Main effects: 0.62		Interactions: 1.23		

applied variety and also the fact that the salinity effects might have been alleviated by the constant and adequate supply of water in the controlled environment. Papadopoulos and Rendig (1983) reported that even at high salinity level plant growth could still occur if enough moisture is supplied.

Although N fertilization obviously increased mean Cl concentration in soil saturated paste, the increasing effect of N was MWC rate dependent (Table 8). For instance, in the absence of MWC, application of 200 mg N kg^{-1} increased Cl concentration only by 6% when compared to control, whereas with 4% of MWC and the same N rate the increase was 54% (Table 8). As it was reported by Irshad et al. (2002) and Tabatabaei (2006), the increasing effect of N on Cl concentration in soil saturated paste can be attributed to anionic competition and restricting effect of NO_3^- on Cl^- uptake by plant.

Conclusions

Results of this study indicate that the combined use of MWC and N fertilizer can improve the growth and chemical composition of tomato. However, their rates of application for each crop needs to be evaluated under field conditions. The major concerns for the use of organic wastes in agricultural soils are the hazards of heavy metals accumulation and the elevated levels of soluble salts in crop root zone. Commonly the metals of concern are Cd, Pb, Zn, and Cu. Although MWC had noticeable concentration of Pb, Cu, and Zn, it had no deleterious effect on tomato growth. As a matter of fact, the soil used in this experiment had high pH and CCE values and contained a large amount of clay minerals which in turn could immobilize heavy metals in the soil. Therefore, MWC had no hazardous effect on plant growth but also played a nutritional role in the case of nutrient metals such as Zn and Cu. Although nitrogen enhanced the concentration and/or plant uptake of cationic micronutrients, the concentration of these elements did not reach to toxic levels. A rise in ECe following addition of high levels of organic wastes to soil suggests that with continued application, total soluble salts may reach toxic levels for some crops especially under arid and semi-arid conditions of Iran. Therefore, there is a clear and urgent need to monitor soluble salt levels when making repeated application of organic wastes in calcareous soils of Iran over an extended period of time.

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