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EFFECT OF DIFFERENT POTASSIUM AND SULFUR FERTILIZATION RATES AND SILICATE AND/OR THIOBACILLI BACTERIA INOCULATION ON GARLIC (*Allium sativum*l.)

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ABSTRACT

Two field experiments were conducted during the two successive winter seasons of 2012/2013 and 2013/2014 at Al-Bramoon Experimental Farm, Hort. Res. Institute, El-Dakahlia Governorate to study the effect of Silicate dissolved bacteria (SDB) and *Thiobacillus* Bacteria (TB) inoculation with different rates of potassium and sulfur fertilization on plant growth, yield and chemical constituents of garlic plants cv Sids-40. The used experimental design was split plot with three replicates. Potassium and sulfur fertilization represented the main plots at rates of 50, 75 and 100 % from the recommended dose, and the subplots were assigned to Silicate and *Thiobacillus* Bacteria either single or combined inoculation.

Results showed that application of potassium and sulfur(100% rates of K + S) had significant enhancing effect on garlic plant growth parameters (plant height, bulb diameter/plant, leaves number/plant, fresh and dry weight/plant and total chlorophyll SPAD unit). In addition, yield and yield components(i.e. total yield/fed, fresh weight/bulb, average clove weight and number of cloves/bulb) significantly increased by this treatment. Chemical constituents also was significantly increased by application of this treatment, in addition N%, P%,K% and volatile oils in garlic cloves were increased by this treatment in compared with other treatments. On the other hand, inoculation with SDB + TB significantly increased all above parameters of plant growth, yield and chemical constituents as compared with other treatments. The combined treatment of K+S at rates of 100% with SDB and TB inoculation was the optimum treatment for improving the produced yield (72.27 and 64.22 % increment in the first and second seasons, respectively comparing to the control treatment). Therefore, the treatment (100 % K+S) with (SDB + TB) could be recommended for raising garlic yield and improving bulb quality under similar conditions to this work.

INTRODUCTION

Garlic (*Allium sativum*, L.) is one of the oldest cultivated vegetables. Its medicinal effects has proved from thousands years. The edible part of garlic plant is the garlic cloves. Garlic contains antibiotics of garlicin and allistatin, number of enzymes, amino acids and some of trace elements. It is eaten directly or added to food for its flavor. Also, it is used in preparation of smoked-meat products and in some medicaments. Nowadays it is valued for its essential oil contents (Malý *et al.* 1998). Garlic has been generally cultivated for both local consumption and export. Therefore, increasing garlic yield and improving bulb quality are essential aims for both growers and consumers.

Potassium (K) is one of the major essential macronutrients required for plant growth and development and commonly applied as fertilizer for optimizing yield. Potassium could be existed in soil in readily available, slowly available and fixed or unavailable forms. Potassium dissolved in soil solution, and that adsorbed on exchangeable sites is considered readily available for plant growth. Although K is not a constituent of any organic molecule or plant structure,it is involved in numerous biochemical and physiological processes and has pivotal role for enhancing plant growth, yield quantity& quality and stress tolerance (Cakmak, 2005). Potassium takes part in many essential processes, such as: enzyme activation, protein synthesis, photosynthesis, phloem transport, osmo regulation, cation–anion balance, stomatal opening and light driven nastic movement, (Marschner, 1995). Potassium fertilization is very indispensable, for horticultural crops particularly to those comprising underground organs including garlic.

Sulfur (S) is considered as fourth major element for most crops nutrition (Hitsuda *et al.*2005). Despite the fact that S is not existed in chlorophyll formation, it is essential for chlorophyll biosynthesis (Messick and Fan, 1999). Sulfur is required for the synthesis of sulfur containing amino acids (cystine, cysteine and methionine), which are essential components of protein. Ali, (2002) found that application of sulfur increased vegetative growth and total yield of potatoes. Awad *et al.* (2002) found that total tuber yield /fed., number of tubers / plant, tuber average weight and tuber dry weight (%) of potato were significantly increased with increasing sulfur levels. They showed also that N, P and K contents in the foliage and tubers of potato significantly increased with increasing sulfur levels. EL- Morsy, (2005) showed that the garlic plants received sulfur element were better than those of the unfertilized ones. Increasing of applied sulfur level from 200 to 400 kg S/fed significantly increased plant height, number of leaves, plant dry weight and bulbing ratio as well as total yield and bulb weight and diameter. Moreover, sulfur application at 400 kg /fed significantly increased TSS %, volatile oils and concentration of N, P,K and micronutrients (Fe, Zn and Mn) in cloves and enhanced the storability. Abou EL- Khair, (2010) indicated that all applied sulphur quantity had significant enhancing effect on garlic plants growth (roots, bulb, leaves and total dry weight/plant), plant nutrients uptake and bulb quality at harvesting time and increased total yield/fed as well as bulb weight. Beside its nutritional value, S has a significant effect on improving soil quality parameters. It is well known that S could have an ameliorating effect on pH value to be suitable for nutrients uptake.

Biofertilizers have been used as sources to improve the status of plant nutrients in sustainable agriculture. The use of plant growth promoting rhizobacteria , including phosphate solubilizing, potassium dissolving bacteria and sulfur oxidizing bacteria (*Thiobacillus spp.*) as biofertilizers, was suggested as a sustainable solution to improve plant nutrient and production, (Vessey, 2003). A productive and sustainable agricultural system is fundamental to the well being of a nation and a corner stone of its development. Silicate bacteria or K – solubilizing bacteria (*Bacillus circulans*)and /or (*B.mucilaginosus)* are generally placed in the spacies and widely used in biological fertilizers. It has the ability to release some relatively insoluble mineral elements from soil. However, in K^+ deficient media, *B. cerculans* can release K^+,AL $^{+3}$ and Si $^{+2}$ from soil mineral. Sheng (2005) documented that, it also has the ability to solubilizes unavailable form of K minerals, by exerting organic acids, which either directly dissolve rock K or chalate silicon ions to bring the K into solution. *Bacillus mucilaginosas* had strong ability for maximum potassium solubilization and it colonize and develop very rapidly, when inoculated into soil. It also markedly improved phosphorus (P) potassium (K) nutritional status in the soil, (Sugumaran and Janarthanam, 2007). They also showed that the bacteria may produce specific bacterial acids, alkalines or chelants to enhance the release of elements from potassium containing minerals. However, (Badr *et al.*, 2006) reported that, residual soil fertility estimated by K and P concentration, after harvest, underwent considerable increases due to inoculation of silicate dissolving bacteria. They recommended the use of silicate dissolving bacteria as an efficiently good bio-fertilizers to replace chemical fertilizers and reducing cost of crop production.

Thiobacillus spp bacteria are chemolithotrophs and secure their energy by sulfur oxidation, Tisdale *et al.*(1984). This feature of *Thiobacillus* bacteria is also effective on the plants Fe uptake. When there is sufficient population of *Thiobacillus* bacteria in soil, they start sulfur oxidation which results in the reduction of pH, increasing the availability of nutrients to plants roots, Killham (1994). Sabagh *et al.*(2014) find out that the presence of *Thiobacillus* bacteria reduced soil pH and rate of iron absorbed is increased.

The main object of this work was to study the effect of different rates with potassium, sulfur fertilization and inoculation with Silicate and *Thiobacillus* bacteria on garlic cv. Sids- 40.

MATERIALS AND METHODS

Two field experiments were conducted at Al-Bramoon Experimental Farm, Hort. Res. Institute, El-Dakahlia Governorate during the two successive winter seasons of 2010/2011 and 2011/2012 to study the effect of different rates of potassium, sulfur fertilization and inoculation with Silicate and Thiobacilli bacteria on garlic cv. (Sids 40). Randomized samples were collected from the experimental soil at 0.0 to 30.0 cm depth, before planting to determine the physical and chemical properties in accordance to the method of Page (1982). Data of soil analysis is presented in Table (1).

Table (1): Some physical and chemical of the experimental soil surface layer (at thedepth of 0 – 30 cm) before planting in 2010/11 (S1) and 2011/12 (S2) seasons.

Properties	Values		Properties	Values	
	S1	S2		S1	S2
Sand (%)	27.1	26.9	pH*	7.7	7.6
Silt (%)	32.1	32.2	EC (dSm^{-1} at25°c)**	0.7	0.7
Clay (%)	40.8	40.9	Total N (%)	0.14	0.16
Texture class	Clay-loam	Clay- loam	Available P (ppm)	11.5	11.7
$CaCo_3$	3.1	3.5	Exchangeable K (ppm)	294	298
OM (%)	2.1	2.2			

*pH: (1:2.5 soil extract). **EC: soil paste

A split plot design in a randomized complete block with three replicates was used. The main plots were assigned to four potassium and sulfur fertilization ratesas follows:

1-(0 K_2O +0 S).

2-72 kg K_2O/fed. + 300 kg S/fed. = 100 % from recommended rate.

3-54 kg K_2O/fed. + 225 kg S/fed. =75 % from recommended rate.

4-36 kg K_2O/fed. +150 kg S/fed. = 50% from recommended rate.

Potassium treatments were applied in the form of potassium sulfate (48 % K_2O), and S was applied in the form of elemental sulfur .

The subplots were devoted to the four inoculations treatments as follows:

1-Without inoculation.

2-Silicate dissolving bacteria inoculation.

3-*Thiobacillus spp inoculation.*

4-Silicate dissolving bacteria + *Thiobacillus spp* inoculation.

The bacteria strains were kindly obtained from the Biofertilizers Unit, Fac. Agric., Ain Shams Univ., Cairo, Egypt. The bacteria strains were added after 21 days from planting date.The subplot area was 10.5 m^2 included 5 ridges (3.5 m long and 0.6 m width). Each treatment was separated by two guard ridges.Garlic cloves were planted in on the first week of October in both seasons.The uniform garlic cloves were soaked in running water for 24 h prior to cultivation and hand – planted at 10 cm apart on two sides of each ridge. All the plants were fertilized with ammonium sulfate (20.6% N)at a rate of 120 kg N /fed, and calcium super phosphate (15.5 % P_2O_5) at rate of 75 kg P_2O_5 /fed. Fertilizers were added in three equal portions. The first portion of calcium super phosphate was broadcasted during soil preparation, and the second portion was added with the first portion of N at 30,60 and 90 days after planting. The other agricultural practices for garlic commercial production were conducted according to the recommendations of the Ministry of Agric. in Egypt. The harvest time was in the first week of April in both seasons.

Data recorded:

1-Growth parameters: a random samples of ten plants were taken from each plot after 120 days from planting,cleaned from the dust, and dried at 70 °C till constant weightto estimate plant height, number of leaves /plant, neck diameter /plant, bulb diameter /plant, fresh weight /plant, dry weight /plant and bulbing ratio, It was measured as reported by Mann(1952).

$$\text{Bulbing ratio} = \frac{\text{Neck diameter (cm)}}{\text{Bulb diameter (cm)}}$$

Diameters of both plant neck and bulbs were determined by caliper, and total chlorophyll (was measured as SPAD units using Minolta SPAD -501 chlorophyll Meter, Minolta Co. Ltd. Japan).

2-Yield and its components : at harvest time , marketable bulbs of each plot were cured, 15 days after harvest, weighted in kg and converted to record as total yield (ton/fed). A random sample (10 bulbs) was taken from each treatment to determine bulb fresh weight (g), as well as number of cloves/bulb and clove weight (g).

3-Chemical analysis : samples of dried cloves were ground, wet digested as described by Hesse (1971) and their nitrogen (N), phosphorus (P) and potassium (K) contents were determined according to the methods described by Bremner and Mulvaney (1982), Olsen and Sommers (1982) and Jackson (1970), respectively.The volatile oils percent was determined according to the method of Guenther (1961).

The statistical analysis:all data were analyzed statistically by the analysis of variance using CoStat software(CoHort Software,Monterey,USA). Mean comparisons were conducted using an ANOVA utilizing the least significant difference (LSD) ($P<0.05$)test.

RESULTS AND DISCUSSION

A-Vegetative growth:

1-Effect of potassium and sulfur levels :

Data in Tables 2 and 3 indicate that increasing K+S levels from zero up to 100 % K + S(72 kg K_2O/fed +300 kg S/fed) significantly increased the growth parameters of garlic plants as expressed as plant height, bulb diameter/plant, leaves number /plant, fresh weight / plant, dry weight /plant and total chlorophyll Reading SPAD unit, as compared with control treatment.

However, this level of K+S significantly decreased bulbing ratio and neck diameter /plant in both seasons . The highest values of bulbing ratio and neck diameter /plant were obtained by the rate of 50% K +S in both season. These results were in agreement with El-Sawy *et al.* (2000) , El-Sirafy *et al.* (2008) , Labib *et al.* (2012) on potato, Geries *et al.* (2011) on onion, El-Morsy(2005), AbouEl-Khair (2010) and Diriba-Shiferaw *et al.*(2014) on garlic.

2-Effect of biofertilizers

Regarding to bio-fertilizers, data in Tables 2 and 3 show that bio-fertilizers application increased significantly plant height, bulb diameter/plant, fresh and dry weight / plant, total chlorophyll Reading SPAD unit in both seasons and leaves number /plant in the second season only. Inoculation of silicate dissolving bacteria (SDB) with *Thiobacillus spp* (TB) was most effective treatment

Meanwhile SDB has a direct effect on plant vegetative growth due to its ability to produce hormones, especially IAA and GA. Former reports illustrated that inoculation with *Bacillus mucilaginosus* increased the groundnut plant dry matter 125 % and oil content 35.41 % compared than control (Sheng *et al.*, 2002a; Sugumaran and Janarthanam 2007). Sabagh *et al.* (2014) found that inoculation of *Thiobacillus spp* (TB) with sulfur fertilizer increased the absorbed macro and micronutrients and increased the vegetative growth of plant. These results were true in both seasons.

Table(2):Plant height, neck diameter/plant, bulb diameter/plant and bulbing ratio of garlic as affected by different rates with potassium, sulfur fertilization and inoculation with silicate bacteria and thiobacilli bacteria and their interactions at 2010/2011(S1) and 2011/2012 seasons

Treatments		Plant height (cm)		Neck diameter/plant(cm)		Bulb diameter/plant(cm)		Bulbing ratio	
		S 1	S 2	S 1	S 2	S 1	S 2	S 1	S 2
K +S levels									
Control		65.84	70.27	1.22	1.27	3.63	3.85	0.337	0.328
50 % (K + S)		71.72	74.77	1.26	1.27	3.72	3.83	0.343	0.336
75 % (K + S)		75.93	80.73	1.15	1.09	4.13	4.27	0.280	0.253
100 % (K + S)		79.02	84.29	0.89	1.01	4.53	4.61	0.195	0.218
L S D 0.05		0.77	0.66	0.06	0.15	0.10	0.08	0.024	0.039
Biofertilizers									
Control		69.57	74.80	1.24	1.20	3.58	3.66	0.353	0.323
SDB		72.02	77.46	1.06	1.07	4.08	4.13	0.260	0.258
T B		73.60	74.50	1.07	1.21	3.92	4.09	0.274	0.297
SDB + T B		77.31	83.31	1.15	1.17	4.44	4.68	0.267	0.257
L S D 0.05		0.48	0.62	0.08	0.10	0.13	0.14	0.023	0.026
Interaction									
Control 0% (K+S)	Without	60.19	68.69	1.26	1.25	3.07	3.41	0.407	0.360
	SDB	66.00	69.39	1.04	1.05	3.93	3.99	0.260	0.263
	TB	64.73	26.85	1.23	1.29	3.97	4.01	0.310	0.320
	SDB+TB	72.42	80.16	1.33	1.49	3.58	3.97	0.370	0.370
50% (K+S)	Without	68.71	71.64	1.27	1.33	3.28	3.29	0.390	0.397
	SDB	72.03	74.07	1.26	1.13	3.84	3.92	0.327	0.283
	TB	70.20	72.47	1.23	1.40	3.57	3.74	0.343	0.373
	SDB+TB	75.93	80.90	1.30	1.26	4.19	4.35	0.310	0.290
75% (K+S)	Without	73.41	77.49	1.33	1.20	3.59	3.73	0.367	0.290
	SDB	76.29	81.36	1.01	1.13	4.10	4.13	0.247	0.270
	TB	74.94	79.69	1.12	1.12	3.99	4.20	0.277	0.267
	SDB+TB	79.07	84.39	1.13	0.93	4.84	5.01	0.230	0.183
100% (K+S)	Without	75.99	81.39	1.09	1.03	4.37	4.19	0.250	0.243
	SDB	80.07	85.00	0.93	0.98	4.46	4.47	0.207	0.217
	TB	78.19	82.99	0.71	1.01	4.15	4.41	0.167	0.227
	SDB+TB	81.82	87.79	0.83	1.01	5.14	5.38	0.157	0.183
L S D 0.05		0.96	1.23	0.16	0.20	0.27	0.28	0.047	0.051

K=Potassium , S = Sulfur , 100 % (K+S) = 72 kg K_2O +300 kg S , 75 % (K+S) =54 kg K_2O +225 kg S , 50 % (K+S) =36 kg K_2O +150 kg S
SDB = Silicate Dissolving Bacteria , T B = *Thiobacillusspp*

Table(3):Leaves number, fresh weight / plant, dry weight /plant and total chlorophyll Reading SPAD unit of garlic as affected by different rates with potassium,sulfur fertilization and inoculation with silicate bacteria and thiobacilli bacteria and their interactions at 2010/2011 (S1) and 2011/2012 (S2) seasons.

Treatments		Leaves number /plant		Fresh weight/plant (gm)		Dry weight/plant (gm)		Total chl. SPAD unit	
		S 1	S 2	S 1	S 2	S 1	S 2	S 1	S 2
K +S levels									
Control		8.97	8.73	62.41	62.60	10.61	10.91	99.44	99.39
50 % (K + S)		9.25	8.88	69.56	69.65	11.59	11.89	99.86	99.99
75 % (K + S)		9.38	9.17	72.35	72.03	13.07	13.17	100.17	100.40
100 % (K + S)		9.72	9.65	75.29	75.09	14.14	14.23	100.47	100.71
L S D 0.05		0.17	0.14	0.57	0.47	0.17	0.15	0.06	0.07
Biofertilizers									
Control		9.58	9.03	64.53	64.32	9.74	10.26	99.21	99.53
SDB		9.28	9.18	70.13	70.03	12.54	12.64	99.81	99.96
T B.		9.18	8.88	69.00	69.27	12.32	12.61	100.02	99.99
SDB + T B		9.27	9.33	75.96	75.76	14.80	14.69	100.91	101.01
L S D 0.05		0.23	0.23	0.55	0.45	0.20	0.25	0.07	0.08
Interaction									
Control 0% (K+S)	Without	9.40	8.73	59.30	60.71	8.65	9.54	98.82	99.06
	SDB	9.00	8.93	60.72	59.87	10.79	10.60	99.00	99.13
	TB	8.60	8.27	59.85	60.42	10.93	11.10	99.94	99.49
	SDB+TB	8.87	9.00	69.78	69.41	12.07	12.40	100.00	99.89
50% (K+S)	Without	9.47	8.80	62.14	61.70	8.83	9.79	99.07	99.48
	SDB	9.13	8.80	71.04	71.18	11.33	12.30	99.80	99.87
	TB	9.33	9.00	69.71	70.60	11.66	11.20	99.74	99.88
	SDB+TB	9.07	8.93	75.34	75.10	14.54	14.26	100.82	100.73
75% (K+S)	Without	9.60	9.00	65.63	64.79	10.04	10.32	99.27	99.66
	SDB	9.40	9.20	72.89	72.95	13.59	13.44	100.08	100.23
	TB	9.20	9.07	72.31	72.06	12.94	13.57	100.08	100.18
	SDB+TB	9.33	9.40	78.58	78.32	15.69	15.34	101.25	101.51
100% (K+S)	Without	9.87	9.60	71.03	70.09	11.44	11.38	99.68	99.96
	SDB	9.60	9.80	75.86	76.10	14.54	14.24	100.34	100.60
	TB	9.60	9.20	74.13	73.99	13.73	14.55	100.30	100.41
	SDB+TB	9.80	10.00	80.14	80.20	16.92	16.74	101.55	101.89
L S D 0.05		0.45	0.45	1.11	0.90	0.40	0.50	0.14	0.16

K=Potassium , S = Sulfur , 100 % (K+S) = 72 kg K_2O +300 kg S , 75 % (K+S) =54 kg K_2O +225 kg S , 50 % (K+S) =36 kg K_2O +150 kg S
SDB = Silicate Dissolving Bacteria , T B = *Thiobacillusspp*

3-Effect of interactions

The interaction among potassium, sulfur fertilization and bio fertilizers had significant effects on growth parameters in both seasons (Tables 2 and 3).The highest values of plant height, bulb diameter/plant, leaves number, fresh and dry weight /plant and total chlorophyll Reading SPAD unit were improved by using 100 % (K + S) with silicate bacteria+ *Thiobacillus*, exept of neck diameter and bulbing ratio. However, the highest value of neck diameter/ plant was associated with the treatment of SDB + TB with 0% K+S and the highest value of bulbing ratio was induced by control treatment in the first season and 50%K+S without inoculation treatment in the second season. These results were true in both seasons. The increment in vegetative growth response to K +S fertilization was reported by (Marschner, 1995). (Sabagh *et al.* 2014) based on the results that sulfur and bacteria *Thiobacillus spp* application had a significant effect on the soil pH by oxidation of sulfur produced some of sulfuric acid in soil, hence reduce the pH in the soil and improved soil chemical properties and increased the availability of certain plant nutrients macro and micronutrients and enhanced the growth in garlic plants over control and Elkholy *et al.*(2012) found that inoculation of SDB and application of K fertilizer significantly increased the growth of potato plants .

B – Yield and its components :

1-Effect of K +S levels :

Data presented in Table 4 show that potassium and sulfur fertilization had significant increases in total yield, fresh weight / bulb and clove weight in comparison with control. In contrast, cloves number/bulb was markedly decreased by potassium and sulfur fertilization addition. These results were true in both seasons. The highest values of total yield, fresh weight/bulb and clove weight were observed by application of 100 % (K+S), may be due to the combined application of K+ S fertilizers while the number of cloves /bulb was reduced by the addition of 100 % (K+S) and the highest value of number of cloves/bulb was obtained by the control treatment (0% K+S). These results were in agreement with El-Sawy *et al.* (2000) , El-Sirafy *et al.* (2008) , Labib *et al.* (2012) on potato and Geries *et al.* (2011) on onion, Al-Morsy (2005), Abou El-Khair (2010) and Dirba-Shiferaw *et al.*(2014) on garlic

2-Effect of biofertilizers

Concerning the effect of bio-fertilizers treatments on garlic yield and its components, data recorded in Table 4 indicate that adding silicate dissolving bacteria SDB and *Thiobacillus* bacteria TB in combination increased significantly the total yield, fresh weight / bulb and clove weight characters, and had the lowest values for cloves number/bulb, as compared with the control treatment in both seasons. The highest value of cloves number/bulb obtained by TB inoculation treatment., (Sugumaran and Janarthanam 2007) on ground nut ,Ahmed*et al.* (2009) on potato and Sabagh *et al.* (2014) on garlic

3-Effect of interaction :

Regarding the interaction effect, there were significant effects on garlic yield and its components Table 4.The highest values of total yield, fresh weight / bulb and clove weight were recorded by using 100 % (K + S) of recommended dose with silicate bacteria+ *Thiobacillus* in both seasons and this treatment significantly decreased the cloves number/bulb. The highest value of cloves number/bulb was obtained by control treatment in the first season and TB inoculation with 0 %(K+S) in the second season. Ahmed *et al.*(2009) indicated that the interaction within mineral – K and bio – K fertilizers caused a significant effect on the total tubers yield, physical and chemical properties of potatoes. Sabagh *et al.* (2014) revealed that application of recommended dose of *Thiobacillus* bacteria and sulfur enhanced the yield attributes in garlic over control.

Table(4):Total yield, fresh weight / bulb, cloves number/bulb and clove weight of garlic as affected by different rates with potassium, sulfur fertilization and inoculation with silicate bacteria and thiobacilli bacteria and their interactions at 2010/2011 (S1) and 2011/2012 (S2) seasons.

Treatments		Total yield (t /fed)		Fresh weight /bulb (gm)		Cloves number/ bulb		Clove weight (gm)	
		S 1	S 2	S 1	S 2	S 1	S 2	S 1	S 2
K +S levels									
Control		5.749	5.798	41.90	42.49	16.38	17.17	2.52	2.43
50 % (K + S)		6.471	6.439	46.22	45.99	15.35	16.02	3.03	2.86
75 % (K + S)		7.316	7.408	53.79	54.33	14.85	15.22	3.53	3.50
100 % (K + S)		7.887	8.079	56.93	58.96	14.23	14.70	3.99	3.94
L S D 0.05		0.101	0.091	0.14	0.55	0.32	0.17	0.09	0.06
Biofertilizers									
Control		6.074	6.233	44.25	44.77	15.42	16.22	2.85	2.77
SDB		6.886	6.934	49.19	49.70	15.28	15.80	3.24	3.14
T B		6.704	6.732	48.65	48.42	15.55	16.35	3.12	2.98
SDB + T B		7.759	7.825	56.76	58.89	14.57	14.73	3.86	3.83
L S D 0.05		0.078	0.081	0.50	0.39	0.23	0.20	0.06	0.07
Interaction									
Control 0% (K+S)	Without	4.991	5.336	38.98	39.11	17.13	17.73	2.08	2.15
	SDB	5.542	5.466	39.59	41.04	15.60	16.73	2.54	2.34
	TB	5.488	5.427	39.20	40.10	16.80	18.30	2.33	2.14
	SDB+T	6.976	6.962	49.83	49.73	16.00	16.07	3.12	3.09
50% (K+S)	Without	5.785	5.768	41.32	41.20	15.20	16.20	2.72	2.54
	SDB	6.547	6.586	46.77	47.04	16.00	16.80	2.92	2.68
	TB	6.352	6.273	45.37	44.81	16.00	16.27	2.84	2.75
	SDB+T	7.199	7.129	51.42	50.92	14.20	14.80	3.62	3.44
75% (K+S)	Without	6.302	6.342	45.15	45.30	14.80	15.53	3.05	2.92
	SDB	7.534	7.609	53.82	54.35	15.27	15.07	3.53	3.61
	TB	7.164	7.234	54.17	51.67	15.20	16.00	3.37	3.23
	SDB+T	8.264	8.446	62.03	66.00	14.13	14.27	4.18	4.23
100% (K+S)	Without	7.217	7.485	51.55	53.47	14.53	15.40	3.55	3.47
	SDB	7.920	8.075	56.57	56.35	14.27	14.60	3.97	3.95
	TB	7.814	7.993	55.84	57.09	14.20	15.00	3.93	3.81
	SDB+T	8.598	8.763	63.75	68.93	13.93	13.80	4.52	4.54
L S D 0.05		0.157	0.162	1.00	0.79	0.45	0.40	0.13	0.14

K=Potassium , S = Sulfur , 100 % (K+S) = 72 kg K_2O +300 kg S , 75 % (K+S) =54 kg K_2O +225 kg S , 50 % (K+S) =36 kg K_2O +150 kg S
SDB = Silicate Dissolving Bacteria , T B = *Thiobacillusspp*

Thiobacillus bacteria by oxidation of sulfur produced some of sulfuric acid and at low buffered properties can considerably reduce pH. With soil sulfur, sulfur oxidation and bacteria population will be increased and it requires more nutrients to bacteria. Therefore, oxidation of sulfur in the fertile soil more quickly has done, (Agrifacts, 2003).

C- Chemical constituents :

1-Effect of K+S levels :

Data presented in Table 5 revealed that potassium and sulfur fertilization had significant increases in the concentration of N %, P %, K % and volatile oils % .The highest values of the concentration of N %, P %, K % and volatile oils % were obtained by application of treatment (100 % K+ S). These increases may be due to the combined application of K+ S fertilizers. These results were in agreement with those of El-Sawy *et al.* (2000) , Labib *et al.*(2012) on potato, Geries *et al.* (2011) on onion, El-Morsy (2005), AbouEl-Khair (2010) and Diriba-Shiferaw *et al.*(2014) on garlic.

Table(5): N % , P % , K % and volatile oils % of garlic as affected by different rates with potassium, sulfur fertilization and inoculation with silicate bacteria and thiobacilli bacteria and their interactions at 2010/2011 (S1) and 2011/2012 (S2) season

Treatments		N %		P %		K %		volatile oils %	
		S 1	S 2	S 1	S 2	S 1	S 2	S 1	S 2
K +S levels									
Control		2.96	2.94	0.433	0.444	1.97	2.00	0.380	0.390
50 % (K + S)		3.03	3.04	0.509	0.502	2.14	2.20	0.435	0.455
75 % (K + S)		3.18	3.23	0.549	0.564	2.29	2.31	0.473	0.481
100 % (K + S)		3.29	3.33	0.561	0.576	2.31	2.33	0.496	0.501
L S D 0.05		0.04	0.03	0.009	0.007	0.01	0.01	0.006	0.003
Biofertilizers									
Control		2.78	2.81	0.379	0.397	1.94	2.02	0.406	0.415
SDB		3.20	3.19	0.491	0.478	2.17	2.19	0.435	0.438
T B		3.04	3.07	0.516	0.527	2.22	2.24	0.448	0.463
SDB + T B		3.44	3.47	0.667	0.685	2.38	2.40	0.495	0.511
L S D 0.05		0.03	0.02	0.008	0.006	0.01	0.01	0.005	0.004
Interaction									
Control 0% (K+S)	Without	2.61	2.62	0.333	0.347	1.61	1.70	0.354	0.372
	SDB	3.06	2.92	0.417	0.403	1.88	1.90	0.383	0.387
	TB	2.90	2.95	0.433	0.443	2.15	2.17	0.391	0.393
	SDB+TB	3.25	3.26	0.550	0.583	2.24	2.25	0.393	0.409
50% (K+S)	Without	2.71	2.76	0.363	0.380	1.91	2.09	0.391	0.404
	SDB	3.06	3.06	0.480	0.453	2.19	2.22	0.423	0.431
	TB	2.96	2.95	0.507	0.510	2.19	2.20	0.432	0.458
	SDB+TB	3.39	3.40	0.687	0.663	2.29	2.30	0.495	0.525
75% (K+S)	Without	2.82	2.88	07403	0.423	2.11	2.14	0.427	07435
	SDB	3.33	3.37	0.530	0.527	2.29	2.30	0.459	0.454
	TB	3.09	3.14	0.553	0.570	2.27	2.26	0.475	0.490
	SDB+TB	3.48	3.54	0.710	0.737	2.49	2.52	0.530	0.545
100% (K+S)	Without	2.98	2.98	0.417	0.437	2.13	2.15	0.453	0.449
	SDB	3.36	3.42	0.537	0.527	2.30	2.32	0.476	0.482
	TB	3.21	3.22	0.570	0.583	2.28	2.31	0.492	0.511
	SDB+TB	3.63	3.68	0.720	0.757	2.50	2.53	0.562	0.563
L S D 0.05		0.07	0.05	0.017	0.013	0.08	0.01	0.009	0.008

K=Potassium , S = Sulfur , 100 % (K+S) = 72 kg K_2O +300 kg S , 75 % (K+S) =54 kg K_2O +225 kg S , 50 % (K+S) =36 kg K_2O +150 kg S

SDB = Silicate Dissolving Bacteria , T B = *Thiobacillusspp*

2- Effect of biofertilizers :

Data in Table 5 show that the treatment of inoculation with silicate dissolving bacteriaand and *Thiobacillus* bacteria significantly gave the highest values of the concentration of N %, P %, K % and volatile oils %. These results were true in both seasons. Meanwhile SDB has a direct effect on due to its ability to produce hormones, especially IAA and GA (Sheng *et al.*, 2002a) , (Sugumaran and Janarthanam 2007)and Sabagh *et al.* (2014) on garlic showed that inoculation of TB decreased soil pH and increased macro and micronutrients absorption.

3-Effect of interaction

The interaction between potassium, sulfur fertilization and bio fertilizers had significant effects on the concentration of chemical constituents parameters in both seasons. The highest values of the concentration of N %, P %, K % and volatile oils % Table 5 were obtained by application of treatment (100% K+S with inoculation with silicate dissolving bacteria and *Thiobacillus* bacteria) in both seasons followed by treatment of (75% K+S with inoculation with silicate dissolving bacteria and *Thiobacillus* bacteria). These results were true in both seasons. . Sabagh *et al.* (2014)on garlic revealed that application of recommended dose of *Thiobacillus* bacteria and sulfur enhanced the concentration of uptake elements in garlic cloves over control treatment. Elkholy *et al.* (2012) on potato showed that the highest potato carbohydrate and protein % content(54.25%) and (18 %) respectively was recorded with full dose of potassium sulfate plus SDB .

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تأثير التسميد بمعدلات مختلفه من البوتاسيوم والكبريت والتلقيح ببكتريا السليكات والثيوباسلس على نبات الثوم

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أجريت تجربتان حقليتان خلال الموسمين الشتويين ٢٠١٠/٢٠١١ و٢٠١١/٢٠١٢ بالمزرعة البحثية بالبرامون محافظة الدقهلية مصر والتابعة لمعهد بحوث البساتين مركز البحوث الزراعية وذلك لدراسة تأثير استخدام معدلات مختلفة من سمادى سلفات البوتاسيوم والكبريت كالتالى (صفر كجم من بو٢أ /فدان + صفر كجم كبريت / فدان)، (٧٢ كجم بو ٢أ /فدان +٣٠٠ كجم /فدان = ١٠٠% من المعدل الموصى به) ، (٥٤ كجم بو٢أ /فدان + ٢٢٥ كجم كبريت / فدان =٧٥ % من المعدل الموصى به) ، (٣٦ كجم بو٢أ /فدان + ١٥٠ كجم / فدان = ٥٠% من المعدل الموصى به)وكان سماد البوتاسيوم المستخدم على صورة سلفات بوتاسيوم (٤٨ % بو٢ أ) وكذلك التلقيح بالبكتريا المذيبة للسيليكات والبكتريا المذيبة للكبريت كل منها منفردا أو معا لنباتات الثوم صنف (سدس – ٤٠) وتأثير ذلك على نمو نباتات الثوم والمحصول ومكوناته وكذلك تركيزالمكونات الكيماوية وتركيز الزيوت الطيارة لبصلة الثوم. وكان التصميم التجريبى المستخدم للتجربة هو القطع المنشقة مرة واحدةوتم إستخدام معدلات البوتاسيوم والكبريت فى القطع الرئيسية واستخدام التلقيح بالبكتريا المذيبة للبوتاسيوم والبكتريا المذيبة للكبريت كل على حده أو معا فى القطع الشقية.

وقد أوضحت النتائج مايلى :-

كان لاضافة ١٠٠% من سمادى سلفات البوتاسيوم والكبريت(٧٢ كجم بو٢أ /فدان + ٣٠٠ كجم كبريت/ فدان) لنباتات الثوم أفضل تأثير معنوى على زيادة صفات النمو الخضرى للنباتات (إرتفاع النبات ، قطر البصلة للنبات ، عدد الاوراق للنبات ، الوزن الغض والجاف للنبات ، تركيز

صبغات الكلوروفيل الكلى للنبات)،وكذلك زيادة المحصول ومكوناته (المحصول الكلى للفدان ، متوسط وزن البصلة ، متوسط وزن الفص وأقل عدد من الفصوص بالبصلة) وزيادة المكونات الكيماوية(تركيز النسبة المئوية للنتروجين، تركيز النسبة المئوية للفوسفور ، تركيز النسبة المئوية للبوتاسيوم وكذلك تركيزالنسبة المئوية للزيوت الطيارة) فى أبصال الثوم.

كان لتلقيح نباتات الثوم بالبكتريا المذيبة للسليكات مع البكتريا المذيبة للكبريت أفضل تأثير معنوى على صفات النموالخضرى و صفات المحصول ومكوناته وتركيزصفات المكونات الكيماويةفى أبصال الثوم .

أدى التفاعل بين التسميد لنباتات الثوم بالبوتاسيوم والكبريت مع التلقيح بالبكتريا المذيبة للسليكات والبكتريا المذيبة للكبريت وخاصة المعاملة ١٠٠% من سمادى البوتاسيوم والكبريت (٧٢ كجم بو٢أ /فدان+ ٣٠٠كجم كبريت/فدان + التلقيح بالبكتريا المذيبة للسليكات + التلقيح بالبكتريا المذيبة للكبريت) إلى الحصول على أعلى تأثير معنوى لكل الصفات السابق ذكرها من صفات النمو الخضرى وكذلك صفات المحصول ومكوناته وكذلك صفات المكونات الكيماوية ، وأدت هذه المعاملة إلى زيادة المحصول الكلى للفدان بنسبة ٧٢,٢٧ % ، ٦٤,٢٢% فى كلا موسمى الدراسة على الترتيب بالمقارنة مع معاملة الكنيرول .

وبناءا عليه توصى هذه الدراسة باستخدام (سمادى سلفات البوتاسيوم والكبريت بمعدل ١٠٠% من الموصى به مع التلقيح بالبكتريا المذيبة للسليكات والبكتريا المذيبة للكبريت)وذلك لرفع إنتاجية محصول الثوم وتحسين جودة أبصال الثوم تحت الظروف المشابهة لهذه الدراسة .