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Determination of Sulphur Contents in Tomato Grown in Greenhouses in West Mediterranean Region, Turkey

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Sulphur contents of soils and tomato plants grown as single crop in greenhouses in Kumluca and Finike districts in Turkey were determined. For this purpose, 20 tomato greenhouses in each district were used as the source of soil samples from 0-20 and 20-40 cm depths prior to planting (1st sample period) and in the middle of the growing season (2nd sample period). When the soil samples in 2nd period were taken, plant samples were also collected. While the average SO_4^{2-}-S contents of soil samples in the 1st and 2nd periods were determined to have similar values in Kumluca. These values for the 2nd period were higher than the 1st period in Finike in both 0-20 and 20-40 cm depths. Considerable relationships were found between the values of 2nd period soil samples and some other soil properties. Whilst, negative correlations were observed between SO_4^{2-}-S contents of soils and pH and sand contents, positive correlations were observed between EC values, clay contents, N, K and Na contents. Sulphur status of soils and plants were determined to be sufficient contents in both Kumluca and Finike districts. However, a sulphur deficiency is not determined in both district's tomato plants, it appears that there is not a balance nutrition for N:S and S:P rate.

Key Words: Sulphur, Sulphur nutrition, N:S rate, S:P rate, Tomato, Greenhouse.

INTRODUCTION

The importance of sulphur in balanced nutrition has been realized with increasing reports of S deficiency around the world. In fact, sulphur is considered the fourth major nutrient. Many crops contain as much sulphur as phosphorus and it ranks in importance with nitrogen and phosphorus in the formation of protein. It is an integral component of certain vitamins and enzymes. Plants can take up sulphur (S) from the soil as sulphate (SO_4^{2-}) ions and from the atmosphere in a gaseous from as SO_2 through the stoma in leaves.

In past, commonly used fertilizers contained large amounts of sulphur and generally supplied enough of this element to meet the needs of the crop. Sulphur from this source and also from rainfall and other sources, was supplied 'incidentally' and masked the real importance of this essential plant nutrient.

Increasing use of more concentrated fertilizer materials which contain little or no sulphur, combined with less sulphur from rainfall areas, have decreased the supply of sulphur to the crops. At the same time, higher crop yields have increased the uptake of sulphur from the soil. Soils which originally contained sufficient sulphur often become deficient as agriculture is intensified, unless sulphur-containing fertilizers are used. In recent years, sulphur deficiencies have been reported with increasing frequency from many parts of the world. The main reasons for greater occurrence of sulphur deficiencies are: (1) increased use of high analysis, essentially sulphur-free fertilizers, (2) decreased use of sulphur as a fungicide and insecticide, (3) increased crop yields which require larger amounts of all of the essential plant nutrients, (4) increased consumption of low sulphur fuels and increased emphasis on control of air pollution, and (5) increased ability to identify soils low in sulphur[1].

Sources for sulphur in agro-ecosystems are informed as atmosphere, soil organic matter, mineral fraction of the soil (especially magmatite and metamorphite), ground water and porous water, mineral fertilizers and organic manures. The major sinks for sulphur in agro-ecosystems are leaching, runoff and removal by harvest products. Adsorption or gaseous losses from the soil surface and from plants are of minor importance[2].

The retention of sulphate in soils is dependent on the nature of the colloidal system, pH, concentration of sulphate and the concentration of other ions in the solution[3]. Sulphate is adsorbed by hydrous oxides of Fe and Al by edges of clay particles[4].

Internationally sulphur values in Turkey are on the high side. The variation, however, is wide and there are many low and high plant and soil sample pairs. Most of the low sulphur areas are in the east of the country. Although the high sulphur sites are numerous there are also many sites with acute or potential deficiency in Turkey[5].

Plant nutrient sulphur has not been studied extensively in Kumluca and Finike districts in Mediterranean region. The cases of nutrition of the plants which have growth up to the present in greenhouses in Mediterranean region, especially in Kumluca and Finike districts, with various elements have been investigated, but the case of nutrition with sulphur is not studied. But now embracing the product varieties with high efficiency capacity, heavily usage of greenhouses and the increase in the use of high purity chemical fertilizers without sulphur makes it necessary to point out this topic.

Starting from this necessity, in the made research, cases of nutrition with sulphur of tomato greenhouses in Kumluca and Finike districts were determined with the taken samples of soils and plants.

EXPERIMENTAL

The soil and plant samples were taken from 40 tomato greenhouses (as single crop grown) located in Kumluca and Finike districts in Antalya province in West Mediterranean region.

Soil sampling and analysis: Total of 160 soil samples were collected 2 times, prior to planting (1st sample period) in September 2001 and middle (2nd sample period) of the vegetation period in March 2002, by using the soil sample techniques as described by Jackson[6], from depths of 0-20 and 20-40 cm in the each greenhouses. Extractable-SO_4 analysis was done which taken soil samples in September 2001 (1st sample period). Taken soil samples in March 2002 (2nd sample period) was performed both extractable-SO_4 and other physico-chemical analysis.

The soil samples were chemically analyzed after they had been air-dried and passed through a 2 mm sieve. The pH of the soil was measured in H_2O (1:2.5 soil:deionized water) and the electrical conductance of the soil value was determined directly on the saturation paste. The soil particle size analysis was done by using the hydrometer method[7] and the $CaCO_3$ content was determined by using a Scheibler calcimeter. Organic matter was determined by using modified Walkley-Black procedure[8]. The total nitrogen of soil was done by using modified Kjeldahl procedure[9]. Extractable P content was extracted by $NaHCO_3$[10] and determined by a molybdate colorimetric method[11], extractable K, Ca, Mg and Na were extracted with ammonium acetate and determined by atomic absorption spectrophotometry[9]. Soil samples were extracted for SO_4 by using 500 mg kg^{-1} P as KH_2PO_4 which contents of Fox *et al.*[12]. Analyses were conducted by the turbidimetric method with $BaCl_2 \cdot 2H_2O$ and the readings were taken using a spectrophotometer at 430 nm[9].

Plant sampling and analysis: When the soil samples in March 2002 (2nd sample period) were taken, leaf samples were also collected. Leaf samples (4th-5th fully expanded leaves) of tomato (as single crop grown) were taken as described by Geraldson *et al.*[13] and were transported to the laboratory in closed polyethylene bags. In order to surface contamination, the leaf samples were carefully rinsed in deionized water and dried in a forced-air oven at 65 ºC to a constant weight. The dried leaf samples were ground in a stainless steel mill which enabled them to be passed through a 20 mesh screen. The samples of 0.5 g each were digested with 10 mL HNO_3 and $HClO_4$ (4:1) acid mixture on a hot plate. The samples were then heated until a clear solution was obtained. The samples were filtered and diluted to 100 mL using distilled water. Total P was measured by spectrophotometry[14] and total N was determined by a modified Kjeldahl procedure[15]. Total S in digested leaf samples with HNO_3 and $HClO_4$ (4:1) acid mixture were conducted by the turbidimetric method with $BaCl_2 \cdot 2H_2O$ and the readings were taken using a spectrophotometer at 430 nm[15].

Statistical analysis: Linear regression analysis was performed for the soil samples in March 2002 (2nd sample period) in order to determine the relationships among the soil extractable S status and other physico-chemical analyses.

RESULTS AND DISCUSSION

Relationship between soil sulphur status and soil properties: In the Kumluca and Finike districts, the extractable SO_4-S contents of tomato greenhouse soils collected from depth of 0-20 cm and 20-40 cm in 1st and 2nd sampling period are given in Table-1.

A surveys to delineate S-deficient areas were conducted using 10 mg S kg^{-1} as the critical level. However, that value was based on the amount of available S extracted by calcium phosphate. The critical level is known to vary from 8 to 25 mg kg^{-1}, depending upon soil, crop, extractant and laboratory procedure[16] and to 8 to 12 mg kg^{-1}. For the critical level, it was accepted as 12 mg kg^{-1} extractable S at the survey study[17] and informed that S deficiency in Ankara, Turkey was around 50 %. A survey study was also done to determine of sulphur status of soils and plants in Pakistan by Rashid *et al.*[18] and the soil samples was divided into four categories; deficient, < 10 mg kg^{-1}; satisfactory, 11 to 30 mg kg^{-1}; adequate, 31 to 100 mg kg^{-1} and excessive, > 100 mg kg^{-1}. In present study, soil extractable SO_4 concentration was classified based on Rashid *et al.*[18] and was given in Tables 2 and 3.

Ülgen *et al.*[19] reported that available sulphur concentration (SO_4-S) was generally higher than the critical level of 10 mg kg^{-1} in Antalya's soils. As the critical levels, soil available sulphur (SO_4-S) concentration was determined for the Morgan extraction 9 mg kg^{-1}; solutions with phosphate 10 mg kg^{-1}; 0.5 N NH_4AOc + 0.25 N HOAc and 0.5 % $CaCl_2$ solutions[20] 14 mg kg^{-1}. The researchers informed that if the soil sulphur concentration was less or more than the critical values, sulphur fertilization was necessary. When a overall evaluation made in present research, it has seen that there are no problems about the nutrition with the available sulphur contents of the soil samples taken from the tomato greenhouses in Kumluca and Finike districts. Due to the intensive growing on greenhouse soils, it is obvious that there is a continuously contribution of sulphur *via* especially irrigation waters and fertilization with manures possessing various levels of sulphur like ammonium sulphate, potassium sulphate and microelement fertilizers.

TABLE-1
EXTRACTABLE SO_4-S CONTENTS OF SOIL SAMPLES IN THE KUMLUCA AND FINIKE DISTRICTS (mg kg^{-1})

Greenhouse No.	Soil depth (cm)	Kumluca Sampling period		Finike Sampling period	
		1st	2nd	1st	2nd
1	0-20	17.30	20.76	30.81	75.19
	20-40	14.05	5.36	11.28	55.66
2	0-20	9.71	5.25	95.86	146.24
	20-40	7.05	3.13	61.09	49.20
3	0-20	21.16	10.67	2.22	42.37
	20-40	13.35	5.19	1.52	14.43
4	0-20	14.16	11.76	48.17	105.62
	20-40	3.69	3.08	14.49	88.16
5	0-20	37.32	81.09	18.77	11.72
	20-40	29.19	71.43	17.79	2.50
6	0-20	45.46	83.31	109.91	216.18
	20-40	34.07	53.96	80.13	144.74
7	0-20	11.83	83.83	2.77	21.27
	20-40	10.25	35.63	0.43	10.14
8	0-20	26.69	47.40	21.86	12.26
	20-40	20.02	14.85	17.52	7.92
9	0-20	77.58	38.56	19.64	55.82
	20-40	33.20	11.76	11.28	50.72
10	0-20	115.55	72.46	29.73	54.58
	20-40	86.15	54.07	22.95	48.12
11	0-20	47.25	26.89	135.30	210.87
	20-40	16.60	16.10	75.19	122.66
12	0-20	104.54	78.43	36.89	53.49
	20-40	67.60	60.53	22.13	39.55
13	0-20	50.72	55.38	39.60	33.96
	20-40	14.65	20.44	29.46	32.01
14	0-20	207.18	111.58	9.93	75.57
	20-40	101.50	80.00	8.57	44.92
15	0-20	45.03	54.07	21.05	40.58
	20-40	33.04	38.77	15.62	16.06
16	0-20	37.70	48.05	151.25	180.43
	20-40	17.85	24.72	111.10	65.53
17	0-20	26.80	61.51	69.87	174.74
	20-40	25.50	22.72	50.45	111.27
18	0-20	10.31	11.60	41.61	70.85
	20-40	6.08	7.69	38.90	50.72
19	0-20	16.82	3.95	39.49	113.11
	20-40	1.09	3.02	15.62	59.95
20	0-20	46.17	3.76	19.53	57.45
	20-40	25.50	3.19	16.71	38.35
Minimum	0-20	10.31	3.76	2.22	11.72
	20-40	1.09	3.02	0.43	2.50
Maximum	0-20	207.18	111.58	151.25	216.18
	20-40	101.50	80.00	111.10	144.74
Average	0-20	48.46	45.52	47.21	87.62
	20-40	28.02	26.78	31.11	52.63

TABLE-2
SULPHUR STATUS OF SOIL SAMPLES IN KUMLUCA

Range of SO_4 (mg kg^{-1})	Number and percent of samples in each category Kumluca							
	0-20 cm				20-40 cm			
	1st sampling period		2nd sampling period		1st sampling period		2nd sampling period	
	No.	%	No.	%	No.	%	No.	%
< 10	1	5	3	15	5	25	7	35
11-30	8	40	5	25	9	45	6	30
31-100	8	40	11	55	5	25	7	35
> 100	3	15	1	5	1	5	–	–

TABLE-3
SULPHUR STATUS OF SOIL SAMPLES IN FINIKE

Range of SO_4 (mg kg^{-1})	Number and percent of samples in each category Finike							
	0-20 cm				20-40 cm			
	1st sampling period		2nd sampling period		1st sampling period		2nd sampling period	
	No.	%	No.	%	No.	%	No.	%
< 10	3	15	–	–	3	15	3	15
11-30	6	30	3	15	11	55	2	10
31-100	8	40	10	50	5	25	12	60
> 100	3	15	7	35	1	5	3	15

It is determined that the mean values of the SO_4-S contents of the soil samples taken from Kumluca district at both depths in the 1st and 2nd sampling periods according to the Table-1 are close to each other. But the SO_4-S contents of the soil samples taken from Finike district in the 2nd sampling period. When it is compared to the 1st sampling period, an increase of 85.60 % at 0-20 cm depth and 69.17 % at 20-40 cm depth have been observed. It is considered that the different fertilization program made in both districts and contribution of SO_4^{2-} *via* different irrigation waters and irrigation methods may be the possible causes of this situation. In addition, generally having a sandy clay loamy texture in the soils of the tomato greenhouses where sampling made in Kumluca district. It is determined that the soils of the tomato greenhouses in Finike district are also generally having a sandy loamy texture, besides the sulphur that added to the soils in various ways in Kumluca district, absorbed by the plants, having higher possibility to distance from the soils by washing rather than Finike district is one of the important factors. It is also considered as another factor that in the result of the organic matter analysis made over the soils samples taken from research area, it is showed that the soils of Finike district have a higher level of organic matter than the soils of Kumluca district. Mukhopadhyay and Mukhopadhyay[16] have determined a higher level of sulphur content in the soils with fine textures. In the sandy soils with coarse textures, they have measured S content of soil very low. They supposed that this is the result of having both low level of S content in organic matter and at the same time loss of sulphur due to high leaching. In addition, they have indicated that the fields which are expected to be short of sulphur, are coarse textured, with low organic matter content, open to irrigation and the areas where the plants growth like oil plants and legumes which needs a higher level of sulphur.

Some other analyzed properties of the soil samples taken from 0-20 and 20-40 cm depth in March 2003 (2nd period) in a total amount of 40 tomatoes greenhouses from Kumluca and Finike districts are given in Tables 4 and 5. The statistical relations between the results of this analysis and available sulphur (SO_4-S) content are given in Table-6.

A significant negative correlation, in a level of 1% (r = -0.489**), between the available sulphur content and pH values of the soil samples taken from 20-40 cm depth of the research area soils and a significant negative correlation, in a level of 1% (r = -0.468**), between the available S content and pH values of the soil samples taken from 0-20 cm depth of the research area soils are determined (Table-6). Hydrous iron and aluminum oxides have an important role in absorption of sulphate in soils. The adsorption of sulphate is intensive in soils with acidic pH. In contrast, the adsorption level of sulphate is very low or none in soils having a pH higher than 6.5. That means, while the pH value gets higher, being held strength of sulphate in soils gets lower[21]. According to Padamja[22], the total sulphur in soils shows a negative correlation with the pH (r = -0.277), inorganic SO_4 extracted in 0.15 % $CaCl_2$ shows a positive correlation (r = 0.505). Nayyar *et al.*[23] in 676 soil samples and Dangarwala *et al.*[24] in 4381 soil samples have made researches in India and declared that the statistical relation between pH of the soils and the percentage of the soils with inadequate sulphur level is not important, that means the available sulphur content in soils is not affected by pH changes.

Many researches suggest that one of the most important resources of the soil sulphur is organic matters. Sulphur comes out while mineralization of the organic matter, at the same time the pH of the soil gets lower. Saglam *et al.*[25], reported that the organic matter decompositions in the soils one cause lowering of the pH. It has considered as on of the reasons of determining negative correlation between pH values and the sulphur content of the soils in Kumluca and Finike districts.

TABLE-4
PHYSICAL AND CHEMICAL ANALYSIS RESULTS OF THE SOIL SAMPLES TAKEN IN 2nd SAMPLING PERIOD IN KUMLUCA DISTRICT

	Depth (cm)	pH	$CaCO_3$ (%)	EC (dS m^{-1})	OM (%)	Sand (%)	Silt (%)	Clay (%)	Total N (%)	P (mg kg^{-1})	K (me 100 g^{-1})	Ca (me $100g^{-1}$)	Mg (me100 g^{-1})	Na (me 100 g^{-1})
Min.	0-20	7.76	1.64	2.23	0.72	42.00	8.00	4.36	0.05	18.58	0.34	10.73	7.42	0.42
	20-40	7.96	2.06	2.28	0.65	38.00	6.00	2.36	0.02	14.13	0.27	6.45	7.52	0.41
Max.	0-20	8.61	23.89	9.25	3.53	71.64	74.64	34.36	0.22	136.06	1.83	32.03	21.69	1.68
	20-40	8.61	26.36	8.04	2.29	75.64	44.00	38.36	0.14	104.71	1.64	36.90	22.37	1.70
Means	0-20	8.17	10.69	5.05	1.77	58.07	28.52	15.66	0.12	85.57	0.83	19.71	12.94	0.84
	20-40	8.25	12.11	4.87	1.39	57.97	23.67	18.76	0.09	58.97	0.61	17.62	12.16	0.78

TABLE-5
PHYSICAL AND CHEMICAL ANALYSIS RESULTS OF THE SOIL SAMPLES TAKEN IN 2nd SAMPLING PERIOD IN FINIKE DISTRICT

	Depth (cm)	pH	$CaCO_3$ (%)	EC (dS m^{-1})	OM (%)	Sand (%)	Silt (%)	Clay (%)	Total N (%)	P (mg kg^{-1})	K (me 100 g^{-1})	Ca (me $100g^{-1}$)	Mg (me100 g^{-1})	Na (me 100 g^{-1})
Min.	0-20	7.51	5.37	3.08	1.25	16.00	11.64	16.72	0.11	64.65	0.49	8.03	4.82	0.15
	20-40	7.58	4.95	2.26	0.99	12.00	5.64	16.72	0.08	40.30	0.39	4.35	5.14	0.14
Max.	0-20	8.03	35.90	10.28	5.21	71.64	51.28	32.72	0.28	206.40	2.67	25.88	22.62	2.43
	20-40	8.13	39.21	9.25	4.69	71.64	49.28	38.72	0.31	183.11	2.29	21.08	19.68	1.77
Means	0-20	7.82	18.34	5.84	2.81	53.52	21.96	24.52	0.18	125.50	1.37	15.56	11.05	0.69
	20-40	7.90	19.48	5.00	2.26	50.72	22.18	27.10	0.16	103.13	1.04	13.58	10.08	0.61

TABLE-6
REGRESSION ANALYSIS AND CORRELATION COEFFICIENTS BETWEEN EXTRACTABLE SOIL SULPHUR AND PHYSICAL AND CHEMICAL PROPERTIES OF SOIL SAMPLES

0-20 cm			20-40 cm		
Correlation relationships	r	Equation	Correlation relationships	r	Equation
S-pH	-0.468^{**}	Y= 877-101X	S-pH	-0.489^{**}	Y= 595-68.8X
S-EC	0.779^{***}	Y= -44.0+20.3X	S-EC	0.713^{***}	Y= -28.8+13.9X
S-Sand	-0.439^{**}	Y= 179-2.02X	S-Sand	-0.460^{**}	Y= 102-1.15X
S-Clay	0.447^{**}	Y= 4.4+3.09X	S-Clay	0.502^{***}	Y= -3.4+1.88X
S-Silt	0.108^{ns}	-	S-Silt	0.181^{ns}	-
S-Organic matter	0.188^{ns}	-	S-Organic matter	0.247^{ns}	-
S-N	0.268^{ns}	-	S-N	0.382^{*}	Y= 12.0+227X
S-P	0.213^{ns}	-	S-P	0.196^{ns}	-
S-K	0.362^{*}	Y= 28.8+34.5X	S-K	0.389^{*}	Y= 14.8+30.3X
S-Ca	0.219^{ns}	-	S-Ca	0.086^{ns}	-
S-Mg	0.291^{ns}	-	S-Mg	0.244^{ns}	-
S-Na	0.355^{*}	Y=35.4+40.5X	S-Na	0.166^{ns}	-

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $r = 0.502^{***}$, $r = 0.403^{**}$, $r = 0.312^{*}$
n = 40, ns = non-significant.

A significant positive correlation, in a level of 0.1 % (r = 0.713***), between the SO_4-S content and electrical conductivity (EC) of the soil samples taken from 20-40 cm depth of the research area soils and a significant positive correlation, in a level of 0.1 % (r = 0.779***), between the SO_4-S content and electrical conductivity (EC) of the soil samples taken from 0-20 cm depth of the research area soils are determined (Table-6). Dangarwala *et al.*[24] reported that the increase in the salinity of the soils (EC 0.1-0.2 sm^{-1}) causes to decrease of sulphur shortage in the soils. Padamja[22] established a statistical relations between the EC of the soil and both total and inorganic sulphur contents. Ülgen *et al.*[19] determined the status of the sulphur of the Turkey soils that are available for the plants. They have determined a significant positive correlation between the total salt content of the soils and sulphur contents. They have also reported that the increase in salinity of the soils causes an increase in the available sulphur contents. Growing is made by fertilization and irrigation in the soils in Kumluca and Finike districts which is the present research area. This situation, generally causes an increase in salt content of the soils and at the same time, SO_4^{2-} anions that come from fertilizers and irrigation waters, may cause an increase in the sulphur content in soils.

A significant negative correlation, in a level of 1 % (r = -0.439**), between the S content and sand content of the soil samples taken from 0-20 cm depth of the research area soils and a significant positive correlation, in a level of 1 % (r = 0.447**), between S content and clay content of the soil samples. A significant negative correlation, in a level of 1 % (r = -0.460**), between the available S content and sand content of the soil samples taken from 20-40 cm depth of the research area soils and a significant positive correlation, in a level of 0.1 % (r = 0.502***), between S content and clay content of the soil samples. A statistically insignificant but positive correlation between the available sulphur content and silt content of the soil samples taken from both depths of the research area soils (Table-6). SO_4^{2-} ions in the soil solution are in balance with the solid phase. Sulphate ions are adsorbed by the clay minerals and sesquioxides in a similar way with phosphate anions. Because the clay minerals has the ability to hold sulphate anions, there is positive correlation between the amount of exchangable SO_4^{2-} anions and the clay minerals in soil[26]. Padamja[22] reported that they have determined positive relations between the clay contents of the soils and total sulphur (r = 0.628) and inorganic SO_4 contents (r = 0.484). In the research made by Nayyar *et al.*[23] on 676 soil samples, it is showed that by getting thickness of the soil texture, sulphur deficient soil percentage becomes less, when the soil texture is sandy loam, sulphur deficient soil percentage is 20 % and when the soil texture is loamy sand, it is around 40 %.

An insignificant but positive correlation between the available sulphur content and organic matter content of the soil samples taken from 0-20 and 20-40 cm depth of the research area greenhouse soils (respectively r = 0.188^{ns}, r = 0.247^{ns}) is determined (Table-6). It is seen that the available sulphur content of the soils augments when the organic matter content augments but this augmentation hasn't been statistically significant. Padamja[22] has indicated that the total sulphur and also the inorganic SO_4^{2-} have a significant negative correlation with the organic C content of the India soils and the researcher determined that this signifies that the organic sulphur forms are not dominant in these soils. Some researchers also indicate that the sulphur content of the soils augments with the increase of the organic carbon content and there is a positive correlation between them[23,24].

It has been determined an insignificant but positive correlation between the available sulphur content and the nitrogen content (r = 0.268^{ns}), an insignificant but positive correlation with the phosphorus contents (r = 0.213^{ns}), a significant and positive correlation with a value of 5 % with the potassium contents (r = 0.362*), an insignificant but positive correlation with the calcium contents (r = 0.219^{ns}), an insignificant but positive correlation with the magnesium contents (r = 0.291^{ns}), a 5 % significant and positive correlation with the sodium contents (r = 0.355*) of the soil samples taken from the 0-20 cm depth of the research area greenhouse soil. It has been determined a significant and positive correlation with a value of 5 % between the available sulphur contents and the nitrogen contents (r = 0.382*), an insignificant but positive correlation with the phosphorus contents (r = 0.196^{ns}), a 5 % significant and positive correlation with the potassium contents (r = 0.389*), an insignificant but positive correlation with the calcium contents (r = 0.086^{ns}), an insignificant but positive correlation with the magnesium contents (r = 0.244^{ns}), an insignificant but positive correlation with the sodium contents (r = 0.166^{ns}) of the soil samples taken from the 20-40 cm depth of the research area greenhouse soil (Table-6).

In the study made by Dangarwala *et al.*[24], with 4381 soil sample indicated that the sulphur content of the soils shows positive correlations with the available phosphorus and potassium contents of the soils. The researchers indicates its reason as the sulphur supply of the fertilizers with N, P and K and they also indicated that besides the sulphur supply with the inorganic fertilizers, the sulphur addition is also realized by the recycle of the organic wastes and materials. The researchers indicated that, in the soils which contain > 200 kg ha^{-1} K_2O, the rate of the sulphur deficient soils is less than the soils which contain < 100 kg ha^{-1} K_2O and also in the soils which contain > 20 kg/ha P_2O_5 the sulphur deficient soils are less than the soils which contains < 10 kg/ha P_2O_5.

Sulphur contents of the leaf samples: The sulphur content of the leaf samples taken from the tomato greenhouses of Kumluca is made between 0.70-1.70 % in dry weight; but it changes between 0.65-1.73 % of Finike (Table-7). When the sulphur analyze results of the leaf samples are compared with the limit values indicated by Campbell[27], it is determined that in the region of Kumluca the 15 % of the tomato leaf samples contain sufficient value (0.20-1.0 %) of sulphur, but 75 % of them contain high value of sulphur (more than 1.0 %); in Finike region 20 % of the tomato leaf samples contain sufficient value (0.20-1.0 %) of sulphur, but 80 % of them contain high value of sulphur (more than 1.0 %) (Table-8).

In the limit values that Anonymous[28] indicated for the dry weight of the tomato leaf the 5 % S has sufficient value and the % 0.8-0.9 S have high values. According to Jones *et al.*[29] the 0.40-1.2 % S have sufficient values. And, also different limit values are reported for the tomato plants having different growth period by Reuther and Robinson[30]. The researchers, indicated that the leaf + stem sufficiency concentration of the tomato plant in fruit growth period is 0.2 % S and the sufficiency concentration for the youngest ripped leaf in the harvest period is 0.21-0.23 % S. When evaluating according to these values, it is seen that all the leaf samples taken from Kumluca and Finike region which is present research areas contain sulphur between the limit values or higher than the limit values.

The maximum portion of S in plants is present in protein either as cysteine, cystine or methionine. Plant proteins generally contain 1 % S and 17 % N[31,32]. A review of published data up to 1967 indicates that the average

TABLE-7
THE NITROGEN, PHOSPHORUS AND SULPHUR CONTENTS OF THE TOMATO LEAF SAMPLES OF KUMLUCA AND FINIKE REGION

Green house no.	Kumluca					Finike				
	N (%)	S (%)	P (%)	N:S	S:P	N (%)	S (%)	P (%)	N:S	S:P
1	3.01	1.63	0.30	1.85	5.43	3.87	1.49	0.38	2.60	3.92
2	3.19	1.24	0.38	2.57	3.26	3.56	1.11	0.30	3.21	3.70
3	3.79	1.39	0.28	2.73	4.96	3.37	0.87	0.18	3.87	4.83
4	4.01	1.45	0.29	2.77	5.00	3.66	1.69	0.26	2.17	6.50
5	2.79	1.31	0.34	2.13	3.85	3.42	1.47	0.33	2.33	4.45
6	3.34	1.70	0.29	1.96	5.86	3.83	0.81	0.33	4.73	2.45
7	4.30	1.20	0.27	3.58	4.44	3.68	1.28	0.41	2.88	3.12
8	4.10	1.46	0.25	2.81	5.84	4.06	1.17	0.40	3.47	2.93
9	4.23	1.31	0.21	3.23	6.24	4.21	1.53	0.48	2.75	3.19
10	4.41	1.50	0.23	2.94	6.52	4.01	1.38	0.26	2.91	5.31
11	4.99	1.25	0.24	3.99	5.21	4.16	1.44	0.34	2.89	4.24
12	3.11	0.98	0.43	3.17	2.28	4.04	1.16	0.36	3.48	3.22
13	3.60	1.10	0.49	3.27	2.24	3.85	0.65	0.29	5.92	2.24
14	3.83	1.10	0.23	3.48	4.78	4.26	1.21	0.32	3.52	3.78
15	3.51	1.09	0.24	3.22	4.54	4.13	1.21	0.45	3.41	2.69
16	3.57	1.60	0.28	2.23	5.71	3.16	0.87	0.46	3.63	1.89
17	4.01	0.70	0.43	5.73	1.63	4.09	1.73	0.34	2.36	5.09
18	3.61	1.50	0.35	2.41	4.29	3.88	1.06	0.19	3.66	5.58
19	3.74	1.06	0.35	3.53	3.03	2.82	1.03	0.31	2.73	3.32
20	3.67	0.85	0.37	4.32	2.30	4.36	1.36	0.30	3.21	4.53
Min.	2.79	0.70	0.21	1.85	1.63	2.82	0.65	0.18	2.17	1.89
Max.	4.99	1.70	0.49	5.73	6.52	4.36	1.73	0.48	5.92	6.50
Ort.	3.74	1.27	0.31	3.10	4.37	3.82	1.23	0.33	3.29	3.85

TABLE-8
CLASSIFICATION OF THE ANALYZE RESULTS OF THE TOMATO LEAF SAMPLES OF KUMLUCA AND FINIKE REGION ACCORDING TO THEIR LIMIT VALUES

Nutrition element	Limit values	Evaluation	Kumluca (%)	Finike (%)
N (%)	3.5 >	Low	25	20
	3.5-5.0	Sufficient	75	80
	5.0 <	High	-	-
S (%)	0.20 >	Low	-	-
	0.2-1.00	Sufficient	15	20
	1.00 <	High	85	80
P (%)	0.30 >	Low	55	25
	0.30-0.65	Sufficient	45	75
	0.65 <	High	-	-

N:S ratio in proteins was 13.7 for gramineous plants and 17.5 for legumes[33]. For three field crops (wheat, corn and beans) an N:S ratio of about 12 15:1 was required for protein synthesis[34]. For any plant species the composition of a given protein, which is controlled by genetics, is constant. Therefore, environmental factors such as N and S supply, age of plant, *etc.*, should have no influence on the N:S ratio in plant proteins. However, the total N: total S ratio can be greatly affected by environmental factors. When S is adequate, non-protein S (mainly SO_4^{2-}) will accumulate in the plant and the total N: total S ratio will be less than the N:S ratio in protein. When S is deficient, protein formation is suppressed and non-protein N accumulates. The resulting bulk plant N:S ratio is higher than the N:S ratio of the proteins[35].

The sulphur has a significant effect on nitrate content, taste and yield of the vegetables and a lot of crop like cabbage, tomato and eggplant need high value of S level[36]. Sulphur deficiencies occur primarily on the sandy soils and when low S containing fertilizers are used over several years. Since S is not a mobile element in the plant, deficiency symptoms tend to first appear in the upper or newly emerging leaf tissue[37]. In the determination of sulphur need of the plants the use of N:S and S:P rates is more useful[38]. The ideal N:S ratio for most crops is 10-15. As the N:S ratio approaches and exceeds 18, sulphur is limiting in relation to nitrogen[39]. In cucumber growing, the N:S rate has to be less[40] than 18. It is indicated that, in Bermuda grass (Tigreen, Tifton-328) growing for the best growth and quality the N:S rate has to be 10-15 and if it is equal or more than 18 the S deficiency could be observed[41]. Abo Rady *et al.*[42] had indicated that, a N:S rate between 6.4-9.4 is appropriate for date palm seedling growing but a N:S rate less than 6.4 is not appropriate for optimum growing. Stewart and Porter[34] had indicated that a N:S rate under 16:1 is an indicator of a S deficiency limiting the protein formation and that if this rate is 20:1 or higher is an indicator of severe sulphur deficiency. For the Coastal Bermuda grass[43] the optimum N:S rate is 9:1 and 12:1. In the experiments made by Gaines and Phatak[44], on water culture, it is determined that when 0, 16, 32 ppm S is applied in the tomato plant the total N:total S is respectively 32.8, 6.0, 4.4; the protein N: protein S rate is 14.0, 11.7, 11.6.

The ideal anion and cation rate for tomato in N:S:P is determined as 58:36:6 and in K:Ca:Mg is determined[45] as 39:32:29. When these values are taken under consideration, the N:S rate has to be 1.6; and the S:P rate has to be 6. As seen in Table-7, in both district he N:S rate is higher than 1.6; and the S:P rate is about 6 in 10 % of the greenhouses of Kumluca and in 5 % of the greenhouses of Finike. For that reason, even a sulphur deficiency is not determined in both district's tomato plants, it appears that there is not a balance nutrition for N:S and S:P rate. Because to get a high and qualified harvest, the equilibration between the nutrition elements has more significance than their one by one concentration in the plant.

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