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Effect of Potassium Fertilization and Foliar Spray with Potassium Silicate and Chitosan on Yield and Quality of Garlic Products in Siwa Oasis

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Abstract: Two successful field trials were carried out at Siwa Oasis research station, Desert Research Center (DRC) Marsa Matrouh Governorate., Egypt during 2015 /2016 and /2016 2017 seasons to study the effect of foliar spray with potassium silicate) PS at 5 and 10g/L and (Chitosan at rate200 and 400 ppm as well as control (and potassium sulphat fertilization at 0, 75 and 100 kg./fed; on growth, yield and bulb quality of garlic cv. Sids 40. Chitosan foliar spray at rate of 400 ppm gave the best values of growth characters (plant height, fresh and dry weight, neck and bulb diameter and leaf number) and total fresh yield as ton per fed. in the same trend K fertilization at rate 100 kg./fed., gave the highest values of growth characters, total yield and NPK uptake addition to protein and NPK leave content. The interaction between foliar spray of chitosan foliar spray at rate 400 ppm combined with fertilization with K at rate of 100 kg / fed., gave the highest growth characters and total yield in both seasons. The garlic bulbs of the last combined treatment were dried by two methods (open air sun drying and microwave drying) after subjected to some pretreatments (without any treatment as control, soaking in 1 % citric acid solution for 5 min. and soaking in 0.3 % potassium metabisulphite for 5 min). The results illustrated that, either sun drying or microwave drying resulted in accepted quality parameters for the dried garlic end product, but microwave dried garlic had more desirable quality parameters than sun dried garlic. In the same time, the studied pretreatments (citric acid or potassium metabisulfite) led to improve the quality attributes of the dried garlic products comparing with control samples.

Key words: Garlic · N, P, K., Chitosan · Yield · Growth · Open air sun drying microwave drying · Pretreatments · Products quality parameters

INTRODUCTION

Siwa Oasis is located in the Northern part of the Western Desert of Egypt it is characterized by hot and dry climate conditions. The main activity in Siwa Oasis is agriculture which is depending on the groundwater and flood irrigation system in most of agricultural areas.

Garlic (*Alium sativium* L.) was grown and consumed in the age of the Egyptian pyramids about 2780-2100 B.C. [1]. It is consider one of the most important bulb vegetable crops and it is the next after onion in importance and consumed as fresh, as well as dried in the spice form. As regard, garlic cloves for several medicinal values and is used all over the world and has Anti-infective properties such as power suppliers, insecticidal, anti-bacterial, antifungal, anti-cancer. Also, reduce blood sugar, blood lipids [2]. Egypt occupied the fourth country in the world for garlic production. The total cultivated area of garlic In Egypt, was about 12657 hectare, during 2017 season which produced 274668 tons with average of 21.7 tons/ha [3].

Increasing garlic production in Egypt has become of great increasing meet the ever increased demand of local consumption and exportation. Such increase could be achieve by growing garlic in the reclaimed areas with using natural and bio substrates for obtaining safe and healthy production, increasing garlic yield and improving bulb quality are essential aim for both growers and consumers.

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Potassium silicate (K_2SiO_3) (10% K_2O and 25% SiO) plays an important role on growth, yield and fruit quality of watermelon by improving plant resistance to disease infections and pests, salinity, drought, high temperature and nutrient imbalance [4]. Silicon (Si) has important potential in the plant growth and development [5]. PS is the main source of soluble potassium and silicon. In general, plants require silica to resist against biotic and abiotic stress [4]. Taking into consideration, silicon increases the control of viral, fungal and bacterial diseases in plants [6]. In addition PS increased the physiological activity such as photosynthetic pigments, osmoregulation solutes and enzyme activity, while decreased the malondialdehyde and membrane leakage of onion plant [7]. Moreover, application potassium silicate led to increasing fresh and dry weight, stem diameter, nutrient concentrations such as P and K in leaves, chlorophyll content, fruit weight, merchantable watermelon fruits and sugar content [8]. Also, Abd-Alkarim *et al*. [9] on cucumber plants found that silicon led to improving fruit quality characteristics such as increased values of ascorbic acid and total soluble solids.

Chitosan is derived from chitin, a polysaccharide found in exoskeleton of shellfish such as shrimp, lobster or crabs and cell wall of fungi [10]. Recently, some researchers reported that chitosan enhanced plant growth [11-13]. They reported that application of chitosan increased key enzymes activities of nitrogen metabolism (nitrate reeducates, glutamine synthetase and protease) and improved the transportation of nitrogen in the functional leaves, which is in turn, enhance plant growth. Also, Mondal *et al.* [14] reported that growth parameters, biochemical constituents and yield of okra were increased with increasing concentration of chitosan application up to 125 ppm. Moreover, chitosan treatment improved storability of post harvest fruits and vegetables. Numerous studies have reported the ability of chitosan to increase plant growth (height, leaves number, fresh and dry weight), yield components (fruit number/plant, fruit weight and total yield), also mineral contents of N, P and K in different plant species such as strawberry, cucumber and tomato [15, 13, 16]. On strawberry plant El-Miniawy *et al*. [17] revealed that the foliar applications of chitosan increased all vegetative growth characteristics (plant length, number of leaves/plant, leaf area, root and vegetative growth fresh and dry weights) and yield attributes (fruit weight, early and total yields/plant). On artichoke plants Gehan and Ghoneim [18] reported that the chitosan foliar spraying at rate 300 ppm significantly increased plant growth characters, head yield and its components.

Potassium is necessary in young growing tissues for cell elongation and possibly for cell division. It is very mobile in plants and therefore circulates freely and has vital role in maintenance of turgor pressure. It has also a role in stomata respiration, photosynthetic transfer, crop development. Fawzy, *et al*. [19] stated that highest dry weight and N, P and K% in eggplant were obtained by foliar application of potassium which was more efficient. On the other hand, K plays a key role in the activation of more than 60 enzyme systems in plants and involved in the formation of cell structure. Potassium is essential for growth, maintains cell turgidity and to regulate the water content of plants [20]. Besma, *et al*. [21] found that K enhances water uptake and root permeability and acts as a guard cell controller, beside its role in increasing water use efficiency. Applied high dose of potassium to the soil with foliar spray at rate 0.5% K_2O, gave the maximum values of garlic total yield. In addition, plant growth, TSS, Vitamin C content and potassium uptake was significantly enhanced due to the applications of higher levels of potassium fertilizer, while N content was significantly reduced [22].

The aim of this work was to study the effect of different rates of potassium fertilizers and foliar spray with chitosan and potassium silicate on growth, total bulb yield and its components, as well as the nutritional contents of garlic cloves in addition to evaluation of the quality parameters of dried garlic (open air sun drying and microwave drying) after some pretreatments (soaking in citric acid and potassium metabisulphite solutions).

MATERIALS AND METHODS

This study was carried out at Siwa Research Station of the Desert Research Center (DRC), Khimisah Farm, Marsa Matruh Governorate, Egypt, during the two consecutive winter seasons of 2015/2016 and 2016/2017 to study the response of Garlic (*Alium sativium* L). Sids 40 cultivar to potassium fertilizer at three rates 0, 75 and 100 kg K_2O/fed. and foliar application with potassium silicate (PS) at 5 and 10g./L and chitosan (CH) at 200 and 400 ppm as well as control treatment on growth parameters, yield and chemical composition under Siwa Oasis conditions.

Garlic cloves were sowing at 10th and 15th October through the two growing seasons, respectively. Experimental unit area was 10.5 m^2. (10.5 m. long x 1.0 m. width), which is consisted of six ridges. Garlic cloves were socked in warm water for 12 hr. The planting within six lines for each ridge 10 cm a part between cloves.

Soil fertilizer application treatments were applied through five times, *i.e*, after 30, 50, 70, 90 and 110 days from planting date, while foliar spray treatments applied after 30, 40 and 50 days from germination date. Organic manure (chicken manure) was added at the rate of 10 m^3/fed; while calcium super-phosphate (15.5% P_2O_5) added at the rate of 300 kg/fed. during soil preparation. Nitrogen fertilizer as ammonium sulphate (20.5% N) at the rate of 300 kg /fed; quantity of nitrogen divided and applied at five times after 30, 60, 70, 80 and 90 days from planting through the irrigation drip irrigation systems.

Processing Materials: Garlic bulbs of the best agricultural treatment (chitosan foliar spray at rate 400 ppm combined with fertilization with K at rate of 100 kg / fed.) were collected fresh from the field at Siwa Oasis, Egypt during April.

- Citric acid E330 manufacture: TTCA OC., Ltd China
- Potassium metabisulfite were purchased from El-Gomhoria Co. Cairo, Egypt.
- Commercial garlic powder (for sensory evaluation) was purchased from the local market.

Experimental Design: A split plot design with three replicates was adopted. Each replicate included 15 treatments which were the combinations of 3 levels of potassium sulphate were added as soil application with 4 different levels of potassium silicate and chitosan as foliar spray as well as control treatment. The main plots were foliar spray application, while sub plots were soil addition treatments.

The physical and chemical soil characteristics of the studied site were determined according to Page *et al.* [23] and Klute [24], respectively as recorded in Table 1. The chemical analysis of irrigation water was carried out using the standard method of Page *et al*. [23] and presented in Table 2. The experimental trails were conducted in sandy soil using drip irrigation systems.

Data Recorded: After 150 days from planting, ten plants from each experimental plot were randomly taken for recording vegetative growth characteristics, *i.e*., plant height, number of leaves /plant, fresh weight/plant (gm) and dry weight of kg /fed., Bulb and neck diameter, fresh total yield of ton/fed. and N, P, K uptake of bulb (kg /fed).

Uptake = (dry weight per bulb X % to elements)/100

Garlic Samples Preparation for Drying: Garlic samples (of the best agricultural treatment for the second season) were cleaned, peeled and sliced (3 mm thickness) before drying. Garlic slices were divided into six parts as follow:

- The first part was dried by open sun drying without any treatment (sun cont.)
- The second part was dried by open sun drying after soaking in 1 % citric acid solution for 5 min. (sun CA)
- The third part was dried by open sun drying after soaking in 0.3 % potassium metabisulphite for 5 min. (sun KMS)
- The fourth part was dried by microwave oven (1200 W) without any treatment (Mwave cont.)
- The fifth part was dried by microwave oven (1200 W) after soaking in 1 % citric acid solution for 5 min. (Mwave CA)
- The sixth part was dried by microwave oven (1200 W) after soaking in 0.3 % potassium metabisulphite for 5 min (Mwave KMS).

Chemical Composition: Sample of garlic plants leaves and bulbs were taken and oven dried at 70 until stable weight, then ground to find particles and wet digested according to Peterburgski [25] by using mixture of H_2SO_4 and $HCLO_4$. N, P and K were determined according to methods described by Black *et al.* [26] and Chapman and Pratt [27]. In addition, the protein percentages were calculated by multiplying nitrogen content by 6.25.

Essential Oil Extraction (Volatile Oil): Essential oil percentage (ml / 100 g) of each dried garlic sample was determined with hydro-distillation for 3 hours at Clevenger-type apparatus using 30 g of dried cloves according to the Egyptian Pharmacopoeia [28]. The resulted essential oil of each processing treatment was separately dehydrated with anhydrous sodium sulphate and kept in the deep freezer until GC-MS analyses.

GC-MS Analysis of Volatile Components: The GC-Ms analysis of the essential oil was carried out using gas chromatography-mass spectrometry instrument stands at the Department of Medicinal and Aromatic Plants Research, National Research Center, Giza, Egypt, with the following specifications;

Instrument: a TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA), coupled with a THERMO mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). The GC-MS system was equipped with a TG-5MS column (30 m x 0.25 mm i.d., 0.25 µm film thickness). Analyses were carried out using helium as carrier gas at a flow rate of 1.0 ml/min and a split

Table 1: Some physical and chemical properties of the experimental soil site (average two seasons)

		Soluble anions (me/l)					Soluble cations (me/l)			
Soil depth (cm)	Texture class	HCO_3^-	$SO_4^=$	Cl^-	pH soil paste	E.C dSm^{-1}	Ca^{++}	Mg^{++}	Na^+	K^+
0 - 25	Sandy loam	0.75	0.85	4.25	6.7	0.58	1.15	0.45	3.92	0.33

pH: Acidity E.C.: Electrical conductivity me/l: milli equivalent per liter.

Table 2: Chemical analysis of the irrigation water (average two seasons)

			Soluble cations (me/l)		Soluble anions (me/l)				
Samples	pH	E.C. dSm^{-1}	Ca^{++}	Mg^{++}	Na^+	K^+	HCO_3^-	$SO_4^=$	Cl^-
Average	7.1	5.54	10.1	13.32	39.4	1.17	9.35	15.1	39.5

pH: Acidity, E.C.: Electrical conductivity, dSm-1: decseime per meter.

ratio of 1:10 using the following temperature program: 60°C for 1 min; rising at 3.0°C /min to 240°C and held for 1 min. The injector and detector were held at 240°C. Diluted samples (1:10 hexane, v/v) of 0.2 µL of the mixtures were always injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 40-450. Most of the compounds were identified using the analytical method: mass spectra (authentic chemicals, Wiley spectral library collection and NSIT library).

Moisture Content: Moisture content of dried garlic was determined according to the AOAC [29].

Browning Index: Browning index dried garlic was calculated as optical density (O.D.) at 440 nm by treating 5gm in 50 ml ethanol alcohol [30].

Rehydration Ratio (%): The rehydration ratio is one of the most important factors in the dehydrated product. The rehydration ratio was determined by placing a weighed sample of dehydration garlic slices (approximately 20 g) in boiling water for 10 min, draining for 2 min and reweighing the sample. All measurements were carried out in triplicate and the averages were reported [31].

Organoleptic Evaluation: Organoleptic evaluation of the dried garlic samples was conducted on a 5 point hedonic scale. A semi-trained panel of 10 judges was selected for the evaluation. The samples were evaluated in terms of color, aroma, texture and overall acceptability. The judges did not taste the samples [32].

Statistical Analysis of Agricultural Trails: The experimental treatments were arranged in split plot design with three replicates; the main plots were assigned for foliar spray with potassium silicate and chitosan treatments, whereas potassium fertilizer levels were randomly arranged in the sub plots. Statistical analyses of the obtained data were analyzed according to Thomas and Hills [33].

Statistical Analysis of Garlic Processing: All determinations were carried out in triplicate and data is reported as mean. Significant differences ($p<0.05$) were calculated using Duncan's multiple range test, followed the method reported by Steel and Torrie [34].

RESULTS AND DISCUSSION

Growth Characters: Data presented in Tables (3 and 4) indicated that the garlic plants were showed significant positive effects for foliar spray with potassium silicate and chitosan on plant height, fresh weight /plant, leaves number and dry weight kg/fed. The highest values on growth characters were recorded with chitosan foliar sprayed at rate 400 ppm; while the highest values of leaves number were found with 10 gm/L. of potassium silicate in both growing seasons. These results may be due to the role of chitosan to improve the transportation of nitrogen in the functional leaves, which is in turn, enhance plant growth. These results agreed with those obtained by Chibu and Shibayama [11]; Gornik *et al.* [12]; Shehata *et al.* [13]; El-Miniawy *et al*. [17] and Gehan and Ghoneim [18].

As for the effect of potassium soil application, date in Table 3 and 4 showed that the highest values of growth parametes were obtained at rate of 100 Kg. K_2O/fed. compared with check and other soil application treatments in both growing seasons. The positive effect of potassium application may be due to helps in several physiological processes and uptake of other nutrient elements and role in the activation of more than 60 enzyme systems in plants and involved in the formation of cell structure. The obtained results were harmony with those obtained by Fawzy, *et al*. [19]; Rengel and Damon [20] and Besma, *et al*. [21].

Table 3: Effect of potassium fertilizer, chitosan and potassium silicate on plant height and fresh weight /plant of garlic during 2015/2016 and 2016/2017 seasons

	Plant height (cm) Potassium fertilizer (Kg./fed.)				Fresh weight (gm) Potassium fertilizer (Kg./fed.)			
				First Season				
Foliar spray treatments	0	75 Kg.	100 Kg.	Mean	0	75 Kg.	100 Kg.	Mean
Check	47.47	54.21	58.85	53.51	112.35	131.97	136.00	126.77
5 gm. PS.	49.08	59.01	56.49	54.86	128.17	140.17	144.81	137.71
10 gm. PS.	56.21	61.48	58.61	58.77	138.39	165.85	170.10	158.11
200 ppm CH.	48.42	55.57	55.79	53.26	127.73	171.47	189.80	163.00
400 ppm CH	58.65	65.72	72.23	65.53	138.00	175.00	196.88	169.96
Mean	51.97	59.20	60.39		128.93	156.89	167.52	
LSD at 0.05	A=1.66	B=2.48	AXB=5.54		A=3.55	B=1.86	AXB=4.17	
				Second Season				
Check	47.53	50.33	55.57	51.14	105.00	123.33	127.33	118.56
5 gm. PS.	48.67	55.67	55.47	53.27	121.33	131.00	135.33	129.22
10 gm. PS.	53.38	55.00	56.67	55.01	129.26	155.00	164.57	149.61
200 ppm CH.	46.00	54.00	54.33	51.44	121.07	155.50	170.10	148.89
400 ppm CH	55.33	62.00	67.33	61.56	129.33	165.17	184.00	159.50
Mean	50.18	55.40	57.87		121.20	146.00	156.27	
LSD at 0.05	A= 1.79	B=1.68	AXB= 3.76		A=2.51	B=2.23	AXB= 4.99	

CH.=Chitosan PS. = potassium silicate

Table 4: Effect of potassium fertilizer, chitosan and potassium silicate on leaves number and dry weight kg/fed. of garlic during 2015/2016 and 2016/2017 seasons

	Leaves number/plant Potassium fertilizer (Kg. /fed.)				Dry weight (kg/fed.) Potassium fertilizer (Kg. /fed.)			
Foliar spray treatments				First Season				
	0	75 Kg.	100 Kg.	Mean	0	75 Kg.	100 Kg.	Mean
Check	9.63	10.70	11.06	10.46	2085.85	2478.30	2551.63	2371.925
gm. PS.	10.77	10.70	10.78	10.75	2439.74	2640.63	2733.23	2604.54
10 gm. PS.	10.70	11.41	11.77	11.29	2573.14	3081.14	3211.13	2955.14
200 ppm CH.	9.63	11.06	10.99	10.56	2351.53	3185.23	3493.87	3010.21
400 ppm CH	9.99	11.06	11.77	10.94	2531.33	3283.67	3614.00	3143.00
Mean	10.14	10.98	11.27		2396.32	2933.79	3120.77	
LSD at 0.05	A=0.79	B=0.57	AXB=1.28		A=4.95	B=4.08	AXB=9.13	
				Second Season				
Check	9.00	10.00	10.33	9.78	1892.16	2311.40	2235.90	2146.49
5 gm. PS.	10.00	10.00	11.00	10.33	2251.10	2485.63	2436.40	2391.04
10 gm. PS.	10.00	10.67	11.33	10.67	2406.50	2183.93	2879.17	2489.87
200 ppm CH.	9.00	10.33	10.67	10.00	2176.47	2264.03	2911.27	2450.59
400 ppm CH	9.33	10.33	11.00	10.22	2367.53	2272.43	3021.77	2553.91
Mean	9.47	10.27	10.87		2218.75	2303.49	2696.90	
LSD at 0.05	A=0.86	B=0.51	AXB=1.14		A=600.18	B=586.72	AXB=1311.94	

CH.=Chitosan PS. = potassium silicate

The interaction between the two studied factors revealed a significant increment of growth characters; the highest values were obtained with K soil application at rate of 100 Kg/fed. combined with foliar spray with chitosan at the rate of 400 ppm compared with all tested treatments in both tested seasons. The highest leave number were found with K soil application at rate of 100 Kg/fed. combined with 10 gm/L. potassium silicate foliar spray. These results agreed with Datnoff *et al.* [5] and Kim *et al*. [8].

Table 5: Effect of potassium fertilizer, chitosan and potassium silicate on fresh total yield (ton/fed.) of garlic during 2015/2016 and 2016/2017 seasons

	Potassium fertilizer (Kg./fed.)				Potassium fertilizer (Kg./fed.)			
	First Season				Second Season			
Foliar spray treatments	0	75 Kg.	100 Kg.	Mean	0	75 Kg.	100 Kg.	Mean
Check	14.83	17.42	17.95	16.73	13.86	16.28	16.81	15.65
5 gm. PS.	16.92	18.50	19.11	18.18	16.02	17.29	17.86	17.06
10 gm. PS.	18.27	21.89	22.45	20.87	17.06	20.46	21.72	19.75
200 ppm CH.	16.86	22.63	25.05	21.52	15.98	20.53	22.45	19.65
400 ppm CH	18.22	23.10	25.99	22.43	17.07	21.80	24.29	21.05
Mean	17.02	20.71	22.11		16.00	19.27	20.63	
LSD at 0.05	A=0.47	B=0.25	AXB=0.55		A=0.33	B=0.29	AXB=0.66	

CH.=Chitosan PS. = potassium silicate

Table 6: Effect of potassium fertilizer, chitosan and potassium silicate on head and neck diameter of garlic during 2015/2016 and 2016/2017 seasons

	Bulb diameter (mm) Potassium fertilizer (Kg./fed.)				Neck diameter (mm) Potassium fertilizer (Kg./fed.)			
Foliar spray treatments				First Season				
	0	75 Kg.	100 Kg.	Mean	0	75 Kg.	100 Kg.	Mean
Check	27.21	32.46	34.95	31.54	11.66	14.84	15.19	13.90
5 gm. PS.	30.17	33.88	36.02	33.36	14.13	14.49	15.29	14.64
10 gm. PS.	32.22	35.67	36.44	34.77	14.30	15.55	16.15	15.33
200 ppm CH.	29.60	34.24	35.87	33.24	13.07	15.35	16.47	14.96
400 ppm CH	30.37	35.56	36.90	34.28	15.55	15.90	17.67	16.37
Mean	29.91	34.36	36.04		13.74	15.23	16.15	
LSD at 0.05	A= 2.63	B=2.48	AXB= 5.55		A= 1.03	B=1.37	AXB= 3.07	
				Second Season				
Check	26.33	30.33	32.67	29.78	11.00	14.00	14.33	13.11
5 gm. PS.	29.67	31.67	33.67	31.67	13.33	13.33	14.67	13.78
10 gm. PS.	30.11	33.33	34.00	32.48	13.78	14.67	15.33	14.59
200 ppm CH.	27.67	32.00	34.00	31.22	12.33	15.33	15.67	14.44
400 ppm CH	27.00	30.00	33.00	30.00	14.67	15.00	16.67	15.44
Mean	28.16	31.47	33.47		13.02	14.47	15.33	
LSD at 0.05	A= 2.71	B=2.42	AXB= 5.41		A=0.84	B=1.31	AXB= 2.93	

CH.=Chitosan PS. = potassium silicate

Bulb and Neck Diameter and Total Yield: Data presented in Table (5 and 6) showed that, foliar spray with potassium silicate and chitosan resulted in a significant increase of fresh total yield, neck and bulb diameter, the highest results were noticed with plants treated with 400 ppm in both growing seasons compared with check and other treatment. These results agreed with Mondal *et al.* [14]; El-Miniawy *et al*. [17] and Gehan and Ghoneim [18] they mentioned that the chitosan foliar applications increased all vegetative growth characteristics and yield and its components when the plant sprayed with chitosan at rate 300 ppm.

As regard to the effect of potassium on the fresh total yield, neck and bulb diameter of garlic plants significant increments were detected due to potassium application as compared with check and other treatments; the highest values were found with K at rate of 100 Kg/fed. in both growing seasons. The positive effect on fresh total yield, neck and head diameter may be due to it's effect on K function on plants, improves yield and quality. Beside K more necessary that essential for growth, maintains cell turgidity and regulate the water content of plants. These results agreed with Rengel and Damon [20].

The interaction between K fertilizer and either potassium silicate or chitosan foliar spray showed that the highest values of fresh total yield, neck and bulb diameter were found with plants sprayed with 400 ppm chitosan per liter combined with soil application of K at rate 100 Kg./fed. compared with the other treatments in both tested seasons. These results agreed with Abdel Mawgoud *et al*. [15]; Shehata *et al*. [13], Abd El Gawad and Bondok [16] and Gehan and Ghoneim [18].

Table 7: Effect of potassium fertilizer, chitosan and potassium silicate on N and P uptake kg /fed of garlic during 2015/2016 and 2016/2017 seasons

	N uptake kg/fed. Potassium fertilizer (Kg./fed.)				P uptake kg/fed. Potassium fertilizer (Kg./fed.)			
Foliar spray treatments				First Season				
	0	75 Kg.	100 Kg.	Mean	0	75 Kg.	100 Kg.	Mean
Check	8.55	10.16	10.46	9.72	3.55	4.21	4.34	4.03
5 gm. PS.	10.00	10.83	11.21	10.68	4.15	4.49	4.65	4.43
10 gm. PS.	10.55	12.63	13.17	12.12	4.37	5.24	5.46	5.02
200 ppm CH.	9.64	13.06	14.32	12.34	4.00	5.41	5.94	5.12
400 ppm CH	10.38	13.46	14.82	12.89	4.30	5.58	6.14	5.34
Mean	9.82	12.03	12.80		4.07	4.99	5.31	
LSD at 0.05	A=0.02	B=0.02	AXB=0.04		A=0.01	B=0.01	AXB=0.02	
				Second Season				
Check	7.76	9.48	9.17	8.80	3.03	3.70	3.58	3.43
5 gm. PS.	9.23	10.19	9.99	9.80	3.60	3.98	3.90	3.83
10 gm. PS.	9.87	8.95	11.80	10.21	3.85	3.49	4.61	3.98
200 ppm CH.	8.92	9.28	11.94	10.05	3.48	3.62	4.66	3.92
400 ppm CH	9.71	9.32	12.39	10.47	3.79	3.64	4.83	4.09
Mean	9.10	9.44	11.06		3.55	3.69	4.32	
LSD at 0.05	A=2.46	B=2.41	AXB=5.38		A=0.96	B=0.94	AXB=2.10	

CH.=Chitosan PS. = potassium silicate

Table 8: Effect of potassium fertilizer, chitosan and potassium silicate on K uptake kg /fed. and protein of garlic during 2015/2016 and 2016/2017 seasons

	K uptake kg/fed Potassium fertilizer (Kg./fed.)				Protein % Potassium fertilizer (Kg./fed.)			
Foliar spray treatments				First Season				
	0	75 Kg.	100 Kg.	Mean	0	75 Kg.	100 Kg.	Mean
Check	9.80	11.65	11.99	11.15	2.56	2.88	3.00	2.81
5 gm. PS.	11.47	12.41	12.85	12.24	3.13	3.27	3.33	3.24
10 gm. PS.	12.09	14.48	15.09	13.89	3.26	3.35	3.44	3.35
200 ppm CH.	11.05	14.97	16.42	14.15	3.06	3.83	4.00	3.63
400 ppm CH	11.90	15.43	16.99	14.77	3.21	4.13	4.44	3.92
Mean	11.26	13.79	14.67		3.04	3.49	3.64	
LSD at 0.05	A=0.02	B=0.02	AXB=0.04		A=0.07	B=0.04	AXB=0.09	
				Second Season				
Check	8.51	10.40	10.06	9.66	2.56	2.77	2.92	2.75
5 gm. PS.	10.13	11.19	10.96	10.76	2.92	2.92	3.44	3.09
10 gm. PS.	10.83	9.83	12.96	11.20	3.20	3.33	3.40	3.31
200 ppm CH.	9.79	10.19	13.10	11.03	2.90	3.71	3.88	3.49
400 ppm CH	10.65	10.23	13.60	11.49	3.10	4.00	4.19	3.76
Mean	9.98	10.37	12.14		2.94	3.35	3.56	
LSD at 0.05	A=2.70	B=2.64	AXB=5.90		A=0.09	B=0.07	AXB=0.16	

CH.=Chitosan PS. = potassium silicate

Chemical Composition: Data presented in Tables (7, 8 and 9) showed the influence of foliar spray with potassium silicate and chitosan as well as K fertilizer on N, P and K uptake, protein and NPK in garlic leaves contents in both investigated seasons. Obtained data indicated that the highest content of N, P and K uptake, protein and NPK in garlic leaves contents were detected with plants sprayed with chitosan at rate 400 ppm., compared with check and other treatments they showed the gradually increased within check to chitosan at rate 400 ppm. These results were true in both growing seasons and agreed with those obtained by Abdel Mawgoud *et al*. [15]; Shehata *et al*. [13] and Abd El Gawad and Bondok [16].

As regard to K fertilization, its application at rate 100 Kg/fed. significantly increased N, P and K uptake, protein and NPK in garlic leaves contents, respectively within plant tissues compared with other level of K treatments. These results were true in both growing

seasons and agreed with those obtained by Fawzy *et al*. [19]; Rengel and Damon [20] and Besma *et al*. [21] they found that K enhances water uptake and root permeability and acts as a guard cell controller, beside its role in increasing water use efficiency.

Concerning effect of the interaction between K fertilization and foliar spray with potassium silicate and chitosan on minerals content and uptake, the highest value of N, P and K uptake, protein and NPK in garlic leaves contents were recorded with K at rate 100 Kg. /fed. combined with chitosan at rate 400 ppm/L., compared with the all investigated treatments in the first and second seasons.

Garlic Processing: Garlic fruits of the best agricultural treatment (chitosan foliar spray at rate 400 ppm/L combined with fertilization with K at rate of 100 kg / fed) were dried by two methods (open air sun drying and microwave drying) after treating with some pretreatments.

The effect of drying method and pretreatments on the quality parameters of the obtained dried garlic samples was studied and the results were presented in Table 10, 11 and 12 and Fig 1.

Data presented in Table (10) indicated that using microwave oven for drying garlic slices led to decrease the required time for drying comparing to sun drying, while the studied pretreatments had no effect on drying time.

Concerning to the moisture content, results in the same Table, it could be noticed that, the end product of sun drying process had more moisture content than that of microwave drying, in the same time pretreatment seem to have negligible effect on moisture content for each drying methods separately. These results agreed with those reported by Mansingh [35], who reported that the maximum moisture content (7.57%) of dried garlic was recorded for solar dried sample while the minimum (5.52%) was recorded for microwave dried sample. This is due the fact that the moisture content decreases rapidly with temperature increasing.

Regarding to the browning index results in Table (10), it could be noticed that microwave drying resulted in darker dried garlic than that of sun dried garlic. In the same time, potassium metabisulfite treatment recorded the lightest end product (the lowest browning index) followed by citric acid treatment, then control samples, for either sun dried or microwaves dried samples. These results are agreed with those reported by Kim *et al*. [36], who reported that soaking of garlic slices in 0.5% sodium metabisulphate solution for 20 min prior to drying reduce pyruvate loss during heating and inhibited browning and reduced microbial counts, which proved better storage for garlic.

In relation to the results of rehydration ratio in the same table, the presented data illustrated that, microwave dried samples had higher rehydration ratio in comparison with sun drying, this may be due to the long period of sun drying resulted in the action of degradable enzymes to take place for soluble fibers. These results are agreed with those of Zheng-Wei *et al*. [31], who reported that, microwave-vacuum air dried garlic sample had the highest rehydration ratio in comparison to hot air drying and freeze drying.

The presented results in Fig. (1), showed the effect of drying method and pretreatments on volatile oil content (%) of dried samples. From the presented data, it could be observed that, microwave drying led to maintain more ratio of volatile oil than sun drying for all studied pretreatments. This may be due to the long period required for garlic drying by sun drying in open air.

The effect of drying method and pretreatments on volatile compounds of garlic was determined and the obtained results were tabulated in Table (11).

Volatiles analysis led to the detection of 37 volatile components belonging to various classes including mostly sulfur compounds. Major identified sulphur volatiles included diallyl disulphide (52.21–60.53%) followed by Trisulfide, di-2-propenyl (20.82- 30.84%). In the current study, several sulphur rearrangement products (*i.e*., identified allyl compounds along with a cyclic, 3-vinyl-1, 2-dithiacyclohex-5-ene (M21)) were detected in *A. sativum* and likely to have been formed at the high temperature of the GC/MS injection port [37].

Also Gregrova *et al*. [38], reported that main Sulfur compounds is un stable (when exposed to air or at elevated temperatures) and degrades into various sulphur compounds after volatile ones (mono, di and trisulphide).

Regarding to the effect of studied treatments on sensory attributes of the obtained dried garlic in comparison with commercial garlic powder, the tabulated data in table (12), illustrated obviously that, all studied treatments produced dried garlic powders with more desirable color than commercial sample, where the highest color value (4.72) was recorded for Sun KMS treatment, followed by Sun CA treatment. On the other hand, the lowest color value (3.88) was recorded for commercial sample followed by Mwave cont. treatment.

Concerning to odor and texture results in the same table, it could be noticed that, commercial sample had the highest odor and texture values (4.05 and 4.33, respectively) followed by Mwave KMS treatment (4.00 and 4.22, respectively).

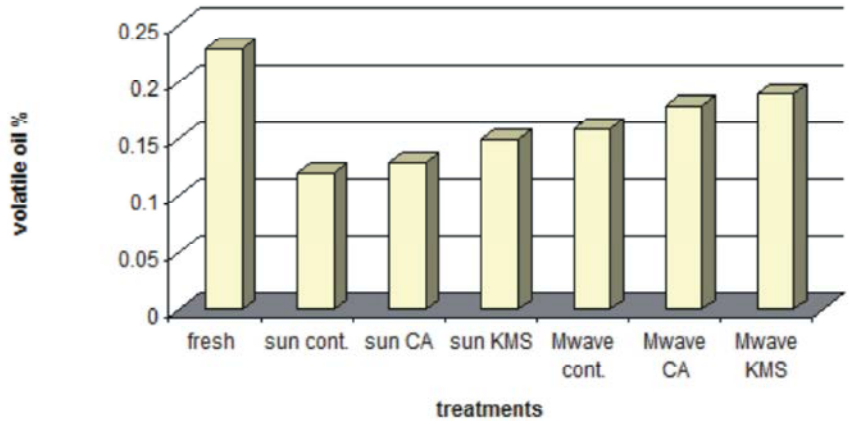

Fig. 1: Effect of drying method and pretreatments on Volatile oil (%)

Table 9: Effect of potassium fertilizer, chitosan and potassium silicate on N, P and K% of leaves garlic during 2015/2016 and 2016/2017 seasons

	First Season				Second Season			
				N %				
	Potassium fertilizer (Kg./fed.)				Potassium fertilizer (Kg./fed.)			
Foliar spray treatments	0	75 Kg.	100 Kg.	Mean	0	75 Kg.	100 Kg.	Mean
Check	0.41	0.46	0.48	0.45	0.41	0.44	0.47	0.44
5 gm. PS.	0.50	0.52	0.53	0.52	0.47	0.52	0.55	0.51
10 gm. PS.	0.51	0.54	0.55	0.53	0.47	0.53	0.54	0.51
200 ppm CH.	0.49	0.61	0.64	0.58	0.46	0.59	0.62	0.56
400 ppm CH	0.51	0.66	0.71	0.63	0.50	0.64	0.67	0.60
Mean	0.48	0.56	0.58		0.46	0.54	0.57	
				P %				
Check	0.16	0.17	0.18	0.17	0.15	0.15	0.16	0.15
5 gm. PS.	0.17	0.19	0.2	0.19	0.15	0.16	0.18	0.16
10 gm. PS.	0.18	0.22	0.23	0.21	0.16	0.19	0.22	0.19
200 ppm CH.	0.19	0.24	0.25	0.23	0.17	0.24	0.25	0.22
400 ppm CH	0.2	0.26	0.28	0.25	0.18	0.25	0.25	0.23
Mean	0.18	0.22	0.23		0.16	0.20	0.21	
				K %				
Check	0.48	0.53	0.56	0.52	0.45	0.51	0.54	0.50
5 gm. PS.	0.49	0.55	0.57	0.54	0.46	0.54	0.55	0.52
10 gm. PS.	0.52	0.65	0.71	0.63	0.49	0.61	0.67	0.59
200 ppm CH.	0.51	0.74	0.76	0.67	0.48	0.71	0.73	0.64
400 ppm CH	0.52	0.77	0.87	0.72	0.49	0.75	0.76	0.67
Mean	0.50	0.65	0.69		0.47	0.62	0.65	

CH.=Chitosan PS. = potassium silicate

Table 10: Effects of drying method and pre-treatments on dried garlic characteristics

Treatments		Drying time	Initial moisture (%)	Final moisture (%)	Browning index O.D.	Rehydration ratio %
Open air sun drying	Sun cont.	10 h	68.00^{b}	8.43^{a}	0.025^{b}	295.0^{d}
	Sun CA	10 h	70.00^{a}	7.85^{b}	0.021^{c}	292.5^{d}
	Sun KMS	10 h	70.00^{a}	7.75^{b}	0.015^{e}	287.5^{d}
Microwave drying	Mwave cont.	25 min	68.00^{b}	4.10^{c}	0.031^{a}	339.5^{c}
	Mwave CA	25 min	70.00^{a}	3.60^{c}	0.026^{b}	364.5^{b}
	Mwave KMS	25 min	70.00^{a}	3.80^{c}	0.018^{d}	410.0^{a}
LSD			1.485	0.479	0.002	7.367

* Values bearing the same superscript within the same column are not significantly different (P> 0.05)

*Mwave cont= control Mwave CA=citric acid Mwave KMS= potassium metabisulphite

Table 11: The Effect of drying method and pretreatments on volatile components of garlic

		Area %							
No.	Compounds	Sun cont	Sun CA	Sun KMS	Mwave cont	Mwave CA	Mwave KMS	Fresh	R T
1	Diallyl sulfide	6.04	1.22	2.78	2.36	1.36	3.36	9.44	3.14
2	Disulfide, methyl 2-propenyl	1.21	--	--	--	--	--	--	4.24
3	Á-Pinene	--	0.61	3.21	0.58	--	0.70	0.98	4.41
4	Camphene	--	--	0.53	--	--	--	0.17	4.82
5	Sabinene	--	--	0.39	--	--	--	--	5.40
6	B-Pinene	--	0.22	2.47	--	--	0.23	0.35	5.54
7	Á-Terpinene	--	--	0.37	--	--	--	--	6.68
8	p-Cymene	--	--	1.39	0.81	0.41	--	--	6.97
9	D-Limonene		5.66	4.45	3.98	2.08	3.54	4.30	7.08
10	1, 8-Cineol	--	--	1.31	0.26	--	0.45	0.57	7.17
11	Γ-Terpinene	--	0.83	1.62	0.66	0.34	0.42	0.52	8.04
12	Diallyl disulphide	55.42	52.21	55.55	54.17	53.40	60.53	58.09	9.02
13	Disulfide, allyl propyl	0.63	0.46	0.44	0.66	0.49	0.70	0.56	9.50
14	Á-Thujone	--	--	0.70	--	--	--	--	9.94
15	2-Trimethylsilyl-1, 3-dithiane	4.02	0.34	--	--	--	0.17	0.26	11.34
16	Camphor	--	--	0.41	--	--	0.23	0.19	11.61
17	3-Vinyl-1, 2-dithiacyclohex-5-ene	1.55	--	--	--	--	0.20	--	12.33
18	2-vinyl-[4H]-1, 3-dithiin		--	--	--	--	0.38	0.23	13.55
19	3-Vinyl-1, 2-dithiacyclohex-5-ene	3.71	0.93	--	--	--	1.40	0.48	14.65
20	Eicosane	--	--	0.33	--	--	0.13	--	16.22
21	Trisulfide, di-2-propenyl	20.82	30.82	21.00	28.33	30.84	25.42	21.11	18.10
22	2-Octenal, 2-butyl-	1.41	--	--	--	0.35	0.19	--	20.78
23	Tetradecane	--	0.61	0.35	--	0.39	0.17	0.24	24.97
24	2-Allyl-5-t-butylhydroquinone	--	0.49	0.82	0.52	0.66	0.29	0.53	26.39
25	Hexadecane, 2, 6, 11, 15-tetramethyl	--	0.24	0.41	--	0.38	0.18	0.29	26.82
26	Tetrasulfide, di-2-propenyl	4.01	0.34	--	--	0.81	--	--	27.93
27	(-)-Caryophyllene oxide	--	0.44	--	--	--	--	0.17	29.10
28	Heptadecane, 2, 6, 10, 15-tetramethyl	--	0.22	0.41	0.28	0.36	--	0.17	34.63
29	3-Isopropyl-4-methyl-dec-1-en-4-ol	--	0.84	--	0.51	0.94	0.24	--	36.30
30	6-methy-l4, 5, 8, 9-tetrathia-1, 11 dodecadiene	1.18	0.64		0.34		0.43		37.89
31	Oleanitrile	--		--	0.44	0.32	--	--	46.46
32	Dotriacontane	--		--	0.64	--	--	--	46.92
33	Tetradecanamide	--	0.27	--	1.04	2.25	--	--	49.62
34	9-Octadecenamide, (Z)-	--	1.49	0.37	1.45	1.92	0.25	0.48	54.75
35	Octadecanamide	--	0.25	0.36	0.69	1.64	--	0.27	55.47
36	Erucylamide	--		--	1.29	--	--	--	56.60
37	Erucic acid	--	0.40	0.33	0.69	0.69	--	0.20	58.01

Table 12: The Effect of drying method and pretreatments on the sensory parameters of dried garlic in comparison with commercial dried garlic

	Color (5)	Odor (5)	Texture (5)	Over all acceptability (5)
Sun cont.	4.33^{c}	3.38^{d}	3.83^{c}	3.61^{f}
Sun CA	4.55^{b}	3.72^{c}	4.11^{ab}	4.22^{b}
Sun KMS	4.72^{a}	3.88^{b}	4.00^{b}	4.00^{d}
Mwave cont.	3.88^{e}	3.66^{c}	4.00^{b}	3.88^{e}
Mwave CA.	4.00^{de}	3.88^{b}	4.11^{ab}	4.11^{c}
Mwave KMS.	4.11^{d}	4.00^{a}	4.22^{a}	4.55^{a}
Commercial sample	3.38^{f}	4.05^{a}	4.33^{a}	3.88^{e}
LSD	0.12	0.10	0.12	0.07

* Values bearing the same superscript within the same colum

*Mwave cont= control Mwave CA=citric acid Mwave KMS= potassium metabisulphite

On the other side the results of over all acceptability in Table (12), demonstrated that the most acceptable sample was that of Mwave KMS treatment followed by that of Sun CA treatment, while the lowest acceptable sample was that of Sun cont. treatment followed by both of Mwave cont. treatment and commercial samples. These results are in agreement with those reported by Neha *et al*. [30], who found that the sensory score of microwave dried garlic sample (pretreated by soaking in 0.5% sodium metabisulphite for a duration of 20 minutes) was higher than that of both sun and solar dried samples either treated by 0.5% sodium metabisulphite or not treated.

CONCLUSION

From the previous results it could be concluded that the highest values of growth characters, total yield and NPK uptake addition to protein and NPK leave content were recorded when foliar spray of chitosan foliar spray at rate 400 ppm combined with fertilization with K at rate of 100 kg / fed., gave the highest growth characters and total yield in both seasons. In the same trend sun drying or microwave drying resulted in accepted quality parameters for the dried garlic end product, but microwave dried garlic had more desirable quality parameters than sun dried garlic. In the same time, the studied pretreatments (citric acid or potassium metabisulfite) led to improve the quality attributes of the dried garlic comparing with control samples.

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