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Full Length Research Paper

Effects of different potassium and iron levels on seasonal changes of nutrient concentrations of tomato plant grown in soilless culture

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Potassium and iron are the main elements that are of great importance in soilless medium in terms of tomato nutrition. However, the activities of plant nutrients are very complex and changes depending on growing stage, environmental condition and element concentrations in nutrient solution. It is necessary to have more information about the combination of K and Fe in different growing stages in soilless culture. Therefore, this study was carried out to determine the effects of different levels of potassium and iron applications on seasonal changes of plant nutrient concentrations of tomato plant grown in soilless culture. For this purpose, treatments were defined by a factorial combination of three potassium (150, 300 and 450 mg L^{-1}) and three iron levels (1, 2 and 3 mg L^{-1}) with 4 replicates. The leaf samples were taken in two periods [26 November 2006 (fruit set), 15th March 2007 (harvest time)] thereby seasonal changes of plant nutrient concentrations were investigated. The evidences provided by this experiment indicated that the different potassium and iron applications had significant effects on plant nutrient concentration of tomato leaves except P and Mn concentration of 2nd periods. High level of K and Fe applications caused antagonistic effect on nutrient uptake and resulted in imbalance on mineral nutrition of tomato plants. Potassium (K), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) concentrations of tomato leaves showed seasonal changes by K and Fe applications. While tomato leaves K, Zn and Mn concentrations were decreasing from fruit set to harvest time, Mg, Fe and Cu concentrations were increased.

Key words: Tomato, perlite, potassium, iron, seasonal changes, plant nutrient.

INTRODUCTION

Tomato is one of the popular and most consumed vegetable in the world. Great efforts have recently been focused in producing a good apperance and quality tomato through the utilization of inexpensive and environmentally friendly resources. Production of quality fruits is controlled by the interaction of genetic, environmental and cultural factors growing substrate, nutrient solution composition in soilless culture (Dorais et al., 2001). Among essential plant nutrients, potassium is the one that is absorbed by the tomato plant in the largest amounts. It functions are mainly in pH stabilization, osmoregulation, enzyme activation and membrane transport processes (Marschner, 2002). Addition of potassium, iron plays an important role in tomato nutrition and fruit quality. This microelement significantly affects the quantity and quality of tomato yield in greenhouses cultivation with a limited volume of the growing medium (Chohura et al., 2009). There is an interaction between macronutrients and micronutrients as reported by different researchers (Mengel and Kirky, 1987; Marschner, 2002).

It can be assumed that nutrient interaction improves iron nutrition without directly iron fertilizing. Increase in Fe availability was associated with potassium in the Strategy

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I and Strategy II categories (Bolle-Jones, 1955; Barak and Chen, 1984). The positive effect of K on Fe nutrition was related to acidification of the rhizosphere caused by excessive K^+ uptake and subsequent release of H^+ ions by roots to maintain a cation/anion balance (Oertilli and Opuku, 1974; Barak and Chen, 1984). At the same time, the role of K in accumulation of these organic acids (citrate), therefore, may be equally important Fe transport as it has role in enhancement of specific Fe-stress response. However, the nutrient content of any tissue depends upon its physiological stage. Therefore, the mineral composition of plants changes markedly with the season. In this research, we investigated the effects of potassium and iron applications on seasonal changes of plant nutrient concentrations of tomato plants grown in soilless culture.

MATERIALS AND METHODS

The experiment was carried out in a plastic greenhouse located in Antalya, Turkey. Tomato seedlings were planted in soilless culture (perlite) on September 13th, 2006. Volume of each perlite bag was about 32 dm^3 (1.2 m length and 25 cm width), with a density of 4 plants per m^2. The experiment was designed according to the completely randomized factorial design with 4 replicates. Each plant was fed by a single dripper. Bumblebees (*Bombus* sp.) were introduced into the greenhouse for the better pollination. The oldest leaves (that is those at the bottom of the stem) were periodically removed. Nutrient solutions K_1, K_2 and K_3, representing 150, 300 and 450 mg L^{-1} of potassium (K_2SO_4 and KNO_3 as source; nutrient solution potassium concentration was arranged by K_2SO_4) and Fe_1, Fe_2 and Fe_3, representing 1, 2 and 3 mg L^{-1} of iron (Fe-EDDHA as source) were applied. One liter of the nutrient solutions also contained 210 mg N (ammonium nitrate, potassium nitrate and calcium nitrate), 40 mg P (mono potassium phosphate), 150 mg Ca (calcium nitrate), 50 mg Mg (magnesium sulfate), 0.75 mg Mn (manganese sulfate), 0.40 mg B (boric acid), 0.50 mg Zn (zinc sulfate), 0.10 mg Cu (copper sulfate) and 0.05 mg Mo (sodium molibdate) (Day, 1991). EC and pH values in each tank were daily checked and maintained 2.5 to 3.5 dS m^{-1} and 5.5 to 6.5, respectively. Nutrient solutions were completely changed once a week.

Leaf samples (5th to 6th fully expanded leaves) of tomato were collected as described by Geraldson et al. (1973). The samplings were done two different periods during the growing season. In the 1st period, leaf samples were taken from the fruit set (November 26th, 2006). In 2 nd period, tomato leaf samples were taken at end of the harvest time (March 15th, 2007). At the end of the 6 month experiment period, plants were harvested. Leaf samples were washed by distilled water and dried in a forced-air oven at 65°C to constant weight. Samples were ground separately in a stainless mill to pass through a 20 mesh screen and kept in clean polyethlene bags for analysis. Dried leaf samples of 0.5 g each were digested with 10 mL $HNO_3/HClO_4$ (4:1) acid mixture on a hot plate. The samples were then heated until a clear solution was obtained. The same procedure was repeated several times. The samples were filtered and diluted to 100 mL using distilled water. Concentrations of K, Ca, Mg, Fe, Zn, Mn and Cu in the digestates were determined by using ICP-OES (Kacar and Inal, 2008). Phosphorus was measured by spectrophotometry (Kacar and Kovanci, 1982) and total nitrogen was determined by a modified Kjeldahl procedure (Kacar and Inal, 2008). Statistical analysis was carried out using the JUMP software. Means were compared by analysis of variance (ANOVA) and the LSD test at $P \leq 0.05$. A factorial analysis was used to determine interaction effects of different potassium and iron levels on nutrient concentrations of tomato plants.

RESULTS AND DISCUSSION

Macro nutrient concentrations of tomato plants significantly varied due to K and Fe applications. Applications data are presented in Table 1 for 1st and 2nd sampling periods. In the 1st period, K and Fe applications were found not to be effective on N concentrations of tomato leaf but their interactive effects were significantly important in the 1st period. The highest leaf N concentration was obtained with K_1Fe_1 (4.30%) treatment and the lowest leaf N concentration was obtained with K_2Fe_3 (3.73%) treatment. Nitrogen concentration significantly differed with K, Fe applications and their interactive effects in 2nd period. The highest leaf (4.56%) N concentration were recorded by K_2Fe_1 treatment and the lowest value was obtained by K_1Fe_3 (3.48%) (Table 1). Seasonal changes in mean nitrogen concentrations of tomato plant were not found to istatistically important (Figure 1). Different levels of potassium and iron applications were not affect in view of P concentrations (Table 1). Furthermore, the taken periods of leaf samples did not affect P concentration. Fernandez-Escobar et al. (1999) reported that there was little or no difference in P among leaves of different stage in olive.

Leaf K concentration significantly differed with K, Fe applications and their interactive effects in the 1st period. The highest leaf K concentration was obtained with K_2Fe_1 (4.85%) and K_3Fe_3 (4.85%) treatments. The lowest leaf K concentration was by K_1Fe_1 (4.03%) treatment. In the 2nd period, leaf K concentration was significantly differed with K applications and KxFe interactions (Table 1). The highest K was evaluated with K_3Fe_2 (5.09%) and the lowest leaf K value was obtained with K_1Fe_1 (3.49%) treatment. Seasonal changes in mean potassium concentrations of tomato plant were found to be statistically important (Figure 1). In the 1st period, mean potassium concentration (4.45%) was higher than in the 2nd period (4.22%). Dibb and Thompson (1985) reported that potassium concentration decreased during the growing season. The reason for this may be increasing of the transportation of K from leaf to fruit and other organs. K and Fe applications were found not to be effective on Ca concentrations of tomato leaf but their interactive effects were significantly important every two periods. The highest leaf Ca concentration was attained with K_2Fe_2 (2.95%) and lowest value (1.65%) was by K_3Fe_2 treatment in the 1st period (Table 1). In the 2nd period, the highest leaf Ca concentration was obtained by K_1Fe_1 (2.56%) treatment and lowest value (1.56%) was by K_1Fe_3 treatment (Table 1). Generally, increasing of K concentration in nutrient solution was negative effect on leaf Ca concentration. This stiuation may be arise from the antagonistic interaction among Ca, Mg and K. K and Mg in nutrient solution due to the antagonism in root zone

Table 1. The effects of different levels of potassium and iron applications on macro nutrients concentrations of tomato plants sampling in two period.

Treatments	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
	I. Period	II. Period	I. Period	II. Period	I. Period	II. Period	I. Period	II. Period	I. Period	II. Period
K_1Fe_1	4.30^{a}	3.80^{cd}	0.78	0.76	4.03^{d}	3.49^{d}	2.51^{abc}	2.56^{a}	0.67^{a}	0.78^{a}
K_1Fe_2	4.21^{ab}	3.76^{cd}	0.67	0.69	4.10^{cd}	3.74^{cd}	2.48^{abc}	2.28^{abc}	0.59^{bc}	0.69^{abc}
K_1Fe_3	3.90^{bcd}	3.48^{d}	0.57	0.61	4.48^{abc}	4.18^{bc}	1.68^{d}	1.56^{d}	0.54^{cd}	0.55^{f}
K_2Fe_1	4.16^{abc}	4.56^{a}	0.73	0.69	4.85^{a}	4.56^{b}	2.02^{bcd}	1.84^{bcd}	0.55^{cd}	0.63^{bcde}
K_2Fe_2	3.99^{abcd}	4.08^{bc}	0.69	0.73	4.26^{bcd}	4.02^{bc}	2.95^{a}	2.36^{ab}	0.63^{ab}	0.70^{ab}
K_2Fe_3	3.73^{d}	3.84^{cd}	0.69	0.66	4.57^{ab}	4.24^{bc}	1.79^{cd}	1.96^{abcd}	0.53^{d}	0.65^{bcde}
K_3Fe_1	4.01^{abcd}	4.79^{a}	0.64	0.63	4.31^{bcd}	4.21^{bc}	1.83^{cd}	2.14^{abcd}	0.57^{cd}	0.67^{bcd}
K_3Fe_2	3.99^{abcd}	4.44^{ab}	0.72	0.70	4.60^{ab}	5.09^{a}	1.65^{d}	1.63^{cd}	0.52^{d}	0.57^{de}
K_3Fe_3	3.84^{cd}	4.10^{bc}	0.76	0.70	4.85^{a}	4.52^{b}	2.62^{ab}	2.19^{abcd}	0.67^{a}	0.59^{cde}
Significance of main effects and mean separation values for interactions										
K	ns	***	ns	ns	***	**	ns	ns	ns	ns
Fe	ns	***	ns	ns	*	ns	ns	ns	ns	*
K X Fe	*	***	ns	ns	**	**	*	*	***	*
LSD	0.3321	0.3795	-	-	0.3609	0.4933	0.7421	0.6650	0.05440	0.1096

* Significant at the α= 0.05 probability level; ** significant at the α= 0.01 probability level; *** significant at the α= 0.001 probability level; ns = non-significant; † For a significant (P ≤ 0.05) K X Fe interaction LSD values (0.05) are for comparing K applications means within or between Fe applications.

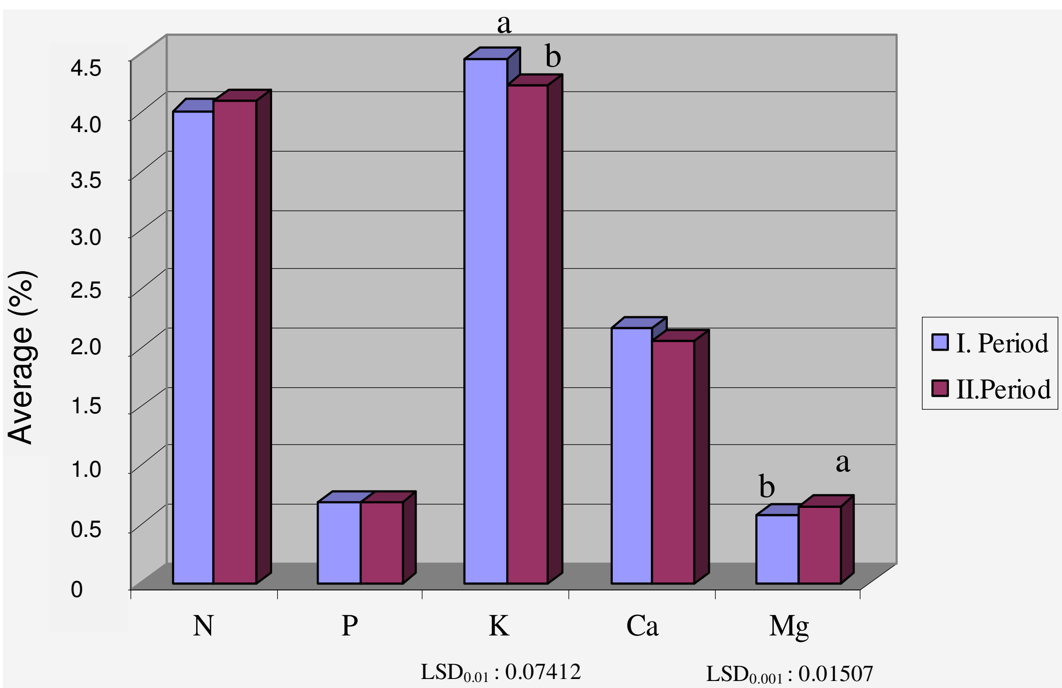

Figure 1. Seasonal changes of average macro nutrients concentrations of tomato leaf.

between the largely hydrated Ca^{2+} ion and the other cations that are smaller and easier to carry and transport, especially K (Marschner, 2002). At the same time, Fe applications caused negative effect in leaf Ca concentration. The Ca uptake mechanism of the roots might be affected by increasing Fe applications in different ways. It is known that the nutrient uptake of roots depends on different mechanisms and these

Table 2. The effects of different levels of potassium and iron applications on micro nutrients concentrations of tomato plants sampling in two period.

Treatments	Fe (mg/kg)		Zn (mg/kg)		Mn (mg/kg)		Cu (mg/kg)	
	I. Period	II. Period	I. Period	II. Period	I. Period	II. Period	I. Period	II. Period
K_1Fe_1	47.6^{d}	87.6^{d}	68.5^{bc}	99.05^{bcd}	162.7^{ab}	205.2	14.7^{c}	18.1^{cd}
K_1Fe_2	47.8^{d}	125.9^{abc}	56.8^{cd}	93.3^{bcde}	146.3^{abc}	178.8	21.9^{a}	17.3^{de}
K_1Fe_3	56.2^{bc}	137.5^{a}	67.2^{bc}	75.6^{e}	129.9^{cd}	119.0	20.2^{ab}	21.5^{bc}
K_2Fe_1	53.3^{c}	85.8^{d}	73.1^{b}	104.9^{ab}	150.4^{abc}	171.9	16.0^{bc}	25.5^{a}
K_2Fe_2	54.3^{bc}	91.4^{d}	72.0^{b}	120.2^{a}	141.3^{bcd}	166.7	18.9^{abc}	15.8^{de}
K_2Fe_3	60.8^{a}	145.2^{a}	57.0^{cd}	82.4^{de}	129.8^{cd}	152.4	15.8^{bc}	19.5^{cd}
K_3Fe_1	53.3^{c}	106.0^{cd}	60.0^{bcd}	94.3^{bcd}	130.1^{cd}	190.0	17.0^{bc}	21.5^{bc}
K_3Fe_2	53.9^{bc}	109.3^{bcd}	52.2^{d}	86.2^{cde}	116.5^{d}	163.8	15.9^{bc}	23.9^{ab}
K_3Fe_3	58.2^{ab}	131.5^{ab}	98.4^{a}	100.7^{bc}	170.0^{a}	191.1	14.4^{c}	14.0^{e}
Significance of main effects and mean separation values for interactions								
K	*	ns	ns	*	ns	ns	ns	ns
Fe	***	**	**	*	ns	ns	ns	*
K X Fe	***	***	***	**	**	ns	*	***
LSD	4.484	24.96	14.29	17.82	27.22	-	4.629	3.87

* Significant at the α= 0.05 probability level; ** significant at the α= 0.01 probability level; *** Significant at the α= 0.001 probability level; ns = non-significant; † For a significant (P ≤ 0.05) K X Fe interaction LSD values (0.05) are for comparing K applications means within or between Fe applications.

mechanisms are controlled by different factors (Mohr and Schopfer, 1994). Seasonal changes in calcium concentrations of tomato plant were not found to istatistically important (Figure 1). Compared to the 1st period, leaf Ca concentration decreased in the 2nd period (2.06%). The reason for this may be increasing of the transportation of Ca from leaf to fruit and other organs. Mirdehghan and Rahemi (2007), accumulation of all the macro and microelement within the fruit also increased during fruit growth and development.

Results revealed that leaf Mg concentration was significantly affected by interactive effect between K and Fe applications in the 1st period. The highest leaf Mg concentration was obtained with treatment K_1Fe_1 and K_3Fe_3 (0.67%) and lowest Mg value was by K_3Fe_2 (0.52%). In the 2nd period, the effects of Fe applications and K*Fe on leaf Mg concentration was found statistically important. The highest leaf Mg concentration was obtained with treatment K_1Fe_1 (0.78%) and lowest Mg concentration was by K_1Fe_3 (0.55%). The Mg leaf concentration was negatively affected by increasing levels of Fe concentration in nutrient solution. The quantities of magnesium accumulate and translocation to different plant parts may be affected by the status of other elements in the plant (Jones et al., 1991). Evaluated in terms of seasonal variation of magnesium in plant, it was found that leaf Mg concentration in 2nd period (65%) was higher than in the 1st period (0.58%). Magnesium is less than the movement within the plant. Therefore, these physiological properties may have caused this increase. Clark and Smith (1990) reported that concentration of Mg generally increased steadily. Iron concentration significantly differed with K, Fe applications and their interactive effects in the 1st period. The highest leaf Fe concentration (60.8 mg/kg) was recorded by K_2Fe_3 treatment. The lowest leaf Fe concentration was obtained by K_1Fe_1 (47.6 mg/kg) (Table 2). In the 2nd period, the highest leaf Fe (145.2 mg/kg) concentration was by K_2Fe_3 treatment and the lowest value obtained by (85.8 mg/kg) K_2Fe_1 treatment. Leaf Fe concentrations changed depending on the seasonal changes and especially increased in harvest time (in the 2nd period) (Figure 2). Reason for this increase may be the realization of irrigation at regular intervals. Similarly, Sheng et al. (2009) reported that Fe concentration increased depending on oranges leaf age.

Leaf Zn concentration was significantly affected by Fe applications, and interactive effects between these applications in the 1st period (Table 2). The highest leaf Zn concentration was obtained with K_3Fe_3 (98.4 mg/kg), the lowest leaf Zn concentration was by K_3Fe_2 (52.2 mg/kg) treatment. Leaf Zn concentration was significantly affected by K and Fe applications, and interactive effects between these applications in the 2nd period. The highest leaf Zn concentration was obtained with K_2Fe_2 (120.2 mg/kg) treatment, the lowest leaf Zn concentration was by K_1Fe_3 (75.6 mg/kg) treatment. Evaluated in terms of seasonal changes in plant zinc concentration in the 2nd period was reduced. Brohi et al. (1994) reported that light quality, intensity and duration of lighting may affect uptake of Zn in production season and low light intensity leads to a decrease in zinc uptake. Leaf Mn concentration

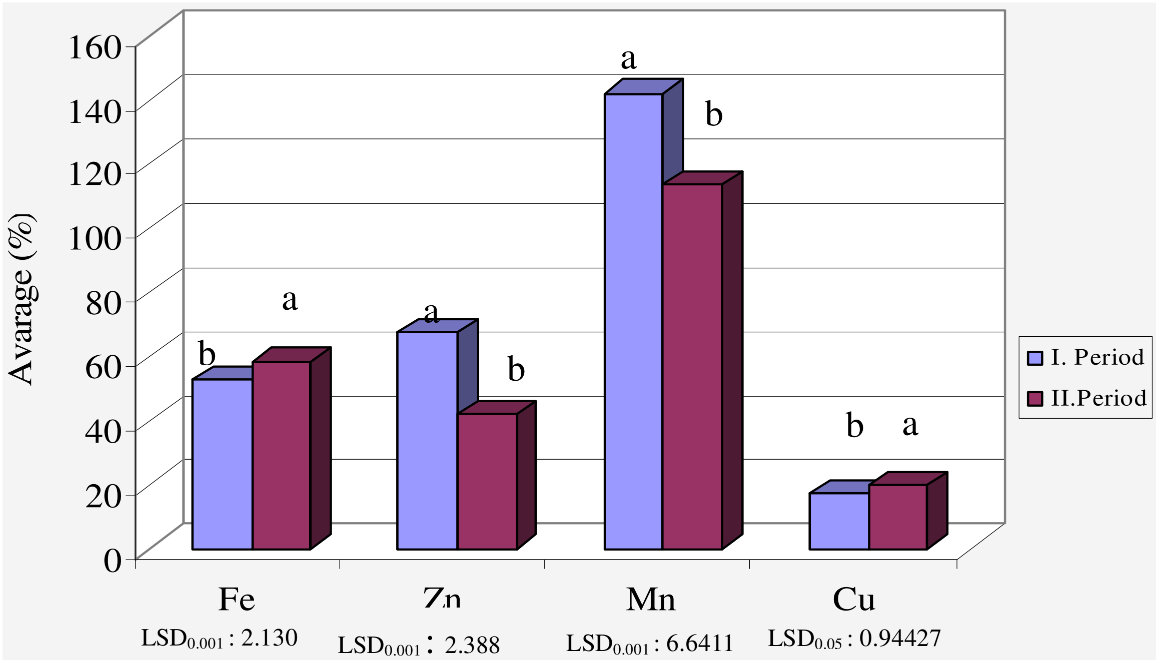

Figure 2. Seasonal changes of average micro nutrients concentrations of tomato leaf.

was significantly affected by interactive effects between K and Fe applications in the 1st period. The highest leaf Mn concentration was obtained with K_3Fe_3 (170.0 mg/kg) and the lowest leaf Mn concentration was by K_2Fe_3 (129.8 mg/kg) treatment. Increase of potassium and iron applications caused decrease in leaf manganese concentration. According to results, increasing levels of K and Fe applications did not affect leaf Mn concentration in the 2nd period. Mn concentrations of tomato leaves ranged from 119.0 to 205.2 mg kg^{-1}. Seasonal changes in mean manganese concentration of tomato plant were found to be statistically important (Figure 2). In the 1st period, mean manganese concentration (141.9 mg/kg) was higher than in the 2nd period (113.3 mg/kg).

In the 1st period, effects of interaction between K and Fe applications on leaf Cu concentration was found to be statistically important. The highest leaf Cu concentration was attained with K_1Fe_2 (21.9 mg/kg) and the lowest Cu value obtained with K_3Fe_3 (14.4 mg/kg). In the 2nd period, leaf Cu concentration was significantly affected by Fe applications, and interactive effects between K and Fe applications. The highest leaf Cu concentration was obtained with K_2Fe_1 treatment (25.5 mg/kg) and the lowest leaf Cu concentrations was recorded by K_3Fe_3 (14.0 mg/kg). Generally, increasing Fe concentration in nutrient solution caused a decrease in leaf Cu concentration. The antagonistic relationship between Cu and Fe is reported by other researchers. The antagonistic relationship between Cu and Fe is reported by other researchers. Karaman et al. (1997) found that the Cu content of bean leaves was decreased by ascending application of Fe. Meanwhile, leaf Cu concentrations changed depending on the seasonal changes and especially in the 2nd period (19.7 mg/kg) increased (Figure 2).

Conclusion

The effects of different levels of potassium and iron applications on tomato plant nutrition status were change depending on growing period. According to obtained results the mean potassium, zinc and manganese concentrations of tomato leaves in fruit set were higher than harvest time; magnesium, iron, and copper concentrations were higher in harvest time.

It is essential to know for fertilization nutrition demand of plants and at which period this nutrition is necessary. As it is known, the total uptake of nutrients varies with many factors such as light intensity, temperature, humidity, aeration and with the health of the plant, growing stage, particularly of the root system (Winsor and Adams, 1987). Therefore, studies related to interaction effects of elements in different growing stage and in different ecological conditions are needed.

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