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The physiological and chemical response of stone fruit rootstocks (*Prunus L*.) to sulphur application under two different soil textures

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A pot experiment was conducted during 2014 seasons at the field of Seed and Plant Institute, Karaj, Iran, to study the effect of sulphur application (with and without thiobacillus) on the physiological and chemical response of stone fruit rootstocks (*Prunus L*.) including "Myrobalan","GF 677", "Penta" and peach seedling rootstock (native) grown on two selected calcareous and alkaline (with pH values greater than 7) soil series of Karaj province. The experiment was laid out in a split- split plot experiment in the randomized complete blocks design with three replications. The main plot treatments included twodifferent soil textures (silty clay loam and loam with pH 8 and 7.3, respectively) while the sub plot treatments were four stone fruit rootstocks (*Prunus L*.) including "Myrobalan","GF 677", "Penta" and peach seedling rootstock (native) and finally six different levels of sulphur application (sulphur application of 0, 500 and 1000 g/pot with and without thiobacillus of 10 g/pot) as sub-sub factor. Statistical analysis of data indicated that the factors alone and together had a significant effect on leaf mineral content, shoot number/rootstock and shoot length of studied rootstocks. The effects of two-fold and three-fold interactions were also significant in these attributes (except for the interactive effects of soil texture × sulphur application and rootstock × sulphur application for shoot number/rootstock). Mean comparisons of the three-fold interaction effects between factors showed that these attributes had higher average value than the control treatment (without any sulphur and thiobacillus application). Also, the results of the project showed that application of 500 g sulphur/pot and/ or 10 g thiobacillus/pot would increase the chlorophyll fluorescence parameters, leaf surface, and leaf SPAF-value.

Key words: Sulphur application, stone fruit rootstocks (*Prunus L*.), physiological and chemical response.

INTRODUCTION

The stone fruit decline condition in Iran has been own to biotic (*Pseudomonas* sp., nematodes, etc.) and abiotic (high soil pH, alkaline soil, nutrition, etc.) factors (Agricultural Scientific Information and Documentation Centre of Iran, 2014). Many soils of Karaj province in Iran contain one or more calcareous horizons or layers and

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Table 1. Different soil textures of Karaj province used for growing rootstocks.

Soil treatment	K-soil (ppm)	soil-P (ppm)	N-soil (%)	Soil pH	Electrical conductivity (dS m^{-1})	Soil organic matters (%)	Total neutralizing value (%)	Saturation percentage (%)
Silty clay loam	94.34	24.14	0.035	8	0.33	0.86	10.75	52
loam	42.5	34.754	0.023	7.3	0.50	1.72	11.80	37.34

have pH values greater than 7 (Fallahi, 1995, 1998). These soils are important for stone fruit rootstocks production in Iran. Increased nutritional management often is required to grow stone fruit rootstocks successfully on calcareous soils with high pH values. Sulphur plays an important role in increasing the growth and nutrient absorption. In other words, it plays a significant role in the growth and nutrient absorption of *Prunus avium* L (Neilsen et al., 1990) as well as a modifier in the soil (Besharati, 1999). Importance of this element in our country soil, which is dominantly limy, will be represented more than other elements. The main objective of this work was to determine the influence of different rate of sulphur (with and without thiobacillus) on physiological attributes, chemical composition and the growth of stone fruit rootstocks (*Prunus L.*) including "Myrobalan","GF 677", "Penta" and peach seedling rootstock (native) grown on two selected calcareous and alkaline (with pH values greater than 7) soils of Karaj province

MATERIALS AND METHODS

A pot experiment was conducted during 2014 seasons at the field of Seed and Plant Institute, Karaj, Iran. At first composite soil samples were prepared from the field in the 0-30 cm depth and after drying the samples, they were analyzed for soil physical and chemical characters. Soil texture was determined using the hydrometric method, pH and electrical conductivity of the saturated paste, soil organic matters, total neutralizing value, total N and available P, K and neutralizing material were measured using standard methods. Treatments in this research were different combinations of three factors namely: 1, two different soil textures (Table 1) as main factor, 2, the stone fruit rootstocks (*Prunus L.*) including "Myrobalan","GF 677", "Penta" and peach seedling rootstock (native) as sub factor and finally 3, six different levels of sulphur application [S_1=0 (control), S_2=500 g/pot, S_3=1000 g/pot, S_4=10 g/pot thiobacillus (without any sulphur application), S_5=10 g/pot thiobacillus+500 g/pot, S_6=10 g/pot thiobacillus+500 g/pot] as sub-sub factor. The young stone fruit rootstocks were grown individually in plastic pots (40 cm in diameter and 42 cm in height), filled with studied soil particles. In the present work, leaves were sampled from 48 treatments and 3 replications (144 experimental units). The leaf samples (gathered at spring of 2014) were dried at 75°C for 72 h and ground to pass a 40-mesh screen, and their mass was measured. The nitrogen content was estimated by the Kjeldahl method. Ca, Mg, Fe, Zn and B were determined by atomic absorption spectrophotometry. P was analyzed by the molybdo-vanadat method. K was analyzed by flame photometry [Association of Official Analytical Chemists (AOAC) 1980]. Nutrient concentrations in leave were expressed on a dry weight (DW) basis. The mean leaf surface of individual rootstocks (cm^2) was determined by portable leaf area meter LI — 3000 (Li-Cor, USA). The plant chlorophyll was indirectly measured during the experimental period using a portable SPAD-502 device (Minolta Camera CO, Ltd., Japan) in two young expanded leaves with two readings per leaf. Chlorophyll fluorescence parameters (F0: minimum fluorescence; Fm: maximum fluorescence; Fv = Fm - F0: variable fluorescence) and value of photochemical capacity of photosystem 2 (FV/FM) were measured with a portable fluorimeter (Plant Efficiency Analyser, PEA, Hansatech Instruments Ltd., England). Prior to the measurements, the leaves were kept in the dark for 30 min using cuvettes. A 5-s light pulse at 400 μmolm^{-2} s^{-1} was used. Shoot length, shoot diameter and shoot number/rootstock was also measured at the end of August 2014. This paper used SAS statistic computer system (version 6.12) to calculate the surveyed data and means were evaluated using Duncan's multiple range test at P=0.05. The relationships between studied parameters were evaluated by Pearson's correlation coefficients at $P \leq 0.05$.

RESULTS

Statistical analysis of data indicated that the main (soil textures), sub (rootstocks) and sub-sub (Sulphur levels) factors alone and together had a significant effect at 1% probability level on leaf mineral content, shoot number/ rootstock and shoot length (soil texture as the main factor had a significant effect at 5% probability level on shoot length) of stone fruit rootstocks including "Myrobalan","GF 677", "Penta" and peach seedling rootstock (native) at the two studied soil textures [loam (pH=7.3) and silty clay loam (pH=8) soil]. The effects of three-fold interactions were also significant at 1% probability level in these attributes (Table 2). Mean Comparisons of the three-fold interaction effects between factors showed that these attributes had higher average value than the control treatment (without any sulphur and Thiobacillus application).

"GF677" rootstocks grown in loam soil had the highest leaf-P (1.39%) and leaf-N (6.78%) content, when sulphur application of 500 g/pot (for leaf-P content) and combination of 500 gsulphur/pot+ 10 g thiobacillus (for leaf-N content) was used. Tree length and leaf-Fe content of the "Myrobalan" rootstock grown in silty clay loam soil were the highest (173.33 cm for shoot length and 32.78 ppm for leaf-Fe content), when sulphur application (500 g/pot for tree length and 1000 g/pot for leaf-P content) was used. "Penta" rootstocks grown in loam soil had the highest leaf-K (6.3%) and leaf-B

Table 2. The results of analysis variance for physiological and chemical parameters of studied stone fruit rootstocks.

S.O.V	df	N	P	K	Ca	Mg	Zn	B	Fe	Chlorophyll fluorescence parameters			SPAD-Value	Leaf surface	Shoot diameter	Shoot number/ rootstock	Shoot length
		%					ppm			F0	FM	FV		cm^2	mm		cm
Block	2	0.01^{ns}	0.0003*	0.29^{ns}	0.02*	0.31*	1.20^{ns}	0.02^{ns}	0.12^{ns}	0.04^{ns}	0.04^{ns}	0.02^{ns}	135.47^{ns}	1375469.96*	29.61^{ns}	3.53*	1844.02*
Soil texture	1	2.88**	0.03**	15.58**	0.08**	9.52**	846.70**	324.24**	68.64**	0.07*	0.16^{ns}	0.02*	0.92^{ns}	558507.11**	0.58^{ns}	11.67**	2268.141*
Soil texture*block	2	0.0004^{ns}	0.0000008^{ns}	0.037^{ns}	0.01^{ns}	0.08^{ns}	2.49^{ns}	2.77*	4.35^{ns}	0.004^{ns}	0.04^{ns}	0.003^{ns}	16.06^{ns}	1195.01^{ns}	22.49^{ns}	1.30^{ns}	1635.94**
Rootstock	3	1.06**	0.005**	1.72**	0.34**	2.98**	1521.37**	45.35**	153.91**	0.50**	0.22*	0.0031^{ns}	112.93^{ns}	386662.87^{ns}	84.27^{ns}	28.49**	16334.31**
Soil texture *Rootstock	3	3.62**	0.004**	13.12**	0.23**	18.66**	130.62**	80.36**	45.71**	0.32**	0.22*	0.0033^{ns}	164.04^{ns}	303963.46^{ns}	57.31^{ns}	10.58**	2196.38*
Soil texture *Rootstock*Block	12	0.19^{ns}	0.0001^{ns}	0.278*	0.004^{ns}	0.21*	2.72^{ns}	1.85**	5.92^{ns}	0.048^{ns}	0.034^{ns}	0.0061^{ns}	97.44^{ns}	213760.54^{ns}	64.22^{ns}	0.95^{ns}	425.12^{ns}
Sulphur application	5	2.41**	0.0009**	5.75**	0.17**	2.08**	389.31**	69.44**	30.43**	0.15*	0.11^{ns}	0.006^{ns}	77.44^{ns}	82943.01^{ns}	45.41^{ns}	5.07**	2439.22**
Soil texture *Sulphur application	5	0.60**	0.002**	1.65**	0.09**	4.63**	198.24**	63.001**	56.40**	0.12^{ns}	0.12^{ns}	0.007^{ns}	53. 86**	676861.11*	43.71^{ns}	1.236^{ns}	2198.71**
Rootstock* Sulphur application	15	2.13**	0.003**	2.44**	0.10**	5.65**	224.53**	69.24**	88.02**	0.109^{ns}	0.08^{ns}	0.0041^{ns}	96.35^{ns}	248414.19^{ns}	57.17^{ns}	1.79^{ns}	686.48^{ns}
Soil texture Rootstock* *Sulphur application	15	2.10**	0.001**	1.58**	0.16**	2.71**	160.10**	105.74**	100.19**	0.04^{ns}	0.05^{ns}	0.0044^{ns}	101.45^{ns}	195544.64^{ns}	44.46^{ns}	3.12**	1794.33**
CV (%)		8.19	0.75	10.51	9.45	15.26	8.55	14.81	9.22	41.27	46.93	46.14	48.89	61.76	48.79	24.65	19.96

ns, * and ** non-significant and significant at the 5 and 1 percent level of probability respectively.

(38.67 ppm) content, when sulphur application of 1000 g/pot (for leaf-K content) and combination of 10 g thiobacillus+500 g sulphur /pot (for leaf-B content) was used. Peach "Seedling" rootstock grown in silty clay loam soil showed the highest shoot number/roots (7), when sulphur application of 500 g/pot +10 g thiobacillus was used (Table 3).

Chlorophyll fluorescence parameters (FV and F0) were significantly affected by using different soil textures, different rootstocks (F0 and FM) and also different sulphur levels (F0), although three-fold interaction of experimental treatments for the chlorophyll fluorescence parameters (FV, FM and F0) was not significant. The results for chlorophyll fluorescence parameters (FM and F0) showed that only the interaction effect between different soil textures and rootstocks was significant (Table 2)."Penta" rootstocks grown in loam soil had the highest value of F0 (0.36) and FV (0.89), when 500 g sulphur/pot (for F0) and 10 g thiobacillus /pot (for FV) was used. FM value of "Myrobalan" rootstock grown in silty clay loam was the highest (0.87), when 10 g thiobacillus /pot was received (Table 3). Moreover, there was remarkable interaction effect (significant at 1% probability level) between soil texture × sulphur applications for SPAD-value. Also, soil texture as main factor had a significant effect at 1% probability level on leaf surface. However, the highest value of SPAD-value (32.8) and leaf surface (46.43 cm^2) was observed with the "Seedling' rootstocks received 10 g thiobacillus /pot grown on silty clay loam (for SPAD-Value) and 500 g sulphur/pot grown on loam soil (for leaf surface). Shoot diameter was not significantly affected by using the treatments. However the highest shoot diameter (37.16 mm) belonged to the application of 10 g thiobacillus/pot for "GF677" rootstock grown in loam soil.

DISCUSSION

According to Duncan multiple range test, all ofstudied physiological and chemical parameters

Table 3. The effects of different treatments on the average of physiological and chemical parameters of studied stone fruit rootstocks.

Treatment			N	P	K	Ca	Mg	Zn	B	Fe	Chlorophyll fluorescence parameters			SPAD-Value	Leaf surface	Shoot diameter	Shoot number/ rootstock	Shoot length
Soil texture	Rootstock	Sulphur	%					ppm			F0	FM	FV		cm^2	mm		cm
Loam	GF677	S1	4.03	1.37	5.78	0.61	1.85	38.91	4.37	28.88	0.13	0.7	0.81	17.97	1.07	11.49	4.00	119.00
		S2	4.03	1.39	4.30	0.68	1.56	37.28	4.09	26.31	0.12	0.7	0.82	19.07	9.63	11.75	4.00	130.67
		S3	3.68	1.33	5.06	0.80	1.73	43.82	12.26	21.76	0.11	0.45	0.58	12.93	6.49	13.23	4.00	152.50
		S4	3.37	1.36	4.61	0.70	1.82	37.29	7.14	20.70	0.11	0.63	0.82	19.67	5.14	37.16	3.67	106.67
		S5	6.79	1.33	3.53	0.80	3.12	34.3	4.56	24.32	0.11	0.48	0.58	26.37	7.6	10.80	4.50	115.00
		S6	4.17	1.34	3.74	0.69	2.60	37.93	3.61	16.10	0.13	0.73	0.82	21.13	9.26	11.88	5.00	126.33
Silty clay loam		S1	4.50	1.33	3.89	0.69	1.91	50.69	4.70	22.49	0.23	0.75	0.82	14.6	8.37	12.23	3.00	151.67
		S2	4.22	1.29	3.74	0.70	3.70	46.76	5.60	25.08	0.13	0.76	0.30	19.97	5.12	11.82	3.00	135.00
		S3	2.55	1.30	2.80	0.63	1.73	38.91	4.75	24.32	0.12	0.69	0.82	15.47	13.75	12.66	3.00	77.50
		S4	3.02	1.30	3.28	0.70	4.16	50.69	4.47	27.55	0.12	0.65	0.82	16.53	11.62	13.92	3.33	105.00
		S5	4.81	1.35	2.72	0.80	1.96	44.14	1.33	29.07	0.15	0.81	0.82	24.03	11.31	15.33	4.50	110.00
		S6	4.52	1.30	3.28	0.72	1.39	29.43	0.10	19	0.12	0.53	0.58	14.27	11.72	13.15	5.00	105.00
Loam	Myrobalan	S1	4.03	1.00	4.40	0.60	4.619	36.30	7.60	30.69	0.11	0.57	0.81	14.57	12.13	17.89	5.00	168.33
		S2	4.10	1.31	4.02	0.72	2.48	33.85	4.99	16.91	0.13	0.69	0.82	14	8.66	13.52	6.33	164.00
		S3	3.55	1.27	5.22	0.70	3.39	37.61	9.12	22.99	0.12	0.48	0.57	13.17	10.67	11.70	5.00	145.00
		S4	3.55	1.31	2.57	0.38	0.81	28.29	6.03	32.39	0.1	0.56	0.82	12.13	12.38	14.81	6.67	145.00
		S5	3.24	1.31	3.79	0.3	3.71	6.54	2.04	31.67	0.13	0.70	0.82	16.07	3.53	14.45	5.5	145.00
		S6	4.46	1.31	4.22	0.81	2.65	23.06	3.18	16.72	0.13	0.73	0.82	15.42	6.61	14.01	6.33	126.67
Silty clay loam		S1	3.33	1.30	3.78	0.57	2.55	34.66	2.95	27.93	0.26	0.8	0.82	16.57	7.46	15.53	4.00	170.00
		S2	3.36	1.31	3.69	0.68	0.23	42.51	1.9	27.55	0.15	0.63	0.83	19.6	8.40	18.19	5.67	173.33
		S3	4.57	1.30	4.35	0.68	1.39	37.61	3.42	32.78	0.13	0.71	0.82	18.6	10.84	14.60	4.67	160.00
		S4	4.08	1.31	3.47	0.59	1.39	28.78	5.13	25.56	0.15	0.87	0.82	18.17	7.43	14.80	4.33	148.33
		S5	3.09	1.27	2.59	0.27	2.25	23.27	5.56	19.49	0.14	0.65	0.79	21.33	7.13	16.745	6.50	157.50
		S6	4.00	1.33	4.81	0.42	0.346	20.28	5.61	24.46	0.18	0.59	0.81	21.37	8.67	15.257	6.00	108.33
Loam	Penta	S1	2.71	1.32	5.01	1.07	0.75	40.55	6.94	22.04	0.10	0.50	0.56	18.33	11.27	6.98	1.67	48.33
		S2	3.24	1.27	3.13	0.69	1.16	40.55	5.80	31.73	0.30	0.75	0.81	24.6	9.16	12.27	4.00	121.67
		S3	4.35	1.31	6.14	0.68	2.19	43.82	5.13	24.61	0.10	0.25	0.33	24.57	8.79	11.18	2.00	160.00
		S4	3.46	1.32	5.83	0.80	1.73	41.53	4.56	26.2	0.13	0.62	0.89	23.94	11.11	10.25	3.50	95.00
		S5	3.02	1.34	5.98	0.87	1.39	55.23	38.66	25.00	0.11	0.45	0.57	22.20	7.29	11.45	4.00	117.50
		S6	3.68	1.33	4.96	0.80	1.27	37.28	4.75	26.73	0.08	0.29	0.33	16.40	9.78	11.51	3.00	110.00

Table 3. Contd.

Treatment			N	P	K	Ca	Mg	Zn	B	Fe	Chlorophyll fluorescence parameters			SPAD-Value	Leaf surface	Shoot diameter	Shoot number/ rootstock	Shoot length
Soil texture	Rootstocks	Sulphur	%					ppm			F0	FM	FV		cm²	mm		cm
		S1	3.06	1.25	5.22	1.05	5.08	53.96	4.94	24.32	0.12	0.31	0.33	13.20	9.24	12.58	6.00	90.00
		S2	2.53	1.26	4.30	0.70	4.388	20.24	4.85	19.57	0.14	0.77	0.82	20.00	5.65	11.53	6.00	97.50
Silty clay loam		S3	3.80	1.30	4.91	0.80	3.41	45.29	4.89	23.66	0.15	0.78	0.81	31.07	7.77	12.39	4.67	98.33
		S4	2.24	1.29	2.04	0.80	1.73	4.002	5.00	15.11	0.12	0.31	0.34	12.50	5.7	11.34	5.00	60.00
		S5	3.41	1.30	3.71	0.95	3.70	36.62	2.56	24.75	0.15	0.73	0.82	23.40	12.46	12.32	4.67	76.67
		S6	4.12	1.33	5.00	0.99	1.62	42.51	2.95	27.00	0.12	0.33	0.34	17.33	1.38	15.13	5.00	105.00
		S1	4.66	1.34	4.66	0.34	0.52	24.85	7.00	3.33	0.13	0.33	0.32	12.17	10.35	13.37	3.00	113.33
		S2	4.00	1.34	3.74	0.80	1.16	40. 5	2.19	22.04	0.14	0.52	0.58	17.17	17.54	13.10	3.00	115.00
Loam		S3	5.77	1.31	3.94	1.10	4.042	39.24	5.13	20.47	0.13	0.47	0.56	28.40	8.88	18.29	3.00	115.00
		S4	2.57	1.30	2.21	0.53	0.924	34.01	8.55	22.80	0.12	0.33	0.33	23.23	12.12	15.17	3.33	121.67
		S5	3.72	1.36	2.16	0.38	1.386	25.18	6.745	26.60	0.14	0.59	0.57	23.5	46.43	12.5	4.00	125.00
	Seedling	S6	3.96	1.29	3.38	0.70	1.79	38.10	5.32	25.46	0.12	0.31	0.33	28.07	10.59	13.11	3.00	103.33
		S1	3.57	1.33	3.87	1.44	1.905	62.13	6.98	30.78	0.14	0.49	0.55	28.87	6.64	17.00	4.00	143.33
		S2	4.79	1.34	3.74	0.76	1.155	40.88	2.19	22.04	0.12	0.47	0.56	15.03	3.92	12.69	5.00	117.50
Silty clay loam		S3	3.02	1.32	2.49	1.06	1.732	54.28	3.42	26.93	0.25	0.71	0.78	27.87	5.69	14.437	4.67	121.67
		S4	3.21	1.32	2.82	0.53	4.85	42.18	5.13	28.50	0.11	0.64	0.8	32.8	4.33	15.48	4.67	108.33
		S5	3.90	1.26	3.53	0.4	4.273	40.88	5.61	27.00	0.13	0.34	0.32	11.77	7.18	15.52	7.00	125.00
		S6	3.59	1.26	2.16	0.7	4.157	44.14	3.71	23.43	0.1	0.1	0.10	8.90	11.52	9.00	2.00	67.00

of "Myrobalan", "GF 677", "Penta" and peach seedling rootstocks had significantly (at the 0.05 probability level) higher mean values (except for SPAD-Value, leaf surface and shoot diameter) by the added different sulphur treatment (as sub-sub factor) compared to the control (without any application of sulphur or Thiobacillus) (Table 4). Data in Figure 1 indicated significant positive correlation (r = 0.411 P<0.05) indicating more N uptake in leaves of studied rootstocks as compared to control treatment where 1000 g/pot sulphur application was added to 10 g/pot thiobacillus).Similar results have been reported elsewhere for apples (Neilsen et al., 1990) as well as for other crops (Besharati, 1999). The results indicate that rootstock as sub factor had also significantly affected the studied physiological and chemical parameters [except for shoot diameter, leaf surface and Chlorophyll fluorescence parameters (F0)] at the 0.05 probability level. Compared to the other studied rootstocks, "GF677" rootstock demonstrated the highest value of leaf-Mg (2.56%), leaf Ca (0.76%), leaf-P (1.33%), and leaf- N (4.02%) content. Also, "Myrobalan" rootstock showed the highest value of leaf-Fe content (25.75 ppm), Chlorophyll fluorescence parameters including FM and FV (0.67), shoot number/rootstock (5.50) and shoot length (150.96 cm). In addition, " penta' rootstock illustrated the highest mean of leaf-B (7.23 ppm), leaf-Zn (43.30 ppm), leaf Ca (0.76%) and leaf-K (4.23%). Compared to the other studied rootstocks, SPAD-value (20.75) and leaf Ca (0.76%) of "Seedling" rootstock were the highest (Table 4). According to previous results, it has been shown that all the studied stone fruit

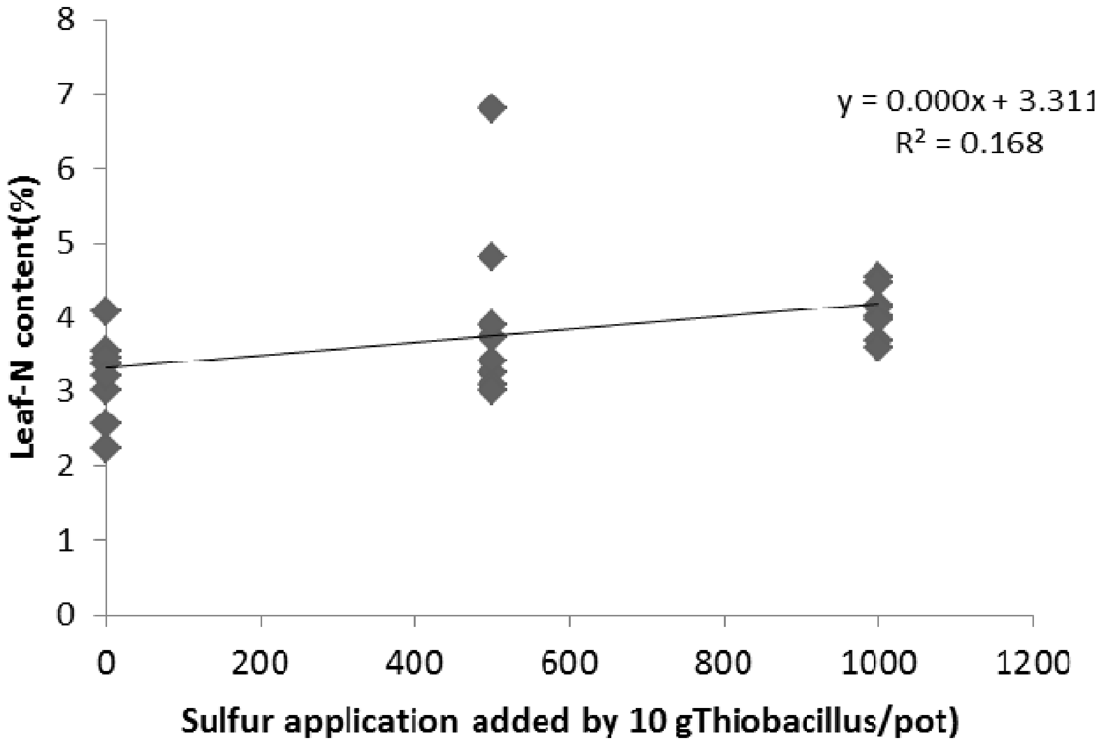

Figure 1. Linear regression of leaf-N content (%) and sulphur application added by Thiobacillus (g/plot).

rootstocks have varying degrees of tree growth and leaf nutrient absorption, stress tolerance such as lime, salt and/or drought (Fulton et al., 1996; Kramer and Boyer, 1995). Most of soils of Iran, such as soil of Karaj province, are calcareous in nature. High pH and carbonate levels are common of these soils (Ghaheri, 2009; Fallahi, 1995, 1998).

In contrast, these textures of soils are important for stone fruit rootstocks. As a result, in this project, the effectiveness assessments of two soil texture as main plot (either or not received sulphur application) for studied rootstocks were performed.

The results showed that the Leaf-Fe (7.07 ppm), leaf-K (4.24%), leaf-N (3.92 and leaf surface (9.34 cm^2) of studied rootstock grown in loam soil had higher average value (at the 0.05 probability level) than those grown in silty clay loam. On the other hand, leaf-Zn (40.53 ppm) and leaf-Mg (2.54%) of studied rootstock grown in loam soil had higher average value at the 0.05 probability level (Table 4).

Conclusions

In summary, the benefits of sulphur application compared to the control (without any application of sulphur or Thiobacillus) increased values of physiological and chemical properties for all stone fruit rootstocks (*Prunus L.*) tested in this study. It must be noted that most data obtained in this research present the first evaluations of the stone fruit rootstocks which were grown in loam or silty clay loam soil with high pH and carbonate levels.

Conflict of interest

The authors did not declare any conflict of interest.

Table 4. The effects of main (Soil textures), sub (Rootstocks) and sub-sub (Sulphur levels) factors on the average of physiological and chemical parameters of studied stone fruit rootstocks.

S.O.V		Leave-Fe	Leave-B	Leave-Zn	Leave-Mg	Leave-Ca	Leave-K	Leave-P	Leave-N	Chlorophyll fluorescence parameters			SPAD-Value	Leaf surface	Shoot diameter	Shoot number/ rootstock	Shoot length
		(ppm)			(%)					F0	FM	FV		cm^2	mm		cm
Soil texture	Loam	23.62a	7.07a	35.68b	2.027b	0.69a	4.24a	1.32a	3.92a	0.13a	0.54a	0.54a	19.34a	9.34a	14.04a	4.06a	125.11a
	Silty Clay loam	25.01a	4.07b	40.53a	2.54a	0.73a	3.59b	1.30b	3.64b	0.14a	0.60a	0.60a	19.18a	8.10b	13.91a	4.63a	117.17a
Rootstocks	GF677	24.89a	5.25b	42.84a	2.56a	0.76a	3.76b	1.33a	4.02a	0.13a	0.54bc	0.54bc	20.20a	7.42a	15.13a	4.31b	120.46b
	Myrobalanan	25.75a	4.79b	29.39c	2.15b	0.57b	3.90b	1.31cb	3.79b	0.14a	0.67a	0.67a	16.75a	8.66a	15.13a	5.50a	150.96a
	Penta	25.37a	7.23a	43.30a	1.94b	0.76a	4.23a	1.31b	3.66b	0.15a	0.59ba	0.59ba	19.33a	9.95a	11.90a	3.33c	111.39bc
	Seedling	21.26b	5.01b	36.91b	2.48a	0.76a	3.77b	1.30c	3.65b	0.13a	0.48c	0.48c	20.75a	8.86a	13.76a	4.22b	101.74c
Sulphur level	S1	23.80bc	5.69b	42.76a	2.40b	0.79a	4.57a	1.32a	3.71c	0.16a	0.56ba	0.56ba	17.03a	9.51a	13.38a	3.83c	125.50ba
	S2	23.91bc	3.95c	37.87b	1.98c	0.72b	3.83b	1.31b	3.78bc	0.15a	0.66a	0.66a	18.30a	8.51a	13.11a	4.58ba	131.83a
	S3	24.69ba	6.02b	42.57a	2.45b	0.81a	4.36a	1.31c	3.91ba	0.15a	0.57ba	0.57ba	21.51a	9.11a	13.56a	3.88c	128.75a
	S4	24.84ba	5.75b	38.09b	2.18c	0.64c	3.29c	1.31c	3.20d	0.12a	0.58ba	0.58ba	19.87a	8.73a	16.62a	4.31bc	111.25bc
	S5	25.98a	8.38a	33.27c	2.72a	0.60d	3.50c	1.31c	5.00a	0.13a	0.59ba	0.59ba	20.96a	7.77a	14.28a	5.06a	123.02ba
	S6	22.67c	3.65c	34.09c	1.98c	0.72b	3.93b	1.31cb	4.08a	0.12a	0.45b	0.45b	17.86a	8.69a	12.92a	4.38bc	106.46c

The values in the same column followed by the same letters are not significantly different at the 0.05 probability level, according to Duncan multiple range test.

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