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Effect of Both Soil Copper Applications and Foliar Copper Application Frequencies on Macronutrients Contents of Tomato Plants

SAHRIYE SONMEZ*, MUSTAFA KAPLAN, N. KEMAL SONMEZ†, HARUN KAYA‡ and ILKER UZ††
Department of Soil Science, Faculty of Agriculture, Akdeniz University 07059, Antalya, Turkey
E-mail: ssonmez@akdeniz.edu.tr

Copper-containing fertilizers, fungicides and bactericides are extensively used to control plant diseases in greenhouses in Turkey. These materials are applied from both soil and foliar. Excessive applications of these materials have led to the imbalance the mineral nutrition of plants. The objective of this study was to evaluate the effects of both soil copper applications (SCuA) and foliar copper application frequencies (FCuAF) on macronutrient contents (nitrogen [N], phosphorus [P], potassium [K], calcium [Ca] and magnesium [Mg]) in different organs of tomato plants grown in greenhouse. For this purpose, tomato seedlings were grown for 8 months in a computer-controlled greenhouse and Cu was applied as a factorial combination of rate (0 [S1], 1000 [S2] and 2000 [S3] mg kg^{-1}, soil) and frequencies (no application [F1], biweekly [F2] and weekly [F3], foliar). Two separate experiments were conducted to observe effects of different Cu-containing chemicals. Two fungicides, Gunner and Tenn-Cop 5E (containing Cu oxychloride and copper salts of fatty and rosin acids, respectively) were used for foliar copper applications, $CuSO_4\cdot5H_2O$ was used to provide copper to soil. In the experiment-I (Gunner, Cu oxychloride), both SCuA and FCuAF did not affect total N contents of plant samples. P content of leaf was improved with SCuA and FCuAF. However, FCuAF generally caused a decline P contents in fruit and root. SCuA initially resulted in an increase and then a decrease in K content of leaf while decline in root samples. FCuAF caused a decline in K content in fruit. Ca content in root was positively affected by SCuA, however FCuAF initially resulted in an increase then a decrease in Ca content of root. Ca contents of fruit and leaf were not changed by any treatment. Mg content of root samples increased with SCuA and decreased with FCuAF. Mg contents of fruit and leaf were not affected by any of the treatments. In the experiment-II (Tenn-Cop 5E, copper salts of fatty and rosin acids); total N content of leaf samples increased due to SCuA and FCuAF, SCuA and FCuAF resulted in a decline in N content of fruit. N content of root did not show any change. P content of leaf increased with SCuA

†Remote Sensing Research & Application Center, Akdeniz University, 07059, Antalya, Turkey.
‡Bati Akdeniz Agricultural Research Institute, 07100, Antalya, Turkey.
††Gazi Osman Pasa University, Tasliçiftlik Campus, 60200 Tokat, Turkey.

and generally decreased with FCuAF. P contents of fruit and root samples were decreased by FCuAF. K contents of leaf samples were found to be increased by SCuA while K content in root dropped. K content of fruit initially increased and then decreased with SCuA and decreased with FCuAF. In addition, FCuAF were not found to be effective on leaf and root K contents. In general, Ca content of leaf was found to be increased by SCuA and generally decreased by FCuAF. None of the applications was found to be effective on Ca content of fruit. Ca content of root was positively affected by SCuA. Mg content of leaf samples were not affected by any of the applications. Mg contents of root and fruit were increased by SCuA and decreased by FCuAF. As a result, both SCuA and FCuAF, especially aiming to control plant diseases, showed different effects on N, P, K, Ca and Mg contents and imbalance the mineral nutrition of tomato plants. Combined applications of Cu to soil and leaves could be more deleterious to plants when Cu is applied only to soil or leaves.

Key Words: Copper, Macronutrients (N, P, K, Ca and Mg), Tomato, Greenhouse.

INTRODUCTION

Even though copper is an essential element for plants, its presence in high level in soils and plants has toxic effect inhibiting plant growth[1-3].

In general, copper content of unpolluted soils varies between 2 and 40 mg kg^{-1}. Polluted soils, however, contain up to 100 mg kg^{-1} copper. In soil, copper is primarily held by organic matter, manganese and iron oxides. Therefore, its availability can be very low. It is also held by silicates. Small amount of copper can be found in exchangeable and soluble forms[4].

Copper is taken up by plants as Cu^{2+} and possibly as low molecule organic complexes and also partly as inorganic complexes. Therefore, in polluted soils, even if the pH is above 5, copper can be present in soil solution in organic, hydroxyl and carbonate forms. However, the presence of high phosphorus in soil solution reduces copper availability[4].

Copper pollution in soils is caused by not only industrial activities but also agricultural practices. In regions where hop production and vineyards are common, copper accumulation was observed due to applications of chemicals for plant protection purposes. Copper content of these soils may reach[5] 600 mg kg^{-1}. In these soils, if another plant is grown following the primary crop, such as hops, the yield of the second crop is reduced considerably.

High level of copper prevents root developments and damages root cell membranes in plants that are not tolerant to copper[6]. For most crop species, the critical toxicity level of Cu in leaves is considered to be above

20 to 30 mg kg^{-1} dry wt[7,8]. There are, however, marked differences in Cu tolerance among plant species (*e.g.*, bean is much more tolerance than maize); these differences are directly related to Cu content of the shoots[9].

A large Cu supply usually inhibits root growth before shoot growth[10]. However, this does not mean that roots are more sensitive to high Cu concentrations; rather, they are the sites of preferential Cu accumulation when the external Cu supply is large. Inhibition of root development and destruction of root cell membranes in plants with low tolerance are the first immediate response to high Cu.

Wang *et al.*[11] conducted a pot experiment with corn plants to investigate the effect of phosphorus fertilization on prevention of copper toxicity. They reported that the copper application hindered root and shoot development. They also observed that plant height and weight were negatively correlated when none or low-level phosphorus were applied. The same workers also indicated that availability of copper was reduced when high level of phosphorus was added.

Cu-containing fertilizers, fungicides and bactericides has been used extensively in the greenhouses in the Antalya, Turkey. Kaplan[12] found that the percentage of soils containing DTPA-extractable Cu greater than the critical toxicity level (20 mg kg^{-1}) was 8.1 in Antalya, Turkey. The Cu content of tomato leaf samples ranged between 2.4 and 1490 mg kg^{-1} (mean 166.5 mg kg^{-1}) and the concentration in leaf samples was very high due to the intensive use of foliar applied Cu-containing chemicals. Kaplan[12] also pointed that it may be necessary to reduce the use of Cu-containing fertilizers being used in those greenhouses where Cu-containing pesticides have been or being used.

Applications of Cu containing fertilizer, pesticides and fungicides to leaf or soil have increased gradually over the years in Mediterranean region and Cu accumulation has reached dangerous levels. Therefore, we investigated effects of both soil Cu applications (SCuA) and foliar copper application frequencies (FCuAF) on macronutrients (N, P, K, Ca and Mg) contents of tomato plants.

EXPERIMENTAL

Pot experiments were conducted in a computer-controlled greenhouse located in Antalya, Turkey. Pots were filled with a Xerorthent soil (Entisol) with the following chemical and physical properties: clayey textured (530.4 g kg^{-1} clay, 367.2 g kg^{-1} silt and 102.4 g kg^{-1} sand); pH 6.5 (1:2.5 soil:water ratio); 26.0 g kg^{-1} organic matter; total carbonates equivalent to 44.0 gkg^{-1}; total N 0.18 %; extractable P 110.80 mg kg^{-1}; extractable K 241.8 mg kg^{-1}; extractable Ca 2750.0 mg kg^{-1}; extractable Mg 541.2 mg kg^{-1}; DTPA-extractable Fe 92.35 mg kg^{-1}; DTPA- extractable Zn 14.80 mg kg^{-1}, DTPA-extractable Mn 295.80 mg kg^{-1} and DTPA-extractable Cu 15.30 mg kg^{-1}. The details of the experiments were previously reported by Sonmez *et al.*[13].

Two separate experiments were carried out, each using different cupric fungicide: Cu oxychloride or copper salts of fatty and rosin acids. The former contains 25 % Cu oxychloride and is sold as a powder. The latter is a liquid fungicide containing 58 % copper salts of fatty and rosin acids, equivalent to 51.4 mg L^{-1} metallic Cu. Copper was applied to soil as $CuSO_4 \cdot 5H_2O$ with 24.5 % copper. Tomato (*Lycopersicon esculentum* L.) mill cv. F144) was selected for this study as a test plant. The seedlings of tomato were obtained from the West Mediterranean Agricultural Research Institute, Antalya, Turkey.

20 kg of air-dried soil are passed through a 4 mm mesh sieve and mixed with 5 kg of a 75 % turf: 25 % perlite mixture and distributed in 25 L pots, fertilized with mono ammonium phosphate and potassium sulphate (36 kg N ha^{-1}, 80 kg P ha^{-1} and 112 kg K ha^{-1}). Copper was applied to soil at three different rates [0 (S1), 1000 (S2) and 2000 mg kg^{-1} (S3)] as $CuSO_4 \cdot 5H_2O$. One seedling of tomato (*Lycopersicon esculentum* L.) Mill cv. F144) was planted per pot. Fungicides were applied at three different frequencies [control, no application (F1), biweekly (F2) and weekly (F3)]. The treatments were set up based on report of Kaplan[12]. Trials were set up in a completely randomized factorial design with nine treatments; three levels of Cu application to soil and three frequencies of fungicide application to leaves in all possible combinations.

Processes during and at the end of the experiment period

Pots were incubated for two weeks without plants after addition of copper sulphate to soil and before planting. Copper application to leaves started at 4 weeks after planting. The seedlings were allowed to grow for a period of 8 months. All pots were fertilized with the drip irrigation system once in a week with mono ammonium phosphate, potassium nitrate, ammonium nitrate and magnesium sulfate. Total amounts of nutrients provided to each pot were: 195 kg N ha^{-1}, 62 kg P ha^{-1}, 177 kg K ha^{-1} and 16 kg Mg ha^{-1}. Pots also received 3.0 kg Fe ha^{-1}, 3.0 kg Mn ha^{-1}, 1.13 kg Zn ha^{-1}, 0.38 kg B ha^{-1} and 0.08 kg Mo ha^{-1}. Fertilizers were applied based on local recommendation.

Leaf samples were collected one week after fungicide applications to leaves were completed. At the end of the eight-months experiment period, plants were harvested. At harvest, plants were washed by distilled water and separated into leaf, fruit and root and dried in a forced-air oven at 65ºC to constant weight. The leaf, fruit and root samples were ground separately in a stainless mill to pass through a 20 mesh screen and kept in clean polyethylene bags for analysis.

Chemical and statistical analysis

The soil used in the experiments was chemically analyzed after they had been air-dried and passed through a 2 mm sieve. Total carbonates were determined according to the calcimeter method of Nelson[14]. Soil texture was determined by hydrometer method[15] and organic matter by the Walkley-Black[16]. Extractable P content was extracted by $NaHCO_3$[14] and determined by a molybdate colorimetric method[17], extractable K, Ca and Mg were extracted with NH_4OAc and determined by atomic absorption spectrophotometry (AAS)[18]. Soil Cu, Fe, Mn and Zn were extracted with diethylene tetraamine pentaacetic acid (DTPA)[19] and then determined in the obtained extract by AAS.

Dried plant samples (leaf, fruit and root) 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 and Mg in the digestates were determined by using AAS[20]. Phosphorus was measured by spectrophotometry[21] and nitrogen was determined by a modified Kjeldahl procedure[20].

Statistical analysis was carried out using the MSTAT-C 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 SCuA and FCuAF on macronutrient contents of tomato plants.

RESULTS AND DISCUSSION

Experiment I (Gunner, Cu oxychloride)

Both Soil Cu applications (SCuA) and foliar Cu application frequencies (FCuAF) provided numerous significant responses for the various measured parameters. The SCuA X FCuAF interactions had significant differences for leaf P content, root Ca content and root Mg content.

The nitrogen contents of leaf, fruit and root samples were not affected by increasing of SCuA and FCuAF (Table-1).

Results revealed that leaf P content was significantly affected by SCuA and interactive between SCuA and FCuAF. SCuA resulted in an increase in leaf P content in treatments F1 and F2, the highest P contents (0.59 and 0.50 %, respectively) were obtained with application S3. Leaf P content was not affected by SCuA in treatment F3 (Table-1). However; FCuAF did not resulted in significant differences in P content of leaf in application S1. P content of leaf increased with increasing of FCuAF in application S2, the highest P content (0.41 %) was obtained with treatment F3. Leaf dry mass decreased due to the fact that dry root weight decreased with SCuA and

TABLE-1
EFFECTS OF BOTH SOIL COPPER APPLICATIONS (SCuA) AND FOLIAR COPPER APPLICATION FREQUENCIES (FCuAF) ON MACRONUTRIENTS CONTENTS OF LEAF, FRUIT AND ROOT SAMPLES IN THE EXPERIMENT I (GUNNER, Cu OXYCHLORIDE)

Variable (%)	Soil Cu Appl.	Foliar Cu application frequencies											
		Leaf				Fruit				Root			
		F1	F2	F3	Means	F1	F2	F3	Means	F1	F2	F3	Means
N	S1	2.80	2.89	2.87	2.85	2.32	2.31	2.22	2.28	1.95	1.85	1.57	1.79
	S2	3.24	2.98	2.83	3.01	2.13	1.83	2.27	2.07	1.98	1.81	1.87	1.88
	S3	2.65	3.33	2.78	2.92	2.02	2.02	2.30	2.11	1.70	1.85	1.95	1.83
	Means	2.89	3.07	2.82	–	2.15	2.05	2.26	–	1.88	1.84	1.79	–
P	S1	0.34b,**A**	0.32b,**A**	0.31a[1],**A**[2]	0.32	0.36	0.35	0.31	0.34	0.17	0.17	0.14	0.16
	S2	0.29b,**B**	0.37b,**AB**	0.41 a,**A**	0.36	0.40	0.35	0.33	0.36	0.16	0.16	0.12	0.15
	S3	0.59a,**A**	0.50a,**A**	0.34 a,**B**	0.48	0.36	0.33	0.29	0.33	0.12	0.17	0.12	0.14
	Means	0.41	0.40	0.35	–	0.38 **A**	0.34 **B**	0.31 **B**[2]	–	0.15 **AB**	0.16 **A**	0.13 **B**[2]	–
K	S1	1.50	1.35	1.24	1.36 ab[1]	2.50	2.30	1.99	2.26	1.21	1.12	1.07	1.13a[1]
	S2	1.71	1.88	1.33	1.64 a	2.63	2.45	2.32	2.47	0.85	0.86	0.71	0.81b
	S3	1.33	1.29	1.07	1.23 b	2.68	2.29	2.29	2.42	0.55	0.65	0.44	0.54c
	Means	1.51	1.51	1.21	–	2.60 **A**	2.35 **B**	2.20 **B**[2]	–	0.87	0.88	0.74	–
Ca	S1	3.82	4.05	4.36	4.08	0.22	0.11	0.10	0.14	1.07 a,**A**	0.98 b,**A**	1.00b[1],**A**[2]	1.01
	S2	3.82	4.15	5.08	4.35	0.22	0.12	0.20	0.18	1.26 a,**A**	1.18 b,**A**	1.25 a,**A**	1.24
	S3	5.01	4.55	4.01	4.47	0.15	0.16	0.20	0.17	1.16 a,**B**	1.58 a,**A**	1.23ab,**B**	1.32
	Means	4.22	4.25	4.48	–	0.20	0.13	0.17	–	1.17	1.24	1.18	–
Mg	S1	0.82	0.91	0.99	0.91	0.15	0.12	0.11	0.13	0.94 b,**A**	0.89 b,**A**	0.93a[1],**A**[2]	0.92
	S2	0.94	0.95	1.15	1.02	0.16	0.15	0.14	0.15	0.86 b,**A**	1.07 b,**A**	1.18a,**A**	1.04
	S3	0.95	1.07	1.16	1.06	0.14	0.15	0.14	0.15	2.28 a,**A**	1.85 a,**A**	1.06a,**B**	1.73
	Means	0.90	0.98	1.10	–	0.15	0.14	0.13	–	1.36	1.27	1.05	–

[1]Means in the same column followed by the same letter are not significantly different at 5 % probability level by LSD test.
[2]Means in the same row followed by the capital and bold same letter are not significantly different at 5 % probability level by LSD test.

FCuAF. As a result, an increase in P content of leaves by SCuA and FCuAF seems to be due to relative increase of P in leaf dry matter. But, P content of leaf decreased with increasing of FCuAF in application S3 and lowest value (0.34 %) was obtained with treatment F3. Phosphorus contents of root and fruit samples were not effected by SCuA, but FCuAF affected the P contents of fruit and root samples. The highest fruit and root P contents (0.38 and 0.16 %, respectively) were obtained with application F1 and F2 (Table-1). Increasing of FCuAF generally caused a decline in P contents of fruit and root. Sonmez[22] reported that the P contents of plant tissues (leaf, stem and root) decreased with increasing Cu supply to soil in tomato plants.

Potassium content of leaf samples was affected by SCuA and highest K content (1.64 %) was obtained with application S2. Potassium content of leaves were initially increased and later decreased by increasing level of SCuA. K content of fruit was not affected by SCuA whereas K content of root dropped (Table-1). The highest root K content (1.13 %) was observed with application S1. FCuAF affected only K content of fruit samples and highest fruit K content (2.60 %) was obtained with application F1. Increasing of FCuAF caused a decline in fruit K content. On other hand, increasing of FCuAF did not have an effect on K contents of leaf and root samples (Table-1). Initial increase in K content of leaf samples by SCuA can be attributed to slower plant growth causing reduction in leaf dry mass, hence concentrated K presence in leaves. Subsequent reduction in K content seems to be due to inhibition of K uptake caused by high level of Cu applications as indicated by Bujtas and Cseh[23]. Sonmez[22] found that the K contents of plant tissues decreased with increasing Cu supply.

Increasing of SCuA and FCuAF were found to be not effective on Ca contents of leaf and fruit. Ca content of root showed significant variations caused by SCuA and interactive effects between SCuA and FCuAF. In treatment F1 in which no copper was applied to leaves, increasing level of SCuA did not change Ca content of root samples; in treatment F2 in which Cu containing fungicide was applied to leaves biweekly, Ca content of root samples increased with increasing level of SCuA. The highest Ca content (1.58 %) was obtained with application S3. In treatment F3 in which Cu applied to leaves weekly, SCuA initially caused an increase and later a decrease in Ca content of root samples and highest Ca content (1.25 %) was obtained with application S2 (Table-1). However, increasing of FCuAF did not resulted in significant differences in Ca content of root in application S1 and S2. In application S3, Ca content of root initially increased and later decreased with FCuAF. In a study investigating effect of fungicides applied in various ratios to coffee plants, Aduayi[24] observed that Ca contents of plants receiving fungicide treatment were significantly higher than those grown without fungicide treatment. Present results are in agreement with Aduayi's findings.

Increasing of SCuA and FCuAF did not affect on Mg contents of leaf and fruit. Mg content of root was significantly affected by SCuA and interactive effects between SCuA and FCuAF. In treatment F1 and F2, increasing of SCuA resulted in an higher Mg contents in root samples. The highest Mg contents (2.28 and 1.85 %, respectively) were obtained with application S3. In a study conducted with lettuce plants, Berzinya and Zhiznevskaya[25] observed that increasing level of Cu applications produced chlorosis and Mg content in leaf dry mass increased. In treatment F3, increasing of SCuA did not change Mg content of root samples (Table-1). However, increasing of FCuAF did not resulted in significant differences in Mg content of root in application S1 and S2. In application S3, Mg content of root decreased with FCuAF. In a study conducted with tomato plants, Sonmez[22] reported that the Mg content of the stem decreased with increasing Cu supply to soil while Mg of leaf and root contents were not affected.

Copper application to soil (SCuA) affected total yield, fruit number, dry root weight and plant height ($p < 0.01$). The results of growth and yield of the experiment were previously reported by Sonmez *et al.*[13]. The greatest total yield, fruit number, plant height and dry root weight were obtained when no copper was applied to soil (S1); the performance traits decreased from S1 to S3. Also, increasing of FCuAF affected dry root weight and plant height after the 5th week and resulted in a decrease in dry root weight and plant height. The smallest dry root weight and plant heights were observed in treatment F3[13].

Experiment II (Tenn-Cop 5E, copper salts of fatty and rosin acids)

High level of both SCuA and FCuAF provided numerous significant responses for the various measured parameters. The SCuA X FCuAF interactions had significant differences for N content of fruit, P content of leaf, K content of fruit, Ca content of leaf Mg contents of fruit and root.

SCuA and FCuAF independently affected N content of leaf samples and there was no significant interactive effect between these applications. N content of leaf increased with increasing level of SCuA and the highest N contents (3.35 and 3.44 %) were obtained with application S2 and S3. However, the increasing of FCuAF initially caused an increase and later a decrease in N content of leaf and the highest N content (3.43 %) was obtained with treatment F2. N content of fruit showed significant variations caused by SCuA, FCuAF and interactive efffects between these applications. In treatment F1 and F2, increasing level of SCuA did not change N content of fruit samples. In treatment F3, the N content of fruit samples was reduced by increasing level of SCuA (Table-2). However, increasing of FCuAF did not resulted in significant differences in N content of fruit in application S1 and S3. In application S2, N content of fruit decreased with increasing of FCuAF. Increasing of SCuA and FCuAF were not found to be effective on N content of root. SCuA and FCuAF result in increase or decrease in the N content of plant samples. Reports published on this subject show contradictory results. It is indicated that increasing level of copper applications resulted in an increase in protein-N and total N in plants[26]. On the other hand, Osawa and Ikeda[27] observed toxicity due to increasing level of heavy metal concentration, causing significant reduction in nitrogen contents of plants compared to control treatments.

Results indicated that SCuA and FCuAF and interaction between these applications, had a significant effect on P content of leaf. In treatments F1, increasing level of SCuA increased P level in leaf samples. However, in treatment F2 and F3, no change was detected. However, P content of leaf increased with increasing of FCuAF in application S1. The highest P content (0.34 %) was obtained with treatment F3. Increasing of FCuAF did not resulted in significant differences in P content of leaf in application S2. P content of leaf decreased with increasing of FCuAF in application S3. The highest P content (0.63 %) was obtained with treatment F1 (Table-2). Similar to the experiment **I**, the increase in P contents can be contributed to reduction in plant dry mass and therefore, relative increase of P level in the dry matter. P contents of fruit and root samples were only affected by FCuAF. P contents in fruit and root tissues declined with increasing of FCuAF (Table-2). Wallace and Cha[28] and Sonmez[22] reported that high Cu concentration reduced P in plants.

Effect of increasing level of SCuA was found to be highly important for K contents of leaf and root samples. The K contents of leaf samples increased whereas K level in root samples decreased. The lowest K contents in leaf samples (1.38 %) were obtained with treatment S1 and treatment S3 gave the lowest K level in root samples (0.73 %) (Table-2). FCuAF were not found to be effective on K contents of leaf and root (Table-2). K content of fruit showed significant variations caused by SCuA and interactive effects between SCuA and FCUAF. Increasing level of SCuA did not change K content of fruit samples in treatments F1 and F3. K content of fruit samples initially increased and later decreased in treatment F2 and the highest K level (2.77 %) was obtained with application S2 (Table-2). However, the increasing of FCuAF decreased in fruit K content in all applications (S1, S2 and S3). Similar to the behaviour of P, the increase detected in K contents of plant samples seems to be due to reduction in plant dry mass causing relative increase of K in the dry mass. On the other hand, the decrease in K content of samples is possibly due to reduction of K uptake by roots as a result of increasing level of Cu additions, as reported by Bujtas and Cseh[23], Alva *et al.*[29], Ali *et al.*[30], Kopittke and Menzies[31] and Sonmez[22].

TABLE-2

EFFECTS OF BOTH SOIL COPPER APPLICATIONS (SCuA) AND FOLIAR Cu APPLICATION FREQUENCIES (FCuAF) ON MACRONUTRIENTS CONTENTS OF LEAF, FRUIT AND ROOT SAMPLES IN EXPERIMENT II (TENN-COP 5E, COPPER SALTS OF FATTY AND ROSIN ACIDS)

Variable (%)	Soil cu Appl.	Foliar Cu application frequencies											
		Leaf				Fruit				Root			
		F1	F2	F3	Means	F1	F2	F3	Means	F1	F2	F3	Means
N	S1	2.37	2.87	2.77	2.67b[1]	2.41a,**A**	2.37a,**A**	2.38a[1],**A**[2]	2.38	1.85	1.79	1.77	1.80
	S2	2.95	3.80	3.30	3.35a	2.26a,**A**	2.26a,**A**	1.70b,**B**	2.07	1.80	1.74	1.88	1.81
	S3	3.34	3.62	3.36	3.44a	2.16a,**A**	2.15a,**A**	1.89b,**A**	2.07	2.17	1.80	1.88	1.95
	Means	2.89 **B**	3.43 **A**	3.14**AB**[2]	–	2.27	2.26	1.99	–	1.94	1.78	1.84	–
P	S1	0.17b,**B**	0.27a,**AB**	0.34a[1],**A**[2]	0.26	0.35	0.31	0.30	0.32	0.17	0.15	0.16	0.15
	S2	0.31b,**A**	0.39 a,**A**	0.24a,**A**	0.32	0.39	0.34	0.33	0.35	0.16	0.15	0.14	0.14
	S3	0.63a,**A**	0.43 a,**B**	0.38 a,**B**	0.48	0.41	0.34	0.31	0.35	0.13	0.12	0.15	0.15
	Means	0.37	0.36	0.32	–	0.38 **A**	0.33 **B**	0.31 **B**[2]	–	0.16 **A**	0.15 **A**	0.13 **B**[2]	–
K	S1	1.31	1.41	1.42	1.38b[1]	2.47a,**A**	2.00b,**B**	2.20a[1],**AB**[2]	2.22	1.04	1.00	1.00	1.01a[1]
	S2	1.96	1.97	1.79	1.91a	2.45a,**AB**	2.77a,**A**	2.32a,**B**	2.51	0.83	0.86	0.91	0.86b
	S3	1.72	2.33	1.42	1.82a	2.60a,**A**	2.32b,**AB**	2.20a,**B**	2.37	0.64	0.85	0.72	0.73c
	Means	1.66	1.91	1.54	–	2.51	2.36	2.24	–	0.83	0.90	0.87	–
Ca	S1	3.34b,**A**	3.30ab,**A**	4.13a[1],**A**[2]	3.59	0.20	0.15	0.14	0.16	1.06	0.98	0.95	0.99c[1]
	S2	3.77ab,**A**	4.17 a,**A**	3.47 a,**A**	3.81	0.26	0.22	0.13	0.20	1.22	1.35	1.36	1.31b
	S3	4.29 a,**A**	3.17 b,**B**	3.64a,**AB**	3.70	0.14	0.17	0.20	0.17	1.52	1.72	1.32	1.52a
	Means	3.80	3.55	3.75	–	0.20	0.18	0.15	–	1.26	1.35	1.21	–
Mg	S1	0.81	0.76	0.98	0.85	0.14a,**A**	0.12b,**A**	0.13a[1],**A**[2]	0.13	0.86b,**A**	0.64b,**A**	0.85b,**A**[2]	0.78
	S2	0.76	0.97	0.98	0.91	0.14a,**AB**	0.17a,**A**	0.13a,**B**	0.15	0.71b,**A**	0.79b,**A**	1.00b,**A**	0.83
	S3	1.01	0.90	1.05	0.99	0.16a,**A**	0.14ab,**A**	0.14a,**A**	0.15	1.76a,**A**	1.41a,**B**	1.60a,**AB**	1.59
	Means	0.86	0.88	1.00	–	0.14	0.14	0.13	–	1.11	0.95	0.82	–

[1]Means in the same column followed by the same letter are not significantly different at 5 % probability level by LSD test.

[2]Means in the same row followed by the capital and bold same letter are not significantly different at 5 % probability level by LSD test

Results indicated that interaction between SCuA and FCuAF had a significant effect on Ca content of leaf samples. Increasing level of SCuA increased Ca content of leaf in F1 treatment and the highest Ca content (4.29 %) was obtained with application S3. SCuA initially caused an increase and later a decrease in treatment F2 and the highest value (4.17 %) was obtained with application S2. SCuA did not change in treatment F3. However; increasing of FCuAF did not resulted in significant differences in Ca content of leaf in application S1 and S2. In application S3, Ca content of leaf initially decreased and then increased with FCuAF (Table-2). Only Ca content of root samples was affected by SCuA and increasing Cu concentration in soil elevated Ca content in root samples. The highest Ca level (1.52 %) in root samples was obtained with application S3 (Table-2). Data obtained in this experiment support findings reported by Aduayi[24].

Increasing of SCuA and FCuAF did not affect Mg content of leaf. Mg content of fruit showed significant variations caused by SCuA, FCuAF and interactive effects between these applications. In treatment F1 and F3, SCuA did not change Mg content of fruit; in treatment F2, increasing level of SCuA initially caused an increase and later a decrease in Mg content of fruit. The highest Mg mean value (0.17 %) was observed in treatment S2. However, increasing of FCuAF did not resulted in significant differences in Mg content of fruit in application S1 and S3. In application S2, Mg content of fruit initially increased and then decreased with FCuAF and the highest Mg content in fruit (0.17 %) was observed in treatment F2 (Table-2). Mg content of root showed significant variations caused by SCuA, FCuAF and interactive effects between these applications. Increasing level of SCuA resulted in an increase in Mg content of root samples in all treatments (F1, F2 and F3). The highest Mg mean values (1.76, 1.41 and 1.60 %, respectively) were observed in treatment S3. However, increasing of FCuAF did not resulted in significant differences in Mg content of root in application S1 and S2. In application S3, Mg content of root initially decreased and then increased with FCuAF and the highest Mg content (1.76 %) was observed in treatment F1 (Table-2). The present findings show similarities with those reported by Berzinya and Zhiznevskaya[25].

The results of growth and yield of the experiment were previously reported by Sonmez *et al.*[13]. Total yield, fruit number, dry root weight and plant height were affected by the level of Cu application to soil ($p < 0.01$) and the greatest total yield, fruit number, plant height and dry root weight were obtained when no copper was applied. Also, Cu application to leaves resulted in a decrease in dry root and copper application to soil and leaves led to a sharper decrease in dry root weight than when copper was only applied to soil[13].

Conclusion

In the experiment **I** in which fungicide Gunner (containing Cu oxychloride) was used as Cu source, the N contents of leaf, fruit and root samples were not affected by increasing of SCuA and FCuAF. While SCuA and FCuAF generally increased P level in leaf samples, FCuAF generally decreased the P contents of fruit and root. K content of leaf initially increased and then decreased as a result of SCuA. Meanwhile, K content of root was decreased by SCuA. FCuAF caused a decline in K content of fruit. Ca content of root were affected in positive way showing an increase with increasing level of SCuA, however FCuAF initially resulted in an increase and then a decrease in Ca content of root. Ca contents of fruit and leaf samples, however, did not show any change. Mg content of root samples increased with SCuA and decreased with FCuAF. Increasing of SCuA and FCuAF did not change Mg contents of fruit and leaf samples.

In the experiment **II** in which fungicide Tenn-Cop 5E (containing copper salts of fatty and rosin acids) were used. N content of leaf was independently affected positively by SCuA and FCuAF. While SCuA and FCuAF resulted in a decrease in N content of fruit, N content of root did not show any change. While P content of leaf was increased by SCuA, FCuAF resulted in a decrease in P content of leaf. Also, FCuAF decreased P level in fruit and root samples. SCuA increased K content of leaf samples while decreasing K content in root samples. While K content of fruit initially increased and then decreased with SCuA, decreased with FCuAF. FCuAF were not found to be effective on K contents of leaf and root. While Ca content of leaf was generally increased by SCuA, FCuAF generally decreased. Ca content of fruit, however, were not affected by any of treatments. SCuA elevated Ca content of root samples. While Mg contents of leaf were not affected by any of the treatment, Mg contents of fruit and root were generally increased by SCuA. FCuAF resulted in a decrease in Mg contents of fruit and root.

As a result, increasing of both SCuA and FCuAF, especially aiming to control plant diseases, showed different effects on N, P, K, Ca and Mg contents and imbalance the mineral nutrition of tomato plants. The use of Cu containing fertilizers and fungicides has increased over the years in Mediterranean region. It was determined that, by taking into account the amount and frequency of applications, the Cu applications to soil and leaves could be more deleterious to plants than when Cu is applied only to soil or leaves.

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