Zagazig J. Agric. Res., Vol. 44 No. (6B) 2017 2501-2514

Horticultural Science

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

RESPONSE OF SWEET POTATO PLANTS TO SULPHUR, FARMYARD MANURE AND FOLIAR SPRAY WITH CHITOSAN
2. YIELD AND ITS COMPONENTS AS WELL AS TUBER ROOTS QUALITY

Fawzy Y.O. Mansour*

Hort. Res. Inst., Agric. Res. Cent., Giza, Egypt

Received: 16/10/2017 ; Accepted : 21/11/2017

ABSTRACT: Two field experiments were carried out during the two successive summer seasons of 2014 and 2015 at El-Gemmeiza Agric. Res. Station, Gharbeya Governorate, Egypt, to evaluate the effect of sulphur, farmyard manure (FYM) levels and chitosan concentration as foliar spray and their interactions on yield and its components as well as tuber roots quality of sweet potato (Buregard cv.) grown in clay soil. Average tuber root diameter, average tuber weight, both marketable and total yield, N, P, K, total sugars and total carbohydrates contents in tuber roots at harvest time were significantly increased with the triple interaction among 150 kg/fad., sulphur, 4 ton/fad., FYM and spraying plants with 150 ppm chitosan. The increases in total yield were about 101.20 and 93.51% in for the triple interaction among 150 kg/fad., sulphur, 4 ton/fad., FYM and chitosan sprayed at 150 ppm than the untreated plants with sulphur, FYM and chitosan in the 1st and 2nd seasons, respectively.

Key words: Sweet potato, sulphur, FYM levels and chitosan as foliar spray, yield and tuber root quality.

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is the seventh most important food crop in the worldwide, after wheat, rice, maize, potato, barley and cassava. The primary importance of sweet potato is in poor regions of the world. It is the fourth most important food crop in developing tropical countries and is grown in most of the tropical and subtropical regions of the earth, where the vine, as well as the roots, are consumed by humans and livestock (Woolfe, 1992). The total cultivated area of sweet potato devoted for production in 2013 in Egypt was 24,750 fad., which produced 320,000 tons with average 12.929 ton/fad., (FAO, 2014).

Sulphur applications frequently reduced soil pH, thus it increased availability of the most nutritional elements. Additionally, lowering pH can increase assimilation of nutrients as well as promote $SO4^-$ ions uptake through preventing their leaching (Hilal, 1990). Sulfur is an essential nutrient element for plant growth. The majority of sulfate taken up by plant is incorporated in cysteine and methionine amino acids which are highly important in proteins and enzymes synthesis (Haneklaus *et al*., 1997).

Treated plants with sulphur increased yield and its components (Pacha, 2003 on potato, Jaggi 2004 on onion; El-Morsy, 2005; Losak and Winiowska-Kielian, 2006; Farooqui *et al*., 2009; Abou El-Khair, 2010 on garlic; Klikocka, 2011; Klikocka *et al.,* 2015 on potato). Tuber root quality (Singh *et al*., 1995; Prakash *et al*., 1997; Chettri *et al*., 2002; Tantawy *et al*., 2009) and Sharma *et al.* 2011 on potato) .

A great attention has been directed towards the use of organic fertilizers to reduce plant and soil contaminations with mineral fertilizers, improve the fertility of soil and reduce nutrient losses. In addition, the organic fertilizers were considered good sources of plant nutrient supply and good soil conditioners. Addition of organic matter, can improve all soil properties especially sand soil; such as water holding capacity, soil aggregation, aggregation stability, soil fertility, and increase cation exchange capacity. Also,

* **Corresponding author: Tel. :** +201145203129
E-mail address: fawzyyehya20@gmail.com

organic fertilizers were used to decrease soil pH and increasing the availability of major and minor nutrients (Tahoun *et al,* 2000). As well as the increase in sweet potato plant growth after organic manure application may be due to the improving physic-chemical and biological properties of soil, *i.e.,* increasing soil organic matter, cation exchange capacity, available water and mineral nutrients and this in turn stimulate plant growth and dry matter (Etman *et al.*, 2002; Ayoub, 2005) on sweet potato plants.

Yield and its components significantly increased with increasing organic manure (Hoa *et al*. 2000; Santos *et al*., 2006; Ojeniyi *et al.,* 2009; Oliveira *et al*., 2010) on sweet potato, in this regard Abdissa *et al*. (2012) reported that significantly highest mean value of average tuberous root length (13.37 cm) was recorded at 20 ton FYM/ha., and the smallest tuberous root length (11.42 cm) was obtained at 5 ton/ha., FYM. Similarly the highest green top (127.70 t ha.) was harvested from 20 ton /ha. FYM followed by 15 ton/ha., FYM that gave a green top yield of 109.63 ton/ha., while, the control treatment gave the lowest (82.41 ton).

Chitosan is a natural, low toxic and inexpensive compound that is biodegradable and environmentally friendly with various applications in agriculture. Structurally, chitosan is a straight-chain copolymer composed of D-glucosamine and N-acetyl D-glucosamine being obtained by the partial deacetylation of chitin. It is the most abundant basic biopolymer and its structurally similar to cellulose, which is composed of only one monomer of glucose (De Alvarenga, 2011). Chitosan is derived from chitin, a polysaccharide found in the exoskeleton of shellfish such as shrimp, lobster, and or crabs and cell walls of fungi (Wojdyla, 2001). Recently, chitosan has been reported to act as a plant growth regulator and considered to elicit the induction of plant defense mechanisms in many plant (Ben-Shalom *et al*., 2003; Photchanachai *et al*., 2006).

Foliar applications with chitosan resulted in higher yield and improvement in fruit quality of radish Farouk *et al.* (2011), Bittelli *et al.* (2001) in pepper plants, Abdel-Mawgoud *et al.* (2010) on strawberry, Mondal *et al.* (2012) on okra and Abou El-khair (2015) on sweet potato. Fruit quality, Ghoname *et al.* (2010) on sweet pepper, El-Tanahy *et al.* (2012) on cowpea and Shehata *et al*. (2012) on cucumber plants.

The objective of this study was to evaluate the effect of sulphur and FYM levels as well as chitosan concentration as foliar spray and their interactions on yield and tuber roots quality of sweet potato (Buregard cv.) plants grown in clay soil.

MATERIALS AND METHODS

Two field experiments were carried out during the two successive summer seasons of 2014 and 2015 at El-Gemmeiza Agric. Res. Station, Gharbeya Governorate, Egypt to evaluate the effect of sulphur, FYM and chitosan concentration as foliar spray and their interactions on yield and tuber root quality of sweet potato Buregard cv. under clay soil conditions.

The physical and chemical properties of the experimental soil are presented in Table 1.

Farmyard manure (FYM) was obtained from El-Gemmeiza Station Agric. The used FYM properties were: 12.17 and 12.27% organic matter, 0.88 and 0.93% total N, 0.13 and 0.12% P, 0.74 and 0.63% K during the 1st and 2nd seasons, respectively.

This experiment included 12 treatments, which were the combinations between two levels of sulphur (without and 150 kg/fad.), three levels of FYM (without, 2 and 4 tons/fad.) and two concentrations of chitosan (without and 150 ppm).

The experimental layout was split split plot in a randomized complete blocks design with three replicates. The rates of sulphur were randomly arranged in the main plots, levels of FYM were randomly arranged in the sub plot, while the concentrations of chitosan were randomly assigned in the sub sub plots. The sub sub plots area was 21 m^2 it contained three ridges each with 10 meter length and 70 cm in width. One ridge was used to measure plant growth traits and the other two ridges were used to measure yield and its components traits.

Sweet potato tem cuttings, of about 20 cm lengths were planted at 25 cm apart, on April 22nd and 26th in the 1st and 2nd seasons, respectively.

Table 1. The physical and chemical properties of the experimental soil in 2014 and 2015 seasons

Season	OM (%)	Clay (%)	Silt (%)	Sand (%)	Texture class	EC mmohs/ cm	pH	Available (ppm)		
								N	P	K
2014 season	1.42	61.53	27.87	10.60	Clay loam	1.42	7.86	8.52	0.031	0.52
2015 season	1.51	62.11	26.76	11.13		1.44	7.92	9.12	0.028	0.49

Sweet potato stem cuttings was obtained from El-Gemmeiza Agric. Res. Station, Gharbeya Governorate, Egypt.

All treatments received equal amounts of calcium superphosphate (15.5% P_2O_5) and potassium sulphate (48.5 % K_2O) at a rate of 150 and 120 kg/fad., respectively. One third of K_2O amount and all amount of P_2O_5, sulphur and different rates of FYM were added during soil preparation in the center of row and covered by clay. The rest of K_2O was added as soil application at three portions at 60, 75 and 90 days after planting (DAP).

Chitosan powder (poly–(1,4-B-D-glycopyranosamine); 2-Amino-2-deoxy- (1->4)-B-D-glucopyranan) was prepared by dissolving a proper amount in 5% acetic acid solution and manufactured by Chengdu Newsun Biochemistry Co., Ltd, China.

The plants were sprayed with chitosan solution or tap water three times at 15 days intervals beginning 25 days after transplanting using spreading agent to improve adherence of the spray to the plant foliage for increasing chitosan absorption by the plants. The untreated plants (check) were sprayed with tap water and spreading agent. One row was left between each two experimental plots without spraying as a guard ridge to avoid the overlapping of spraying solutions. The other conventional practices were applied

Data Recorded

Yield and its components

At harvest time (at 150 days after planting), all tuber roots of each treatment were classified into two grades (marketable and non-marketable roots), then weighed to determine the total yield per faddan (ton). Marketable tuber roots have a weight about 100 to 250 g, while non-marketable roots have a weight of less than 100g or more than 250 g. In addition tuber root diameter was determined and average tuber root weight was calculated.

Tuber root quality at harvest time

Nitrogen, phosphorus and potassium percentages in tuber roots were determined in dry matter according to both methods described by AOAC (1995).

Total carbohydrate (%)

It was determined colorimetrically in dry tuber roots as (g/100g) following the methods described by Michel *et al*. (1956).

Total sugars (%)

It was determined according to both method described by Forsee (1938).

Statistical Analysis

Recorded data were subjected to the statistical analysis of variance according to Snedecor and Cochran (1980), and means separation were done according to Duncan (1955).

RESULTS AND DISCUSSION

Yield and its Components

Effect of sulphur

It is obvious from results presented in Table 2 that sulphur application had significant effect on yield and its components in both season. Average root diameter, average tuber root weight, yield of marketable and total yield/fad., were increased by application of sulphur at 150 kg/fad., to sweet potato under clay soil conditions.

The increases in total yield were about 19.00 and 14.9% for sulphur application than untreated plants in the 1st and 2nd seasons, respectively.

Table 2. Effect of sulphur, FYM and chitosan as foliar spray on yield and its components of sweet potato plants in 2014 and 2015 seasons

Treatment	Tuber root diameter (cm)		Average tuber root weight (g)		Marketable yield (ton/fad.)		Total yield (ton/fad.)		The relative increases in total yield (%)	
	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season
Effect of sulphur (kg/fad.)										
Without	5.51 b	5.78 b	184.95b	172.19a	10.548b	10.543b	13.433b	12.410b	100.0	100.0
150 kg/fad.	6.12 a	6.31 a	222.20a	195.88a	12.732a	13.351a	15.986a	14.265a	119.0	114.9
Effect of FYM (ton/fad.)										
Without	5.17 c	5.40 c	167.90c	160.46b	8.670c	9.145c	11.801c	10.597c	100.0	100.0
2 (ton/fad.)	5.78 b	5.98 b	202.80b	169.67b	11.550b	11.837b	14.583b	13.359b	123.6	126.1
4 (ton/fad.)	6.49 a	6.75 a	240.10a	221.97a	14.694a	14.859a	17.744a	16.056a	150.4	151.5
Effect of chitosan foliar spray (ppm)										
Without	5.40 b	5.71 b	181.25b	171.67b	10.970b	11.185b	14.158b	12.584b	100.0	100.0
150 ppm	6.22 a	6.38 a	225.95a	196.4a	12.310a	12.709a	15.261a	14.091a	107.8	112.0

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

These results are in line with Sud and Sharma (2002) who reported that the increases in tuber yield with increasing sulphur levels may be attributed to its role in better partitioning of the photosynthates in the shoot and tubers. Similarly, Lalitha *et al.* (2002) have also reported significant effect on grade tuber yield and increase in bulking rate with sulphur application.

The obtained results are in harmony with those reported by Pacha (2003) on potato, El-Morsy (2005), Losak and Winiowska-Kielian (2006) and Farooqui *et al*. (2009), Abou El-Khair (2010) on garlic and Klikocka (2011) and Klikocka *et al.*(2015) on potato. They found that treated plants with sulphur application increased yield and its components.

Effect of farmyard manure rates

Results presented in Table 2 show that FYM rates (0, 2 and 4 ton/fad.) had a significant effect on yield and its components such as tuber root diameter, average tuber root weight, marketable and total yield/fad., in the both seasons. Fertilizing sweet potato plants with 4 ton/fad., recorded average tuber root weight (240.1 and 221.97 g), marketable yield (14.694 and 14.859 ton/fad.) and total yield (17.744 and 16.056 ton/fad.) in the 1st and 2nd seasons, respectively against tuber root weight (167.90 and 160.46 g), marketable yield (8.670 and 9.145 ton/fad.) and total yield (11.801 and 10.597 ton/fad.) for 0 FYM in the 1st and 2nd seasons, respectively.

The increases in total yield were about 23.6 and 26.1% for 2 ton FYM/fad., and 50.4 and 51.5% for 4 ton/fad., than unfertilized plants with FYM in the 1st and 2nd seasons, respectively.

Obtained results can be explained in the light of the facts that using organic manure increases organic matter, availability of nutrients nitrogen fixation, rizosphere microorganisms that release phyotohrmones and substances which lead to increase plant growth parameters and dry matter accumulation as shown in part 1 and this in turn increase average tuber root weight, hence the increase in the total yield. Rizk (2002) cleared that organic manure at a high rate gave the highest content of nutritional elements and consequently increased uptake of those elements in plant tissues which improved yield.

These results are in agreement with those of Hoa *et al*. (2000), Santos *et al*. (2006), Ojeniyi *et al.* (2009) and Oliveira *et al*. (2010) and Abdissa *et al*. (2012) on sweet potato.

Effect of chitosan concentration

Presented results in Table 2 show that, spraying sweet potato plants grown in clay soil with chitosan had significant effect on tuber root diameter, tuber root weight, marketable and total yield/fad., than unsprayed plants in the both seasons.

The increases in total yield were about 7.8 and 12.0% for chitosan sprayed than unsprayed plants in the 1st and 2nd seasons, respectively.

The increase in yield from chitosan treated plants is a result of protecting plants against microorganisms (Nge *et al*., 2006), stimulation of roots, shoots, leaves, chlorophyll content and photosynthetic rate (which led to the increment in the vigor growth followed by active translocation of photoassimilates from source to sink tissues and hence increased yield (Gornik *et al*., 2008).

These results are in agreement with those of Farouk *et al.* 2011) on radish, Bittelli *et al.* (2001) on pepper plants, Abdel-Mawgoud *et al.* (2010) on strawberry, Mondal *et al.* (2012) on okra and Abou El-khair (2015) on sweet potato.

Effect of the interaction between sulphur and FYM rates

It is obvious from results in Table 3 that, the interaction between sulphur and FYM rates reflected a significant effect on yield and its components in both seasons. The interactions between 150 kg/fad. sulphur application and FYM (4 ton/fad.) recorded the highest values of tuber root diameter, average tuber root weight, marketable and total yield/fad., while unfertilized plants with sulphur or FYM recorded the lowest values in this respect.

The increases in total yield were about 84.6 and 72.4% in for the interaction between sulphur application and FYM at 4 ton/fad., than the interaction between without sulphur and without FYM in the 1st and 2nd seasons, respectively.

Effect of interaction between sulphur and chitosan foliar spray

The interaction between sulphur application and chitosan foliar spray had significantly increased tuber root diameter, average tuber root weight, marketable and total yields/fad., in both seasons (Table 3).

The increases in total yield were about 28.7 and 28.5% for the interaction between sulphur application and chitosan spray than untreated plants with sulphur and chitosan in the 1st and 2nd seasons, respectively.

Effect of the interaction between FYM and chitosan foliar spray

The interaction between FYM rates and chitosan as foliar spray had significantly increased yield and its components' in both seasons (Table 3). Tuber root diameter, average tuber root weight, marketable and total yields/ fad., gave the maximum values with the interaction between 4 ton/fad., FYM and sprayed plants with 150 ppm chitosan in both seasons.

The increases in total yield were about 57.4 and 68.8% for the interaction between 4 ton/ fad., FYM and chitosan sprayed at 150 ppm than without FYM and chitosan in the 1st and 2nd seasons, respectively.

Effect of triple interaction between sulphur, FYM and chitosan foliar spray

The triple interaction between sulphur application, FYM rates and chitosan as foliar spray reflected a significant effect on yield and its components in both seasons (Table 4). It is clear that, the interaction among sulphur application, FYM 4 ton/fad., and chitosan foliar spray increased tuber root diameter, average tuber root weight, marketable and total yields/fad., than other treatments.

The increases in total yield were about 101.2 and 93.5% for the triple interaction among 150 kg/fad. Sulphur; 4 ton/fad., FYM and 150 ppm chitosan foliar spray than untreated plants in the 1st and 2nd seasons, respectively.

Tuber Root Quality

Effect of sulphur

The obtained results in Tables 5 and 6 show that sulphur treatments had significant effect on N, P, K, total sugars and total carbohydrates in tuber roots at harvest time in both seasons. Treated sweet potato with sulphur under clay soil recorded the higher values of each of N, P, K, total sugars and total carbohydrates in tuber roots at harvest time than untreated plants in both seasons.

Table 3. Effect of dual interaction between sulphur and FYM, sulphur and chitosan as well as FYM and chitosan on yield and its components of sweet potato plants in 2014 and 2015 seasons

Treatment		Tuber root diameter (cm)		Average tuber root weight (g)		Marketable yield (ton/fad.)		Total yield (ton/fad.)		The relative increases in total yield (%)	
		2014 season	2015 season	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season
Sulphur	**FYM**	**Sulphur and FYM rates**									
Without	**Without**	4.85 f	5.20 e	158.4f	144.96c	7.800f	8.185d	10.39d	9.794d	100.0	100.0
	2 ton/fad.	5.41 e	5.63 d	183.9d	173.77bc	10.635d	10.130c	13.605c	12.212c	130.9	124.7
	4ton/fad.	6.26 b	6.51 b	212.6c	197.84ab	13.205b	13.310b	16.304b	15.223b	156.9	155.4
150 kg/fad.	**Without**	5.50 d	5.61 d	177.4e	175.95bc	9.535e	10.100c	13.211c	11.399c	127.2	116.4
	2 ton/fad.	6.15 c	6.33 c	221.65b	165.58bc	12.475c	13.540b	15.562b	14.506b	149.8	148.1
	4ton/fad.	6.71 a	6.98 a	267.6a	246.11a	16.180a	16.405a	19.185a	16.889a	184.6	172.4
Sulphur	**Chitosan**	**Sulphur and chitosan foliar spray**									
Without	**Without**	5.12 d	5.50 d	166.8d	155.84a	9.945d	9.765d	12.762c	11.801c	100.0	100.0
	150 ppm	5.90 b	6.06 b	203.15b	188.53a	11.150c	11.315c	14.104b	13.019b	110.5	110.3
150 kg/fad.	**Without**	5.68 c	5.92 c	195.7c	187.50a	11.990b	12.600b	15.553a	13.367b	121.9	113.3
	150 ppm	6.55 a	6.70 a	248.7a	204.26a	13.465a	14.100a	16.419a	15.163a	128.7	128.5
FYM	**Chitosan**	**FYM and chitosan foliar spray**									
Without	**Without**	4.75 f	5.06 e	144.4f	140.93c	8.175f	8.408f	11.727e	10.049d	100.0	100.0
	150 ppm	5.60 d	5.75 d	191.4d	179.98bc	9.160e	9.881e	11.874e	11.144d	101.3	110.9
2 ton/fad.	**Without**	5.45 e	5.71 d	178.0e	174.88bc	10.720d	10.932d	13.717d	12.554c	117.0	124.9
	150 ppm	6.11 b	6.25 c	227.6v	164.47bc	12.390c	12.742c	15.450c	14.164b	131.7	140.9
4 ton/fad.	**Without**	6.01 c	6.35 b	221.35c	199.21b	14.010b	14.216b	17.028b	15.148b	145.2	150.7
	150 ppm	6.96 a	7.15 a	258.85a	244.74a	15.375a	15.502a	18.461a	16.964a	157.4	168.8

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 4. Effect of triple interaction between sulphur, FYM and chitosan as foliar spray on yield and its components of sweet potato plants in 2014 and 2015 seasons

Treatment			Tuber root diameter (cm)		Average tuber root weight (g)		Marketable yield (ton/fad.)		Total yield (ton/fad.)		The relative increases in total yield (%)	
			2014 season	2015 season	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season
Sulphur	**FYM**	**Chitosan**										
Without	**Without**	**Without**	4.43 j	4.86 k	140.65k	126.72a	7.375i	7.775g	9.970h	9.400f	100.0	100.0
		150 ppm	5.26 h	5.53 h	176.15h	163.19a	8.230k	8.600f	10.805h	10.185ef	108.4	108.4
	2 ton/fad.	**Without**	5.06 i	5.40 i	161.15i	158.33a	9.700i	9.105f	12.565g	11.290e	126.0	120.1
		150 ppm	5.76 g	5.86 g	206.65e	189.20a	11.565g	11.150e	14.640def	13.130cd	146.8	139.7
	4 ton/fad.	**Without**	5.86 ef	6.23 e	198.50f	182.47a	12.750e	12.425d	15.745cd	14.710bc	157.9	156.5
		150 ppm	6.66 b	6.80 b	226.65d	213.20a	13.655c	14.195c	16.860bc	15.735b	169.1	167.4
150 kg /fad.	**Without**	**Without**	5.06 i	5.26 j	148.15j	155.14a	8.980j	9.040f	13.480efg	10.695ef	135.2	113.8
		150 ppm	5.93 e	5.96 fg	206.65e	196.77a	10.090h	11.160e	12.940fg	12.100de	129.8	128.7
	2 ton/fad.	**Without**	5.83 fg	6.03 f	194.85g	191.42a	11.735f	12.755d	14.865de	13.815bc	149.1	147.0
		150 ppm	6.46 c	6.63 c	248.50b	139.74a	13.215d	14.330c	16.255cd	15.195b	163.0	161.6
	4 ton/fad.	**Without**	6.16 d	6.46 d	244.15c	215.94a	15.265b	16.005b	18.310b	15.585b	183.7	165.8
		150 ppm	7.26 a	7.50 a	291.00a	276.27a	17.095a	16.805a	20.060a	18.190a	201.2	193.5

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 5. Effect of sulphur, FYM and chitosan as foliar spray on N, P and K contents in tuber roots of sweet potato at harvest time in 2014 and 2015 seasons

Treatment	N		P		K	
	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season
Effect of sulphur (kg/fad.)						
Without	2.89 b	3.03 b	0.242 b	0.239 b	1.59 b	1.71 b
150 kg/fad.	2.95 a	3.12 a	0.266 a	0.277 a	1.93 a	1.97 a
Effect of FYM (ton/fad.)						
Without	2.83 c	2.90 c	0.216 c	0.225 c	1.58 c	1.62 c
2 (ton/fad.)	2.91 b	3.07 b	0.249 b	0.257 b	1.76 b	1.84 b
4 (ton/fad.)	3.03 a	3.25 a	0.296 a	0.291 a	1.94 a	2.05 a
Effect of chitosan foliar spray (ppm)						
Without	2.87 b	2.99 b	0.246 b	0.249 b	1.68 b	1.77 b
150 ppm	2.97 a	3.15 a	0.261 a	0.267 a	1.84 a	1.90 a

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 6. Effect of sulphur, FYM and chitosan foliar spray on tuber roots quality of sweet potato at harvest time in 2014 and 2015 seasons

Treatments	Total sugars (%)		Total carbohydrates (%)		Relative increases in total sugars (%)	
	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season
Effect of sulphur (kg/fad.)						
Without	10.18 b	10.52 b	61.63b	61.99b	100.0	100.0
150 kg/fad.	10.71 a	10.64 a	63.92a	64.15a	105.2	101.1
Effect of FYM (ton/fad.)						
Without	9.76 c	9.70 c	59.80c	59.22c	100.0	100.0
2 (ton/fad.)	10.31 b	10.72 b	62.77b	63.26b	105.6	110.5
4 (ton/fad.)	11.27 a	11.32 a	65.75a	66.73a	115.5	116.7
Effect of chitosan foliar spray (ppm)						
Without	10.21 b	10.32 b	61.94b	61.98b	100.0	100.0
150 ppm	10.69 a	10.83 a	63.61a	64.16a	104.7	104.9

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

The increases in total sugars in tuber roots were about 5.2 and 1.1% for sulphur application than untreated plants in the 1st and 2nd seasons, respectively.

Calcium is reported to increase nitrogen, potassium and phosphorous absorption in roots, stimulates photosynthesis, increases the plant size and improves fruit quality in various vegetables like sweet potato (Fenn *et al*., 1991). The obtained results were confirmed by Awad *et al*. (2002) and Pacha (2003) on potato

Effect of FYM rates

Presented results in Tables 5 and 6 illustrate that FYM rates had a reflect significant effect on N, P, K, total sugars and total carbohydrates contents in tuber roots at harvest time in both seasons. Fertilization of sweet potato with 4 ton/fad., FYM gave the maximum values of all above mentioned parameters in both seasons than either 2 ton/fad., or without application of FYM. The increases in total sugars in tuber roots were about 5.6 and 10.5% for 2 ton farmyard manure/fad., and 15.5 and 16.7% for 4 ton/fad., FYM than that plants which were unfertilized with FYM in the 1st and 2nd seasons, respectively.

The enhancing effect of FYM at the highest rate on the percentage of N,P and K may be due to that organic manure contains many species of living organisms which release phytohormones as GA_3, IAA and CYT, *etc*. necessary for stimulating plant growth, and dry matter content. These observations may indicate that micro-organisms have the ability to supply growing plants with N,P, K and phytohormones which in turn may increase N, P and K concentrations in soil solution and their uptakes by plant (Reyndres and Vlassake, 1982).

Results are in harmony with those obtained by Hoa *et al*. (2000), Santos *et al*. (2006), Ojeniyi *et al.* (2009) and Oliveira *et al*. (2010) on sweet potato, in this regard Abdissa *et al*. (2012) showed that, significantly the highest mean value of average tuberous root length was recorded at 20 ton FYM /ha. and the smallest tuberous root length.

Effect of chitosan concentration

The obtained results in Tables 5 and 6 indicate that chitosan concentration reflect a significant effect on N, P, K, total sugars and total carbohydrates in tuber root of sweet potato at harvest time in both seasons than unsprayed plants.

The increases in total sugars in tuber roots were about 4.7 and 4.9% for chitosan sprayed than unsprayed plants in the 1st and 2nd seasons, respectively.

The favorable effect of chitosan on chemical composition of tuber roots might be referred to greater availability of amino compounds released from it (Chibu and Shibayama, 2001) and increases the availability and uptake of water and essential nutrients. In addition, chitosan also contains high amount of calcium minerals where they aid structural rigidity (BoBelmann *et al*., 2007) and the hydroxylated amino groups present on chitosan oligomers make them extremely effective scavengers of hydroxyl radicals, hydrogen peroxide and anion superoxide (Sun *et al.,* 2008). Moreover, chitosan increased photosynthetic rate (Khan *et al*., 2002) and therefore, increase the accumulation of photosynthetic output compound in tuber roots.

Similar results are recorded by Ghoname *et al.* (2010) on sweet pepper, El-Tanahy *et al.* (2012) on cowpea and Shehata *et al*. (2012) on cucumber plants and Abou El-Khair (2015) on sweet potato.

Effect of interaction between sulphur and FYM rates

It is obvious from results in Tables 7 and 8 that the interaction between sulphur and FYM rates reflected a significant effect on N, P, K, total sugars and total carbohydrates contents in tuber root of sweet potato. The interaction between sulphur application and 4 ton/fad., FYM recorded the maximum values of all tuber roots quality in both seasons.

The increases in total sugars in tuber roots were about 21.3 and 20.5 for the interaction between sulphur application and FYM rate at 4 ton/fad., than the interaction between without sulphur and FYM in the 1st and 2nd seasons, respectively.

Effect of interaction between sulphur and chitosan

The obtained results in Tables 7 and 8 indicate that the interaction between sulphur

Table 7. Effect of dual interaction between sulphur and FYM, sulphur and chitosan as well as FYM and chitosan on N,P and K contents in tuber roots at harvest of sweet potato in 2014 and 2015 seasons

Treatment		N		P		K	
		2014 season	2015 season	2014 season	2015 season	2014 season	2015 season
Sulphur	**FYM**			**Sulphur and FYM rates**			
Without	**Without**	2.80 f	2.87 f	0.205 e	0.212 e	1.45 e	1.51 e
	2 ton/fad.	2.88 d	3.00 d	0.233 d	0.237 d	1.61 d	1.74 d
	4 ton/fad.	3.01 b	3.21 b	0.288 b	0.269 c	1.70 c	1.87 c
150 kg/fad.	**Without**	2.86 e	2.93 e	0.227 d	0.238 d	1.70 c	1.72 d
	2 ton/fad.	2.95 c	3.14 c	0.266 c	0.278 b	1.90 b	1.94 b
	4 ton/fad.	3.05 a	3.29 a	0.305 a	0.313 a	2.19 a	2.24 a
Sulphur	**Chitosan**			**Sulphur and chitosan foliar spray**			
Without	**Without**	2.84 d	2.95 d	0.236 d	0.231 d	1.54 d	1.66 d
	150 ppm	2.95 b	3.11 b	0.248 c	0.247 c	1.64 c	1.76 c
150 kg/fad.	**Without**	2.91 c	3.04 c	0.257 b	0.267 b	1.83 b	1.888 b
	150 ppm	2.99 a	3.19 a	0.275 a	0.287 a	2.03 a	2.05 a
FYM	**Chitosan**			**FYM and chitosan foliar spray**			
Without	**Without**	2.79 d	2.84 d	0.210 f	0.219 f	1.52 e	1.58 f
	150 ppm	2.87 c	2.96 c	0.222 e	0.231 e	1.63 d	1.65 e
2 ton/fad.	**Without**	2.87 c	2.97 c	0.241 d	0.250 d	1.70 c	1.79 d
	150 ppm	2.96 b	3.16 b	0.258 c	0.265 c	1.82 b	1.89 c
4 ton/fad.	**Without**	2.97 b	3.17 b	0.288 b	0.279 b	1.83 b	1.94 b
	150 ppm	3.08 a	3.33 a	0.304 a	0.304 a	2.06 a	2.17 a

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 8. Effect of dual interaction between sulphur and FYM, sulphur and chitosan as well as FYM and chitosan on tuber roots quality of sweet potato at harvest time in 2014 and 2015 season

Treatment		Total sugars (%)		Total carbohydrates (%)		Relative increases in total sugars (%)	
		2014 season	2015 season	2014 season	2015 season	2014 season	2015 season
Sulphur	**FYM**			**Sulphur and FYM rates**			
Without	**Without**	9.43 f	9.52 f	58.99f	58.60f	100.0	100.0
	2 ton/fad.	10.02 e	10.87 c	61.08d	61.52d	106.3	114.2
	4 ton/fad.	11.10 b	11.17 b	64.82b	65.87b	117.7	117.3
150 kg/fad.	**Without**	10.10 d	9.88 e	60.60e	59.85e	107.1	103.8
	2 ton/fad.	10.60 c	10.57 d	64.46c	65.00c	112.4	111.0
	4 ton/fad.	11.44 a	11.47 a	66.68a	67.59a	121.3	120.5
Sulphur	**Chitosan**			**Sulphur and chitosan foliar spray**			
Without	**Without**	9.97 d	10.24 c	60.92d	60.90c	100.0	100.0
	150 ppm	10.39 c	10.80 a	62.35c	63.09b	104.2	105.5
150 kg/fad.	**Without**	10.45 b	10.41 b	62.95b	63.06b	104.8	101.7
	150 ppm	10.98 a	10.87 a	64.87a	65.23a	110.1	106.2
FYM	**Chitosan**			**FYM and chitosan foliar spray**			
Without	**Without**	9.53 f	9.52 e	59.00f	58.27f	100.0	100.0
	150 ppm	10.00 e	9.88 d	60.60e	60.17e	104.9	103.8
2 ton/fad.	**Without**	10.03 d	10.35 c	61.82d	61.76d	105.2	108.7
	150 ppm	10.59 c	11.08 b	63.72c	64.76c	111.1	116.4
4 ton/fad.	**Without**	11.07 b	11.09 b	65.00b	65.92b	116.2	116.5
	150 ppm	11.47 a	11.55 a	66.51a	67.55a	120.4	121.3

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

application and chitosan sprayed reflected a significant effect and increased N, P, K, total sugars and total carbohydrates of tuber root than in untreated plants in both seasons.

The increases in total sugars in tuber roots were about 10.1 and 6.2% for the interaction between sulphur application and chitosan spray than the interaction between without both sulphur and chitosan in the 1st and 2nd seasons, respectively.

Effect of interaction between FYM and chitosan foliar spray

The interaction between FYM rates and chitosan spray had significant effect on sweet potato quality such N, P , K , total sugars and total carbohydrates of tuber root in both seasons (Tables 7 and 8). Sweet potato plants grown under clay soil which fertilized with 4 ton/fad., FYM and sprayed with 150 ppm chitosan recorded the highest values of all parameter of quality than other interaction treatments in both seasons.

The increases in total sugars in tuber roots were about 20.4 and 21.3% for the interaction between 4 ton/fad., FYM and 150 ppm chitosan as foliar spray than the interaction between the untreated plants with FYM and chitosan in the 1st and 2nd seasons, respectively.

Effect of triple interaction between sulphur, FYM and chitosan foliar spray

The interaction between sulphur, FYM and chitosan foliar spray had significant effect on N, P, K, total sugars and total carbohydrates contents in tuber root in both seasons (Tables 9 and 10). The triple interaction among 150 kg/fad., sulphur, 4 ton/fad. FYM and 150 ppm chitosan as foliar spray recorded the maximum values of N, P, K, total sugars and total carbohydrates contents in both seasons.

The increases in total sugars in tuber roots were about 27.6 and 26.7% for the interaction between 150 kg/fad., sulphur, 4 ton/fad. FYM and 150 ppm chitosan foliar spray than the interaction among the untreated plants with sulphur, FYM and chitosan in the 1st and 2nd seasons, respectively.

Generally, it could be concluded that under the same conditions, treated plants with sulphur at 150 kg/fad., and fertilized plants with 4 ton/ fad. FYM and sprayed plants with 150 ppm chitosan recorded the maximum yield and best quality of sweet potato.

Table 9. Effect of triple interaction between sulphur, FYM and chitosan foliar spray on N,P and K contents in tuber roots of sweet potato plants at harvest time in 2014 and 2015 seasons

Treatment			N		P		K	
			2014 season	2015 season	2014 season	2015 season	2014 season	2015 season
Sulphur	FYM	Chitosan						
Without	Without	Without	2.75 i	2.81 j	0.198 i	0.205 k	1.41 g	1.48 j
		150 ppm	2.84 g	2.93 h	0.213 h	0.219 j	1.49 f	1.55 i
	2 ton/fad.	Without	2.83 h	2.90 i	0.228 fg	0.230 i	1.57 e	1.70 h
		150 ppm	2.93 d	3.11 e	0.237 f	0.243 g	1.65 d	1.79 f
	4 ton/fad.	Without	2.94 d	3.14 d	0.283 cd	0.259 f	1.63 de	1.80 f
		150 ppm	3.08 b	3.28 b	0.292 bc	0.280 d	1.78 c	1.95 d
150 kg/fad.	Without	Without	2.82 h	2.88 i	0.223 gh	0.233 h	1.63 de	1.69 h
		150 ppm	2.90 f	2.99 g	0.231 fg	0.244 g	1.78 c	1.75 g
	2 ton/fad.	Without	2.91 e	3.05 f	0.254 e	0.269 e	1.83 c	1.89 e
		150 ppm	2.99 c	3.22 c	0.278 d	0.288 c	1.98 b	1.99 c
	4 ton/fad.	Without	3.00 c	3.20 c	0.294 b	0.299 b	2.03 b	2.08 b
		150 ppm	3.09 a	3.38 a	0.316 a	0.328 a	2.35 a	2.40 a

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 10. Effect of triple interaction between sulphur, FYM and chitosan foliar spray on tuber roots quality of sweet potato plants at harvest time in 2014 and 2015 seasons

Treatment			Total sugars (%)		Total carbohydrates (%)		Relative increases in total sugars (%)	
Sulphur	FYM	Chitosan	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season
Without	Without	Without	9.18 k	9.26 i	58.22k	57.62k	100.0	100.0
		150 ppm	9.68 j	9.78 h	59.78j	59.58i	105.4	105.6
	2 ton/fad.	Without	9.78 i	10.48 e	60.47i	60.18h	106.5	113.2
		150 ppm	10.27 g	11.25 bc	61.69g	62.85f	111.9	121.5
	4 ton/fad.	Without	10.97 d	10.97 d	64.07e	64.92d	119.5	118.5
		150 ppm	11.23 b	11.36 b	65.58d	66.83b	122.3	122.7
150 kg/fad.	Without	Without	9.88 h	9.78 h	59.78j	58.92j	107.6	105.6
		150 ppm	10.33 f	9.97 g	61.43h	60.76g	112.5	107.7
	2 ton/fad.	Without	10.29 g	10.23 f	63.16f	63.35e	112.1	110.5
		150 ppm	10.91 e	10.91 d	65.75c	66.66c	118.8	117.8
	4 ton/fad.	Without	11.18 c	11.21 c	65.93b	66.92b	121.8	121.1
		150 ppm	11.71 a	11.73 a	67.43a	68.26a	127.6	126.7

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

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استجابة نباتات البطاطا لإضافات الكبريت والسماد البلدي والشيتوزان
٢- المحصول ومكوناته وكذلك جودة الجزور المتدرنة

فوزى يحيى عمر منصور

معهد بحوث البساتين – مركز البحوث الزراعية- مصر

أُجريت تجربتان حقليتان خلال موسمى صيف ٢٠١٤، ٢٠١٥ وذلك بمزرعة البحوث الزراعية بالجميزة، محافظة الغربية، مصر وذلك لتقييم تأثير إضافة الكبريت ومستويات السماد البلدى والرش بالشيتوزان والتفاعل بينهم على المحصول ومكوناته وكذلك جودة الجذور المتدرنة للبطاطا صنف بيوروجارد النامية فى الأرض الطينية، إزداد معنويا كل من متوسط قطر الجذور المتدرنة ومتوسط وزن الجزر، كل من المحصول القابل للتسويق والمحصول الكلى، محتوى الجذور المتدرنة من النيتروجين، الفوسفور والبوتاسيوم والسكريات الكلية والكربوهيدرات الكلية بمعاملة التفاعل الثلاثى بين إضافة الكبريت بمعدل ١٥٠ كيلو جرام فدان، السماد البلدى بمعدل ٤ طن/فدان والرش بالشيتوزان بتركيز ١٥٠ جزء في المليون، كانت مقدار الزيادة النسبية فى المحصول الكلى حوالى ١٠١,٢٠، ٩٣,٥١% والتى تعود إلى معاملة التفاعل الثلاثي بين إضافة الكبريت بمعدل ١٥٠ كيلو جرام/فدان، السماد البلدي بمعدل ٤ طن/فدان والرش بالشيتوزان بتركيز ١٥٠ جزء في المليون عن معاملة التفاعل الثلاثي بين بدون كبريت + بدون سماد بلدي + بدون شيتوزان خلال الموسم الأول والثاني على التوالي.

المحكمون :

١- أ.د. السيد السيد محمد أبو الخير أستاذ الخضر– معهد بحوث البساتين – مركز البحوث الزراعية- الجيزة.

٢- أ.د. محسن حســـن الســـــواح أستاذ الخضر المتفرغ – كليه الزراعة – جامعة الزقازيق.