Journal of Agricultural Science and Technology B 6 (2016) 168-174
doi: 10.17265/2161-6264/2016.03.003

Influence of Soil Application of Micronized-Sulfur with Bentonite on Tomato Growth under Greenhouse Condition

Hayriye Yildiz Dasgan[1], Nazmi Cemaloglu[1], Yelderem Akhoundnejad[1], Gunce Akkuzu Dogan[2] and Mahmut Bayram[3]

1. Department of Horticulture, Agricultural Faculty, Cukurova University, Adana 01330, Turkey

2. Balkan Sulfur, Fertilizer Limited Company, Istanbul 34956, Turkey

3. GAP Agricultural Research Institute, Sanliurfa 63040, Turkey

Abstract: In this study, the influence of four different sulfur products applied to the soil on the organically grown greenhouse tomato was investigated. The sulfur treatments were: (1) micronized-sulfur with bentonite (MSB) alone (90% sulfur + 10% bentonite); (2) MSB + Fe (87% sulfur + 10% bentonite + 3% Fe); (3) MSB + Zn (87% sulfur + 10% bentonite + 3% Zn); (4) MSB + Fe + Zn (86% sulfur + 10% bentonite + 2% Fe + 2% Zn) and (5) control without sulfur treatment. The effects of sulfur products on plant growth, total crop yield, some fruit quality parameters, Fe and Zn content of the leaves and soil, pH and electrical conductivity (EC) of soil, were investigated. Results showed that the effects of treatments on plant growth parameters and fruit quality properties were not significant. However, total fruit yield increased by about 14%, 21%, 15% and 27% in MSB, MSB + Fe, MSB + Zn and MSB + Fe + Zn, respectively, as compared with control. Leaves Fe and Zn content were increased in some sampling times in related treatments. Soil Fe content was not changed by the treatments, however Zn content was significantly increased by the MSB + Zn and MSB + Fe + Zn applications. Soil pH was decreased by the all sulfur treatments in comparison to control; however the most important pH decrease was recorded as 0.28 units in MSB + Fe + Zn treatment. Soil EC values of the all sulfur treatments were higher than the control.

Key words: Organic greenhouse, micronized-sulfur with bentonite, *Solanum lycopersicum*, soil pH, Fe, Zn.

1. Introduction

Intensive use of artificial fertilizers, hormones and pesticides impairs soil, water, air, food and living quality. In organic farming, in order to achieve environmentally friendly approaches instead of synthetic pesticides and fertilizers, organic and green manure, crop rotation for soil conservation, parasites and predators for plant protection are consciously preferred. In organic production, the main target is not the increasing amount of production; it is increasing of product quality. So the concept of organic farming has been used in many countries [1].

Sulfur is one of the materials that permitted for using in organic plant production in Turkey and all over the world in many years. There are four major reasons for the application of sulfur to the soil: reducing soil pH, ensuring plant nutrient availability, advantages of sulfur to against soil pests and diseases, and source of sulfur as nutrient for the plant. Main expectation of sulfur products used in this study are reducing soil pH and increasing nutrient availability, therefore increasing crop yield and quality of organic tomato. Soil pH has important impact factors on the availability of nutrients, soil productivity and plant nutrition programs. The most important problems of high pH soil are unavailability of phosphor and trace elements, especially Fe and Zn [2].

Corresponding author: Hayriye Yildiz Dasgan, professor, research fields: vegetables sciences, plant nutrition and abiotic stress, greenhouse soil and soilless cultures.

In order to increase of H^+ concentration in soils, elemental sulfur, sulfuric acid or ammonium sulfate are applied to the soil. Among these, the sulfur is the most common one [2]. Using of sulfur products into the soil, besides lowering the pH, it also plays a role in soil disinfection. It promotes resistance to soil born fungal and bacterial disease [3]. Therefore using of sulfur products has very important roles in organic greenhouse vegetable production.

Traditionally longstanding practice as a sulfur source was powder form. However, recently new generation product that is called the micronized-sulfur with bentonite (MSB) has become popular in the agricultural sector. In this new product, the liquid sulfur is absorbed by the bentonite clay, through solidification on rotoform granulation system and after drying, the final product is a granule that similar to lentil [4]. The bentonite increases its volume by factor of 3 to 5 when it comes into contact with water. When a MSB granule comes into contact with soil moisture, it breaks apart into fragments of micron-size particles, thus allowing swift and continuous solubilisation [4].

The particle size of any sulfur product is the most important factor for soil pH reducing. The smaller particle size increases the sulfur activity, because the oxidation of elemental sulfur to the SO_4^{2-} will be faster. The smaller particle size also gives benefits to the *Thiobacillus* bacteria being larger infection area. In the MSB technology, the particle size is ultra small like microns that provides rapid and more acid formation [4]. The bentonite clay easily absorbs and storages plenty of water. Water availability, presence of the bacteria, small sulfur particle size and appropriate temperature allow easy oxidation [4]. Therefore, in weak soil, pH can be easily decreased in comparison to longer period of oxidation time for the conventional powder sulfur [5]. Nowadays, the conscious plant growers prefer the MSB product for soil application, due to its fast oxidation in the soil and more rapid pH reducing in comparison to powder form sulfur [5].

The objective of the article was to provide reducing soil pH for a yield increase in organic greenhouse tomato production by using MSB with the additives of Fe and Zn.

2. Materials and Methods

The experiment was carried out at plastic greenhouse with an area of 360 m^2 in two consecutive years in Horticulture Department of Cukurova University. The study presented here is the second year experiment. Soil properties of the experimental greenhouse can be seen in Table 1, initial pH was 8.36 that was high, Fe concentration 3.24 ppm was low and Zn 1.62 ppm was critical for the greenhouse tomato crop. Alsancak F_1 tomato cultivar is used as plant material. Seeds were sown into 2:1 peat:perlite containers on January 15, 2014 in glasshouse. When five true leaves emerged, tomato seedlings were transplanted in plastic greenhouse on February 20, 2014. The following treatments were used in the experiment:

(1) control without sulfur treatment;

(2) MBS alone (90% sulfur + 10% bentonite);

(3) MBS + Fe (87% sulfur + 10% bentonite + 3% Fe);

(4) MBS + Zn (87% sulfur + 10% bentonite + 3% Zn);

(5) MBS + Fe + Zn (86% sulfur + 10% bentonite + 2% Fe + 2% Zn).

The MSB treatments applied to the greenhouse soil with 500 kg/ha dose at five months before the transplanting. Decomposed farmyard manure with the dose of 2,500 kg/ha was equally applied at all treatment parcels before planting. Initial soil analysis was performed (Table 1). Plant nutrition protocols were the same for each treatment and obtained from the organic fertilizers: 180 kg/ha N, 45 kg/ha P_2O_5, 400 kg/ha K_2O and 205 kg/ha MgO. The experiment was arranged in a completely randomized block design with five treatments and four replications. Each

Table 1 Initial some properties of soil taken from 0-30 cm depth.

Soil properties	Methods	Results
pH	1:2.5 soil:water (v:v)	8.36
Calcareous (%)	Calcimetric	24.60
Salt (%)	1:2.5 soil:water (v:v)	0.093
Organic matter (%)	Walkley Black	0.90
Available Fe (ppm)	DTPA-ICP	3.24
Available Zn (ppm)	DTPA-ICP	1.62

DTPA-ICP: diethylenetriaminepentaacetic acid-inductively coupled plasma.

replication included 16 plants. The tomato seedlings were planted with double rows and plant density of 33,333 plants/ha. The spacing between double rows was 100 cm and 50 cm, and the spacing between plants was 40 cm, respectively. In order to see the effect of treatments, during the cultivation period, soil samples taken from 0-30 cm depth three times on March 28, 2014, April 25, 2014 and May 30, 2014, respectively, for the analysis of soil pH, electrical conductivity (EC) and micronutrient contents of Fe and Zn.

Stem diameter and number of leaves were recorded during the experiment three times in the same dates of soil sampling. Fruit harvests were performed weekly. Fruit harvest began on May 16, 2014, continued until the date of July 10, 2014 and the totally nine harvests were made. At the middle of the harvest period, 10 fruits from each replicate were selected randomly for the fruit pomological and some quality properties analysis.

Data were statistically analyzed using analysis of variance (ANOVA) and the means were separated by least significant difference (LSD) ($P < 0.05$) using JUMP software.

3. Results and Discussion

The MSB treatments affected soil and yield at different grades. pH was decreased by 0.28 unit and yield was increased by 27%.

3.1 Plant Growth Parameters

Plant height, leaf number and stem diameter on different three measuring dates were not significantly different in the MSB treated plants (Tables 2-4). Although these vegetative parameters were not significant, maybe photosynthesis, leaf area or plant dry weights were higher in MSB treated plants, because sulfur treatment caused the yield increases (Table 5). It is reported by Yaras and Dasgan [5] that when comparing conventional greenhouse tomato cultivation by 150 kg/ha MSB, 2,000 kg/ha leonardit, plant height measurements was the highest with 156.21 cm/plant in leonardit treatment, the lowest in control plants with 138.14 cm/plant and middle in MSB treatment with 145.02 cm/plant. The leaf number in the same study was the highest with 26.18 leaves/plant in leonardit, the lowest in control plants with 24.66 leaves and middle in MSB with 25.73 leaves.

3.2 Yield Production

The effects of the MSB treatments on tomato yield

Table 2 Effect of MSB treatments on plant height (cm) in organically grown greenhouse tomato plants.

Treatments	Plant height (cm)		
	March 28, 2014	April 25, 2014	May 30, 2014
Control	56.50	116.63	190.23
MSB	57.80	115.03	194.05
MSB + Fe	57.20	113.93	193.93
MSB + Zn	55.93	112.70	192.75
MSB + Fe + Zn	57.53	115.03	194.35
$LSD_{0.05}$	ns	ns	ns

ns: not significant.

Table 3 Effect of MSB treatments on the number of leaves (number/plant) in organically grown greenhouse tomato plants.

Treatments	Number of leaves/plant		
	March 28, 2014	April 25, 2014	May 30, 2014
Control	13.45	19.93	28.50
MSB	13.03	20.65	29.55
MSB + Fe	13.15	19.73	30.55
MSB + Zn	13.47	20.10	29.58
MSB + Fe + Zn	13.10	19.80	30.80
$LSD_{0.05}$	ns	ns	ns

ns: not significant.

Table 4 Effect of MSB treatments on stem diameter (mm) in organically grown greenhouse tomato plants.

Treatments	Stem diameter (mm)		
	March 28, 2014	April 25, 2014	May 30, 2014
Control	12.09	14.24	16.49
MSB	12.39	14.05	16.20
MSB + Fe	12.17	14.63	16.89
MSB + Zn	12.29	14.52	16.84
MSB + Fe + Zn	12.19	14.14	17.08
$LSD_{0.05}$	ns	ns	ns

ns: not significant.

Table 5 Effect of MSB treatments on tomato fruit yield in organically grown greenhouse tomato plants.

Treatments	Tomato fruit yield (kg/m^2)
Control	15.30^c
MSB	17.39^b
MSB + Fe	18.46^{ab}
MSB + Zn	17.58^b
MSB + Fe + Zn	19.37^a
$LSD_{0.05}$	1.32

$^{a-c}$ The same letters present the non-significant difference at 95% confidential level.

were statistically significant (Table 5). The highest yield with 19.37 kg/m^2 was obtained from the MSB + Fe + Zn treatment. The application of MSB + Fe took the second place with 18.46 kg/m^2. The treatments MSB alone and Zn added sulfur products were very close to each other with 17.39 kg/m^2 and 17.58 kg/m^2, respectively. The lowest yield of organically grown tomato in the experiment was 15.30 kg/m^2 from the control. When the MSB products applied to greenhouse soil, two consecutive years led to increase of organic tomato yield by about 13.7%, 20.7%, 14.9% and 26.6% in the treatments of MSB, MSB + Fe, MSB + Zn, MSB + Fe + Zn, respectively, as compared with control (Fig. 1).

In the organically grown greenhouse tomato production, use of the MSB and its derivatives with Fe and Zn increased the fruit yield between 14% and 26%. Soil pH was reduced 0.28 units in comparison to the beginning pH. In greenhouse tomato cultivation, use of the MSB products, beside the pH-reducing effects and increasing nutrient availability by increasing soil EC, could also have some possible benefits on soil disinfection against soil born diseases (no data shown, but there was observation).

Tomato yield reported from the conventional greenhouse tomato production with 150 kg/ha MSB and 2,000 kg/ha leonardite were increased 23% and 18%, respectively [5]. Some organic and inorganic

Fig. 1 Tomato fruits during harvest stage from the experimental organic greenhouse.

Table 6 Effect of MSB treatments on fruit physical quality characteristics in organically grown greenhouse tomato plants.

Applications	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Fruit firmness (kg/cm^2)	Flesh thickness (mm)	Fruit volume (cm^3)
Control	219	60	75	1.3	9.8	176
MSB	202	60	73	1.2	8.9	162
MSB + Fe	197	58	74	1.3	9.3	156
MSB + Zn	208	60	75	1.2	9.9	167
MSB + Fe + Zn	220	60	76	1.1	9.1	179
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns

ns: not significant.

Table 7 Effect of MSB treatments on fruit juice quality characteristics in organically grown greenhouse tomato plants.

Applications	TSS (%)	Acidity (%)	pH	EC (dS/m)
Control	3.83	0.30	4.77	5.30
MSB	3.79	0.29	4.67	5.20
MSB + Fe	4.03	0.31	4.60	5.50
MSB + Zn	3.73	0.27	4.70	5.30
MSB + Fe + Zn	3.98	0.30	4.68	5.30
$LSD_{0.05}$	ns	ns	ns	ns

TSS: total soluble solids; ns: not significant.

Table 8 Effect of MSB treatments on leaf Fe concentration in organically grown greenhouse tomato plants.

Applications	Leaf Fe concentration (ppm)		
	March 28, 2014	April 25, 2014	May 30, 2014
Control	168^{a}	100	135
MSB	128^{b}	126	173
MSB + Fe	131^{b}	118	161
MSB + Zn	143^{ab}	124	141
MSB + Fe + Zn	126^{b}	122	155
$LSD_{0.05}$	26.30	ns	ns

$^{a, b}$ The same letters present the non-significant difference at 95% confidential level; ns: not significant.

fertilizer treatments on yield and quality of conventionally grown cherry tomato were also reported by Demirtas et al. [6] and the highest yield was obtained from the combination of inorganic and organic fertilizer in 1:1 ratio. Wang et al. [7] examinated the effects of organic and inorganic fertilizers with additional 35 L/ha humic acid on grape yield. Organic fertilizer with combination humic acid provided the highest yield in comparison to the other treatment, and increased sugar content of fruit. For potato production, among the sources of MSB and gypsum, MSB was found to be best source of S because of high concentration, slow release and minimum leaching loss [8, 9].

3.3 Fruit Quality

In the middle of the harvest season, 10 fruits from each replication were used for some physical and chemical analyses of the fruits. The MSB treatments in this experiment were not significantly different in the fruit size and juice features (Tables 6 and 7). The reason of increasing total fruit yield in MSB treatments (Table 5) could be due to increasing the number of fruit or fruit set on a plant. Because there were no any significant effects of the MSB treatments on fruit size characteristics as weight, width and diameter. In the conventional greenhouse tomato production with 150 kg/ha MSB and 2,000 kg/ha leonardite informed that the treatments did not make any significant difference on fruit characteristics [5].

3.4 Micronutrient Content of Leaves

Iron (Fe) concentration in leaves of the MSB treatments have been increased by the time (Table 8). In the first leave analysis, the control plants showed the higher Fe content, however in the 3rd analyses, the MBS treatments increased Fe contents. These increases could be due to pH reduction effects of MSB treatments on experimental soils, and Fe availability could be increased for the plants. There were no any remarkable difference among the MSB treatments for the leaf Fe concentrations (Table 8). In the report about the conventional greenhouse tomato production with 150 kg/ha MSB and 2,000 kg/ha leonardite [5], it was informed that leaves Fe contents were 62.31 ppm and 70.76 ppm in MSB and leonardit treatments, respectively. In the case of adequate Fe nutrition in tomato plants, leaf Fe concentration was reported to be between 50 ppm and 200 ppm [10].

The differences of the MSB treatments on leaf Zn concentrations were not noticeable as in the case of Fe (Table 9). Leaf Zn contents in the treatments were similar. In the conventional greenhouse tomato production [5] with 150 kg/ha MSB and 2,000 kg/ha leonardite, leaf Zn concentrations were reported 140.91 ppm and 82.40 ppm in MSB and leonardit treatments, respectively. In the case of adequate Zn nutrition in tomato plants, leaf Zn concentration was reported to be between 20 ppm and 250 ppm [10].

3.5 Soil pH and EC

At the completion of the experiment, approximately 10 months after the soil application of the treatments, pH reduction of MSB treatments were between 0.10 and 0.28 units (Table 10). While the control pH was 8.36, remarkable reduction from the MSB + Fe + Zn treatment was 0.28 units and pH was 8.08. The minimum pH reduction was 0.10 units from the MSB alone and pH was 8.25. In studies of the conventional greenhouse tomato production with 150 kg/ha MSB and 2,000 kg/ha leonardite [5], MSB and leanardite treatments reduced the soil pH by 0.51 and 0.45 units, respectively, during approximately 10 months.

Table 9 Effect of MSB treatments on leaf Zn concentration (ppm) in organically grown greenhouse tomato plants.

Applications	Leaf Zn concentration (ppm)		
	March 28, 2014	April 25, 2014	May 30, 2014
Control	204	88	157
MSB	219	69	180
MSB + Fe	220	56	146
MSB + Zn	230	66	146
MSB + Fe + Zn	225	61	162
$LSD_{0.05}$	ns	ns	ns

ns: not significant.

Table 10 Effect of MSB applications on soil pH and EC values organically grown greenhouse tomato plants.

Treatments	pH	EC (dS/m)
Control	8.36^{a}	0.48^{c}
MSB	8.25^{ab}	0.60^{bc}
MSB + Fe	8.19^{ab}	0.64^{bc}
MSB + Zn	8.22^{ab}	0.71^{b}
MSB + Fe + Zn	8.08^{b}	1.14^{a}
$LSD_{0.05}$	0.15	0.16

$^{a-c}$ The same letters present the non-significant difference at 95% confidential level.

Table 11 Effect of MSB applications on soil Fe and Zn concentrations (ppm) in organically grown greenhouse tomato plants.

Treatments	Soil Fe concentration (ppm)	Soil Zn concentration (ppm)
Control	2.96	2.92^{c}
MSB	2.97	2.62^{c}
MSB + Fe	2.72	2.22^{c}
MSB + Zn	2.82	12.17^{b}
MSB + Fe + Zn	2.96	18.59^{a}
$LSD_{0.05}$	ns	2.52

$^{a-c}$ The same letters present the non-significant difference at 95% confidential level; ns: non significant.

The EC values of the experimental soils at the end of the production period were increased by the MSB treatments. Among the EC values, the lowest one was the control treatment (0.48 dS/m), as shown in Table 10. The highest EC was from the MSB + Fe + Zn by 1.14 dS/m. The EC values of the MSB + Zn, MSB + Fe and MSB alone were 0.71, 0.64 and 0.60 dS/m, respectively.

3.6 Soil Fe and Zn Concentrations

At the end of the experiment, Fe and Zn concentrations of the experimental soils were measured and there was no any significant difference for Fe concentrations of the treatments. However, MSB + Zn treatments showed the higher Zn contents. MSB + Fe + Zn and MSB + Zn had 18.59 ppm and 12.17 ppm of soil Zn concentrations, respectively (Table 11). Tomato plants generally require more Fe than Zn; for this reason, all Fe added to the soil with MSB applications could be consumed by the plants, and maybe in future during the manufacturing, it could be required to add more Fe into the MSB products [4].

4. Conclusions

From the conclusion of this study in greenhouse tomato production during soil tillage, the MSB products, preferably Fe and Zn added ones, can be applied to the soil and this soil application will increase yield due to pH reducing and nutrient availability for the plants. In future studies, the content of Zn and Fe as additives can be investigated with more detail, maybe Fe content needs to increase.

Acknowledgments

This study was supported by the Republic of Turkey Ministry of Food Agriculture and Livestock, by the project TAGEM/12/AR-GE/29 and Cukurova University by the project ZF2013YL28. The authors want to thank to the Balkan Sulfur Limited Company for providing the MSB products.

References

[1] Rehber, E., and Turhan, S. 2002. "Prospects and Challenges for Developing Countries in Trade and Production of Organic Food and Fibers: The Case of Turkey." *British Food Journal* 104 (3-5): 371-90.

[2] The Sulphur Institute. 2016. "Sulpur—An Advantaged Element." Accessed November, 2016. http://www.sulphurinstitute.org/.

[3] Bloem, E., Haneklaus, S., and Schnug, E. 2005. "Significance of Sulfur Compounds in the Protection of Plants Against Pests and Diseases." *Journal of Plant Nutrition* 28 (5): 763-84.

[4] Akkuzu, G., Kamisli, M., Dasgan, H. Y., Turemis, N., and Uncu, E. 2016. *Efficiencies of Micronized Bentonite Sulfur and Its Derivatives with Fe and Zn on Tomato, Strawberry and Wheat.* TAGEM12/AR-GE/29, Final Project Report, TAGEM, Ankara.

[5] Yaras, K., and Dasgan, H. Y. 2012. "Effects of Soil-Applied Micronized-Sulphur with Bentonite and Organic Matter on Soil pH, Tomato Plant Growth, Yield and Fruit Quality under Greenhouse Conditions." *Tarım Bilimleri Araştırma Dergisi* 5 (1): 175-80.

[6] Demirtas, E. I., Ari, N., Arpacioglu, A. E., Ozkan, C. F., and Aslan, H. 2007. "The Effects of Using Mushroom West on Soil Properties of Greenhouse Tomato and Crop Yield." In *Proceeding of the 5th National Horticultural Congress,* 220-3.

[7] Wang, C. D., Chan, H. T., and Lay, C. L. 1991. "Effect of Organic Manures on the Yield and Quality of Grapes." *Bulletin of Taichung District Agricultural Improvement Station* 32: 41-8.

[8] Jena, D., and Kabi, S. 2012. "Effect of Gromor Sulphur Bentonite Sulphur Pastilles on Yield and Nutrient Uptake by Hybrid Rice-Potato-Green Gram Cropping System in an Inceptisol." *Int. Res. J. Agri. Sci. Soil Sci.* 2 (5): 179-87.

[9] Nayak, K. V., and Vijayrao, P. 2012. "Role of Bentonite Sulphur in Improving Yield and Quality of Crops." *Indian Journal of Fertilizers* 8 (4): 84-92.

[10] Winsor, G., and Adams, P. 1987. *Glasshouse Crops.* Vol. 3. London: Her Majesty's Stationery Office (HMSO), 109-35.