REDUCE THE ADVERSE IMPACT OF HIGH TEMPERATURE ON THE GREEN GARLIC PRODUCTION FOR EXPORT

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ABSTRACT

This work was carried out at a private farm in Tokh, Kalubia, Gov., Egypt during the two successive seasons of 2013/14 and 2014/15, using randomized complete block design with three replications to study the effect of pre-soaking seed cloves and foliar spray of silicon (Si), selenium (Se) concentrations and their combinations on germination, early seedlings growth, marketable and total green yield as well as chemical constituents of garlic planted under high temperature conditions of late summer (End of August). The results of this study showed that planting garlic under high temperature stress lead to drop in both rate and speed of germination, which reflected on growth and yield. However, soaking seed cloves in 4 mg/L silicon and/or 2 mg/L selenium solutions significantly increased in each of percentage, speed and coefficient velocity of germination as well as seed vigor index compared with untreated control. The soaking seed cloves in silicon at 4 mg/L. was found to produce more increase in germination index and early seedlings growth compared to selenium at 2 mg/L. The highest values of bulb characters, marketable and total green yield, as well as chemical constituents were achieved with application both Si and Se together as combination in a mixture.

Key words: Green Garlic, high temperature stress, Silicon, Selenium, Soaking, Foliar spray, Germination, Total green yield, Marketable yield, Allicin, Soluble sugars, Soluble protein.

INTRODUCTION

Egyptian garlic (*Allium sativum* L.) is a high-value cash crop due to its multifarious use in local consumption, food processing, and exportation (El-Eshmawiy *et al.*, 2010 and Abdel-Razzak and El-Sharkawy., 2013). Garlic growers planting garlic starting the second half of September and extends until the end of October in some areas due to variable climate factors. Moreover, the green garlic (not fully mature) is exported during February until March. One of the most important problems in the field of cultivation and production of the green garlic, the current system to product it depends on the collecting the large-size plants from the fields where, the weak plants are remaining, these plants will produce small-sized bulbs then, small seed cloves, which, will using as a seeds in the next season and this leads to the deterioration of the crop in Egypt.

Planting date considered one of the most important agriculture practices, which affect garlic crop. Many investigators showed that, Earliest planting date for garlic resulted in the highest vegetative growth characteristics and yield component of garlic compared with the latest one (Rahim *et al.*, 1984; Das *et al.*, 1985; Qaryouti and Kasrawi (1995); Sultana *et al.*, 1997; Islam *et al.*, 1998; Swati Barche *et al.*, 2013 and El-Zohiri and Farag (2014). On the other hand, the high temperature in late summer can play the important role on germination and growth of seedlings before the climate begin in improvement. Early planting on the late of August with an average temperature (34.0/20.0 and 33.3/19.6 °C) in the first and second seasons respectively, with an increase of 2-3 °C compared with the usual planting date may allow producing good yield with high quality of green garlic for export by protecting plants against damage from temperature stress by using Si and/or Se treatments. However, high temperature stress is a major environmental stress that limits plant growth, metabolism, and productivity worldwide. Plant growth and development involve numerous biochemical reactions that are sensitive to temperature (Hasanuzzaman *et al.*, 2013). High temperature causes loss of cell water content for which the cell size and ultimately the growth is reduced (Ashraf and Hafeez, 2005 and Rodriguez *et al.*, 2005). The optimum temperature for sprouting (emergence of new leaves from the cloves) of garlic is in the range of 10 to 20°C (Miedema, 1994). Sprouting garlic delayed or completely inhibited by continuous exposure to temperature above 25°C.Garlic thrives well in warm climates but it can survive inter temperatures. Most of the conditions that are suitable for the production of onions are also suitable for garlic. The suitable growth temperature for garlic is 13 to 24 °C. The plants influenced by temperature and day length but to a lesser extent than temperature. Onion seedlings grow the best at temperatures between 20 and 25°C. for optimum vegetative growth a temperature of between 18 and 22°C is needed, however plants will still grow at temperatures as low as 10 and as high as 27°C (Comrie, 1997). Reduced germination percentage, plant emergence, abnormal seedlings, poor seedling vigor, reduced radicle, and plumule growth of geminated seedlings are major impacts caused by heat stress documented in various cultivated plant species (Toh *et al.*, 2008 and Kumar *et al.*, 2011).

In recent years, a number of exogenous protectants, such as silicon, selenium, proline, glycinebetaine, nitric oxide, salicylic acid and polyamines have been tested and found to be beneficial in protecting plants against damage from temperature extremes (Hasanuzzaman *et al.*, 2013). In this concern, Silicon resulted in the highest germination on canola seeds (Solatni *et al.*, (2012), also enhanced the germination percentage and increased total fresh and dry weight of seedlings of borage plant specially when used at 1.5 mM (Torabi *et al.*, 2012). Foliar Se application of garlic at rates of 10–50 μg of Se/mL can recommended to increase the number of large bulbs and increase bulb antioxidant capacity (Poldma *et al.*, 2011). Numerous studies have shown that at low concentrations, Se exerts a beneficial effect on growth and stress tolerance of plants by enhancing their antioxidative capacity (Hartikainen and Xue 1999, Xue and Hartikainen 2000, Xue *et al.* 2001, Djanaguiraman *et al.* 2005, Kong *et al.* 2005).

The goal of this study was to evaluate the effect of pre-soaking seed cloves and foliar spraying of Si and Se concentrations separately or in combinations on green garlic production under high temperature stress.

MATERIAL AND METHODS

Experimental site:

This study was carried out at a private farm in Tokh, Kalubia, Gov., Egypt during the two successive winter seasons of 2013/14 and 2014/15, using a randomized complete block design with three replications to study the effect of the presoaking seed cloves and foliar spray of silicon (Si), selenium (Se) concentrations and their combinations on germination, early seedlings growth, marketable and total green yield as well as chemical constituents of garlic cv. Balady under high temperature stress of late summer planting (End of August). The site is located at an altitude of 21.1 m above sea level, latitude 30°16'N and longitude 31°12' E.

Soil samples were randomly collected from experimental site before planting and during land preparation from the top layer (0 - 30 cm) for soil physical and chemical analysis. Soil physical properties were analyzed using the procedures described by Black *et al.* (1981), while soil chemical analysis was determined according to the procedures described by Jackson (1973). Soil physical and chemical properties presented in Tables (A and B).

Table (A): The physical and chemical properties of the soil.

Seasons	Particle size distribution(%)				pH	$CaCO_3$	Organic matter
	Clay	Silt	Sand	Texture	1:2:5	%	
2014	31.4	33.5	35.1	Clay loam	7.6	3.65	1.80
2015	32.6	32.9	32.9	Clay loam	7.8	3.75	1.80

Table B: Chemical properties of the soil

Seasons	HCO_3^-	SO4-2	Cl^-	Na^+	K^+	Ca^{++}	Mg^{+2}	Available		
								N	P	K
	M-mole L^{-1}							ppm		
2014	3.65	2.56	4.00	4.20	0.31	2.97	2.73	38.50	9.12	193.30
2015	3.75	2.78	4.20	4.42	0.49	2.94	2.88	37.00	10.15	190.40

Field environmental conditions

The metrological data for the experimental area obtained from Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), values were calculated and expressed as monthly interval means during the two growing seasons as shown in Table (C). Soil temperature were taken at 10 cm depth using a digital soil temperature tester between 2:00 and 4:00 pm daily beginning of planting time till the recommended of planting date.

Experimental design and treatments:

The experiment was arranged as a randomized complete block design with seven treatments, and each treatment was replicated at least 3 times. Each experimental plot consisted of five ridges each was 0.70 m in width and 3.70 m in length with an area about 12.95 m^2, where four ridges were planted and the fifth one was left without planting as empty gap between plots. The treatments were T_1 = Control without any treatments; T_2 = soaking seed cloves in Si at 4 mg/L.; T_3= soaking seeds in Se at 2 mg/L.; T_4= soaking seeds in Si 4 mg/L + Se 2 mg/L (T_2* T_3); T_5= soaking seeds in Si at 4 mg/L + spraying Se at 0.5 mg/L. T_6= soaking seeds in Se at 2 mg/L. + spraying Si at 2 mg/L.; T_7= soaking seeds in (Si at 4 mg/L + Se at 2 mg/L.) + spraying (Si at 2 mg/L + Se at 0.5 mg/L.). The soaking treatments were applied for 8 hours before planting, while the foliar spray was carried out 40, 60 and 80 days after the planting.

Table (C): Monthly soil temperature, solar radiation, maximum and minimum air temperatures and relative humidity at the experimental area during both seasons of study.

Date	Soil temperature (°C)	Solar radiation (MJ/m2)	Air temperature (°C)		Relative humidity (%)
	Average	Average	Min	Max	Average
	First season				
Aug. 2013	31.1	479	23.5	38.7	52
Sept. 2013	30.4	359	21.9	33.8	54
Oct. 2013	23.4	245	17.6	28.8	55
Nov. 2013	19.8	236	14.6	25.9	59
Dec. 2013	13.5	197	10.1	19.5	56
Jan. 2014	14.2	238	9.8	19.0	53
Feb. 2014	16.5	290	11.5	21.6	48
	Second season				
Aug. 2014	31.7	473	26.7	39.6	53
Sept. 2014	30.2	404	23.0	34.2	50
Oct. 2014	25.6	346	19.6	29.9	52
Nov. 2014	19.9	211	13.7	25.5	59
Dec. 2014	15.8	208	12.2	22.2	57
Jan. 2015	12.9	227	8.2	18.7	56
Feb. 2015	14.7	285	10.5	21.9	59

Planting technique:

Uniform seed cloves obtained from outer ring cloves of bulb, free of bruises or infections with an average weight of > 1 g of garlic cv. Balady were planted in the experimental field on August 23rd and 25th in both growing seasons of 2013/14 and 2014/15. Cloves were soaked in silicon, selenium and their combination for eight hours before planting then, manually planted based on 10 cm apart between cloves in both sides of ridges running east to west.

Horticultural practices that were common applied in garlic management were followed as usual.

Data recorded:

A. Germination and early seedling growth:

1- Germination percentage (GP): it was calculated after 22 days from planting date while, the germinated cloves were counted and germination percentage was estimated using the following formula:

$$GP\,\% = \frac{\text{Number of germinated cloves per plot}}{\text{Total number of planted cloves per plot}} x\ 10$$

2- Speed of Germination (SG): high quality seeds germinate faster than poor quality seeds. The number of normal seedling b s recorded in the first count represents the population of fast germinating seeds and thus functions as a vigor measurement (AOSA Seed Vigor Testing Handbook). The following formula is used to calculate the speed of germination (SG):

$$SG = \frac{No.of\ normal\ seedlings}{days\ of\ 1st\ count} + \frac{No.of\ normal\ seedlings}{days\ of\ final\ count}$$

3- Coefficient of velocity of germination (CVG) was evaluated according to Maguire (1962) as follows:

$$CVG = \frac{(G1+G2+\cdots+Gn)}{(1xG1+2xG2+\cdots..+n\ xGn)}$$

Where G is the number of germinated seeds and n is the last day of germination.

4- Seed vigor index (SVI) was calculated according to Baki and Anderson (1973) as follows:

SVI = Seedling length (cm) x GP (%).

5-Early seedlings growth: Seedlings height (cm) and number of leaves/seedling. It was measured at 40 days after planting.

***B-Plant growth characteristics*:**

At 150 days after planting seven plants were randomly chosen for recording the vegetative growth which included, plant height (cm), number of leaves per plant, leaf area /plant (cm^2), leaves fresh weight (g) and whole plant fresh weight (g).

C- Bulb characteristics and total green yield.

At harvesting time (15 February), 170 days after planting ten plants were taken from each experimental plot for recording bulb characters i.e., neck diameter (cm), bulb diameter (cm), bulbing ratio and average bulb fresh weight (g).

D- Total green yield (ton/fed.):

At green harvest stage, all plants for each experimental plot were collected and the total yield per fed. was estimated according to the following equation:

$$\text{Total green } yield\ /fed. = \frac{grrn\ yield\ per\ plot}{Aria\ of\ plot} x\ 4000$$

E- Bulb quality and marketable yield.

Bulb grading: After collecting all the plants from the experimental plots, the plants graded ranked according to the size of the bulb (< 3 cm, 3.1:4.0 cm, 4.1-5 cm and > 5 cm) and then the marketable yield (ton/fed.) was calculated after the exclusion the plants less than 3 cm.

F- Chemical constituents:

Leaf pigment contents, chlorophyll (a, b and total) and total carotenoids in the fourth leaf of garlic plant were determined on each sampling date according to the method described by Devlin and Barker (1971). Estimation of Soluble sugars: The pellet was suspended in 5 mL of ethanol at 80%, pre-heated and centrifuged again, collecting the supernatant and add to the flask, completing the volume of the flask to 50 mL with distilled water. From this sample, an aliquot of 200 µL of supernatant was used for quantification of total soluble sugars (TSS) by enthrones method (Dische, 1962) in a spectrophotometer at 620 nm of wavelength. Soluble protein was determined by spectrophotometry following the method of Lowry *et al.* (1951). Allicin: it was determined using a spectrophotometric method according to Han *et al.* (1995).

Statistical analysis:

Obtained data during the two seasons were subjected to analysis of variance as a simple experiment in a complete randomize block design. LSD method was used to compare between of treatment means according to Snedecor and Cochran (1989).

Results and Discussion

Maximum and minimum temperature at planting date until the end of germination:

Data in Figure (1) show the comparison between maximum temperature threshold (32°C) and maximum daily temperature during germination period (from 23/8 to 18/9) at 2013 and 2014 seasons. Results reveal that, the temperature degrees were lower than maximum threshold at seven and nine days during 2013 and 2014, respectively. The maximum differed between threshold (32 °C) and daily temperature were 4.2 and 5.4 °C at 2013 and 2014. Generally, the average maximum air temperature were (34.0 and 33.3 °C) in both seasons during the germination period (23/8 to 18/9).

Comparison between minimum temperature threshold (18°C) and minimum daily temperature during the germination period (from 23/8 to 18/9) at 2013 and 2014 years are presented in Fig. 2. Six and five days at 2013 and 2014, respectively, the temperature was lower than minimum threshold. The maximum different between threshold and minimum daily temperature were 4.9 and 6 °C at 2013 and 2014 respectively. Generally, the average air minimum temperature were (20.0 and 19.6 °C) in both seasons during the germination period (23/8 to 18-9).

The soaking seed cloves of silicon and selenium reduce temperature stress in germination period. These results were agreement with those reported by Comrie, (1997) and Abu- Rayyan *et al.* (2012). They reported that the seeds of onion and garlic could germinate at temperatures as low as 1.4 to 3.5°C. However, for a germination and emergence percentage of more than 70%, temperatures between 7.5 and 30 °C are required and the optimum temperature for high germination is 24°C. In addition, silicon and selenium have been tested and found to be beneficial in protecting plants against damage from temperature extremes (Hasanuzzaman *et al.*, 2013).

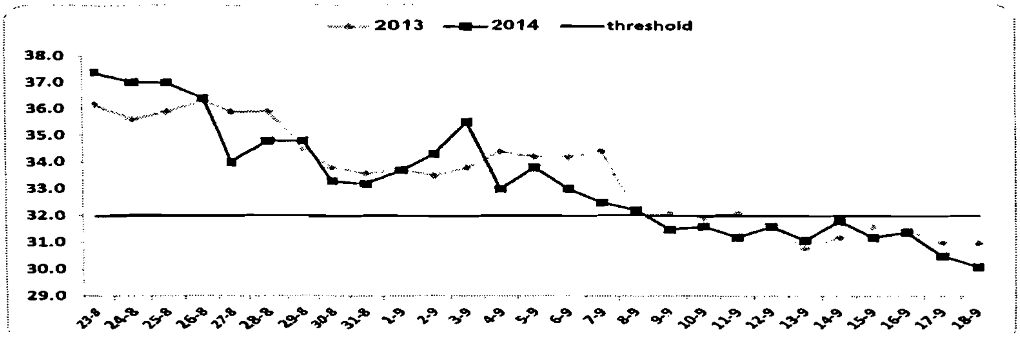

Fig. 1: Maximum daily air temperature and temperature threshold (32 °C) during germination period at 2013 and 2014.

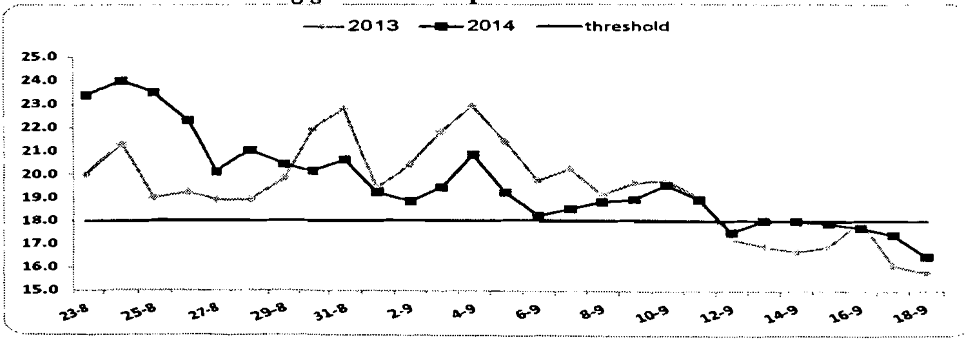

Fig. 2: Minimum daily air temperature and temperature threshold (18 °C) during germination period at 2013 and 2014.

Average soil Temperature from planting date until the end of germination:

Comparison between average soil temperature threshold (30 °C) and average daily soil temperature during germination period (from 23/8 to 18/9) at 2013/2014 and 2014/2015 seasons are shown in Figure 3. Data presented that, soil temperature was lower 30 °C from date of 3/9 at both seasons than threshold. The maximum differences between threshold and soil temperature were 4 and 3.5 °C at 2013/2014 and 2014/2015, respectively. The pre-soaking seed cloves of Silicon and Selenium can reduce soil temperature stress on the germination where the soil temperature over 30 °C. Kretschmer, (1994) obtained 90% and more emergence percentage with soil temperatures ranging between 10 to 25°C.

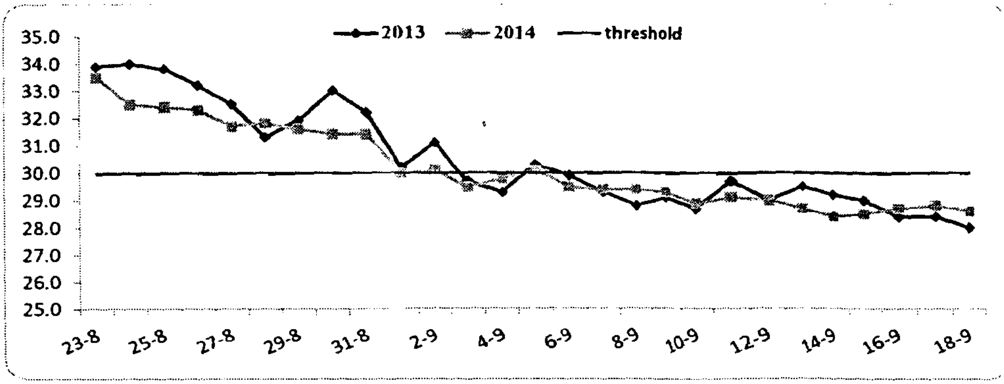

Fig. 3: Average daily soil temperature and temperature threshold (30 °C) during germination period at 2013 and 2014

Germination and early seedling growth:

Germination index.

The effect of high temperature on germination percentage, speed of germination, coefficient of velocity of germination and germination vigour index of garlic seed cloves are shown in control treatment (Table 1). In this regard, the average maximum and minimum temperature during the germination period were (34.0/20.0 and 33.3/19.6 °C) in both 1st and 2nd seasons, respectively. However, Temperatures higher than the optimum during the germination period (T_1) relatively decreased all germination indices where, germination percentage was (53.2 and 54.6 %) in both 1st and 2nd seasons, respectively, while, the germination speed was 22.04 and 21.41 day to germinate, coefficient of germination recorded (4.54 and 4.67 %) and germination vigour index produced (9.77 and 10.45 %) respectively, in untreated control (T_1). The decrease in seed germination percentage under the higher temperature stress could be particularly attributed to the exposure of seeds during germination to heat, which resulted in malfunctioning of the enzymatic system. This situation would lead to limitation in many physiological processes vital for seed germination (Al-Thabet *et al.*, 2004).

Increasing of germination index was higher with soaking seed cloves in silicon at 4 mg/L alone (T_2) and/or the combination of silicon and selenium of T_7 compared with untreated one (T_1). The highest values were obtained by using T_7 (soaking seed cloves in a mixture containing Si at 4 mg/L. + Se at 2 mg/L. and spraying plant leaves by a mixture containing Si at 2 mg/L. + Se at 0.5 mg/L.) followed by T_4 (Soaking seed cloves in solution contained Si at 4 mg/L. + Se at 2 mg/L.) with no significant differences between T_4 and T_7 were observed on all germination indices in both seasons. Whereas, untreated control (T_1) recorded the highest values in case of germination speed. On the contrary, T_4 and T_7 were contributed in reducing the number of days required to produce the highest germination percentage through short period. This results might be due to the role of Silicon in plant biology is subjected to multiple stresses including biotic and abiotic stresses. It is also known to increase drought tolerance in plants by maintaining plant water balance, photosynthetic activity, erectness of leaves and structure of xylem vessels under high transpiration rates. Similar result was reported by Torabil *et al.*, (2012). They showed that, the different treatments of silicon had considerable effect on the germination rate and germination index. The highest germination percentage was obtained at 1.5 mM silicon. Furthermore, exogenous silicon and selenium have been tested and found to be beneficial in protecting plants against damage from temperature extremes (Hasanuzzaman *et al.*, 2013). These results confirm the earlier study on improved percent seed germination, mean germination time, seed germination index, seed vigour index, seedling fresh weight and dry mass by utilization of nano-silicon in germination medium of tomato (Siddiqui and Al-Whaibi, 2014). Janmohammadi and Sabaghnia (2015) on sunflower found that, seed soaking in low concentration nano-silicon solutions (0.2 and 0.4 mM) significantly reduced days to 50% germination and mean germination time and improved root length, mean daily germination, seedling vigour index and final germination percentage.

Table 1: Effect of silicon, selenium and their combinations on germination of garlic seed cloves under heat stress during 2013/14 and 2014/15 seasons.

Treatments	Germination (%)		Germination speed (day)		Coefficient of germination (%)		Germination vigour index (%)	
	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015
T1	53.2	54.6	22.04	21.41	4.54	4.67	9.77	10.45
T2	76.8	78.7	18.98	18.45	5.28	5.44	16.56	17.71
T3	63.8	64.1	19.53	18.72	5.12	5.34	13.38	14.25
T4	88.6	89.4	15.38	14.93	6.47	6.64	24.15	24.53
T5	75.7	76.2	18.72	18.50	5.36	5.41	16.65	17.12
T6	66.9	68.7	18.22	18.72	5.49	5.34	15.11	15.16
T7	89.7	89.4	15.36	14.97	6.52	6.68	24.15	24.55
L.S.D at 0.05	4.45	4.57	1.06	1.10	0.30	0.25	0.78	1.05

T_1 = Control; **T_2** =soaking seed cloves in Si at 4mg/L.; **T_3**= soaking seeds in Se at 2mg/L.; **T_4**= (T_2* T_3); **T_5**=soaked seeds in Si at 4mg/L + spraying Se at 0.5mg/L. **T_6** = soaking seeds in Se at 2mg/L. + spraying Si at 2mg/L. **T_7** = soaking seeds in (Si at 4mg/L + Se at 2mg/L.) + spraying (Si at 2mg/L + Se at 0.5 mg/L.).

Early seedling growth.

Data presented in Figures 4 & 5 show that height and leaves number of garlic seedlings after 40 days from planting in T_1 were significantly decreased as a result of planting garlic seed cloves under high temperature stress (34.0/20.0 and 33.3/19.6 °C) in both seasons, respectively. This result was due to seeds are susceptible to abiotic stresses during germination and growth period (Carter and Chesson, 1996) which makes that garlic take a long time to germination then, the coefficient of germination and germination vigour index were decreased (Table,1). High temperature causes loss of cell water content for which the cell size and ultimately the growth is reduced (Ashraf and Hafeez, 2005 and Rodriguez *et al.*, 2005).

Pre-soaking seeds cloves in solution containing both Si at 4 mg/L and Se at 2 mg /L. together (T_4) for 8 hours or T_7 have potential to enhance crop emergence, stand establishment and seedling growth. Similarly, seed priming with sodium silicate improved all germination attributes and seedling growth under water deficit stress (Hameed *et al.*, 2013). Also, Janmohammadi and Sabaghnia (2015), on sunflower, found that, seed soaking in low concentration nano-silicon solutions (0.2 and 0.4 mM) significantly increased seedling growth.

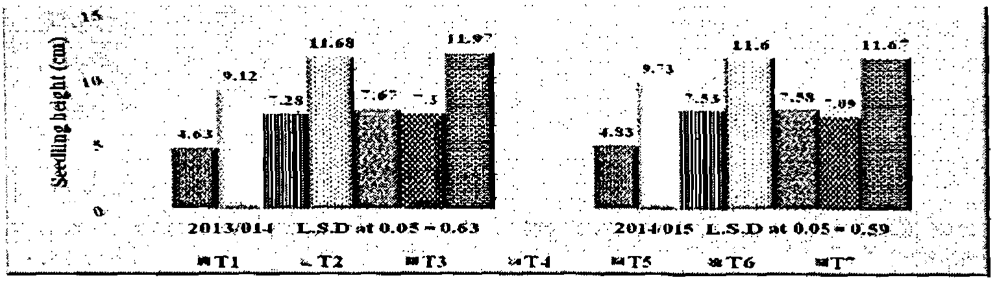

Fig. 4: Effect of Si, Se and their interaction on seedling height.

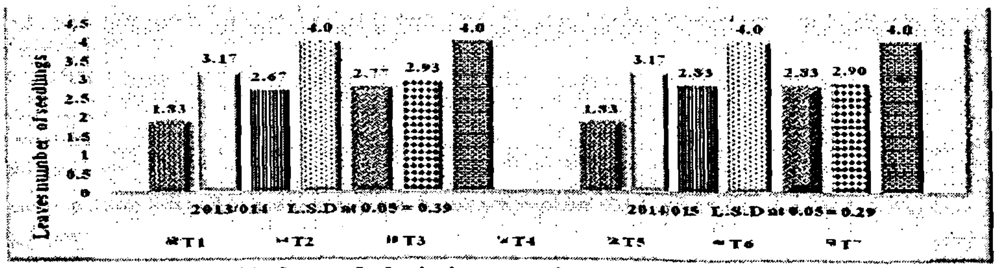

Fig. 5: Effect of Si, Se and their interaction on leaves number of seedlings

Chlorophyll and carotenoides:

Results shown in Table (2) revealed that application of Si and Se concentrations which were used as soaking application and/or foliar spray (either as single or in a combination) led to significant increases in chlorophyll a, b and total chlorophylls as well as total carotenoids compared with untreated control in both seasons. The maximum values of assayed photosynthetic pigments were connected with T_7 (pre-sawing soaking seed cloves in Si at 4 mg/L. + Se at 2 mg/L. combined with foliar spray of Si at 2 mg/L. + Se at 0.5 mg/L.). Moreover, there was no significant differences between T_7 and T_4 on chlorophyll a in the second season. On the other hand, the untreated control recorded the lowest values in all photosynthetic pigments in both seasons. Chen-Ping *et al.*, (1997) found that the addition of sodium silicate (SiO_2 80 µg/ml) together with selenite increased the chlorophyll content of flag leaf at flowering and later milky stag of wheat. Liu *et al.* (2014) on garlic found that adding Si at 1.5 mM/L. increase the pigment contents and photosynthetic rate in leaves.

Table 2: Effect of silicon, selenium and their combinations on chlorophyll a, b, total chlorophylls and carotenoides under heat stress during 2013/14 and 2014/15 seasons.

Treatments	Chlorophyll (mg/100g F.W.)						Carotenoides (mg /100 g F.W.)	
	a		b		Total (a + b)			
	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015
T1	206	197	199	191	405	389d	130	128
T2	238	235	222	226	460	461b	235	235
T3	221	209	212	200	432	409d	195	186
T4	263	247	247	231	510	478b	246	244
T5	234	227	220	219	454	446bc	231	235
T6	229	214	219	201	449	415cd	217	213
T7	284	264	274	260	558	524a	284	284
L.S.D at 0.0	10. 9	20.8	14.6	16.7	21.4	34.3	14.3	23.8

T_1 = Control; T_2 =soaking seed cloves in Si at 4mg/L.; T_3= soaking seeds in Se at 2mg/L.; T_4= (T_2* T_3); T_5=soaked seeds in Si at 4mg/L + spraying Se at 0.5mg/L. T_6 = soaking seeds in Se at 2mg/L. + spraying Si at 2mg/L. T_7 = soaking seeds in (Si at 4mg/L + Se at 2mg/L.) + spraying (Si at 2mg/L + Se at 0.5 mg/L.).

Plant growth characteristics:

Data recorded in Table (3) show that, high temperature stress at planting time and seedlings stage inhibited the growth parameters of garlic plants as compared with the silicon and/or selenium treatments, each separately and/or in combinations (T_2 to T_7). The untreated control (T_1) produced the lowest values in most growth aspects due to the planting seed cloves under high temperature stress take longer time to emergence and the seedlings were grown slowly.

In addition, there is also a very close association between heat and water stress; it is very difficult to separate these two types of stress. Crop water use increases greatly with increasing temperature, resulting in rapid depletion of soil moisture. As the soil dries out a couple of things happen. First, the pores on the leaf responsible for evaporative cooling start to close, resulting in an increase in leaf temperature. Evaporative cooling is also an important factor in soil temperature, so the drier the soil, the closer the soil temperature will be to the air temperature. (Thornton *et al.*, 1995). This results was inconformity with those reported by, Comrie, (1997) reported that onion seedlings grow the best at temperatures between 20 and 25°C. For optimum, vegetative growth needed a temperature between 18 and 22°C is needed. However plants will still grow at temperatures as low as 10 and as high as 27°C. The temperature stress is one of the main abiotic stresses that limit plant growth and survival. The morphological symptoms of heat stress include scorching of leaves and twigs, leaf senescence and abscission, shoot and root growth inhibition (Wahid *et al.*, 2007). Liu *et al.* (2014) on garlic reported that the plant fresh weight and height, pseudo stem length and diameter are increased with the increase of silicon concentration from 0 to 1.5 mmol/L, while these items is decreased when the silicon concentrations are from 1.5 to 3.0 mmol/L.

Meanwhile, the effect of silicon on plant growth may refer to that Si enhances the growth, improves protection against pathogens (Greger *et al.*,2011) and maintains of photosynthetic activity and that one of the reasons of increasing dry matter production (Agurie *et al.*,1992). Further, the beneficial effects of silicon are mainly associated with its high deposition in plant tissues, enhancing their strength and rigidity, increased mechanical strength reduces lodging and pest attack, increases the light – receiving posture of the plant and increasing photosynthesis and hence growth (Epstein, 1999 and Crooks and Prentice,2011).

As regard to the effect of silicon and selenium applications, the results showed that, increase in growth rate such as plant height, number of leaves per plant, leaf area, leaves fresh weight and whole plant fresh weight under high temperature conditions was obtained as a results of different treatments from T_2 to T_7 in both seasons of study. However, the T_7 was more effective than other treatments, which reflected the highest values on all growth aspects. On the other hand, there were no significant differences among T_2, T_4, T_5, T_6 and T_7 in the first season and T_2, T_4, T_5 and T_7 in the second one on leaves fresh weight. Agarie *et al.* (1998) observed that electrolyte leakage caused by high temperature (42.5°C) was less pronounced in the leaves grown with Si than in those grown without Si. These results suggest that Si may be involved in the thermal stability of lipids in cell membranes although the mechanism has not been elucidated.

Table 3: Effect of silicon, selenium and their combinations on vegetative growth of garlic plants under heat stress during 2013/14 and 2014/15 seasons.

Treatments	Plant height (cm)		Leaves number/ plant		Leaf aria (m2)		Leaves F.W (g)		Whole plant F.W (g)	
	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015
T1	74.7	67.7	5.53	5.36	7.21	7.11	75.7	73.0	109.3	105.0
T2	88.6	88.0	6.86	6.96	8.67	8.61	92.0	92.0	133.7	133.0
T3	82.7	83.3	6.27	6.43	7.40	7.39	79.7	82.0	126.3	127.3
T4	98.0	99.3	8.40	8.17	9.87	9.85	95.3	96.3	154.7	155.0
T5	96.6	97.6	7.83	7.83	9.72	9.67	94.7	92.3	159.6	158.7
T6	92.3	92.0	7.43	7.63	8.88	8.94	90.0	88.0	146.3	144.0
T7	107.0	108.0	8.70	8.67	10.38	10.42	94.7	97.0	166.0	165.7
L.S.D at 0.05	4.65	3.87	0.33	0.50	0.27	0.15	6.02	7.21	6.16	5.83

T_1 = Control; T_2 = soaking seed cloves in Si at 4mg/L.; T_3= soaking seeds in Se at 2mg/L.; T_4 = (T_2* T_3); T_5=soaked seeds in Si at 4mg/L + spraying Se at 0.5mg/L. T_6 = soaking seeds in Se at 2mg/L. + spraying Si at 2mg/L. T_7 = soaking seeds in (Si at 4mg/L + Se at 2mg/L.) + spraying (Si at 2mg/L + Se at 0.5 mg/L.).

Bulb characters and total green yield:-

Data recorded in Table (4) show that, high temperature stress at planting time reduced all bulb characters and total green yield/fed. except the bulbing ration compared with other treatments in both seasons. This result may be due to the high temperature at planting time and during emergence of seedlings (Fig., 1) causing delay the cloves germination (Table 1), slow seedlings growth (Fig. 2 and 3) and the decrease in vegetative growth (Table 3). On the contrast, the application of silicon and selenium each of them alone or in a mixture with other image either in the form of soak and/or spray were significantly increased all bulb characters as compared with control treatment. Whereas, the highest values of nick and bulb diameters as well as total green yield were obtained due to pre-soaking seed cloves by 4 mg/L. Si +2 mg/L. Se plus spraying the plant leaves by 2 mg/L. Si + 0.5 mg/L. Se in both seasons. However, the maximum increments of bulbing ratio were recorded by the control treatment.

Table 4: Effect of silicon, selenium and their combinations on bulb characters and total green yield of garlic plants under heat stress during 2013/014 and 2014/015 seasons.

Treatments	Neck diameter (cm)		Bulb diameter (cm)		Bulbing ratio		Average bulb F.W (g)		Total green yield (ton/fed.)	
	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015
T1	1.20	1.14	2.57	2.55	0.47	0.45	33.66	32.00	3.708e	3.508
T2	1.48	1.49	3.20	3.30	0.46	0.45	41.67	41.00	6.710c	6.675
T3	1.35	1.34	2.93	2.86	0.46	0.47	46.67	45.33	5.861d	5.810
T4	1.69	1.69	4.53	4.37	0.38	0.39	59.33	58.66	8.105b	7.999
T5	1.61	1.61	3.90	3.80	0.42	0.42	65.00	66.33	8.079b	7.902
T6	1.51	1.51	3.60	3.54	0.42	0.43	56.33	56.00	6.848c	6.825
T7	1.75	1.79	5.27	5.50	0.37	0.36	71.33	68.67	8.797a	8.775
L.S.D at 0.05	0.06	0.08	0.31	0.27	0.05	0.05	3.0	6.46	0.45	0.41

T_1 = Control; T_2 =soaking seed cloves in Si at 4mg/L.; T_3= soaking seeds in Se at 2mg/L.; T_4= (T_2* T_3); T_5=soaked seeds in Si at 4mg/L + spraying Se at 0.5mg/L. T_6 = soaking seeds in Se at 2mg/L. + spraying Si at 2mg/L. T_7 = soaking seeds in (Si at 4mg/L + Se at 2mg/L.) + spraying (Si at 2mg/L + Se at 0.5 mg/L.).

Bulb quality and marketable yield.

Data in Table (5) show the bulb quality and marketable green yield as affected by silicon and selenium concentrations and the method of applied. In this concern, The significantly higher value of (4.1: 5.0 and > 5 cm) grade bulbs were recorded with T_7 treatment (pre-soaking seeds cloves in Si at 4 mg/L. + Se at 2mg/L.) + (spraying leaves in Si at 2 mg/L. + Se at 0.5 mg/L.) followed by T_4 (pre-soaking seeds in 4 mg/L Si + 2 mg/L. Se). However, the untreated control produced the highest values in case of < 3 cm grade bulbs in both seasons compared with other treatments while, T_7 recorded the lowest values in this respect. The marketable green yield was significantly increased with T_7 flowered by T_4 in both seasons. The increments in the marketable green yield as a result of using T_7 were, 437.7 and 454.8 % compared with untreated control in both seasons respectively, and it was 162.4 and 160.5 %, 205.9 and 204.2 % compared with T_2 (pre-soaking seeds in 4 mg/L. Si) and T_3 (pre-soaking seeds in 2 mg/L. Se), individually. However, the increment between T_7 and T_4 was 111.2 and 110.0 %, respectively. These results may be elucidate that Si was effective than Se and when the seeds were soaking seeds cloves in a solution containing Si + Se and spraying the leaves with Si + Se was more effective than Si alone and combination between Si and Se on germination and growth initiation of garlic grown under high temperature stress. Marja *et al.* (2004) application of 0.3 mg Se kg/ sand, the potato yield was composed of relatively few tubers but it was large size. Poldma *et al.* (2011) foliar Se fertilization of garlic at rates of 10: 50 µg of Se/mL can be recommended to increase the number of large bulbs, increase bulb weight and antioxidant capacity.

Table 5: Effect of silicon, selenium and their combinations on yield gradients and total green yield of garlic plants under heat stress during 2013/014 and 2014/015 seasons.

Treatments	Yield gradients (ton/fed.)								Marketable green yield (ton/fed.)	
	< 3 cm		3.1 : 4.0		4.1 : 5 cm		> 5 cm			
	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015
T1	2.039	1.929	1.112	1.052	0.445	0.421	0.111	0.105	1.668	1.578
T2	2.214	2.203	3.154	3.137	0.604	0.600	0.738	0.734	4.495	4.472
T3	2.315	2.295	2.608	2.586	0.645	0.639	0.293	0.290	3.546	3.515
T4	1.543	1.520	3.242	3.242	1.216	1.199	2.107	2.080	6.565	6.522
T5	2.343	2.291	3.635	3.556	0.888	0.869	1.211	1.185	5.736	5.610
T6	2.157	2.150	3.253	3.241	0.616	0.614	0.821	0.819	4.691	4.675
T7	1.495	1.470	3.079	3.026	1.759	1.729	2.463	2.421	7.301	7.177
L.S.D at 0.05	0.21	0.14	0.15	0.15	61.6	58.2	51.2	73.8	268	275

T_1 = Control; T_2 =soaking seed cloves in Si at 4mg/L.; T_3= soaking seeds in Se at 2mg/L.; T_4= (T_2* T_3); T_5=soaked seeds in Si at 4mg/L + spraying Se at 0.5mg/L. T_6 = soaking seeds in Se at 2mg/L. + spraying Si at 2mg/L. T_7 = soaking seeds in (Si at 4mg/L + Se at 2mg/L.) + spraying (Si at 2mg/L + Se at 0.5 mg/L.).

Chemical constituents:

Data illustrate in Table (6) revealed that all treatments which received silicon or selenium significantly increased soluble sugars, soluble protein and allicin contents in garlic bulbs fresh weight as compared with untreated control. However, pre-soaking seed cloves in selenium and silicon and foliar spray of the two trace elements resulted the highest selenium content in garlic bulbs in both seasons. The same results were obtained by Marja *et al.* (2004) on potato reported that the higher Se addition (0.3 mg Se/kg sand) was observed as high concentrations of soluble sugar and starch of tubers. Liu *et al.* (2014) on garlic reported that the contents of soluble sugars in leaves and pseudo stems are highest under the 1.5 mmol/L silicon content, and are improved by 25.37 % - 41.96 % and 21.28 % - 40.82 % higher than those with the control. The content of soluble protein in leaves is reduced by 15.76 – 21.62 % in pseudo stems is improved by 32.85 % - 53.73 % when the silicon concentration is 1.5 mMol/L. Xia *et al.* (2014) on garlic found that foliar spray of 10 mg/L. of sodium selenite two times increased the soluble sugars, soluble protein and vitamin C in bolts and bulbs by 73.05 %, 104.66 %, 18.95 % and 82.01 %, 51.27 %, 69.82 %, respectively while Allicin in bolts and bulbs was reduced compared with control.

Table 6: Effect of silicon, selenium and their combinations on yield gradients and total green yield of garlic plants under heat stress during 2013/014 and 2014/015 seasons.

Treatments	Soluble sugars (% F.W)		Soluble protein (mg/ F.W		Allicin (mg/g F.W)		Se (mg/kg)	
	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015	2013/014	2014/015
T1	6.22	6.19	10.79	10.77	5.57	5.73	3.27	3.57
T2	7.92	8.07	12.81	12.88	7.23	7.18	3.50	3.90
T3	7.74	7.88	13.17	13.29	6.22	6.54	5.38	5.80
T4	8.37	8.32	13.77	13.74	6.85	6.83	6.61	6.27
T5	9.40	9.74	13.92	14.13	7.46	7.39	6.67	6.83
T6	10.12	10.30	14.27	14.33	7.11	7.33	5.86	5.85
T7	12.77	13.12	16.59	16.88	7.91	7.41	8.72	9.41
L.S.D at 0.05	0.26	0.46	0.34	0.45	0.18	0.41	0.54	0.34

T_1 = Control; T_2 =soaking seed cloves in Si at 4mg/L.; T_3= soaking seeds in Se at 2mg/L.; T_4= (T_2* T_3); T_5=soaked seeds in Si at 4mg/L + spraying Se at 0.5mg/L. T_6 = soaking seeds in Se at 2mg/L. + spraying Si at 2mg/L. T_7 = soaking seeds in (Si at 4mg/L + Se at 2mg/L.) + spraying (Si at 2mg/L + Se at 0.5 mg/L.).

Conclusion

We could conclude that pre-soaking seed cloves and foliar spray the plant leaves by Si and Se together protect garlic plants from the high temperature stress during germination and growth initiations which, reflected on germination percentage, germination speed, vegetative growth and bulb characters as well as total green, marketable yield and its quality.

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تقليل الأثر السلبي لارتفاع درجة الحرارة على إنتاج الثوم الأخضر للتصدير

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تم تنفيذ هذه التجربة في مزرعة خاصة بناحية طوخ - محافظة القليوبية - مصر فى موسمين متتاليين ٢٠١٤/٢٠١٣ و٢٠١٥/٢٠١٤، باستخدام تصميم القطاعات العشوائية الكاملة في ثلاث مكررات لدراسة تأثير نقع فصوص الثوم قبل زراعتها (التقاوى) ورش أوراق النباتات بمحاليل كل من السيليكون والسيلينيوم كلا على حدة أو في صورة مخاليط على إنبات التقاوى ونمو البادرات، المحصول الأخضر القابل للتسويق والمحصول الكلي وكذلك المكونات الكيميائية لنباتات الثوم المنزرعة تحت ظروف درجات الحرارة العالية في أواخر فصل الصيف (نهاية أغسطس).

هذا وقد أظهرت نتائج هذه الدراسة ما يلي: -

- زراعة الثوم تحت ظروف الإجهاد الحراري أدى إلى انخفاض نسبة وسرعة الإنبات معنويا، والتي انعكست سلبيا على النمو والمحصول النهائى.
- أدت معاملة النقع لفصوص الثوم قبل زراعتها في محلول السليكون بتركيز ٤ مجم/لتر، أو السيلينيوم بتركيز ٢ مجم/لتر الى زيادة كبيرة في كل من نسبة وسرعة ومعامل سرعة الإنبات وكذلك مؤشر وقوة الفصوص المنزرعة مقارنة مع معاملة الكنترول. تفوقت معاملة نقع فصوص الثوم في محلول السليكون بتركيز ٤ مجم/لتر مقارنة بالنقع في محلول السيلينيوم بتركيز ٢مجم / لتر حيث أعطى مزيدا من الزيادة في مؤشر الإنبات ونمو البادرات.
- حققت معاملة النقع للفصوص قبل زراعتها في مخلوط مكون من ٤مجم/لتر سليكون + ٢ مجم/لتر سلينيوم لمدة ٨ ساعات بالإضافة الى رش النباتات بمخلوط مكون من ٢ مجم /لتر سليكون + ٠.٥ مجم /لتر سلينيوم ثلاث مرات (٤٠و ٦٠ و٨٠ يوما من الزراعة) أعلى القيم في متوسط وزن البصلة، المحصول الأخضر القابل للتسويق والمحصول الكلي، وكذلك المكونات الكيميائية.

التوصية: لإنتاج ثوم أخضر للتصدير ذو مواصفات تصديرية جيدة ومحصول وفير ينصح بزراعة الثوم مبكراً في نهاية شهر أغسطس ولحماية التقاوى والبادرات الصغيرة من التأثير السىء لدرجات الحرارة العالية في هذا التوقيت ينصح بنقع الفصوص قبل زراعتها في مخلوط السليكون بتركيز ٤ مجم/لتر + السيلينيوم بتركيز ٢ مجم/لتر وكذلك رش النباتات ٣ مرات (٤٠، ٦٠ و٨٠ يوما من الزراعة) بالسليكون بتركيز ٢ مجم/لتر + السلينيوم بتركيز ٠.٥ مجم لتر.