Universal Journal of Environmental Research and Technology
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Available Online at: www.environmentaljournal.org
Volume 2, Issue 6: 551-559

Open Access **Research Article**

Microbial Sulfur Oxidation Effect on Micronutrients Availability of Municipal Compost for Wheat Plant

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Abstract:

Dual application of municipal compost and elemental sulfur may reduce soil pH and increase phosphorous and some micronutrients availability in soil. This study was aimed to investigate the impact of supplemented compost with sulfur on phosphorus, iron, zinc, manganese and copper availability in soil. A factorial completely randomized design with wheat (*Triticum aestivum* L. CV. Alvand) was established in the greenhouse, having two main factors including compost and elemental sulfur with four replicates. The compost treatments were consisted of 0, 50 and 100 ton/ha denoted as C_o, C_l and C_2, respectively. The elemental sulfur including 0, 500, 1000 and 2000 kg/ha applications represented as So, S_l, S_2 and S_3, respectively. loamy sand soil samples collected from the depth of 0-30 cm, powdered compost and powdered sulfur were air dried and passed through the 4-mm, 1-mm and 100µm sieves respectively. Compost and sulfur contents were mixed with soil filled in plastic pots.Wheat seeds were sown in pots and after 75 days of the growth period crops were harvested and P, Zn, Fe, Cu and Mn concentrations in crop extracts were measured by atomic absorption system of Perkin-Elmer 3110 model. The results indicated that the shoot and root growth as well as nutrients uptake are increased by increasing compost content. However, in most cases there was no significant difference between C_1 and C_2. The increasing of sulfur content up to 1000Kg/ha, caused a significant increase in wheat root and shoot growth as well as nutrient uptake. But they were reduced by increasing sulfur level from S_2 to S_3. It can be concluded that application of 50 ton/ha compost and 1000 kg/ha of elemental sulfur can improve wheat growth and nutrients uptake from municipal compost.

Keywords :Microbial sulfur oxidation, Municipal compost, Micronutrients, Phosphorus, Wheat

1.0 Introduction:

The availability of iron (Fe), zinc (Zn), copper (Cu), manganes (Mn) and phosphorous (P) is greatly depends on soil pH. In calcareous soils, high pH (~8) and a great amounts of calcium (ca^{2+}) make these elements to be change to insoluble and unavailable form for plants (Kaplan and Orman, 1998). Chemical fertilizers have been used as an effective solution for this problem. Exceed utilization of these fertilizers in addition to economic costs, causes to damage to ecosystems. Nowadays, high amount of municipal solid waste production specially in developed countries, needed energy to incinerate these solid wastes and contaminative effects of it's produced gases, limitations for burying in soil and attention to other environmental problems made the recycling and applying produced compost in agricultural fields, an important solution (Hue, 1988). Although there are higher amounts of micronutrients in compost, the availability of these elements is too low due to the high pH and forming complexes between these elements and organic matter (Soumar et al., 2003). Supplementation of compost with different amendments such as sulfur, H_2SO_4, NH_4SO_4 and etc. is the best solution for this problem. Regarding the abundance of sulfur in our country, the use of powder form of S seems to be an appropriate alternative. Sulfur can decrease soil pH by oxidation and proton production, at least in rhizosphere and can

increase the availability of insoluble micronutrients in soil (Modaihsh et al., 1989).
Sulfur oxidation would take place in biological and chemical ways. Through oxidation process, for each mole of elemental sulfur, 2 moles of proton would be released and sulfur changes to sulfate (Wainwright, 1987). Proton production would increase the mobility of some micronutrients and phosphorus in soil and compost and would release metallic elements from organic-element complexes.. The sulfur microbial oxidation process in soil can take place by various groups of microorganisms. Some photolithotrophes, chemolithotrophs and chemoorganotrophs can accomplish this process. Amoung theme, chemolithotrophs are efficient and their most important genus is *Thiobacillus*. But their population in calcareous soils is usually low. Also it has been reported that sulfate production by oxidation process,in poroton prodauction is dependent on oxidizing microorganisms population in soil (Lindemann et al., 1991). *Arthrobacters, Micrococcus, Mycobacterium, Psudomonas*, and some actinomycets and chemoorganotroph fungi are able to oxidize sulfides to sulfates too. The population of these microorganisms in soil are usually higher than chemolithotrophs and photolithotrohs (Aliasgharzadeh et al., 1998).. Beneficial effects of sulfur application in soil such as crop yield enhancement, pH reduction and increasing the availability of micronutrients, have been demonstrated by several studies (Modaihsh et al.,1989, Kalbasi et al., 1986, Razeto, 1982, Kaplan and Orman, 1998). Zheljazkov and Warman (2004), studied about changes in phytoavailability of micronutrients in soil by compost application, and concluded that long term utilization of compost causes to increase pH. We hypothesized that adding compost to the soil as organic matter, would increase the activity of these microorganisms and accelerate sulfur oxidation process.

2.0 Materials and Methods:

Experimental soil was collected from Khalat Pooshan research station of the Tabrize university from depth of 0-30 cm. Soil samples were transferred to the laboratory and then air dried and passed through a 4-mm sieve. Some physical, chemical and biological characteristics of the soil are shown in Table 1 (Page et al.,1982). The compost(produced from municipal solid waste in Tabrize Municipal Organic Fertilizer Office) was air dried and then powdered and passed through a 1-mm sieve. Characteristics of the compost are shown in Table 2. Elemental sulfur was passed through a100µmsieve to increase its contact surface with soil and compost. Seeds of *Triticum aestivum L.CV. Alvand* were disinfected in 0.5% sodium hypochlorite solution for 20 minutes and washed 3 times with distilled water. Plastic pots were filled with 1.5 Kg air dried soil. A greenhouse experiment was carried out in factorial form with two factors of compost and sulfur in completely randomized design with 4 replications. Compost with three levels (C_0:no addition, C_1:50T/ha[32g/kg] and C_2: 100T/ha[64g/kg]) and sulfur with four levels (S_0:no addition, S_1:500Kg/ha[320mg/kg], S_2:1000Kg/ha[640mg/kg] and S_3:2000Kg/ha1280mg/kg]) were mixed with soil and in each pot 10 seeds were sown. After two weeks the number of plants was thinned to four plants per pot. During the growth period, soil moisture in pots was adjusted to 80% of field capacity by weighting.growth of plants in different temperatures has different responses,sometimes shortage of water is more effect.methodologr section is very useful in greenhouses. To supply optimized growth condition, pots were kept at 25/20 $^\circ C$ day/night and light period of 16 hours. After 75 days of the growth, shoot and root were harvested individually and after washing with distilled water were dried at 75 $^\circ C$ then they were weighted. plant samples were digested by dry ashing method (Cottenie, 1980). The amount of P was measured in plant tissue by colorimetery method with a spectrophotometer (Cottenie 1980). Mn, Fe, Cu and Zn elements were measured by atomic absorption of Perkin-Elmer 3110 model (Page et al., 1982). Analysis of variance and mean comparisons were performed by MSTATC software.

3.0 Results and Discussion:

3.1 Compost and soil characteristics:

Some physical and chemical characteristics of the compost and soil used in this experiment are shown in Tables 1 and 2.

Table 1- Characteristics of the soil used in this experiment

Soil Texture	Loamy Sand
Sand(%)	76.8
Clay(%)	9
Silt(%)	14.2
pH	8
EC_e (dS/m)	2.3
O.C (%)	0.31
K^b Available content (mg/Kg)	79
P^a Available content (mg/Kg)	2.6

Fe Available content (mg/Kg)	3.54
Cu Available content (mg/Kg)	0.62
Mn Available content (mg/Kg)	10
Zn Available content (mg/Kg)	1.23
FC%	12
CCE%	21.23
Sulfur oxidizing chemoorganotrophs population (cells/g soil)	2×10^2

a: Olsen method (Page et al., 1982)
b: Ammonium acetate methode (Page et al., 1982)

Table 2-Characteristics of the compost used in this experiment

Mn Total content (mg/kg)	297
Cu Total content (mg/kg)	49
Zn Total content (mg/kg)	575
Fe Total content (mg/kg)	27700
P^b Available content (mg/kg)	45
K^a Available content (mg/kg)	4500
P Total content (%)	0.14
K Total content (%)	0.75
C/N	7.85
O.C (%)	12.16
EC (dS/m) 1:2.5	16.4
pH 1 :2.5	7.97

a: Olsen method (Page et al., 1982)
b: Ammonium acetate methode (Page et al., 1982)

3.2 Shoot Dry Matter

Compost application increased root dry matter (Figure 1). The greatest increase being seen at the C_2 level that was 49.78% higher than the control.

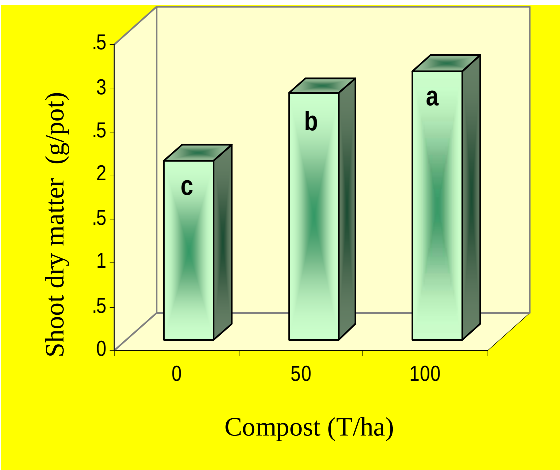

Figure 1- Main effect of compost on shoot dry matter

3.3 Root Dry Matter

Mean comparison of the main effects of compost and sulfur on root dry matter is shown in figures 2 and 3 respectively. Increasing compost levels from C_0 to C_1 improved root dry matter production but there was not a significant difference between C_2 and C_3 (Figure 2). Dry of root matter also increased by increasing sulfur levels (Figure 3). Application of 1000Kg S/ha caused an increase in root dry matter by 23.71% with respectively to the control.

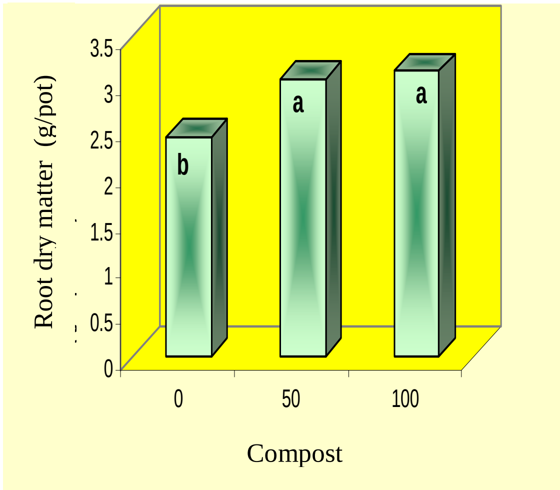

Figure 2- Main effect of compost on root dry matter

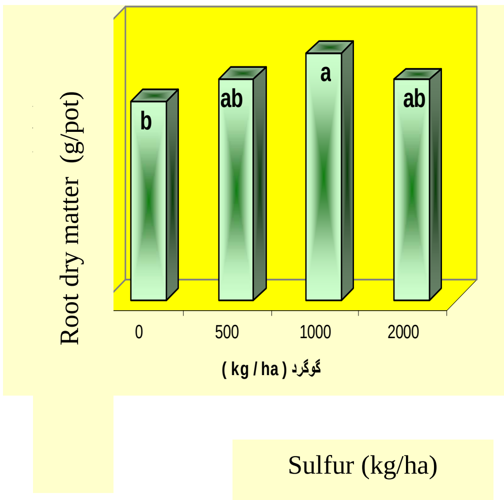

Figure 3- Main effect of sulfur on root dry matter

3.4 Shoot Phosphorus Content

As it was expected, increasing of sulfur and compost level, both enhanced shoot p content(Table 3).Compost application by rates of

50 T/ha and 100T/ha caused an enhancement in shoot P content by 95.77% and 139% respectively in comparison of the control. Phosphorus content enhancement was due to the presence of sufficient amounts of available P in compost which releases during the growth period. Mantovi et al., (2005) studied the effect of sewage sludge compost application on wheat growth and yield, and observed that the compost would significantly increase P content in wheat seed. Soumar et al., (2003) investigated the effect of municipal compost application on ryegrass yield and growth in two kinds of acidic soil in a greenhouse experiment and reported that the content of shoot dry matter would enhance by increasing in compost contents (25, 50 and 100 T/ha, respectively). These researchers introduced the level of 50 ton compost /ha which enhanced dry matter by 10% in one soil and 17.5% in another soil as the best level of compost. Adding sulfur to the soil would change soil unavailable P to available form. The highest shoot P content was 6.31mg.pot^{-1} (S_2 level) that was 14.31% higher than the control.

3.5 Root Phosphorous Content:

The content of root P enhanced by increasing the compost levels (Table 3). Root P content increased by 65.34% and 102% in C_1 and C_2 levels in comparison to the control.

3.6 Shoot Cu Content:

Shoot *Cu* content enhanced by increasing compost levels from C_0 to C_1 by 50% but there was not a significant change in shoot *Cu* content at C_2 level (Tble 3). Mantovi et al., (2005) studied the effect of composted agricultural wastes on wheat growth, and observed enhancement of *Cu* in wheat seed. In an experiment, the effect of application of sewage sludge and compost to the soil on the *Cu* and Cd sorption and bioavailability in the soil was investigated. Application of either SW or C increased the *Cu* sorption capacity of soil. The availability of *Cu* was low due to its occurrence in the acid soluble fraction(Vaca-Paulin et al., 2006).

3.7 Root Cu Content:

The effect of increasing sulfur application rates on *Cu* availability is apparent at the third level of compost. Considering low level of *Cu* in the compost, it is possible that a great amount of *Cu* in plant is originated from soil. At the third level of compost, sulfur efficiency in releasing *Cu* from soil and compost had been more than other application rates (Figure 4).

Table 3: Mean comparison of sulfur and compost effects on nutrients content in wheat

Measured indices (mg/pot)	Compost levels			Sulfur levels			
	C_0 (No compost)	C_1 (50 T/ha)	C_2 (100 T/ha)	S_0 (No Sulfur)	S_1 (500 Kg/ha)	S_2 (1000 Kg/ha)	S_3 (2000 Kg/ha)
1)Root P	3.78c	6.25b	7.65a	5.69a	5.71a	6.45a	5.70a
2)Shoot P	3.31c	6.48b	7.93a	5.52c	5.69bc	6.31a	6.10ab
3)Root Fe	0.822c	1.21b	1.421a	1.087b	1.168ab	1.281a	1.065b
4)Shoot Fe	0.122b	0.225a	0.239a	0.181b	0.193b	0.232a	0.176b
5)Root Zn	0.162c	0.202b	0.25a	0.146b	0.178b	0.253a	0.246a
6)Shoot Zn	0.049c	0.120b	0.183a	0.130a	0.113a	0.115a	0.112a
7)Root Cu	0.0513c	0.119b	0.169a	0.112a	0.107a	0.124a	0.108a
8)Shoot Cu	0.02b	0.03a	0.03a	0.24ab	0.02b	0.026ab	0.030a
9)Root Mn	0.3b	0.38a	0.39a	0.294b	0.352ab	0.424a	0.348ab
10)Shoot Mn	0.167a	0.114b	0.159a	0.115b	0.132b	0.170a	0.168a

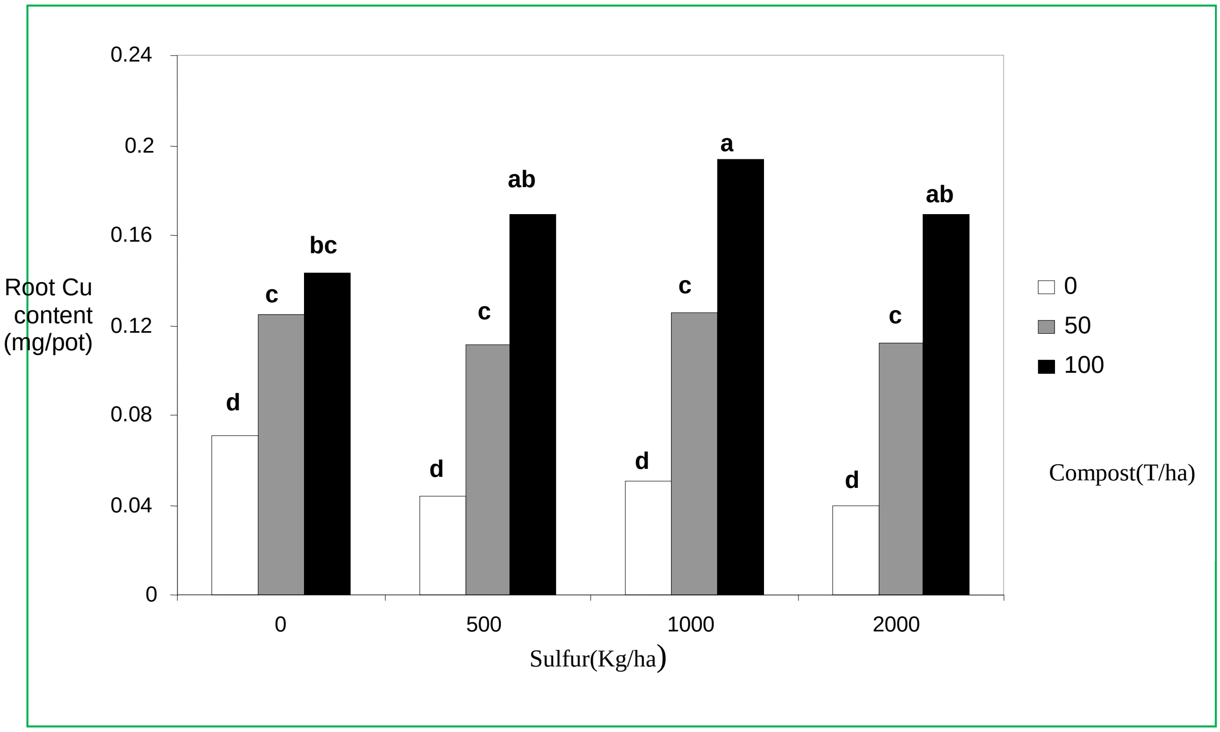

Figure 4- The effect of mixture treatment of compost × sulfur on the root Cu content

3.8 Shoot Mn Content

According to the table 3, there was a significant decrease in shoot Mn content by increasing compost levels from C_0 (no compost) to C_1 (50 T compost/ha) (-31.73%). Formation of element-organic complexes would enhance by increasing compost level and hence Mn availability would decrease. Composted residuals derived from MSW have a high affinity to binding heavy metals, limiting their solubility and potential bioavailability in soil.(Smith, 2009). Also the activity of chemoorganotroph bacteria such as Mn oxidizing bacteria would be enhanced by increasing organic matter and available Mn changes to unavailable (Mn^{4+}) form. Zheljazkove and Warman (2004), studied the effect of two kinds of compost (municipal solid waste compost and manure compost) on the growth and yield of basil, dill, sweet chard and peppermint, and reported that increasing both kinds of organic fertilizers, would decrease the soil exchangeable Mn. The content of shoot Mn enhanced by increasing compost rates from C_1 (50 T compost/ha) to C_2 (100T compost/ha) (39.47%) because of enough amounts of available Mn in C_2 level of compost which supplied both crop and microorganisms need. Increasing sulfur application rates enhanced shoot Mn content too (Table 3).

3. 9 Root Mn Content

Sulfur application could enhance root Mn content (Table 3). Although increasing compost application rates decreased shoot Mn content, but caused to increase root Mn content by 26.66% at C1 level in comparison to the control. According to the mentioned reasons, in C_1 level (50 T compost/ha) the content of soil available Mn has been decreased. It is proven that if there is not enough content of each element in soil, a great amount of available element will remained in the root and will not transfer to the shoot. (Mortvedt et al., 1972). Enough content of this nutrient would be available for plant in C_2 (100T compost/ha) level and the element is distributed equally between shoot and root.

3.10 Shoot Fe Content

In C_0 and C_1 levels, increasing sulfur up to 1000Kg/ha(S_2) caused an increase in shoot Fe content, but the content of Fe in S_3 level decreased (Figure 5). This trend observed not only for Fe, but also for the other nutrients and even for the shoot and root dry matter, although the decrease in S_3 level was not significant for all cases. Excessive sulfur in S_3 level probably had a negative effect on microorganisms which were effective in compost mineralization process, thus it made difficulty in releasing nutrients from the compost.

3.11 Root Fe Content

Figure 6 illustrates that in C_0 level of compost, increasing sulfur from S_2 to S_3 level has been decreased root Fe content.

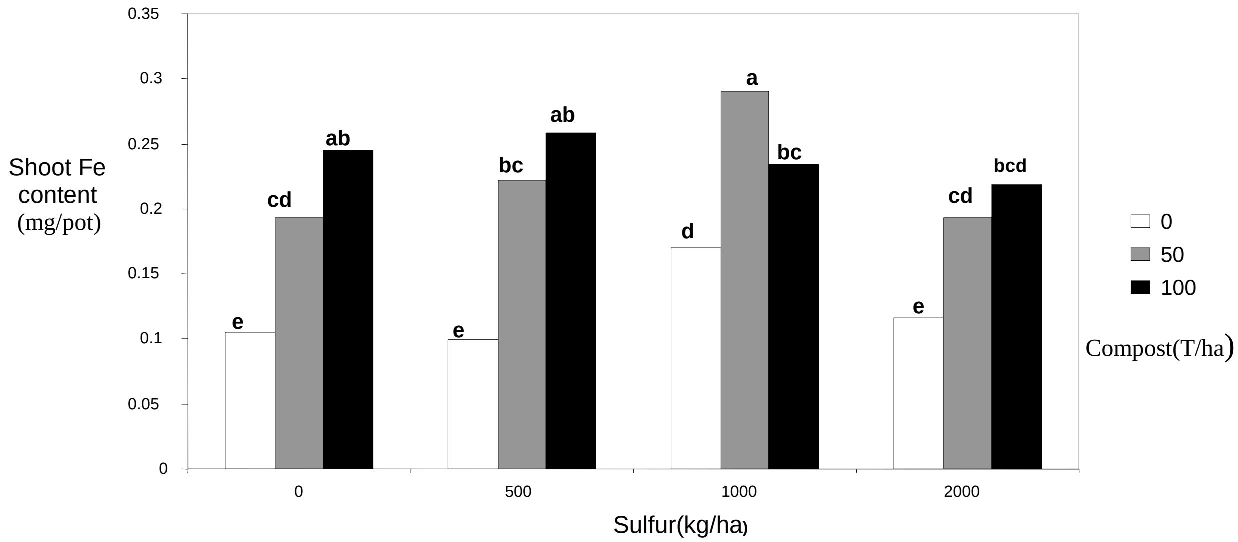

Figure 5- The effect of mixture treatment of compost × sulfur on the shoot Fe content

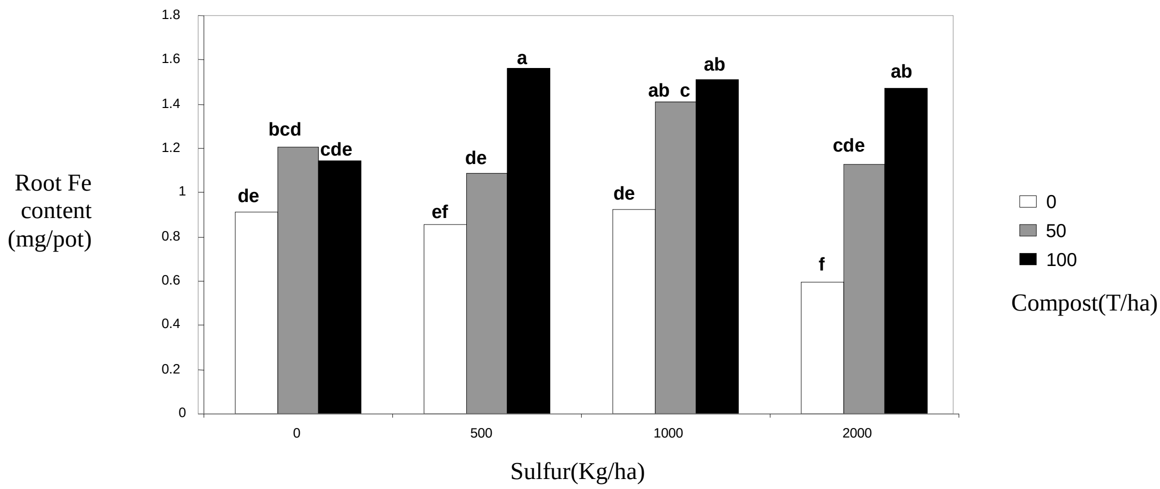

Figure 6- The effect of mixture treatment of compost × sulfur on the root Fe content

There was not a significant difference between S_0, S_1 and S_2 levels. In C_1 level of compost, a significant difference was not observed between S_0 and S_1 levels but increasing sulfur from S_1 to S_2 level caused an increase in root Fe content. In C_2 level of compost, increasing sulfur from S_0 to S_1 level caused an increase in root Fe content. For all nutrients both in shoot and root proceeding of nutrient concentration had a perfect coordination with nutrient content. But this process had a little difference about root Fe, so the effect of sulfur and compost mixture on root Fe concentration, has been shown in Figure 7. In C_0 and C_1 levels of compost, increasing sulfur levels caused to decrease in root Fe concentration. It can be explained by dilution effect, so that the crop weight has been increased by sulfur levels up to S_2, therefore Fe concentration has been decreased but the content of Fe has been increased. Decreasing effect of S_2 level on the concentration and content of root Fe is shown in Figures 3 and 4.The concentration of root Fe, has been increased in the third level of compost because of Fe abundance in this compost level.

3.12 Shoot Zn Content

According to the Figure 8, in C_0 level of compost, sulfur levels increasing from S_0 to S_1 caused to a significant decrease in shoot Zn content. In C_1 level of compost, there was not a significant difference between sulfur treatments and in C_2 level of compost, a significant decrease in shoot Zn content was observed by increasing sulfur rates from S_0 to S_2. . Antagonistic effect between Zn and P is the main reason which prevents Zn transferring to the shoot. Rupa et al., (2003) studied Zn transferring in wheat plant by applying different levels of manure and phosphorus, and reported the same results.

3.13 Root Zn Content:

Figure 9 illustrates that the content of root Zn has been increased by increasing sulfur levels in different levels of compost. Thus it can be concluded that Zn is uptaken by plant but it is not transferred to the shoot. The antagonistic effect of Zn and P has been proved by other researchers (Mortvedt et al., 1972; Rupta et al., 2003).

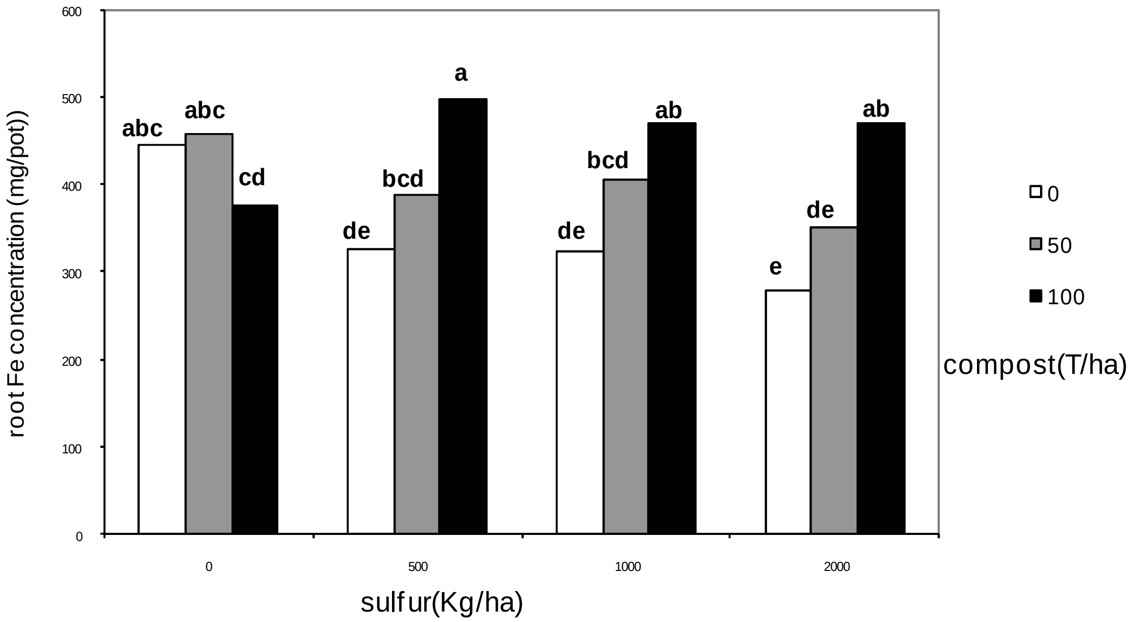

Figure 7- The effect of mixture treatment of compost × sulfur on the root Fe concentration

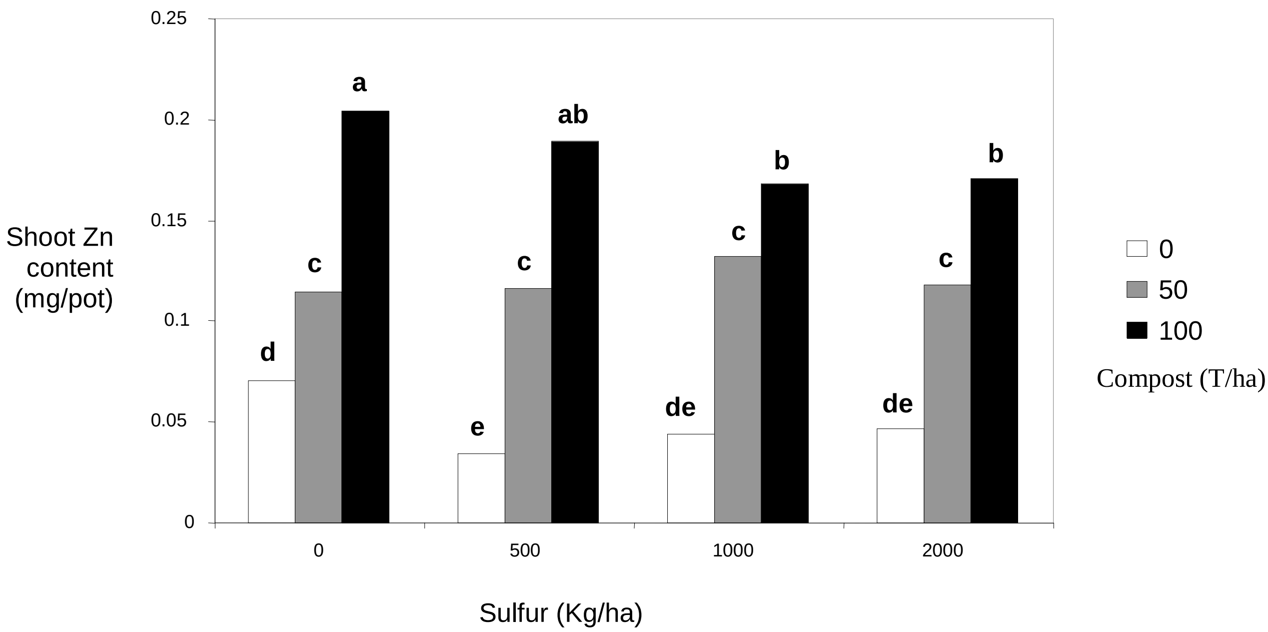

Figure 8- The effect of mixture treatment of compost × sulfur on the shoot Zn content

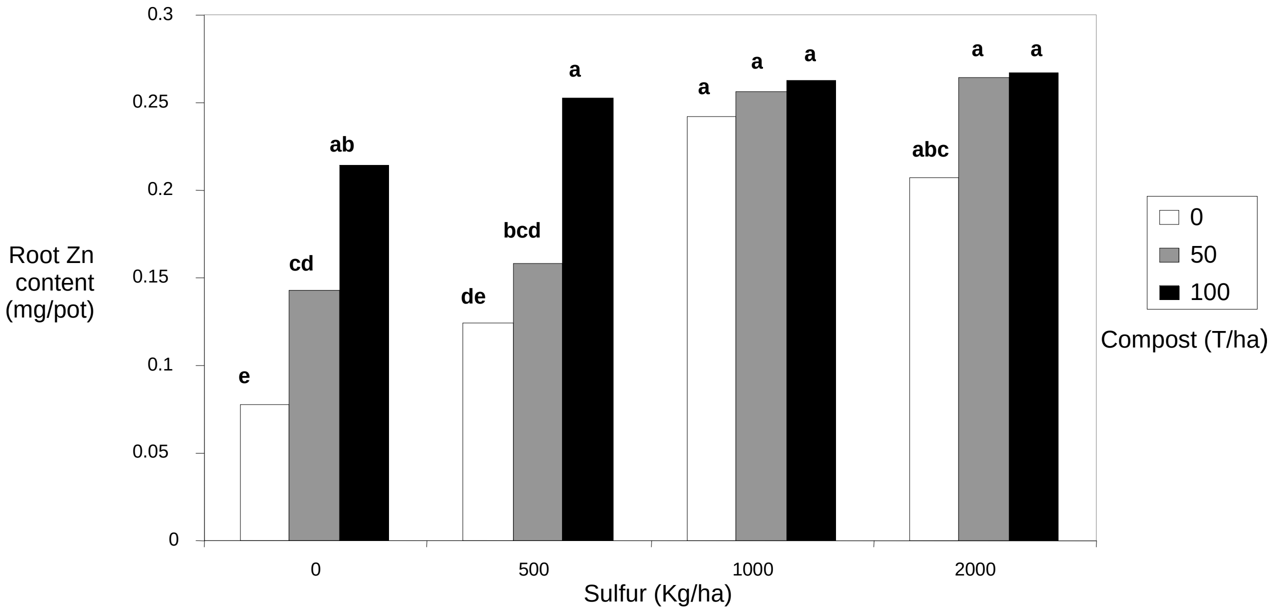

Figure9- The effect of mixture treatment of compost × sulfur on the root Zn content

4.0 Conclusion:

Compost application improved shoot and root growth as well as nutrients uptake in wheat. But there was not a significant difference between C_1 and C_2 levels in most cases. Application of sewage sludge and compost to the soil on the *Cu* and Cd sorption and bioavailability in the soil was investigated. Application of either SW or C increased the *Cu* sorption capacity of soil The availability of *Cu* was low due to its occurrence in the acid soluble fraction, Increasing sulfur level up to S_2, caused a significant enhancement in root and shoot growth and nutrients uptake by wheat but they were diminished by increasing S level from S_2 to S_3. Excessive sulfur in S_3 level probably had have a negative effect on microorganisms which were effective in compost mineralization process. So it can be concluded that application of 1000Kg/ha sulfur with 50T/ha municipal solid waste compost can be useful in growth enhancement and micronutrients uptake by wheat.

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