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Determination optimum concentration of iron in hydroponic medium of Tomato (*Lycopersicom esculentum*)

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ABSTRACT: In order to determine optimum concentration of iron in hydroponic medium of tomato, was performed an experiment in completely randomized design (CRD) by using 14 iron concentration and five replications. For this purpose, were selected 3-liters plastic containers and the pots were filled by Hoagland solution (without iron). Then were added different concentrations of iron (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5 mgL^{-1}) to the nutrient solution in each containers. The plants were transferred to the containers and were grown until 10% of the plants reached to the flowering stage. Then the plants were cut from the root, and shoots fresh and dry weight; chlorophyll content; iron and manganese in the leaves were measured. Data was analyzed by using MSTAT-C software and the means were compared by Duncan's multiple range test (DMRT). The obtained results indicated that the best iron concentration for growth of tomato was 0.6 mgL^{-1} so that the highest fresh and dry weight, total uptake of manganese, chlorophyll content and total iron uptake were observed in this iron level.

***Keywords*:** Iron, Manganese, Hydroponic, Tomato.

INTRODUCTION

Iron (Fe) is among effective micro elements in plant growth and development, which its efficiency in the plant is important (Mengel *et al*., 1982; Morales *et al*., 1998). Iron is one of the necessary and principle elements for several metabolic functions in the plant such as chlorophyll synthesis, photosynthesis, electron transfer system in respiration and enzyme activities. This element does not transferred from the mature leaves to the young leaves and in fact, is an immobile nutrient element (Mengel *et al*., 1994), which due to iron role in chlorophyll synthesis, its deficiency can be leading to iron chlorosis (Rafaati, 2003; Musavi and Rounaghi, 2005). Iron chlorosis is one of the limited agents on plant growth in calcareous soils that this soil not only prevents iron uptake by plant, but make inactive leaf iron by increasing the plant cell pH and high uptake of bicarbonate ions (HCO3-) and does not perform chemical reactions. There is the interconnected between pH of apoplast and cytoplasm, therefore by changes of cell pH can be increase active iron in the plant and consequently increase leaf chlorophyll and photosynthesis activities (Chen and Barak, 1982). According to the report of Basar, (2000), iron chlorosis had been an important problem in the grown peach trees in calcareous and alkaline soils. Hu *et al*. (2004) reported that chlorosis arising from iron deficiency can be decreased soybean yield in calcareous soil. Chen and Lu, (2006) reported Gorge area has important portion in china's citrus production but due to be calcareous soil in this area, iron chlorosis is a main problem in citrus production in this area. Kosegarten et al, (1999) indicated that contrary to green young leaves, in the yellow and growing leaves due to be low photosynthesis rate and consequently limitation of enzyme H^+-ATPase of plasma membrane, is made the place with high apoplast pH, which it has negative effect on intensity of Fe^{3+} reduction. In physiological iron chlorosis that typically occurs in the calcareous soils, there is no distinct relation between iron amount in the leaves and chlorosis rate and in fact, in some cases iron amount in the

chlorotic leaves has been more than green leaves (Chen and Lu, 2006; Handreck, 1997; Mengel, 2000; Roomizadeh and Karimian, 1996; Taize and Zeiger, 1998). High amounts of iron in the leaves of fruit trees affected by iron chlorosis, is indicator iron accumulation unavailability in the chlorotic leaves. This subject can be has high importance in the new methods for controlling iron chlorosis in the fruit trees because iron resource in the potential leaf can be convert to the mobile form (Nikolic and Romheld, 1999). Iron is used in plant metabolism, chlorophyll production, respiration, and photosynthesis and enzyme activities. Iron is an immobile element in the plant and its deficiency symptoms is similar to magnesium deficiency with this difference that in iron deficiency, the symptoms in the first occur in the young leaves in the form of chlorosis or yellowing and this condition quickly is expanding in the leaves. The leaf's vines are remaining green in iron deficiency but leaf's vines chlorosis is expanding in sever deficiency. Iron deficiency is beginning by creation of small spots and then the leaves become lime-yellow to white color, stem growth is stopped and leaf burning is visible then on the whole chlorophyll is disappearing. Lateral shoots and the fruits also are indicating deficiency symptoms (Nikolic and Romheld, 1999).

MATERIALS AND METHODS

In this study, in order to determine optimum concentration of iron element in hydroponic medium of Tomato (*Lycopersicom esculentum*) plant, were separately prepared different concentration of iron (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5 mgL^{-1}) by using iron chelate. For each iron concentration was selected one petri dish covered by filter paper and 10 seeds were cultured in each petri dish and was added 15 ml Hogland solution containing each iron concentration to the petri dishes. Totally were used 14 petri dishes and 140 seeds. After germination and root formation in the seedlings, were selected 5 seedlings from each petri dish and were transferred to the containers equipped by spongy guardian containing each one of the treatments. Then the 4-leaves plants were transferred to the 3-liters hydroponic containers containing its relative treatment. To provide other nutrient elements was equally added 3 liters Hogland solution without iron element to each container. In order to stabilize concentration of elements around the root was replaced the solution every three days. When 10% of the plants produced flower, the plants were cut from root and their fresh weight was measured. Then the plants were put in the paper bags and were dried in the 65 °C oven and their dry weight was measured. The dried plants were ground and one 1.0 g sample was turned to the ash in 450 °C. The ashes were extracted by HCl 2 N and boiling water and amounts of iron and manganese was measured in them by using atomic absorption device. The applied statistical design for this study was completely randomized design with 14 treatments (iron concentrations) and five replications. Data analysis was done by MSTAT-C software and the means were compared by Duncan's multiple range test (DMRT)

RESULTS AND DISCUSSION

Results

Plant fresh and dry weight

As the results of the means comparison in table 1, is considered that plant fresh weight extremely increased by enhancement iron concentration, so that from 287.21 g in control treatment reached to 501.08 g in 0.8 mgL^{-1}, which had no significant difference to 0.6 and 1.0 mgL^{-1} treatments. By increasing iron concentration higher than 1.0 mgL^{-1}, the plant fresh weight gradually decreased so that the plant fresh weight in 5 mgL^{-1} iron treatment has been decreased till 268.67 g, which even is less than fresh weight in control treatment, namely excessive enhancement of iron in the medium not only has not been increased plant fresh weight but has been caused to reduction of plant fresh weight. Changes trend of plant dry weight also was similar to the plant fresh weight so that dry weight from 108.00 g in control treatment increased till 203.67 g in the treatment of 0.6 mg. Although in the concentrations of 0.8 and 1.0 mg iron, increasing growth trend continued but this enhancement had no significant difference than 0.6 mg treatment. Plant dry weight gradually decreased by increasing iron level up to 1.0 mgL^{-1} so that plant dry weight reached to 105.26 g in the 5 mgL^{-1} iron level, which had no significant different to control treatment.

Table 1. Effect of different iron concentrations on fresh and dry weight and leaf chlorophyll in Tomato

Iron concentration (mgL^{-1})	Plant fresh weight (g/pot)	Plant dry weight (g/pot)	Chlorophyll (mg/g PFW)
0	287.21^{e}	108.00^{e}	0.15^{d}
0.2	357.46^{d}	143.14^{cd}	1.17^{c}
0.4	393.29^{c}	160.45^{bc}	2.22^{b}
0.6	499.00^{a}	203.67^{a}	2.92^{ab}
0.8	501.08^{a}	204.28^{a}	3.59^{a}
1	500.45^{a}	204.62^{a}	3.63^{a}
1.5	456.00^{b}	178.15^{b}	3.65^{a}
2	401.27^{c}	158.00^{c}	3.63^{a}
2.5	389.22^{c}	152.08^{c}	3.60^{a}
3	351.34^{d}	140.19^{cd}	3.64^{a}
3.5	338.00^{de}	135.51^{d}	3.65^{a}
4	292.42^{e}	119.19^{de}	3.65^{a}
4.5	278.11^{e}	109.37^{e}	3.63^{a}
5	268.67^{f}	105.26^{e}	3.62^{a}

†Means in each column with similar letter have not significant difference (p<0.01) according to DMRT.

Leaf chlorophyll amount

According to the results of table 1, leaf chlorophyll enhanced by increasing iron level in the plant medium and then remained constant. Leaf chlorophyll amount was 0.15 mgg^{-1} plant fresh weigh (PFW) in control treatment and increased by enhancement iron concentration and reached to 2.92 mgg^{-1} PFW in 0.6 mg iron treatment and then reached to 3.59 mgg^{-1} PFW in 0.8 mg iron level. Two recent treatments had no significant difference together but had significant enhancement than before them iron level. Leaf chlorophyll amount did not indicate any significant change up to 0.8 mg iron concentration so that leaf chlorophyll amount attained to 3.62 mgg^{-1} PFW in 5.0 mgg^{-1} iron level, which had no significant difference to 0.8 mg iron treatment.

Concentration and total iron uptake

The exhibited results in the table 2, demonstrated that plant iron concentration high significantly enhanced by increasing iron level in the medium, so that from 18.45 mg iron attained to 95.53 mgg^{-1} plant dry weight (PDW) in the 0.2 mgL^{-1} iron treatment and during a gradual trend, iron concentration in the plant increased until iron concentration in the plant reached to 228.12 mgg^{-1} PDW in 3.5 mg iron treatment and after this, by increasing iron level in the medium non-significantly iron concentration in the plant increased. Total iron uptake increased by enhancement iron level in the medium, so that from 1993 mgg^{-1} PDW in control treatment increased to 31402 mgg^{-1} PDW in 0.6 mg iron in the medium and after that till 1.5 mg iron level did not make significant change in total iron uptake. But total iron uptake gradually decreased to 26341 mgg^{-1} PDW by increasing iron level in the medium.

Table 1. Effect of different iron levels on concentration and total Fe and Mn uptake in Tomato

Iron concentration (mgL^{-1})	Iron (Fe)		Manganese (Mn)	
	Concentration in the plant (mg/g PDW)	Total uptake (mg/pot)	Concentration in the plant (mg/g PDW)	Total uptake (mg/pot)
0	18.45^{g}	1993^{g}	121.12^{c}	13081^{f}
0.2	95.53^{f}	13674^{f}	143.23^{b}	20502^{d}
0.4	137.25^{e}	22021^{e}	152.44^{ab}	24459^{c}
0.6	154.18^{e}	31402^{a}	163.52^{a}	33304^{a}
0.8	155.66^{de}	31798^{a}	157.15^{a}	32103^{a}
1	156.34^{de}	31990^{a}	147.89^{ab}	30261^{b}
1.5	178.12^{d}	31732^{a}	140.17^{b}	24971^{c}
2	193.19^{c}	30524^{b}	131.34^{bc}	20752^{d}
2.5	204.16^{bc}	31049^{ab}	122.77^{c}	18671^{de}
3	216.23^{b}	30313^{b}	117.10^{c}	16416^{de}
3.5	228.12^{ab}	30913^{ab}	118.78^{c}	16096^{e}
4	237.89^{a}	28354^{c}	106.67^{cd}	12714^{f}
4.5	243.26^{a}	26605^{d}	98.71^{d}	10796^{fg}
5	250.25^{a}	26341^{d}	91.89^{d}	9672^{g}

†Means in each column with similar letter have not significant difference (p<0.01) according to DMRT.

Concentration and total manganese uptake

The results of table 2 show that manganese (Mn) concentration in the plant high significantly enhanced by increasing iron concentration in the medium. So that Mn concentration from 121.12 mgg^{-1} PDW in the control treatment reached to 163.52 mg in 0.6 mg iron treatment and after that gradually decreased and attained to 91.89 mgg^{-1} PDW in 5.0 mg iron treatment. Namely, plant Mn concentration in 5.0 mg iron treatment was even less than

Mn concentration in control treatment. Also, was observed highly significant changes in total Mn uptake in the plant by increasing iron level in the medium so that total Mn uptake in the plant reached to 33304 from 13081 mgg^{-1} PDW by increasing iron concentration in the medium from 0 to 0.6 mg. Total Mn uptake gradually decreased by increasing Mn concentration from 0.6 to 5.0 mg iron in the medium and attained to 9672 mgg^{-1} PDW, which had high significant reduction than control treatment and other levels of iron.

Discussion

Just as before was explained, in the first plant fresh and dry weight is increasing by enhancement iron concentration in the tomato medium and then it remained constant from 0.6 to 1.0 mg iron levels and after that gradually decreased. Because of at first, the plant medium culture was lacking iron and this element is the limited agent for plant growth, therefore the plant growth and plant fresh and dry weight increased by enhancement iron level in the medium and whereas augmenting the first levels of one nutrient element to medium culture than its next levels has more effect on plant growth, to this same reason, the highest increasing of plant fresh and dry weight was relative to 0.2-0.6 mg iron treatments, which is indicator the role of this element on growth and development of tomato. After that, plant fresh and dry weight increased with gentle slope by increasing iron level in the medium from 0.6 to 1 mg. Plant fresh and dry weight gradually decreased by enhancement iron concentration more than 1.0 mg and even reached to the amounts less than control treatment. In fact, excessive increasing of iron concentration in the medium prevents uptake of the elements such as Mn, Zn, K, Ca and even ammonium ion and via prevention of above element uptake, plant growth and plant fresh and dry weight also have been decreased. In a study that performed by Handreck (1997) on sunflower, had been shown that the leaf area enhanced by increasing iron level and reduction of medium pH and then plant fresh and dry weight significantly increased than control treatment.

Tomato's leaf chlorophyll amount increased by enhancement iron in the medium and remained constant up to 0.8 mg iron. Whereas, central nucleus of chlorophyll has been formed from iron, it is normal that leaf chlorophyll to be increase by increasing iron amount in the medium but higher iron concentration (more than 0.8 mg) not only had no influence on chlorophyll formation but it may due to reduction of other elements uptake, chlorophyll formation confused. Although the elements such as Mn and Zn there are not in chlorophyll structure but reduction of them in the plant is leading to reduction of the enzymes activity involved to chlorophyll formation. Therefore, increasing iron amount in the plant can be reduced the amount of above elements in the plant and consequently chlorophyll amount decrease. The obtained results of Alam *et al*, (2001) in the medium culture of barley are confirmer to above results.

Iron amount in the plant severely increased by enhancement iron level in the medium and by continuation iron enhancement, iron amount in the plant with gentle slope increased and iron amount in the plant remain constant in up to 3.5 mg iron levels. It is might as a result of excessive uptake of iron by plant, uptake of the effective elements in iron absorption, has been confused.

By increasing iron level in medium, at first was observed sever enhancement in total iron uptake so that the greatest total iron uptake was relative to 0.6 mg iron level. Because of the highest plant fresh and dry weight obtained in 0.6 mg iron in the medium consequently total iron uptake, which is product of iron concentration and plant dry weight (Fe × PDW), will be the highest in this iron treatment. Total iron uptake decreased by enhancement iron concentration in the medium due to reduction of plant weight. Manganese concentration in the plant increased by enhancement iron level in the medium so that when iron level in the medium reached to 0.6 mg, Mn concentration in the plant was the highest amount, which is indicator of positive interaction of Fe and Mn for uptake by plant in low iron concentration treatments. Namely, in the low iron concentrations, each one of these elements is facilitating uptake of other element by the plant. Total Mn uptake also increased by increasing iron level in the medium due to increase Mn uptake as well as increasing plant weight. Because of increasing iron level in the medium is preventing from Mn uptake and also plant weight is decreasing consequently total Mn uptake decreased and Mn concentration in the plant reached to minimum amount in 5.0 mg iron treatment, which was less than control treatment. Accumulation of each elements of Fe or Mn in the plant medium culture can be prevent uptake of other element by plant and appear deficiency symptoms of the element. Roomizadeh and karimian (1996) indicated that excessive increasing of each elements of Fe or Mn in the Soybean medium culture prevents uptake of other element and appear deficiency of this element.

Regards to the total obtained results, can be concluded that the best iron concentration for tomato in hydroponic system at 0.6 mgL^{-1} so that the highest plant fresh and dry weight; concentration and total Mn uptake; leaf chlorophyll and total Fe uptake was observed in 0.6 mgL^{-1} treatment.

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