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Original Research Article

The Role of Sulphur and Certain Foliar Spray Levels of Micro-nutrients on Garlic (*Allium sativum* L.) Plant

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A b s t r a c t

Two field trials were conducted on garlic clone Sids-40, in private vegetable farm at Kafr Meet Faris, Dakahlia Governorate, during 2012/2013 and 2013/2014 seasons to study the effect of sulphur application levels, either single and/or in combination with mixed micronutrients (Fe, Ze and Mn) at 0, 150, 200 and 250 ppm levels as foliar application on plant growth, yield and its components, as well as chemical constituents and storability of bulbs. The results showed that the plants received elemental sulphur were better than those of the unfertilized ones. Increasing the applied sulphur 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, application of sulphur at 400 kg/fed significantly increased TSS%, volatile oils and concentrations of N, P, K and micronutrients (Fe, Zn and Mn) in cloves. This S-level had the most interesting observation was the enhancing of storability. On the other hand, foliar application of micronutrients at 250 ppm caused significant increases in the most studied parameters also comparing with those of the other treatments. However, weight loss percent of bulbs was significantly reduced during the storage period. The combined treatments of S-levels and micronutrients were generally more effective on the most studied parameters than with single ones. The best results were obtained by using 400 kg S/fed with foliar application of micronutrients at 250 ppm. This treatment achieved increases in yield at the end of the storage period reached to 20.30% and 20.50% in the first and the second seasons, respectively comparing with the untreated ones. Therefore, this treatment could be recommended for raising garlic yield and improving bulb quality during the storage period under similar conditions to this work.

K e y w o r d s

Foliar spray

Garlic

Micro-nutrients

Nutrient interactions

Sulphur

Introduction

Garlic (*Allium sativum* L.) is one of the most important bulb vegetable crops and is next to onion in importance. It is commonly used as a spice or in the medicinal purposes. In Egypt, it 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, but it usually depends on many factors especially that influence the plant growth throughout the growth period.

Dahdouh et al. (1993), Mehana (1994) and Mehana and Farag (2000) mentioned that application of sulphur elemental had an important role in soil pH reduction, that increased availability of some nutrient elements such as P, Fe, Zn, Mn and Cu which were reflected on plant uptake and plant growth. Several investigators reported that garlic plants growth, yield and its quality as well as N, P and K content in the plant tissue and bulbs were affected by sulphur application rate. In this respect, El-Habbasha et al. (1985), Khalaf and Taha (1988), Hilal et al. (1992), Singh et al. (1995) and Mee et al. (1997) found that plant growth, total yield and quality were increased significantly with increasing rate of applied S.

With regard to micronutrients, several investigators indicated that spraying garlic plants enhanced plant growth, stimulated dry matter accumulation and increased bulb yield and quality (Eid et al., 1991; Ibrahim et al., 1991; Saravanan and Nambisan, 1994; Phor et al., 1995; Abdel-Hamed, 1997; Abdel-Fattah et al., 2002; Hegazi et al., 2002 and El-Morsy et al., 2004). On the other hand, the interaction between applied sulphur and micronutrients was beneficial to plant growth and yield (Fathi et al., 1996 on peanut; Abdel-Hamed, 1997 on garlic; Attia, 2001 on onion and Radwan and Tawfik, 2004 on potato).

Thus, this study was planned to determine the effects of sulphur application levels and some micronutrients (Fe + Zn + Mn), in addition to their interactions on garlic productivity and storability under the conditions of Dakahlia District.

Materials and methods

Two field experiments were carried out in vegetable private Farm at Kafr Meet Faris, Dakahlia Governorate, during two growing seasons of 2012/ 2013 and 2013/2014, to study the effects sulphur application levels and micronutrients (Fe, Zn and Mn) on garlic (Sids-40) growth, yield and its components, as well as chemical constituents in cloves and bulb storability. The soil of the experimental field was clay loam in texture with pH 7.9. Available N, P and K contents were 19.6 - 22.3, 2.6 - 2.9 and 290 - 310 ppm during the first and second seasons, respectively. Each experiment included 16 treatments which were 4 levels of sulphur and 4 levels of micronutrients as follows:

a- Sulphur levels

1- Control treatment (untreated sulphur).
2- 200 kg S/fed.
3- 300 kg S/fed.
4- 400 kg S/fed.

b- Micronutrients

The mixture of chelated micronutrients Fe, Zn and Mn (1:1:1) was supplied as a foliar application in four levels (0, 150, 200 and 250 ppm) at 60 and 90 days after planting in the rate of 300 L/fed. The control treatment was sprayed with tap water. Garlic cloves were planted in 3rd and 7th of October in the first and the second seasons, respectively. The four sulphur levels occupied the main plots which were subdivided to 4 sub plots each contained one of the micronutrients levels.

Nearly uniform garlic cloves were soaked in running water for 24 h prior to sowing and hand-planted at 10 cm apart on two sides of each row. The sulphur levels were applied as the two equal doses, at soil preparation (pre-rowing) and 30 days after planting. All the plants were fertilized with 120 kg N/fed (ammonium sulphate, 20.5% N), 90 kg P_2O_5/fed (super-phosphate, 15.5% P_2O_5) and 96 kg K_2O/fed (potassium sulphate 48% K_2O) which added in three equal doses 30, 60 and 90 days after planting. The other cultural practices for garlic commercial production were used according to the instructions laid down by the Ministry of Agriculture, Egypt. The harvesting time was in the first week of April, for both seasons.

Data recorded

Growth parameters: A random sample of ten plants was taken from each plot after 120 days from planting

to estimate plant height, number of leaves/plant, plant dry weight (without bulb) and bulbing ratio.

Yield and its components: At harvest time, marketable plants 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 weight and diameter, as well as the number of cloves/bulb and clove weight.

Chemical analysis: Samples of the dried cloves were ground, wet digested as described by Hesse (1971) and their nitrogen (N), phosphorus (P), potassium (K), iron (Fe), Zinc (Zn) and manganese (Mn) contents were determined according to the methods described by Pregl (1945), John (1970), Brown and Lilleland (1946) and Chapman and Pratt (1961), respectively. Percentage of total soluble solids (TSS%) and volatile oils (cm^3/kg bulbs fresh weight) were determined according to A.O.A.C. (1970) and Guenther (1961), respectively.

Storability: After curing, random samples (10 kg of marketable yield from every plot) were taken, stored at the normal room conditions (Table 1) and the percentage of weight loss was recorded monthly during the storage period (five months).

Table 1. Average (max. + min.) air temperature and relative humidity in store room during 2013 and 2014 seasons.

Months	2013		2014	
	Temp. (°C)	Humidity (%)	Temp. (°C)	Humidity (%)
May	18.1	65	16.8	63
June	19.7	66	18.3	64
July	22.3	67	21.7	68
August	23.7	70	22.9	71
September	22.9	69	22.3	69

Data obtained during the two seasons of the study were statistically analyzed according to Gomez and Gomez (1984).

Results and discussion

Vegetative growth

Effect of sulphur levels

The data presented in Table 2 show that plant height, number of leaves/plant and plant dry weight were significantly increased with increasing sulphur levels up to 400 kg S/fed. Also, the bulbing ratio was better with supplying sulphur in both seasons. These results may be due to the beneficial effect of the applied-S as a one of many elements required for plant growth, its important in the formation of protein and chlorophylls (Morris et al., 1984). These results are in agreement with those of Khalaf and Taha (1988), Hilal et al. (1992) and Singh et al. (1995) found that plant growth, total yield and quality were increased significantly with increasing rate of applied sulphur.

Application of zinc, boron, and poultry manure significantly had increased plant height, number of leaves/plant, cloves/bulb, diameter, and weight of bulb and yield/ha in both years. The study revealed that application of fertilizer at the rate of 150 kg N, 50 kg P, 100 kg K, 40 kg S, and 5 kg Zn/ha would be economical for higher garlic production in Grey Terrace Soil of Shibgonj, Bogra. Application of Zn at 5 kg/ha along with blanket dose of N, P, K, and S fertilizers would be profitable (MRR of 5650% in 2005-2006 and 1562% in 2006-2007) for garlic cultivation in the Gray Terrace Soil of Shibgonj, Bogra (Nasreen et al., 2009).

Effect of micronutrients

Data in Table 2 also, reveal that foliar application of micronutrients (Fe + Zn + Mn) resulted in significant increases on all studied parameters of vegetative growth in both seasons of the study. Plants sprayed with 250 ppm micronutrients were generally stocky and healthy in appearance than other treatments. These results could be attributed to the effective role of such micronutrients in controlling various enzymes activities and photosynthetic pigments formation, consequently affecting plant growth. The obtained results are in harmony with those reported by Eid et al. (1991), Ibrahim et al. (1991), Saravanan and Nambisan, (1994), Phor et al. (1995), Abdel-Hamed, (1997), Abdel-Fattah et al. (2002), Hegazi et al. (2002) and El-Morsy et al. (2004).

Effect of interaction between S-levels and micronutrients

It is obvious from the same data in Table 2 that all vegetative growth characteristics are affected by

interaction, except the number of leaves in the first season. In general, plants received sulphur at 400 kg/fed with 250 ppm level micronutrients spray gave the highest values of plant growth parameters investigated in both seasons followed by 300 kg S/fed level with the same treatment of micronutrients. These results may be due to the beneficial effect of sulphur on increasing the availability of P and some micronutrients i.e., Fe, Zn, Mn and Cu in soil under plants (Dahdouh et al., 1993; Mehana, 1994; Mehana and Farag, 2000). Similar results were also reported in other plants by Fathi et al. (1996) on peanut, Abdel-Hamed (1997) on garlic and Attia (2001) on onion.

Table 2. Vegetative growth characters of garlic plants as affected by Sulphur levels, micronutrients and their interactions during 2012/2013 (S1) and 2013/2014 (S2) seasons.

Characters / Treatments		Plant height (cm)		Number of leaves/plant		Shoot dry weight (g)		Bulbing ratio	
		S1	S2	S1	S2	S1	S2	S1	S2
S-levels									
Control		80.35	79.10	10.8	9.9	11.12	10.26	0.36	0.38
200 kg S/fed		83.07	79.61	11.7	10.6	12.15	11.76	0.34	0.36
300 kg S/fed		84.87	80.45	12.3	10.7	12.88	12.45	0.32	0.35
400 kg S/fed		86.70	82.14	12.6	11.0	13.86	12.74	0.30	0.33
LSD at 5%		01.14	01.63	00.3	00.5	00.31	00.23	0.02	0.01
Micronutrients levels									
Control		81.93	77.38	11.4	10.0	11.77	10.76	0.35	0.37
150 ppm		83.07	79.42	11.7	10.4	12.30	11.16	0.33	0.36
200 ppm		83.97	81.18	12.0	10.7	12.59	12.26	0.33	0.35
250 ppm		86.02	83.33	12.2	11.1	13.36	13.02	0.32	0.34
LSD at 5%		00.97	01.20	00.2	00.2	00.55	00.34	0.01	0.01
Interactions									
S-levels	**Micronutrient levels**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Control	Control	78.47	74.80	10.1	9.2	10.23	9.25	0.38	0.40
	150 ppm	79.27	78.43	10.4	9.8	10.77	9.73	0.36	0.37
	200 ppm	80.67	80.37	11.2	10.1	11.72	10.69	0.35	0.37
	250 ppm	83.00	82.80	11.3	10.3	11.74	11.36	0.35	0.36
200 kg S/fed	Control	80.87	76.77	11.2	10.1	11.10	10.66	0.36	0.37
	150 ppm	82.60	78.43	11.7	10.5	12.27	11.17	0.34	0.37
	200 ppm	83.00	80.43	11.9	10.7	12.13	12.42	0.34	0.35
	250 ppm	85.80	82.80	11.9	11.0	13.10	12.78	0.33	0.35
300 kg S/fed	Control	83.40	78.00	12.0	10.2	12.38	11.44	0.33	0.36
	150 ppm	84.13	79.80	12.3	10.6	12.50	11.73	0.32	0.36
	200 ppm	85.07	80.73	12.5	10.9	12.78	12.97	0.32	0.34
	250 ppm	86.87	83.27	12.5	11.1	13.84	13.66	0.31	0.34
400 kg S/fed	Control	85.00	79.93	12.3	10.4	13.36	11.69	0.32	0.34
	150 ppm	86.27	81.00	12.5	10.8	13.64	12.02	0.30	0.33
	200 ppm	87.13	83.20	12.6	11.1	13.71	12.96	0.30	0.32
	250 ppm	88.40	84.43	12.9	11.8	14.74	14.29	0.30	0.31
L.S.D. at 5%		01.95	02.40	N.S	00.5	01.09	00.69	0.02	0.01

Yield and its components

Effect of sulphur levels

Data illustrated in Table 3 show the effect of sulphur levels on yield and its components of garlic. Such data indicate that the application of sulphur increased the yield and improved its components comparing with the control treatment. Total yield, bulb weight and diameter as well as clove weight were significantly increased with increasing the sulphur application level up to 400 kg S/fed in both seasons. The positive effect of this sulphur level may be due to lowering soil pH factors that improved soil structure, soil chemical properties and increased the availability of certain plant nutrients such as P and several micronutrients i.e. Fe, Zn and Mn. The obtained results are in accordance with

those of El-Habbasha et al. (1985), Khalaf and Taha (1988), Hilal et al. (1992), Singh et al. (1995) and Mee et al. (1997) stated that total yield and quality were increased significantly with increasing rate of applied sulphur.

Effect of micronutrients

Data in Table 3 indicate that total yield and its components, except of the number of cloves/bulb in the first season were better with spraying the plants with mixture of micronutrients (Fe + Zn + Mn). Moreover, application of micronutrients at 250 ppm was more effective than the other treatments. These increases might be ascribed to the favourable role of the used micronutrients in pigments formation, photosynthesis activation and carbohydrates assimilation diverted to the bulbs which represent the economic part of plant (Hilman and Asandhi, 1987). Similar results were reported by Eid et al. (1991), Abdel-Fattah et al (2002), Hegazi et al. (2002) and El-Morsy et al. (2004).

Table 3. Total yield and its components as affected by Sulphur levels, micronutrients and their interactions during 2012/2013 (S1) and 2013/2014 (S2) seasons.

Characters / Treatments		Total yield (ton/fed)		Bulb weight (g)		Bulb diameter (cm)		No. of cloves/bulb		Clove weight (g)	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
S- levels											
Control		6.219	5.680	54.4	49.5	5.3	4.8	15.8	15.5	3.2	3.0
200 kg S/fed		6.747	6.075	59.0	54.5	5.7	5.2	16.3	16.7	3.6	3.2
300 kg S/fed		6.995	6.507	61.3	59.0	5.9	5.4	15.1	15.4	4.0	3.6
400 kg S/fed		7.471	6.976	65.8	62.0	6.3	5.6	15.6	15.0	4.2	3.9
LSD at 5%		0.140	0.108	01.1	01.3	0.2	0.2	N.S	00.5	0.2	0.1
Micronutrient levels											
Control		6.385	5.926	56.5	51.5	5.6	4.9	16.5	16.4	3.4	3.1
150 ppm		6.657	6.041	58.3	54.6	5.6	5.2	15.3	16.3	3.7	3.2
200 ppm		6.947	6.450	60.8	57.4	6.0	5.4	15.3	15.1	3.8	3.6
250ppm		7.442	6.822	65.1	61.4	6.1	5.6	15.7	14.8	4.1	3.9
LSD at 5%		0.053	0.151	00.7	01.1	0.2	0.1	N.S	00.6	0.1	0.1
Interactions											
S-levels	**Micronutrient levels**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Control	Control	5.847	5.351	51.2	45.3	5.0	4.2	17.0	15.0	2.9	2.8
	150 ppm	6.000	5.412	52.5	47.6	5.0	4.8	15.3	16.0	3.2	2.9
	200 ppm	6.266	5.804	54.8	50.9	5.5	5.0	15.0	16.0	3.2	3.0
	250 ppm	6.762	6.154	59.2	53.9	5.6	5.2	16.0	15.0	3.6	3.4
200 kg S/fed	Control	6.228	5.569	54.5	49.5	5.3	4.7	17.7	18.0	3.0	3.0
	150 ppm	6.495	5.823	56.8	52.0	5.5	5.1	14.7	18.0	3.7	3.0
	200 ppm	6.876	6.254	60.2	56.5	5.9	5.4	16.7	15.3	3.8	3.4
	250 ppm	7.930	6.656	64.7	59.9	6.2	5.5	16.0	15.3	3.9	3.5
300 kg S/fed	Control	6.571	6.289	58.0	54.0	5.7	5.2	15.3	17.0	3.7	3.1
	150 ppm	6.800	6.180	59.5	58.5	5.8	5.3	15.0	15.3	3.9	3.2
	200 ppm	7.047	6.652	61.7	59.3	6.1	5.4	14.3	14.3	4.2	3.9
	250 ppm	7.561	6.909	66.2	64.1	6.2	5.6	15.7	15.0	4.2	4.3
400 kg S/fed	Control	6.895	6.496	62.2	57.0	6.2	5.4	16.0	15.7	3.9	3.5
	150 ppm	7.333	6.750	64.2	60.2	6.2	5.5	16.0	16.0	4.0	3.7
	200 ppm	7.600	7.088	66.5	62.9	6.4	5.6	15.3	14.7	4.2	4.0
	250 ppm	8.057	7.571	70.5	67.7	6.3	6.0	15.0	13.7	4.6	4.4
L.S.D. at 5%		0.107	0.303	01.5	02.1	N.S	N.S	N.S	01.2	N.S	0.1

Effect of interaction between S-levels and micronutrients

It is clear from data in Table 3 that there were significant interactions between sulphur levels and micronutrients (Fe + Zn + Mn) on total yield and bulb weight in both seasons and number of cloves/bulb and clove weight in the first season only. Bulb diameter was not significantly influenced in both seasons. In general, plants fertilized by 400 kg S/fed and sprayed with micronutrients at 250 ppm produced the highest values. These results coincide with those of Abdel-Hamed (1997) on garlic, Attia (2001) on onion and Radwan and Tawfik (2004) on potato.

Chemical constituents

Effect of sulphur levels

Data in Table 4 evident show that the sulphur application levels had a significant effect on TSS %, volatile oils, N, P, K and micronutrients (Fe, Zn and Mn) in cloves. All elements concentrations in cloves were significantly increased with increasing sulphur application level in both seasons. Application of 400 kg S/fed gave the highest records followed by the 300 kg S/fed in both seasons. These results may be related to the positive effect of sulphur on the availability of some nutrient elements, which was reflected on plant uptake and plant growth (Dahdouh et al., 1993; Mehana, 1994 and Mehana and Farag, 2000). These results are in agreement with those of Khalaf and Taha (1988) and Singh et al. (1995).

Effect of micronutrients

Data in Table 4 show that TSS %, volatile oils and all concentrations of elements in cloves were significantly increased due to spraying the plants with mixture of micronutrients (Fe + Zn + Mn) at 250 ppm comparing with the other treatments. These results agree with those reported by Eid et al. (1991), Abdel-Fattah et al. (2002) and El-Morsy et al. (2004). El Sayed and El Morsy (2012) found that the K-levels from 0 up to 96 kg K2O/fed treatment significantly increased concentration of N, P, K, TSS and volatile oils in cloves comparing with those of the other treatments.

Effect of interaction between sulphur levels and micronutrients

It is obvious from data in Table 4 that the interaction between S-levels and micronutrients (Fe + Zn + Mn) had significant effects on all chemical constituents in cloves in both seasons except TSS% and P% in the first season and N% in the second season. On the other hand, the concentration of zinc in cloves was not affected by the interaction in both seasons. The highest values of TSS%, volatile oils and all elements were shown when garlic plants supplied 400 kg S/fed and sprayed with 250 ppm micronutrients. Similar results were obtained by Khalaf and Taha (1988), Hilal et al. (1992), Singh et al. (1995) and Abdel-Hamed (1997) and their study concluded that the sulphur application with trace elements significantly increased the chemical contents in cloves.

Storability

Effect of sulphur levels

Data in Table 5 reveal that the total weight loss percentage of bulbs was significantly affected during storage period in both seasons. The lowest total weight loss percentage was obtained by applied-S at 400 kg/fed. This treatment achieved increase in yield at the end of storage period (five months) reached to 11.73% and 11.53% in the first and the second seasons respectively comparing to control treatment. These results may be due to increase dry matter in plants (Table 2), TSS% and chemical constituents in cloves (Table 4).

Zamani et al. (2011) they used six levels of sulphur viz., 0, 15, 30, 45, 60, and 75 kg/ha and control treatment was in the experiment. The fertilizer package N150P60K120Zn4 B1 kg/ha was applied to each plot as blanket dose. Results revealed that most of the growth and yield parameters increased progressively with increasing rate of sulphur application. Bulb yield increased with successive increase in the level of sulphur up to 45 kg/ha and thereafter decreased. Sulphur at 45 kg/ha produced 54.5% and 54.9% higher yield over control treatment in both the years. The optimum and economic dose of sulphur for the yield of garlic were 44.0 and 43.6 kg/ha, respectively.

Diriba-Shiferaw et al. (2013) concluded that, garlic plants showed differential response to different rates of compound fertilizers, cropping season and soil types. Significantly superior response of garlic, as observed by the vegetative growth, nutrients content and uptake of the crop, was obtained when garlic planted in offseason by irrigation over Andosol with the fertilizations of D-coder fertilizer at the rate of 200 kg ha^{-1} (28% N + 18% P + 42% S + 0.2% Zn) followed by Azofertil fertilizer at the rate of 300 kg ha^{-1} (90% N + 75% S). But, basic fertilizer responded to higher growths and nutrient uptake of nutrients at higher levels (400 and 600 kg ha^{-1}) (36% N + 24% P + 88% K + 40% CaO and 54% N + 36% P + 132% K +60% CaO) than the other treatments. This led to conclude that Azofertil and D-coder fertilizers at the rates of 200 and 300 kg ha^{-1}, respectively are better to substitute the locally recommended NP fertilizers for garlic production on the soils of the area under the dry conditions by irrigation.

Effect of micronutrients

Data in Table 5 indicate that bulb storability of plants sprayed with micronutrients (Fe + Zn + Mn) was better than that of the untreated plants. Moreover, application of micronutrients at 250 ppm was more beneficial than the application once. These results are in harmony with those of Abdel-Fattah et al. (2002) and El-Morsy et al. (2004) who observed that weight loss percent of bulbs was significantly reduced during the storage period with plants sprayed by micronutrients. El Sayed and El Morsy (2012) results suggested that garlic plants received K-levels better than those of the unfertilized ones. Also, El Sayed and El Morsy (2012) studied the most characteristics of garlic plants which were significantly increased with increasing K-levels from 0 up to 96 kg K_2O/fed. Besides, the most interesting observation was the increase of the storability by 96 kg K_2O/fed in both seasons.

Effect of interaction between S-levels and micronutrients

It is clear from data in Table 5 that the positive interactions between application of sulphur and micronutrients (Fe + Zn + Mn) levels often observed on storability of bulbs. The lowest total weight loss percentage during and in the end of the storage period (five months) was obtained from application of 400 kg S/fed with foliar spray of micronutrients at 250 ppm in both seasons.

Diriba-Shiferaw et al. (2014) found that the highest bulb weight losses were recorded at the higher and lower rates of applied fertilizers on both soil types. More amounts of nitrogen and sulphur fertilizers were required to produce good quality and to increase the nutrients content of garlic bulb on Vertisol as compared to that of Andosol. It could be concluded that application of nitrogen, phosphorus, and sulphur at the combination rates of 92 kg N + 40 kg P + 30 kg ha-1 on Andosol and 138 kg N + 40 kg P + 60 kg ha^{-1} on Vertisol led to increased bulb quality and its mineral contents. The quality of the crop was markedly higher on Andosol than Vertisol at the medium rates of the applied fertilizers.

Therefore, farmers in the study area could apply 92 kg N ha^{-1} + 40 kg P ha^{-1} + 30 kg S ha^{-1} to attain maximum quality of the crop for enhanced household income and livelihoods and to reduce the cost of fertilizer inputs.

Diriba-Shiferaw et al. (2014) indicated favorable effects of integrated application of nitrogen, phosphorus and sulphur on garlic bulb quality. Combined applications of 92 kg N + 40 kg P + 30 kg S ha^{-1} and 138 kg N + 40 kg P + 60 kg S ha^{-1} led to the attainment of optimum bulb quality attributes on Andosol and Vertisol, respectively. However, it was application of 92 kg N + 40 kg P + 30 kg S ha^{-1} that was found to be economical for farmers.

Rizk et al. (2012) found that there was no significant interaction effect of nitrogen plus phosphorus and sulphur treatments on bulb yield, harvested bulb attributes and nutrient contents of garlic in both seasons except for length of bulb and neck in the first season and bulb dimensions (length and diameter) as well as K, Fe and Mn contents in the second season. Also, under the conditions of this study, application of N + P fertilizer at rate of 90 + 45 unit/fed, and 400 kg S/fed. Sulphur, is advisable for better grown of onion plant and to ensure high yield and good quality of onion bulbs in Giza 20 cultivar in newly reclaimed sandy soil.

Table 4. Chemical constituents in garlic bulbs as affected by sulphur levels, micronutrients and their interactions during 2012/2013 (S1) and 2013/2014 (S2) seasons.

Characters / Treatments		T.S.S %		Volatile oils (cm^3/kg F.W)		Macro-elements						Micro-elements					
						N %		P %		K %		Fe (ppm)		Zn (ppm)		Mn (ppm)	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
S- levels																	
Control		4.15	4.22	0.35	0.37	1.38	1.36	0.422	0.407	1.38	1.35	170	162	121	117	55	47
200 kg S/fed		4.58	5.00	0.40	0.41	1.47	1.42	0.443	0.420	1.41	1.36	177	167	123	120	55	48
300 kg S/fed		5.28	5.33	0.41	0.44	1.53	1.50	0.462	0.452	1.45	1.37	179	170	127	123	57	52
400 kg S/fed		5.89	5.64	0.44	0.45	1.65	1.61	0.485	0.468	1.46	1.40	182	178	130	125	60	57
LSD at 5%		0.13	0.06	0.01	0.01	0.01	0.02	0.014	0.028	0.01	0.01	0.9	1.5	1.8	1.8	0.6	1.5
Micronutrients levels																	
Control		4.33	4.45	0.37	0.38	1.44	1.40	0.422	0.417	1.40	1.34	169	164	119	116	52	47
150 ppm		4.77	4.80	0.39	0.40	1.47	1.44	0.439	0.427	1.41	1.35	174	167	124	120	55	50
200 ppm		4.18	5.17	0.42	0.43	1.53	1.50	0.460	0.442	1.44	1.38	180	172	127	123	58	52
250ppm		5.63	5.78	0.43	0.46	1.59	1.55	0.490	0.460	1.46	1.40	186	175	131	127	62	55
LSD at 5%		0.20	0.11	0.01	0.01	0.01	0.01	0.011	0.009	0.01	0.01	0.7	2.0	1.0	1.1	0.8	0.7
Interactions																	
S-levels	**Micronutrients levels**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Control	Control	3.50	3.70	0.33	0.35	1.32	1.29	0.390	0.380	1.36	1.32	161	157	115	112	49	43
	150 ppm	3.90	4.10	0.34	0.35	1.35	1.33	0.407	0.387	1.38	1.33	168	159	119	115	53	47
	200 ppm	4.30	4.10	0.36	0.37	1.40	1.38	0.430	0.420	1.39	1.36	171	165	124	119	57	48
	250 ppm	4.90	5.00	0.39	0.40	1.46	1.42	0.460	0.440	1.39	1.37	179	169	127	124	61	48
200 kg S/fed	Control	4.00	4.40	0.36	0.37	1.41	1.36	0.420	0.390	1.39	1.33	169	162	116	116	51	45
	150 ppm	4.20	4.70	0.39	0.39	1.43	1.38	0.430	0.410	1.39	1.34	174	165	121	119	53	47
	200 ppm	4.80	5.20	0.41	0.43	1.48	1.44	0.450	0.430	1.41	1.38	181	170	124	123	57	48
	250 ppm	5.30	5.70	0.42	0.45	1.56	1.51	0.470	0.450	1.43	1.38	185	172	129	125	61	51
300 kg S/fed	Control	4.30	4.70	0.38	0.39	1.47	1.42	0.420	0.440	1.41	1.35	171	164	120	118	53	48
	150 ppm	5.20	5.00	0.39	0.42	1.49	1.47	0.450	0.450	1.43	1.36	175	167	125	123	55	50
	200 ppm	5.60	5.50	0.43	0.45	1.55	1.53	0.470	0.450	1.47	1.39	182	173	129	125	58	53
	250 ppm	6.00	6.10	0.45	0.48	1.60	1.57	0.510	0.470	1.49	1.40	187	177	132	128	61	58
400 kg S/fed	Control	5.50	5.00	0.41	0.41	1.56	1.52	0.460	0.460	1.42	1.37	173	172	124	120	56	52
	150 ppm	5.77	5.40	0.43	0.43	1.61	1.59	0.470	0.460	1.43	1.39	179	175	129	125	60	56
	200 ppm	6.00	5.87	0.46	0.47	1.69	1.64	0.490	0.470	1.48	1.40	184	179	132	126	61	58
	250 ppm	6.30	6.30	0.47	0.49	1.73	1.68	0.520	0.480	1.51	1.43	191	184	134	130	63	61
L.S.D. at 5%		N.S	0.22	0.01	0.01	0.02	N.S	N.S	0.018	0.02	0.03	1.3	3.9	N.S	N.S	1.6	1.4

Table 5. Weight loss percentage of garlic as affected by Sulphur levels, micronutrients and their interactions during 2012/2013 (S1) and 2013/2014 (S2) seasons.

Characters / Treatments		Weight loss (%) during the storage period									
		30 days		60 days		90 days		120 days		150 days	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
S- levels											
Control		31.02	30.35	41.91	41.35	47.33	47.10	51.33	50.78	55.93	54.81
200 kg S/fed		26.82	25.98	37.98	38.05	43.70	43.23	47.45	46.89	51.55	50.73
300 kg S/fed		24.05	23.52	34.10	33.52	40.13	39.55	44.00	44.23	47.22	45.93
400 kg S/fed		23.70	23.11	32.45	31.77	37.83	37.23	40.93	40.18	44.20	43.28
LSD at 5%		0.27	00.23	00.34	03.19	00.11	00.18	00.13	00.29	00.18	00.30
Micronutrient levels											
Control		29.05	28.55	40.03	40.00	45.97	45.68	50.23	49.60	54.78	53.93
150 ppm		26.27	25.58	37.13	36.60	42.90	42.29	46.78	46.18	50.83	49.88
200 ppm		25.50	24.88	35.25	34.70	40.90	40.43	44.40	43.89	47.64	46.80
250ppm		24.78	23.96	34.03	33.40	39.20	38.70	42.30	42.40	45.65	44.13
LSD at 5%		00.36	00.24	00.18	00.25	00.20	00.27	00.19	00.25	00.19	00.27
Interactions											
S-levels	**Micronutrient levels**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Control	Control	33.08	32.60	44.60	43.90	51.30	51.80	56.00	55.30	61.80	61.00
	150 ppm	31.50	30.80	42.90	42.60	48.00	47.40	52.80	52.20	57.30	56.53
	200 ppm	30.00	29.50	41.00	40.90	46.10	45.70	49.00	48.50	53.50	52.50
	250 ppm	29.50	28.50	38.73	38.00	43.90	43.50	47.50	47.10	51.10	49.20
200 kg S/fed	Control	30.00	29.50	42.20	43.80	47.60	47.13	52.00	51.30	56.70	55.90
	150 ppm	26.17	25.30	37.40	37.00	44.00	43.47	47.80	47.20	53.00	52.10
	200 ppm	25.80	24.90	36.30	35.90	41.90	41.40	45.00	44.97	48.50	47.70
	250 ppm	25.33	24.20	36.00	35.50	41.30	40.90	45.00	44.10	48.00	47.20
300 kg S/fed	Control	26.60	26.30	37.40	37.00	43.80	43.10	48.00	47.40	52.00	51.20
	150 ppm	23.70	23.00	35.00	34.30	41.60	41.00	45.80	45.30	49.00	47.80
	200 ppm	23.30	22.80	32.60	32.00	39.20	38.80	43.70	43.10	45.87	45.10
	250 ppm	22.60	22.00	31.40	30.80	35.90	35.30	38.50	41.10	42.00	39.60
400 kg S/fed	Control	26.50	25.80	35.90	35.30	41.20	40.70	44.90	44.40	48.60	47.60
	150 ppm	23.70	23.20	33.20	32.50	38.00	37.30	40.70	40.00	44.00	43.10
	200 ppm	22.90	22.30	30.70	30.00	36.40	35.80	39.90	39.00	42.70	41.90
	250 ppm	21.70	21.13	30.00	29.30	35.70	35.10	38.20	37.30	41.50	40.50
L.S.D. at 5%		0.72	00.49	00.35	00.50	00.40	00.53	00.38	00.49	00.38	00.55

Al-Fraihat (2009) showed that increasing application nitrogen and sulphur rates significantly enhanced plant height, number of green leaves/plant and weight of plant and bulb at different stages of onion growth. Total yield, marketable yield, culls yield, percentage of marketable, doubles and bolters as well as total soluble solids (TSS%) were also increased with increasing the rates of nitrogen and sulphur up to 200 kg N/ha and

100 kg S/ha in both seasons, respectively; whereas the lowest percentage of pickles yield was recorded with the highest level of nitrogen and sulphur fertilizers. In general, the application of 200 kg N/ha + 100 kg S/ha increased the total and marketable yield of onion bulbs. Mishu et al. (2013) indicates that the sulphur at 40 kg ha^{-1} may be recommended for better growth and yield of onion under silty loam in texture having pH around 6.5. This experiment was conducted to study the effect of different doses of sulphur on growth and yield performances of onion.

The experiment comprised of five levels of sulphur (0, 20, 40, 60 and 80 kg S ha^{-1}) and was laid out in RCBD design with four replications and other fertilizers were applied according to recommended doses. Individual bulb weight, dry weight of root, dry weight of bulb, dry weight of shoot, dry weight of leaf, total dry matter (TDM), leaf area index (LAI), absolute growth rate (AGR), relative growth rate (RGR), net assimilation rate (NAR**)**, individual bulb weight, bulb yield of onion and sulphur content were increased significantly with the application of sulphur fertilizer. The maximum sulphur content (0.49%) of onion bulb was observed in 40 kg S ha^{-1} followed by 20 kg S ha-1(0.45 %), 60 (0.45%) and 80 kg S ha^{-1} (0.44%) at average of 45 and 85 days after transplanting. However, number of splitted bulb, bulb diameter, neck diameter, and neck bulb ratio were not significantly affected by different doses of sulphur application. Application of 40 kg S ha^{-1} resulted in the highest yield (10.65 t ha^{-1}) among the different doses of sulphur.

Assefa et al. (2015) identified the increment of garlic yield with balanced fertilization is a key important factor. However, use of correct type and rate of fertilizer applications are major problems in the study area. The yield and growth parameters were increased progressively with combined application of N, P, S, and Zn. It can therefore be concluded that for increased garlic yield in the study area, application of 130 kg N, 20 kg P, 21 kg S and 15 kg Zn fertilizers per hectare could be needed.

From the results of this study, it could be concluded that, application of 400 kg S/fed with spraying the plants with mixture of micronutrients (Fe + Zn + Mn) at 250 ppm are the recommended treatments for increasing garlic yield, improving bulb quality and storability of garlic under similar conditions to this work. Therefore, El Sayed and El Morsy (2012) found this treatment could be recommended for raising garlic yield and improving bulb quality during the storage period under similar conditions for this work. Assefa et al (2015) found from the results of a study during the two consecutive irrigation seasons, the yield of garlic crop in terms of bulb and growth parameters increased with combined application of N, P, S and Zn. Based on the obtained results, combined application of nitrogen, phosphorous, sulfur, and zinc with the rate of 130 kg, 20 kg, 21 kg and 15 kg per hectare, respectively, is the most suitable and recommendable dose for maximum growth and yield of garlic in the study area.

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