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The Effect of Iron-Enriched Vermicompost on Growth and Nutrition of Tomato

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ABSTRACT

Iron deficiency or lime induced chlorosis is a common problem in calcareous soils. Application of mineral iron fertilizer in these soils is not usually fully effective in curing iron deficiency as compared to organic chelates. Cow manure and iron refuse (oxides), a by-product of iron melting factories were mixed in different properties of: 0, 5, 10, and 20 % V/V to make mixtures which of after four months incubation were converted into iron-enriched vermicompost through the action of earthworms. In a greenhouse study, growth and nutrient uptake by tomato grown in pot soils treated with normal vermicompost and Fe-EDDHA (synthetic iron chelate) and compared with those in plants grown in soils receiving iron-enriched vermicompost. The study design was a randomized complete block one with three replications. Total and available forms of iron in iron-enriched vermicomposts as well as in tomato tissues increased by an increase in the proportion of iron refuse in vermicompost. Shoot dry matter of plants produced in soil treated with iron-enriched vermicompost (15-20% V/V), was significantly higher than that of plants produced in the other treatments. Iron uptake by tomatoes grown in Fe-EDDHA treated soil was higher than that in plants grown in vermicompost amended soil and that in control, but it was lower than the uptake by plants grown in iron-enriched growth media.

Keywords: Iron-enriched, Nutrition, Tomato, Vermicompost.

INTRODUCATION

Iron is one of the mineral nutrients highly needed for many physiological processes in plants. Despite high total iron contents of soils, iron deficiency is very common in soils of high pHs. Iron concentration in soil solution of aerobic calcareous soils is usually lower than 10^{-15} molar and if some interventional mechanisms which cause an increase in iron availability did not exist, no plant would be able to grow in such soils (Marschner, 1995). With an increase of soil pH by one unit, the solubility of iron species decreases 1,000 times. Furthermore iron deficiency is a serious problem in calcareous soils of high pH figures (Mortvedth *et al.*, 1991), and soil-plant analysis techniques not being highly appropriate for diagnosis and prediction of iron deficiency.

The effectiveness of synthetic chelates in curing iron deficiency chlorosis is higher than that of inorganic iron fertilizers because inorganic iron fertilizers precipitate as insoluble compounds in soil (Mortvedth *et al.*, 1991). The results of several researches have revealed that Fe-EDDHA (ethylene diamin di-oxy hydroxyl acetic acid) is an effective iron fertilizer for calcareous soils and is a stable chelate in a pH range of 4-9. Due to high cost of synthetic chelates, their application is limited in agriculture. The cost in some cases constitutes up to 60% of total fertilizer costs (Pestana *et al.*, 2003).

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Application of ferrous sulphate in calcareous soils is not highly beneficial since this compound precipitates immediately afterwards and becomes unavailable to plants (Mortvedth *et al.*, 1991). When inorganic sources of iron fertilizers were used accompanied by organic materials, the fertilizer use efficiency increased. Natural organic compounds are able to produce stable chelates with iron ion to increase the solubility of this element in soil solution. Application of organic matter to soil, can decrease the incidence of iron chlorosis and help remedy this disorder (Loeppert, 1986). Some organic compounds produced from decomposition of organic materials in soil or microbial secretions, called sidrophore, create stable natural chelates with iron (Marschner, 1995). Efficiency of organic materials to remedy iron chlorosis depends on organic material composition, their capacity in creation of organo-mineral complexes with iron, and stability of produced chelates (Hastorm, 1984). Tagliavini *et al.* (2000) in an experiment on pear grown in calcareous soil could treat the iron deficiency with addition of blood powder and enriched compost with ferrous sulphate. In several studies carried out about the use of compost made of mixing iron soluble salts with organic materials such as manure, compost, sewage sludge, and peat in Israel, it was found that these composts could successfully treat iron chlorosis (Chen and Barak, 1982; Chen *et al.*, 1982; Bazak *et al.*, 1989; Braness and Chen, 1991).

Usage of industrial by-products and refuses to supply iron requirement of herbaceous species were of different levels of success. Iron humate produced from reaction of iron sulphate with sewage effluent humic and fulvic acid, contains 20 to 25% iron and 32% organic matter and is used as a rich source of iron for plants. Alva *et al.* (1992) reported that iron humate, a by-product of discoloration process in potable water treatment plants, is an effective source of iron for citrus fruits grown on calcareous soils. Alva and Obzera (1998) showed that usage of iron humate increased leaf iron concentration as well as yield in citrus and in grape fruit. Prez-Sanz *et al.* (2002) investigated the efficiency of iron-enriched sewage sludge as a substitute for synthetic chelotes in a remedy of citrus and peach chlorosis and observed that yield did not increase but the size and quality of fruits were improved.

Several studies have been carried out on the usage of refuses from iron and steel industries to remedy iron deficiency induced chlorosis. Parkpian (1983) used iron dust mixed with sulphuric acid for treatment of iron chlorosis, and it was shown that the yield of sorghum in treatments receiving iron dust was significantly higher than that in control. Frohar (1999) reported that the application of iron oxides (a refuse of steel industries) reduced the pH and significantly increased the available iron content in soil. Abbaspour *et al.* (2001) reported that addition of iron dust with sulphuric acid, organic materials, and elemental S improved iron and manganese uptake by plant.

Refuses of iron and steel industries if mixed with organic materials and incubated before being applied to soil, iron availability in produced mixture will increase. Nutrient contents of vermicomposts are much higher than those of commercial horticultural composts (Dickerson, 1999). Humic substances in vermicomposts are 3 to 4% more than those in composts (Dominguez, 1997). Hashemimajd *et al.* (2004; 2006) reported that nutrients content, except N and K, in vermicompost were higher than those in original solid wastes. The objectives of this research were: (1) to increase the available iron content by mixing industrial iron refuse with cow manure, and (2) to investigate the effectiveness of iron-enriched vermicompost (as an alternative for synthetic iron chelates) in improvement in iron nutrition for tomato crop.

MATERIALS AND METHODS

Iron refuse (Iron dust) obtained from Isfahan Iron Melting Factory in 2002, was mixed with cow manure with the proportions of 0, 5, 10, 15, and 20 percent of manure volume (F_1, F_2, F_3, and F_4 treatments, respectively), then the mixtures was added to 3 liter pots. At the beginning of the experiment, mixtures were composted for 3 weeks; afterwards 200 mature earthworms (*Eisenia foetida*) were added to each pot and incubated for four months. The temperature of incubation room was 20 to 30°C and the moisture of the material kept close to 60% of saturation. After the incubation period, the produced vermicomposts were harvested and dried at 65°C. The soil sample was collected from a farm land around the Isfahan University of Technology campus from 0-30 cm depth, dried at room temperature and passed from 2 mm screen. The main soil classification group of this soil was argil and wheat as its last plantation. The chemical composition of iron refuse along with the characteristics of soil and iron-enriched vermicomposts used in this study are presented in Table 1 to 3, respectively.

The pH of soil saturated paste, EC of saturated extract, and total soil N were measured as described by Thomas, (1996); Rhoades, (1996); and Bolta and Howell, (1978), respectively. The organic carbon content of soil was determined by Walkly and Black method (Nelson and Sommers, 1996), calcium carbonate equivalent (CCE) by back-titration method, available P in 0.5 M sodium bicarbonate extract using ascorbic acid colorimetric method (Kuo, 1996), available K in 1 M ammonium acetate extract by flame photometer (Jones, 2001), and soil texture through hydrometry (Gee and Bauder, 1996). Available Fe, Mn, Zn, and Cu were detected in AB-DTPA extract through atomic absorption spectroscopy (Jones, 2001).

The pH and EC of iron-enriched vermicompost were measured in 1:5 (w/v) suspension using distilled water (Jones, 2001). Total nitrogen in oven dried (65ºC) samples was evaluated through sulphuric acid digestion using Se, $CuSO_4$, and K_2SO_4 as catalyst mixture and by Autokjeltic instrument model Foss Tecator 2300 (Boltz and Howell, 1978). Total organic carbon was determined through Walkly Black method (Nelson and Sommer, 1996). To continue for a determination of some of the rest of elemental content, one gram of materials was dry-ashed at 560ºC in a muffle furnace and the ash extracted with 2 M HCl. The extract was analyzed for total P using ascorbic acid method (Kuo, 1996), total K by flame photometer, and total Ca, Mg, Fe, Zn, Mn, and Cu content by Perkin Elmer model 3030 atomic absorption spectroscopy (Wright and Stuczynski, 1996). Available Fe, Mn, Zn, and Cu content in vermicompost were evaluated in AB-DTPA extract through atomic absorption

Table 1. Chemical composition of iron dust and properties of soils used in the experiments.

Iron dust		Soil	
Properties	Value	Properties	Value
P_2O_5 %	0.275	Total N (%)	0.066
Al_2O_3 %	0.10	Available P (mg kg^{-1})	79
MgO %	0.24	Available K (mg kg^{-1})	480
CaO %	6.12	CCE (%)	20.75
FeO %	19.22	pH	7.8
Total. Fe %	63.52	EC (ds m^{-1})	5.09
SiO_2 %	1.30	Available Fe (mg kg^{-1})	10
K_2O %	0.30	Available Mn (mg kg^{-1})	26
Na_2O %	0.20	Available Zn (mg kg^{-1})	4.9
S %	0.13	Available Cu (mg kg^{-1})	0.72
V_2O %	0.07	Silt (%)	28
ZnO %	0.03	Sand (%)	26
MnO %	0.02	Clay (%)	46

Table 2. Nutrient content of iron-enriched vs. non-enriched vermicomposts.

Properties*	T_v [a]	F_1 [b]	F_2 [c]	F_3 [d]	F_4 [e]
Total N (%)	1.72	1.67	1.62	1.56	1.13
Total P %	0.30	0.16	0.19	0.11	0.20
Total K %	0.25	0.43	0.36	0.34	0.24
Total Ca %	3.1	2.7	2.4	2.6	2.3
Total Mg %	1.1	0.94	0.91	0.70	0.72
Total Fe (mg kg^{-1})	2700	3050	3250	4800	5000
Total Mn (mg kg^{-1})	305	402	492	645	918
Total Zn (mg kg^{-1})	53	42	48	37	32
Total Cu (mg kg^{-1})	12	7	10	9	9
Available Fe (mg kg^{-1})	-	84	120	129	132
Available Mn (mg kg^{-1})	-	124	113	118	112
Available Zn (mg kg^{-1})	-	31	29	23	22
Available Cu (mg kg^{-1})	-	3.56	3.76	3.40	3.32

[a] Vermicompost; [b] Iron-enriched vermicompost made with 5% iron dust (v/v); [c] Iron-enriched vermicompost made with 10% iron dust (v/v); [d] Iron-enriched vermicompost made with 15% iron dust (v/v)), [e] Iron-enriched vermicompost made with 20% iron dust (v/v).

spectroscopy (Jones, 2001).

In a greenhouse experiment, the effect of iron-enriched vermicomposts on growth and chemical composition of tomato plant were studied. Tomato seedlings were grown in 3 liter pots filled with 70% soil and 30% washed sand (v/v) with 37 gram of different vermicomposts added to the pots (10.3 mg of vermicomcopost per gram of soil+ sand mixture. Treatments were: T_0 (control), T_v (vermicompost), F_1 (iron-enriched vermicompost made with 5% iron dust (v/v)), F_2 (iron-enriched vermicompost made with 10% iron dust (v/v)), F_3 (iron-enriched vermicompost made with 15% iron dust (v/v)), F_4 (iron-enriched vermicompost made with 20% iron dust (v/v)), and SE (18.5 mg of Fe-EDDHA per pot (5.2 µg Fe per gram of soil (soil + sand)). A total number of 21 pots (seven treatments each in three replicates) were used in a randomized complete block design. Tomato plants were thinned to three per pot 10 days after transplanting. Pots were watered to keep moisture close to field capacity as based on pot weight, all pots receiving equal water in each time of irrigation. All treatments received 30 mg kg^{-1} of N as urea at 5 leaf stage. The necessity of supplementary N fertilizer application *via* vermicompost to potting media has been concluded in former studies (Hashemimajd *et al.*, 2004; Handreck *et al.*, 1986). After one month of growth plants' shoots (of each individual pot) were harvested at an early bloom stage, dried at 65°C for 48 hours, weighed, ground and passed through 40 mesh screen (Jones *et al.*, 1991). Leaf samples (young mature leaves) that had been collected from a pot's plants were prepared in a similar manner.

Sub-samples of plant material were dry-ashed at 560°C and extracted with 2 M HCl for total nutrient analysis. Total N, P, K, Ca, Mg, Fe, Zn, Cu, and Mn were determined in extracts through the same procedures as described for the vermicompost samples. Data were analyzed by one way ANOVA in a general linear model, using SAS statistical software (23). Duncan's multiple range test was employed to compare the shoot dry matter and nutrients uptake mean figures.

RESULTS AND DISCUSSION

Due to unsuitable condition of some iron dust media such as high pH (pH= 11), earthworms' living activities were started one month after they were added to the media. After this period, the earthworms followed similar activities in all treatments. The nutrient contents of soils used in the

Table 3. Mean square data from the ANOV as for shoot dry matter (SDM) yield and nutrient uptake by tomatoes grown in the experimental pots.

	Replication		Treatments		Error	
Properties	df	MS	df	MS	df	MS
SDM	2	2.87 ns	6	3.83 *	12	1.00
N	2	1531 ns	6	2347 ns	12	918.7
P	2	100.3 ns	6	109.32 *	12	31.05
K	2	14680 ns	6	35106.4 *	12	5496.8
Ca	2	1330.9 ns	6	3151.4 ns	12	1072.2
Mg	2	415.5 ns	6	450.38 *	12	132.5
Fe	2	16.22 ns	6	482.2 **	12	10.19
Mn	2	1.15 ns	6	7.35 **	12	0.637
Zn	2	0.345 ns	6	0.567 *	12	0.134
Cu	2	0.053 ns	6	0.317 **	12	0.0349

* and ** *F*-test significant at the 0.05 and 0.01% level, ns= Non significant.

experiment were in sufficiency range for tomato groth as according to Marx *et al.* (1999) (Table 1). There are different soil critical levels for iron recorded in literature. Viets and Lindsay (1973) reported an iron critical level of 2.5 mg kg^{-1} for Florida soils. Soltanpour and Follet (1999) declared that the adequate level of iron for most crops determined *via* AB-DTPA extraction is 5 PPM, but values below 10 PPM may be too low for turf and many of ornamentals. A strong relationship between extractable soil Fe, plant tissue level of Fe content, and predictable responses to applied Fe does not apparently exist, so decision concerning iron nutrition status of plants as based on mere soil testing is not recommended (Sartain, 2001).

In addition to iron, iron refuse contained a considerable amount of manganese (Table

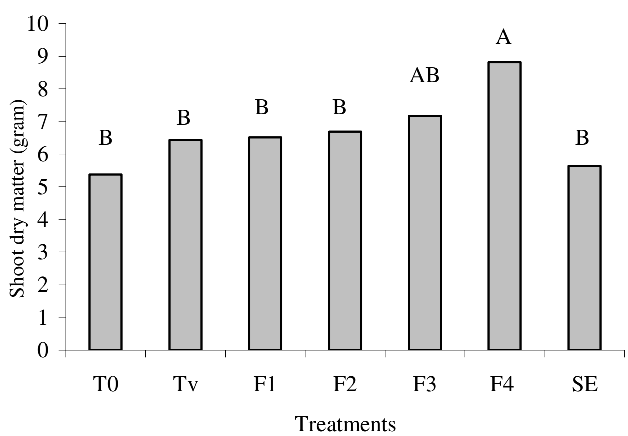

Figure 1. Effect of treatment on tomato Shoot Dry Matter (SDM) in different treatments; Bars marked with similar capital letters were not significantly different at 5% level (Duncan's Multiple Range Test): T_0= Control; T_v= Vermicompost; F_1= Iron-enriched vermicompost made with 5%iron dust (v/v); F_2= Iron-enriched vermicompost made with 10%iron dust (v/v); F_3= Iron-enriched vermicompost made with 15% iron dust (v/v); F_4= Iron-enriched vermicompost made with 20% iron dust (v/v), and SE= Fe-EDDHA.

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Table 4. Nutrient uptake by tomato shoot in different treatments (mg pot-1).

Treatment*	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
T_0 [a]	129±12** B *	19±2 B	218±21 B	93±9 B	46±4 C	3.5±0.3 B	1.9±0.2 E	1.0±0.1 C	0.5±0.005 E
T_v [b]	121±18 B	24±4B	378±61 A	167±26 A	70±10 AB	4.7±0.5 B	5.3±0.8 B	2.2±0.3 A	1.4±0.2 A
F_1 [c]	119±14 B	25±6 AB	369±25 A	164±12 A	75±5 A	6.8±0.5 B	5.1±0.4 BC	2.2±0.2 AB	1.2±0.8 AB
F_2 [d]	163±6 AB	21±0.7 B	444±15 A	176±5 A	66±3 ABC	5.0±0.2 B	6.8±0.12 A	1.5±0.06 BC	1.1±0.05 ABC
F_3 [e]	180±30 A	26±4 AB	456±76 A	166±27 A	51±8 BC	9.2±1.4 B	3.7±0.6 CD	1.9±0.3 AB	0.7±0.1 DE
F_4 [f]	184±20 A	35±5 A	468±64 A	181±26 A	78±10 A	39.1±4.7 A	4.2±0.4 BCD	1.9±0.3 AB	0.9±0.1 BCD
SE [g]	133±18 B	16±2 B	212±31 AB	124±15 AB	71±9 AB	5.6±0.8 B	3.3±0.5 DE	1.7±0.3 AB	0.8±0.06 DE

[a] Control; [b] Vermicompost; [c] Iron-enriched vermicompost made with 5% iron dust (v/v); [d] Iron-enriched vermicompost made with 10% iron dust (v/v); [e] Iron-enriched vermicompost made with 15% iron dust (v/v)); [f] Iron-enriched vermicompost made with 20% iron dust (v/v), [g] Fe-EDDHA.

* Numbers in columns with similar capital letters were not significantly different at 5% level.

** Means±Standard error.

1). Total and available concentrations of iron in iron-enriched vermicomposts increased with increasing proportions of iron refuse in composting mixtures. Despite an increasing in the total Mn content of vermicomposts, the available form of this element was not increased with increasing the iron dust mixing proportion (Table 2). Smith *et al.* (2003) point out that if a high concentration of Fe is present, Fe replaces Mn in organo-mineral complexes, and released Mn is precipitated, thus reducing Mn availability. Total N. Mg, Zn, and Cu contents of vermicomposts decreased with increasing iron dust mixing proportions. Concentrations of these nutrients in iron refuse were lower than in manure.

The results of analysis of variance for shoot dry matter yield and for nutrient uptake are shown in Table 3. The effect of different treatments on shoot dry matter (SDM) yield in tomato is shown in Figure 1. Plant SDM of tomatoes grown in iron-enriched vermicomposts (obtained by mixing manure with 15% and 20% of iron dust on a volume basis (F_3 and F_4)) was higher than those in the other treatments. Despite higher yield in SE, F_1, and F_2 treatments than in control, the yield increase in these treatments was not statistically significant. Greater yield obtained from treatments containing iron-enriched vermicompost as compared with SE treatment did not match the results of other experiments in which iron humate was used for remediation of iron deficiency and which might show the advantage of iron-enriched vermicompost. Iglesias *et al.* (2000) showed that pear fruit yield in trees treated with iron phosphate was somewhere between iron chelate and control treatments. Karaman (2002) reported that the effectiveness of in soil application of humate, iron humate, and inorganic forms of iron for remediation of iron chlorosis of peach was lower than the application of Fe-EDDHA. Ingram and Roach (1996) showed that application of humate did not affect yield and quality in azalea. Yeager *et al.* (1996) reported that use of 17.8 kg of iron-humate in each cubic meter of substrate was not effective on shoot and root yield in *Ligustrum japanicum*, but improved its quality. A supply of other mineral nutrients through vermicompost application or production of stable chelates during vermicomposting process as well as in soils probably resulted in greater yields in F_3 and F_4 treatments as compared with SE (Fe-EDDHA).

Incorporation of vermicomposts in pot plant growth media improved nutrient uptake especially N, P and K by tomato plants (Table 4). Several investigators have confirmed the positive rule of vermicompost in supplying plant's essential nutrients (Atiyeh *et al*., 2000; Metzger, 1998; Dominguez, 1997). Iron uptake in F_3 and F_4 treatments was greater than in the other treatments, this shows the positive effect of these treatments on iron nutrition of tomato plant. Iron uptake in SE treatment was higher than those in control and in T_v, but lower than those in iron-enriched treatments, although the uptake of other nutrients was not enhanced with the same proportion. Lucena *et al.* (1990) noted that use of industrial iron chelates for plants grown in hydroponics media caused nutrient imbalance as well as decrease in concentration of other nutrients. Decrease in other nutrients uptake such as Mn, Zn, and Cu might be due to either competition effect of iron or a lower supply of these nutrients in comparison with iron. These elements also decreased in availability in iron-enriched vermicomposts, with an increase in the rate of iron dust. Jones *et al.* (1990) reported the existence of these competition effects between iron and other micronutrients.

CONCLUSIONS

Iron refuse contains a high level of iron and of some other plants' required nutritional elements. Iron-enriched vermicompost is a rich source of total and available iron. Iron content of iron-enriched vermicompost increased in proportion to the rate of iron dust added. Tomato shoot dry matter yield grown in pots treated with vermicomposts (obtained by mixing manure with 15%-20% iron dust on a volume basis) was higher than that in control and in Fe-EDDHA treated pot soil. Iron-enriched vermicompost is a suitable source of iron for calcareous soils. Further research and investigation on the effects of iron-enriched vermicompost (obtained from different inorganic iron compounds and organic wastes) for different plants and comparison with iron-enriched composts is recommended.

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تاثیر ورمی کمپوست غنی سازی شده با آهن بر رشد و تغذیه گوجه فرنگی

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چکیده

کمبود آهن یا زردی ناشی از آهک یک مشکل رایج در خاک های آهکی می باشد. مصرف کودهای معدنی آهن در این خاکها معمولا در برطرف کردن کمبود آهن در این خاک ها نا کارآمد می باشد. کود گاوی و ضایعات کارخانه ذوب آهن (اکسیدهای آهن) با نسبتهای مختلف (۰، ۵، ۱۰ و ۲۰ درصد حجمی/حجمی) مخلوط شده و پس از چهار ماه در نتیجه فعالیت کرم های خاکی به ورمی کمپوست غنی سازی شده با آهن تبدیل شدند. در آزمایشی گلخانه ای، رشد و جذب عناصر غذایی در گلدان های تیمار شده با ورمی کمپوست و کلات آهن Fe-EDDHA اندازه گیری و با ارقام متناظری که از تیمارهای حاوی ورمی کمپوست غنی سازی شده با آهن بدست آمده بود مقایسه شدند. طرح آزمایشی، در قالب بلوک های کامل تصادفی با سه تکرار بود. با افزایش درصد اختلاط ضایعات آهن مقدار آهن کل و قابل استفاده ورمی کمپوست های غنی سازی شده با آهن و بافت های گیاهان گوجه فرنگی افزایش یافت. عملکرد ماده خشک اندام هوایی در گلدان های تیمار شده با ورمی کمپوست غنی سازی شده با آهن (۱۵ الی ۲۰ درصد حجمی/حجمی) بطور معنی داری بیشتر از تیمارهای دیگر بود. میزان جذب آهن در تیمار کلات مصنوعی آهن هر چند بیشتر از گلدان های تیمار شده با ورمی کمپوست و شاهد بود ولی کمتر از تیمارهای غنی سازی شده با آهن بود.

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