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The Effect of Vesicular–arbuscular (VA) Mycorrhizal Fungi on Vitamin C Content of Tomato in the Presence of Lead and Different levels of Phosphorus

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ABSTRACT
In a greenhouse experiment, tomato (lycopersicum esculentum L. cv. Soltan) seedlings germinated were inoculated with Glomus versiform (G1) and Glomus etunicatum (G2) in a pasteurized low phosphorus (P) and lead (Pb); the uninoculated one was the control (G0). Three Pb levels (5, 10, 50 mg/kg; Pb_1, Pb_2 and Pb_3, respectively) as $PbSO_4$, and three P levels (5, 20 and 40 mg/kg; P_1, P_2 and P_3 respectively) as KH_2PO_4 were applied to the soil during transplanting. Based on the results obtained, vitamin C content of fruits was affected by Pb and P levels in both mycorrhizal and non-mycorrhizal plants. It was observed that vitamin C content of fruits was enhanced significantly with increased P level, but decreased significantly in Pb level; and it was significantly higher in mycorrhizal plants than in non-mycorrhizal plants at the same level of P and lower at the same level of Pb. Percentage of root colonization was negatively affected by Pb level of soil and positively affected by P levels. Percentage of root colonization was significantly higher in mycorrhizal plants than in non- mycorrhizal plants at the same level of P and lower at the same level of Pb. However, there was no significant difference between G. versiform and G. etunicatum.
Key words: *Lead (Pb), phosphorus (P), tomato, vesicular–arbuscular (VA) mycorrhiza, vitamin C.*

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INTRODUCTION

Soil ecosystems have been extensively contaminated with heavy metals due to various human activities. Shilev *et al.* [1] studied that metal uptake by plants can be influenced by soil microorganisms that intimately associate with plants' roots to form the rhizosphere community. Donald [2] reported that arbuscular mycorrhiza is a fungus which colonizes most species of plants' roots; the association is usually beneficial to both the fungus and the host plant. The fungal symbiont increases its host's uptake of nutrient and can improve its growth and quality as well as resistance to environmental stresses. Arbuscular mycorrhizal fungi (AMF) have repeatedly been demonstrated to elevate heavy metal stress of plants [3]. AMF contributions to metal tolerance mechanisms of host plants are not well understood and documented [4]. A protection mechanism is the immobilization of metals by intra and extra radical mycelium, preventing the translocation of metals to shoot [5]. Metal transfer from fungi to plant is restricted by fungal immobilization [6]. The present work was carried out to study the relationship between P, Pb and vitamin C contents in tomato seedling inoculated with two species of vesicular–arbuscular mycorrhizal (VAM) fungi in sterile sand soil under greenhouse condition. It aimed to determine that we can use vesicular–arbuscular (VA) mycorrhizal fungi to reduce Pb toxicity in tomato.

MATERIALS AND METHODS

Tomato seeds (*lycopersicum esculentum L.* cv. Soltan) were sterilized in 0.5% sodium hypochlorite and germinated with distilled water during the first two weeks; and then with half strength of Rorison's nutrient solution for up to 40 days. Homogeneous seedlings (one per pot) were transplanted into plastic pots containing 8 Kg pasteurized soil [7] and inoculated with *Glomus versiform* (G1) and *Glomus etunicatum* (G2) or left uninoculated (control) (G0). Three levels of phosphorus (5, 20 and 40 mgP/kg soil; P_1, P_2 and P_3, respectively) as KH_2PO_4 and three levels of lead (5, 10 and 50 mgPb/kg soil; Pb_1, Pb_2

and Pb_3, respectively) as $PbSO_4$ were applied to the soil during transplanting. The P_3 level (~100 kgP/ha) is the recommended P rate for production of tomato at Azarbaijan Province of Iran. All pots received nitrogen at a rate of 90 mgN/kg as urea and potassium and at a rate of 76 mgK/kg as potassium sulfate [8]. Plants were arranged in a factorial randomized complete – block design with three mycorrhizal fungi, three phosphorus levels, three lead levels and four replications. The pots were watered when measurement indicated that soil moisture was below 0.8 field capacity (FC) moisture. The experiment was conducted in a glasshouse with average maximum day and night temperature of 26 and 14°C, respectively. After five months, the fruits were harvested and vitamin C content was measured [9]. Mycorrhizal colonization of root was measured by the gridline intersect method suggested by Dalpe *et al.* [10]. The data were subjected to analysis of variance using the analysis of variance (ANOVA) procedures of the SPSS program.

RESULTS AND DISCUSSION

Analysis of variance shows that vitamin C content of fruits and percentage of root colonization were significantly affected by inoculation with fungi, Pb and P levels (Table 1). P increased vitamin C content of fruits. Inoculated plants were enhanced significantly more than uninoculated plants at same level of P (Figure 1), but Pb levels significantly decreased vitamin C content of fruits. Vitamin C content of VAM colonized plants was increased at the same level of Pb (Figure 2). Gurgul *et al.* [11] pointed out that increasing of P level enhanced ascorbic acid content of fruits. This could be due to the fact that mycorrhizal fungi absorb more phosphorus element and P helps some enzymes to synthesis vitamin. Koyuturk *et al*. [12] reported that vitamin C decreases toxicity of heavy metals in human body. Vogel-Mikus *et al*. [13] pointed out that VAM colonization positively correlated with total soil Pb. Colonized plants showed significantly improved nutrient and decreased Pb uptake. The percentage of root colonization was positively affected by P levels and mycorrhizal fungi (Figure 3). Root colonization percent (RCP) was negatively affected by Pb level. However, there was no significant difference between *Glomus versiform* and *Glomus etunicatum* (Figure 4). Alizadeh -oskouie *et al*. [8] studied that the highest P level was not high enough to suppress mycorrhizal colonization. Asimi *et al*. [14] pointed out that P fertilization above the critical level considerably diminishes mycorrhizal colonization, but moderately available P has a stimulatory effect on this symbiosis. Ortega *et al*. [15] reported that heavy metals of soil decreased root colonization percent in plants.

Table 1. Analysis of variance of Vitamin C, fruit phosphorus (F. P), percent of root length colonization (RLC), and fruit lead (F. Pb) in response to mycorrhizal inoculations and different lead and phosphorus levels.

Source of variation	Mean square				
	df	**Vitamin C**	**RLC**	**F. Pb**	**F. P**
Replication	2	6790.009**	0.006ns	297.274**	0.012*
Mycorrhiza (M)	2	13360.260**	7491.331**	411.816**	0.078**
P	2	12340.897**	15.899**	9.668ns	0.051**
Pb	2	3317.574**	111.27**	30800.138**	0.003ns
P*Pb	4	59.821ns	1.783ns	26.107**	0.002ns
M*P	4	137.972**	4.593*	5.517ns	0.000ns
M*Pb	4	114.134**	28.404**	40.152**	0.001ns

*,**Significance at probability levels of 0.05 and 0.01 respectively; ns, Non significant).

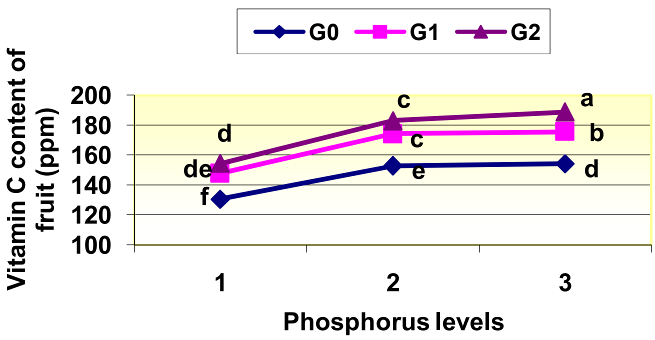

Figure 1. Interaction of P and fungi on vitamin C content.

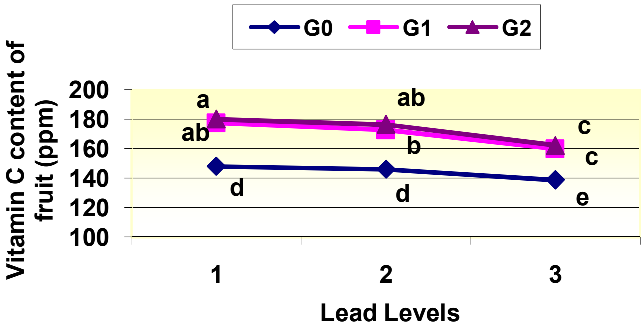

Figure 2. Interaction of Pb and fungi on vitamin C content.

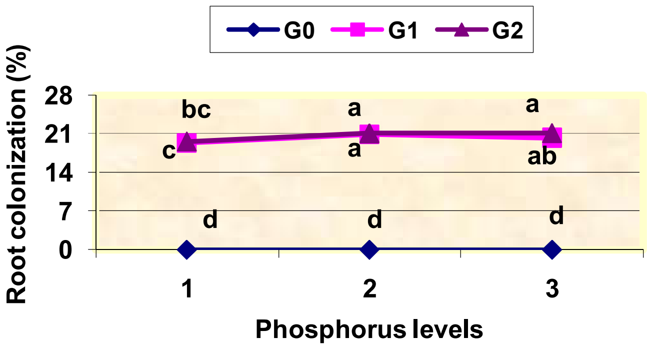

Figure 3. Interaction of P and fungi on root colonization percent.

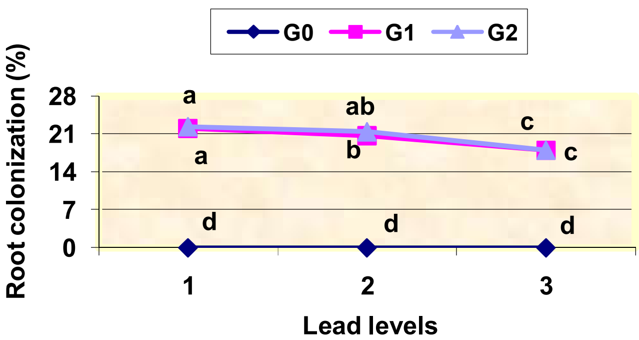

Figure 4. Interaction of Pb and fungi on root colonization percent.

CONCLUSION

Considering the results, we can use VA mycorrhiza to reduce Pb toxicity in tomato. AM symbiosis influences the quality of tomato fruits, P and Pb uptake in tomato fruits.

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