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RESPONSE OF SWEET POTATO PLANTS TO SULPHUR, FARMYARD MANURE AND FOLIAR SPRAY WITH CHITOSAN
1. PLANT GROWTH AND PLANT CHEMICAL CONSTITUENTS

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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 plant growth and chemical constituents of sweet potato (Buregard cv.) grown in clay soil. Results showed that, the triple interaction among sulphur application at 150 kg/fad., FYM at 4 ton/fad., and spraying sweet potato plants with chitosan at 150 ppm, significantly increased vine length, both number of branches and leaves/plant, dry weight of shoot, chlorophyll a and total chlorophyll, N, P and K contents and its uptake by shoot. On the other hand, the lowest values of each of the above-mentioned traits were recorded with the interaction treatment among without sulphur, without FYM and without chitosan in both seasons.

Key words: Sweet potato, sulphur, FYM, chitosan, plant growth and chemical constituents.

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 (S) is now viewed as the fourth major plant nutrient which crops absorb in amounts comparable to that of phosphorus. Sulphur metabolism provides several efficient mechanisms by which plants are able to tackle abiotic (*e.g.,* xenobiotics and increasing surface ozone levels) and biotic (*e.g.,* pests and diseases) stress, particularly *via* the glutathione metabolism which again is closely related to the S supply of the plants (Haneklaus *et al*. 2003). Other mechanisms involved in response to plant pathogens include the production of S containing compounds in the secondary metabolism of the agriculturally important *Brassica* species, the release of volatile S compounds, the production of S rich proteins, localized deposition of elemental S and the production of phytochelatines, which detoxify heavy metals by forming complexes (Schnug, 1998). The resistance of the crops to certain plant diseases is also improved by the S supply and could therefore minimize the input of pesticides (Klikocka *et al*., 2005). An insufficient supply of S to the crop does not only reduce its economic yield, but it has also a decisive influence on the quality of the crop.

Treated plants with sulphur increased plant growth (Niyonsaba *et al*., 1990 on sweet potato, Awad *et al*., 2002 and Pacha 2003 on potato, Saeed and Ahmad 2009 on tomato), also

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increased plant chemical constituents (Pandey *et al*., 1985 on bean, Singh and Pandey, 1995; Abd El-Hameed 1997 and Abou El-Khair, 2010 on garlic).

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, 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 growth of sweet potato plant after organic manure application may be due to 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.

Fertilized sweet potato plants with organic manure recorded the highest values of vine length, both number of leaves and branches, leaf area index, fresh and dry weight of shoot of sweet potato (Balemi, 2012 on potato, Abdissa *et al*., 2012; Yeng *et al*., 2012; Olaoye *et al*., 2013) on sweet potato.

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 has been shown to stimulate plant growth (Mondal *et al*., 2012) to posses antioxidants activity (Chen *et al*., 2009), act as antitransparent compound that has proved to be effective in many crops (Karimi *et al*., 2012).

Foliar applications with chitosan resulted in higher plant growth (Farouk *et al.,* 2011) on radish, (Bittelli *et al.,* 2001) on pepper, (Abdel-Mawgoud *et al.* 2010) on strawberry, (Ghoname *et al.,* 2010) on sweet pepper, plant chemical constituents, (Sheikha and Al-Malki, 2011) on bean and (El-Tanahy *et al.* 2012) on cowpea and (Abou El-Khair, 2015) on sweet potato.

The objective of this study was to evaluate the effect of sulphur, FYM levels and chitosan as foliar spray and their interactions on growth and plant chemical constituents of sweet potato plants (Buregard cv.) 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 application, FYM levels and chitosan concentration as foliar spray and their interactions on plant growth and chemical constituents of sweet potato (Buregrad 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. and a good decomposition. 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 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 component traits.

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

Season	OM (%)	Clay (%)	Silt (%)	Sand (%)	Texture class	E.C 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, of about 20 cm lengths were planted at 25 cm apart, on April 22nd and 26th in the 1st and 2nd seasons, respectively. Sweet potato stem cuttings were obtained from El-Gemmeiza Agricultural Research 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 to avoid the overlapping of spraying solutions. The other conventional practices were applied.

Data Recorded

Plant growth

A random sample of three plants from every experimental unit were randomly taken at 110 DAP in the two growing seasons to measure the plant growth and plant chemical constituents:

a. Vine length (cm), both number of leaves and branches/plant,

b. Dry weight of shoot: Leaves and branches (shoots) of each plant were dried at 70°C till constant weight and then weighed.

Plant chemical constituents

Photosynthetic pigments

Chlorophyll a, b and carotenoids were determined in the fourth leaf according to both methods described by Wettestein (1957).

N, P and K contents and its uptake in shoots

Nitrogen, phosphorus and potassium percentages in shoots (leaves and branches) were determined in dry matter according to both methods described by AOAC (1995) and N,P and K uptake by shoots were calculated (mg/ shoot).

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

Plant Growth

Effect of sulphur

Results in Table 2 show that sulphur application at 150 kg/fad., had significant effect on vine length, both number of branches and leaves/plant and dry weight of shoots/ plant of sweet potato at 110 DAP under clay soil. Treated sweet potato plants with sulphur gave higher values of vine length, both number of branches and leaves/plant and dry weight of shoots/plant than untreated ones.

Table 2. Effect of sulphur, FYM and chitosan as foliar spray on vegetative growth of sweet potato plants at 110 DAP in 2014 and 2015 seasons

Treatment	Vine length (cm)		Number of branches/ plant		Number of leaves/ plant		Dry weight of shoots (g)		Relative increases in dry weight of shoots (%)	
	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	244.44b	245.08b	19.44b	19.94b	193.39b	214.33b	79.26b	75.23b	100.0	100.0
150 kg/fad.	278.56a	293.39a	24.88a	21.77a	295.72a	301.83a	104.27a	92.83a	131.6	123.4
Effect of FYM (ton/fad.)										
Without	224.67c	234.37c	15.83c	17.66c	201.92c	211.25c	69.31c	63.75c	100.0	100.0
2 ton/fad.	267.50b	268.17b	22.33b	20.66b	241.17b	266.50b	91.53b	81.62b	132.1	128.0
4 ton/fad.	292.33a	305.17a	28.33a	24.25a	290.58a	296.50a	114.46a	106.73a	165.1	167.4
Effect of chitosan as foliar spray (ppm)										
Without	248.17b	255.08b	20.05b	19.38b	232.22b	246.17b	86.00b	76.81b	100.0	100.0
150 ppm	274.83a	283.39a	24.27a	22.33a	256.89a	270.00a	97.53a	91.25a	113.4	118.8

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.

The increases in dry weight of shoot/ plant were about 31.6 and 23.4% for sulphur application than untreated plants in the 1st and 2nd seasons, respectively.

The favorable effect of sulphur application on vegetative growth of sweet potato might be due to its role in lowering pH of the soil, such reduction in pH lead to an increase in availability of P, Fe, Mn, Cu, Mg, SO_4 and Zn to the sweet potato plant roots. Each of these elements has distinct role in improving plant growth. Also, application of sulphur resulted in improving the movement of P from bulk soil to rhizosphere and stimulating its uptake. Moreover, sulphur plays a role in improving soil water relation, increasing root growth and regulating urea transformation in the soil, then improved growth parameters (Hilal, 1990).

These results are in harmony with those reported by Niyonsaba *et al*. (1990) on sweet potato, Awad *et al*. (2002) and Pacha (2003) on potato, Saeed and Ahmad (2009) on tomato.

Effect of FYM

The obtained results in Table 2 indicate that FYM rates had significant effect on vine length, both number of branches and leaves/plant and dry weight of shoots/ plant at 110 DAP. Each of vine length, both number of branches and leaves/plant and dry weight of shoots/plant were the highest by increasing FYM rates up to 4 ton/fad., in both seasons.

The increases in shoot dry weight were about 65.1 and 67.4% for FYM rate at 4 ton/fad., and 32.1 and 28.0% for FYM rate at 2 ton/fad., than without FYM in the 1st and 2nd seasons, respectively.

The increase in sweet potato plant growth after organic manure application may be due to improving physic-chemical and biological properties of sandy 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.

Fertilized sweet potato with organic manure recorded the highest values of each of vine length both number of leaves and branches, leaf area index, fresh and dry weight of shoot of sweet potato (Balemi, 2012 on potato, Abdissa *et al*., 2012; Yeng *et al*., 2012; Olaoye *et al*., 2013) on sweet potato.

Effect of chitosan foliar spray

Spraying sweet potato plants with chitosan at 150 ppm had significant effect on vine length, both number of branches and leaves/plant and dry weight of shoots/plant at 110 DAP in both seasons (Table 2).

The increases in shoot dry weight were about 13.4 and 18.8% for sprayed plants with chitosan than unsprayed plants in the 1st and 2nd seasons, respectively.

The positive effect of chitosan on plant growth, could be attributed to that it had molecular signals that served as plant growth promotes (Hadwiger *et al*., 2002) and a role in increasing key enzymes activities of nitrogen metabolism (nitrate reductease, glutamine synthetase and protease), in addition, chitosan improved the transportation of nitrogen in the functional leaves which enhanced plant growth and development (Qiang *et al*., 2007; Mondal *et al*., 2012) as well as, the greater availability of amino compounds released from it (Chibu and Shibayama, 2001).

Furthermore, foliar application of chitosan increased the net photosynthetic rates of soybean (Khan *et al*., 2002), it stimulates plant immune systems, plant growth and plant production, also protects plants against attack by microorganism (Nge *et al*., 2006) and increases the availability and uptake of water and essential nutrients through adjusting cell osmotic pressure and reducing the accumulation antioxidants and enzyme activities (Guan *et al*., 2009).

Effect of interaction between sulphur and FYM rates

It can be seen from the results presented in Table 3 that the interaction between sulphur and FYM rates had significant effect on all sweet potato growth in both seasons. The interaction between sulphur application and FYM at 4 ton/ fad., gave the maximum values of vine length, both number of branches and leaves/ plant and dry weight of shoots/ plant.

These increases in shoot dry weight were about 123.3 and 108.4% for the interaction between sulphur application and FYM at 4 ton/fad.; 87.6 and 80.2% for the interaction between without sulphur and FYM at 4 ton/fad., than without sulphur and without FYM in the 1st and 2nd seasons, respectively.

Effect of interaction between sulphur and chitosan

The interaction between sulphur and chitosan reflected a significant effect on all plant growth of sweet potato in both seasons (Table 3). Treated plants with sulphur and sprayed plants with chitosan recorded the highest values of each of vine length, both number of branches and leaves/plant and dry weight of shoots/plant in both seasons. These increases in shoot dry weight were about 49.7 and 46.9% for the interaction between sulphur application and chitosan than untreated plants with sulphur or chitosan in the 1st and 2nd seasons, respectively.

Effect of Interaction between FYM and chitosan

The interaction between FYM rates and chitosan concentration had a significant effect on all plant growth of sweet potato in both seasons (Table 3). Fertilized plants with FYM at 4 ton/fad., and sprayed plants with 150 ppm chitosan recorded the highest values of each of vine length, both number of branches and leaves/plant and dry weight of shoots/ plant in both seasons. While the lowest values in these respect were recorded with the interaction between without FYM and unsprayed plants with chitosan in both seasons. The increases in shoot dry weight of sweet potato plant were about 87.2 and 100.2% for the interaction between FYM at 4 ton/fad., and sprayed plants with chitosan than without FYM and 0 chitosan in the 1st and 2nd seasons, respectively.

Effect of triple interaction among sulphur, FYM and chitosan

The interaction between sulphur, FYM rates and chitosan concentrations had a significant effect on all plant growth parameters of sweet potato in both seasons (Table 4). The triple

Table 3. Effect of dual interaction between sulphur and FYM, sulphur and chitosan as well as FYM and chitosan foliar spray on vegetative growth of sweet potato plants at 110 DAP in 2014 and 2015 season

Treatment		Vine length (cm)		Number of branches/ plant		Number of leaves/ plant		Dry weight of shoots (g)		Relative increases in dry weight of shoots (%)	
		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**	208.67 f	217.73 f	14.66 e	16.50 f	163.67 f	178.50 d	55.70 e	54.92 f	100.0	100.0
	2 ton/fed.	255.83 d	240.50 e	20.66 c	20.16 d	196.50 e	229.17 c	77.59 d	71.80 e	139.3	130.7
	4 ton/fed.	268.83 c	277.00 c	23.00 b	23.16 b	220.00 d	235.33 c	104.51 b	98.97 b	187.6	180.2
150 kg/fad.	**Without**	240.67 e	251.00 d	17.00 d	18.83 e	240.17 c	244.00 c	82.93 c	72.59 d	148.9	132.2
	2 ton/fed.	279.17 b	295.83 b	24.00 b	21.16 c	285.83 b	303.83 b	105.47 b	91.44 c	189.4	166.5
	4 ton/fed.	315.83 a	333.33 a	33.66 a	25.33 a	361.17 a	357.67 a	124.40 a	114.48 a	223.3	208.4
Sulphur	**Chitosan**	**Sulphur and chitosan foliar spray**									
Without	**Without**	230.22 d	231.93 d	17.44 c	18.66 d	180.11 d	207.56 d	73.50 d	68.33 d	100.0	100.0
	150 ppm	258.67 c	258.22 c	21.44 b	21.22 b	206.67 c	221.11 c	85.02 c	82.13 c	115.7	120.2
150 kg/fad.	**Without**	266.11 b	278.22 b	22.66 b	20.11 c	284.33 b	284.78 b	98.50 b	85.30 b	134.0	124.8
	150 ppm	291.00 a	308.56 a	27.11 a	23.44 a	307.11 a	318.89 a	110.04 a	100.37 a	149.7	146.9
FYM	**Chitosan**	**FYM and chitosan foliar spray**									
Without	**Without**	211.67 e	222.40 f	14.50 f	16.50 e	190.50 f	200.83 e	63.69 f	57.92 f	100.0	100.0
	150 ppm	237.67 d	246.33 e	17.16 e	18.83 d	213.33 e	221.67 d	74.94 e	69.59 e	117.7	120.1
2 ton/fad.	**Without**	255.00 c	253.33 d	19.83 d	19.33 c	226.50 d	253.33 c	84.64 d	75.00 d	132.9	129.5
	150 ppm	280.00 b	283.00 c	24.83 c	22.00 b	255.83 c	279.67 b	98.42 c	88.24 c	154.5	152.3
4 ton/fad.	**Without**	277.83 b	289.50 b	25.83 b	22.33 b	279.67 b	284.33 b	109.68 b	97.53 b	172.2	168.4
	150 ppm	306.83 a	320.83 a	30.83 a	26.16 a	301.50 a	308.67 a	119.23 a	115.93 a	187.2	200.2

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.

interaction among sulphur application, 4 ton/ fad., FYM and sprayed plants with chitosan recorded the highest value of each of vine length, both number of branches and leaves/ plant and dry weight of shoots/plant in both seasons. While the lowest values in these respect were recorded with the interaction among without sulphur + without FYM and unsprayed plants with chitosan in both seasons. The increases in shoot dry weight of sweet potato plant were about 150.4 and 152.5% for the triple interaction between among sulphur application, 4 ton/fad., FYM and sprayed plants with chitosan at 150 ppm than that the plants which untreated with any of them in the 1st and 2nd seasons, respectively.

Leaf Pigments

Effect of sulphur

Results in Table 5 show that, sulphur application had significant effect on leaf pigments, *i.e.,* chlorophyll a (Chl) and total (a + b), but had no significant effect on chlorophyll b and carotenoides in leaf tissues of sweet potato at 110 DAP in both seasons. Application of 150 kg/fad., sulphur to clay soil recorded higher concentration of chl. a and total chls (a+b) than untreated plants in both seasons.

Table 4. Effect of triple interaction between sulphur, FYM and chitosan foliar spray on vegetative growth of sweet potato plants at 110 DAP in 2014 and 2015 seasons

Treatment			Vine length (cm)		Number of branches/ plant		Number of leaves/ plant		Dry weight of shoots (g)		Relative increases in dry weight of shoots (%)	
			2014 season	2015 season	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season	2014 season	2015 season
	FYM	Chitosan										
Without	Without	Without	196.67h	206.80k	13.33 i	15.33h	152.67l	168.00k	51.13k	49.32k	100.0	100.0
		150 ppm	220.67g	228.67 j	16.00h	17.66g	174.67k	189.00 j	60.27j	60.52j	117.9	122.7
	2 ton/fad.	Without	245.00f	228.33j	18.66g	19.00f	179.67j	226.67i	70.81i	65.07i	138.5	131.9
		150 ppm	266.67d	252.67h	22.66e	21.33 d	213.33h	231.67gh	84.36g	78.53g	165.0	159.2
	4 ton/fad.	Without	249.00ef	260.67g	20.33f	21.66 d	208.00 i	228.00hi	98.57e	90.59e	192.8	183.7
		150 ppm	288.67c	293.33d	25.66d	24.66b	232.00f	242.67f	110.45d	107.35b	216.0	217.7
150 kg/fad.	Without	Without	226.67g	238.00i	15.66h	17.66g	228.33g	233.67g	76.25h	66.52h	149.1	134.9
		150 ppm	254.67e	264.00f	18.33g	20.00e	252.00e	254.33 e	89.60f	78.66g	175.2	159.5
	2 ton/fad.	Without	265.00d	278.33e	21.00f	19.66e	273.33d	280.00d	98.46e	84.93f	192.6	172.2
		150 ppm	293.33c	313.33c	27.00c	22.66c	298.33c	327.67c	112.48c	97.94d	220.0	198.6
	4 ton/fad.	Without	306.67b	318.33b	31.33b	23.00c	351.33b	340.67b	120.78b	104.46c	236.2	211.8
		150 ppm	325.00a	348.33a	36.00a	27.66 a	371.00a	374.67a	128.02a	124.51a	250.4	252.5

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 leaf pigments (mg/g DW) of sweet potato plants at 110 DAP in 2014 and 2015 seasons

Treatment	Chlorophyll (a)		Chlorophyll (b)		Total chlorophyll (a+b)		Total carotenoides		Relative increases in total chlorophyll (%)	
	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	2.44 b	2.56 b	2.33 a	2.41 a	4.77 b	4.98 b	2.05a	2.29 a	100.0	100.0
150	2.48 a	2.65 a	2.41 a	2.49 a	4.89 a	5.14 a	2.20 a	2.31 a	102.5	103.2
Effect of FYM (ton/fad.)										
Without	2.41 c	2.50 c	2.32 a	2.38 a	4.73 c	4.89 c	2.04 a	2.18 a	100.0	100.0
2 ton/fad.	2.46 b	2.62 b	2.36a	2.48 a	4.83 b	5.10 b	2.13 a	2.32 a	102.1	104.3
4 ton/fad.	2.50 a	2.70 a	2.42 a	2.48 a	4.93 a	5.19 a	2.19 a	2.40 a	104.2	106.1
Effect of chitosan foliar spray (ppm)										
Without	2.44 b	2.55 b	2.34 a	2.42 a	4.79 b	4.98 b	2.10 a	2.26 a	100.0	100.0
150	2.47 a	2.66 a	2.39 a	2.48 a	4.87 a	5.14 a	2.14 a	2.34 a	103.0	105.1

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 chlorophyll in leaf tissues were about 2.5 and 3.2% for sulphur application than untreated in the 1st and 2nd seasons, respectively. Results are in harmony with Pandey *et al*. (1985) on bean

Effect of FYM

Chlorophyll a and total Chls. (a+b) were significantly increased by increasing FYM rates up to 4 ton/fad., in both seasons. While chlorophyll b and carotenoides did not affected by FYM treatments in both seasons (Table 5). The increases in total chlorophyll in leaf tissues were about 4.2 and 6.1% for FYM rate at 4 ton/ fad., and 2.1 and 4.3% for FYM rate at 2 ton/ fad., than without FYM in the 1st and 2nd seasons, respectively. Applications of organic manure led to increase soil acidity, organic matter, available P, exchangeable Mn, and Zn and this in turn may affect leaf pigments Hseih and Hsu (1993).

Results are in harmony with those obtained by Shazly (2008) on tomato and Bardisi *et al*. (2011) on garlic.

Effect of chitosan foliar spray

Spraying sweet potato plants with chitosan had significant effect on chlorophyll a and total chlorophyll at 110 DAP than unsprayed plants in both seasons (Table 5).

The increases in total chlorophyll in leaf tissues were about 3.0 and 5.1% for sprayed plants with chitosan at 150 ppm than unsprayed plants in the 1st and 2nd seasons, respectively.

Chitosan increased photosynthetic pigments by enhancing endogenous levels of cytokinins, which stimulate chlorophyll synthesis (Chibu and Shibayama, 2001). These results are in agreement with the results obtained by Farouk *et al.* (2008 and 2011) on cucumber and radish, respectively and Sheikha and Al-Malki (2011) on bean.

Effect of interaction between sulphur and FYM rates

It can be seen from the results presented in Table 6 that the interaction between sulphur and FYM rates had significant effect on all leaf pigments of sweet potato in both seasons except chlorophyll b in the 2nd season and carotenoides in both seasons. The interaction between sulphur application and FYM at 4 ton/fad., recorded the maximum concentrations of Chl. a, b, and total Chl (a+b) in both seasons.

These increases in total chlorophyll (a+b) in leaf tissue were about 6.4 and 10.2% for the interaction between sulphur application and FYM at 4 ton/fad., than without sulphur and FYM in the 1st and 2nd seasons, respectively.

Effect of Interaction between sulphur and chitosan

The interaction between sulphur and chitosan reflected a significant effect on Chl. a , b and total Chls (a+b). in both seasons, except Chl. b in the 2nd season. While carotenoides did not affected by the interaction treatment in both seasons (Table 6). The interaction between sulphur application and sprayed plants with chitosan recorded the maximum concentrations of Chl. a and total in both seasons.

The increases in total chlorophyll in leaf tissues were about 4.00 and 6.7% for the interaction between sulphur application and chitosan sprayed than without sulphur and without chitosan in the 1stand 2nd seasons, respectively.

Effect of interaction between FYM and chitosan

Fertilized plants with 4 ton/fad., FYM and sprayed plants with chitosan (150 ppm) had significant effect on all leaf pigments in both seasons, except Chl. b in the 2nd season (Table 6).

The increases in total chlorophyll (a+b) in leaf tissues of sweet potato plant were about 5.8 and 10.4% for the interaction between FYM at 4 ton/fad., and sprayed plants with chitosan at 150 ppm than without FYM and without chitosan in the 1st and 2nd seasons, respectively.

Effect of triple interaction between sulphur, FYM and chitosan

The triple interaction between sulphur application, FYM 4 ton/fad., and sprayed plants with chitosan recorded the highest values of chl. a, b and total (a+b) as well as carotenoides concentrations in leaf tissues in both seasons. While the lowest values in these respect were

Table 6. Effect of dual interaction between sulphur and FYM, sulphur and chitosan as well as FYM and chitosan on leaf pigments (mg/g DW) sweet potato plants at 110 DAP in 2014 and 2015 seasons

Treatments		Chlorophyll (a)		Chlorophyll (b)		Total chlorophyll (a+b)		Total carotenoides		Relative increases in total chlorophyll (%)	
		2014 season	2015 season	2014 season	2015 season	2014 season	2014 season	2014 season	2015 season	2014 season	2015 season
Sulphur	**FYM**	**Sulphur and FYM rates**									
Without	**Without**	2.40 e	2.47 e	2.29 f	2.35 a	4.70 e	4.82 d	1.98 a	2.15 a	100.0	100.0
	2 ton/fad.	2.44 c	2.54 d	2.32 e	2.46 a	4.76 d	5.04 bc	2.04 a	2.31 a	101.3	104.6
	4 ton/fad.	2.48 b	2.58 c	2.38 c	2.42 a	4.86 c	5.08 bc	2.12 a	2.41 a	103.4	105.4
150 kg/fad.	**Without**	2.42 d	2.66 b	2.35 d	2.42 a	4.77 d	4.96 cd	2.11 a	2.21 a	101.5	102.9
	2 ton/fad.	2.49 b	2.65 b	2.41 b	2.49 a	4.90 b	5.15 b	2.22a	2.33a	104.3	106.8
	4 ton/fad.	2.52 a	2.76 a	2.47 a	2.55 a	5.00 a	5.31 a	2.26 a	2.39 a	106.4	110.2
Sulphur	**Chitosan**	**Sulphur and chitosan foliar spray**									
Without	**Without**	2.43 c	2.52 d	2.31 d	2.39 a	4.74 d	4.91 c	2.03 a	2.24 a	100.0	100.0
	150 ppm	2.45 b	2.61 b	2.35 c	2.43 a	4.81 c	5.05 b	2.06 a	2.34 a	101.5	102.9
150 kg/fed.	**Without**	2.46 b	2.59 c	2.38 b	2.45 a	4.85 b	5.04 bc	2.17 a	2.28 a	102.3	102.6
	150 ppm	2.49 a	2.71 a	2.43 a	2.52 a	4.93 a	5.24 a	2.22 a	2.352 a	104.0	106.7
FYM	**Chitosan**	**FYM and chitosan foliar spray**									
Without	**Without**	2.39 f	2.46 f	2.29 e	2.33a	4.69 f	4.79d	2.03 f	2.12 d	100.0	100.0
	150 ppm	2.43 e	2.55 e	2.34 d	2.44 a	4.78 e	4.99 c	2.06 e	2.25 c	101.9	104.2
2 ton/fad.	**Without**	2.45 d	2.56 d	2.34 d	2.48 a	4.80 d	5.05 bc	2.11 d	2.28 c	102.3	105.4
	150 ppm	2.47 c	2.68 b	2.39 c	2.47 a	4.86 c	5.15 b	2.15 c	2.36 b	103.6	107.5
4 ton/fad.	**Without**	2.49 b	2.65 c	2.40 b	2.45 a	4.89 b	5.10 bc	2.17 b	2.37 b	104.3	106.5
	150 ppm	2.51 a	2.76 a	2.45 a	2.52 a	4.96 a	5.29 a	2.21 a	2.42 a	105.8	110.4

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

recorded with no application of sulphur, FYM and chitosan in both seasons (Table 7). The increases in total chlorophyll of sweet potato plant were about 8.2 and 14.4% for the triple interaction between sulphur application, FYM 4 ton/fad., and sprayed plants with chitosan at 150 ppm than untreated plants with sulphur, FYM and chitosan in the 1st and 2nd seasons, respectively.

N, P and K Contents and its Uptake by Shoots

Effect of sulphur

Treated sweet potato with sulphur at 150 kg/ fad., under clay soil had significant effect on mineral contents in shoots, *i.e.,* N, P and K as well as N,P and K uptake by shoots at 110 DAP in both seasons, except P content in shoots in the 1st season (Table 8). N, P and K contents as well as N, P and K uptake by shoots were the highest with sulphur application in both seasons.

The increases in nitrogen uptake by shoots were about 40.2 and 32.2 for sulphur application than untreated plants in the 1st and 2nd seasons, respectively.

The higher percentage of NPK in shoots could be due to the positive effect of sulphur in reducing the pH value of the soil, which lead to more absorption of nutrients by plants (Brown and Tiffin, 1982).

These results agree with those reported by Singh and Pandey (1995) in garlic, Pacha (2003) on potato and Jaggi (2004) on onion.

Table 7. Effect of triple interaction between sulphur, FYM and chitosan as foliar spray on leaf pigments (mg/g DW) of sweet potato plants at 110 DAP in 2014 and 2015 seasons

Treatment			Chlorophyll (a)		Chlorophyll (b)		Total chlorophyll (a+b)		Total carotenoides		Relative increases in total chlorophyll (%)	
			2014 season	2015 season	2014 season	2015 season	2014 season	2014 season	2014 season	2015 season	2014 season	2015 season
Sulphur	**FYM**	**Chitosan**										
Without	**Without**	**Without**	2.39 i	2.43 j	2.26 k	2.28 c	4.65 i	4.72 g	1.97 j	2.08 h	100.0	100.0
		150 ppm	2.42 g	2.50 h	2.32 i	2.41 bc	4.743 h	4.92 ef	1.99 i	2.23 f	102.0	104.2
	2 ton/fad.	**Without**	2.43 f	2.52 g	2.30 j	2.52 ab	4.74 h	5.04 de	2.02 h	2.28 ef	101.9	106.8
		150 ppm	2.45 e	2.63 e	2.34 h	2.41 bc	4.79 g	5.05 de	2.06 g	2.34 cd	103.0	107.0
	4 ton/fad.	**Without**	2.47 d	2.60 f	2.36 g	2.38 bc	4.83 f	4.98 ef	2.11 e	2.37 bc	103.9	105.5
		150 ppm	2.49 c	2.71 c	2.40 d	2.47 ab	4.90 d	5.18 b-d	2.13 d	2.44 a	105.4	109.7
150 kg/fad.	**Without**	**Without**	2.40 h	2.48 i	2.32 i	2.38 bc	4.73 h	4.87 f	2.09 f	2.17 g	101.7	103.2
		150 ppm	2.44 e	2.59 f	2.37 f	2.46 ab	4.81 f	5.06 c-e	2.13 d	2.26 ef	103.4	107.2
	2 ton/fad.	**Without**	2.47 d	2.60 f	2.39 e	2.45 ab	4.86 e	5.05 de	2.19 c	2.29 de	104.5	107.0
		150 ppm	2.50 b	2.72 b	2.43 c	2.53 ab	4.94 c	5.26 ab	2.24 b	2.38 bc	106.2	111.4
	4 ton/fad.	**Without**	2.51 b	2.70 d	2.45 b	2.51 ab	4.96 b	5.21 bc	2.23 b	2.37 bc	106.7	110.4
		150 ppm	2.53 a	2.82 a	2.50 a	2.58 a	5.03 a	5.40 a	2.29 a	2.40 ab	108.2	114.4

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 sulphur, FYM and chitosan as foliar spray on N, P and K contents and its uptake by shoots of sweet potato plants at 110 DAP in 2014 and 2015 seasons

Treatment	Contents (%)						Uptake						Relative increases in N uptake (%)	
	N		P		K		N		P		K			
	2014 season	2015 season	2014 season	2015 season	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	3.95b	4.05b	0.355a	0.356b	3.65b	3.79b	3163.9b	3092.5b	286.1b	270.5b	2926.0b	2892.2b	100.0	100.0
150	4.22a	4.35a	0.386a	0.396a	3.97a	3.96a	4435.4a	4089.2a	403.3a	371.1a	4161.4a	3715.4a	140.2	132.2
Effect of FYM (ton/fad.)														
Without	3.90c	3.93c	0.358 b	0.357c	3.67b	3.67c	2724.4c	2531.0c	251.4c	229.5c	2571.2c	2355.7c	100.0	100.0
2 ton/fad.	4.07b	4.22b	0.366ab	0.380b	3.79b	3.88b	3740.4b	3456.4b	337.0b	312.6b	3495.5b	3182.0b	137.3	136.6
4 ton/fad.	4.29a	4.45 a	0.388a	0.391a	3.97a	4.08a	4934.2a	4785.1a	445.6a	420.2a	4564.3 a	4373.7a	181.1	189.1
Effect of chitosan foliar spray (ppm)														
Without	4.02 b	4.09 b	0.371a	0.371b	3.78a	3.79b	3499.8b	3180.1b	322.8b	288.3b	3296.1b	2946.7 b	100.0	100.0
150	4.15 a	4.31 a	0.370 a	0.381 a	3.84 a	3.96 a	4099.5a	4001.6a	366.5 a	353.2 a	3791.2a	3660.9a	117.1	125.8

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.

Effect of FYM

Nitrogen, phosphorus and potassium contents and its uptake in shoots of sweet potato were significantly increased by increasing FYM rates up to 4 ton/fad., in both seasons (Table 8). The increases in nitrogen uptake by shoots were about 81.1 and 89.1% for FYM rate (4 ton/fad.) and 37.3 and 36. 6% for FYM rate (2 ton/fad.) than unfertilized plants in the 1st and 2nd seasons, respectively.

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, organic fertilizers were used to decrease soil pH and increasing the availability of major and minor nutrients (Tahoun *et al.,* 2000).

These results are in line with those reported with Morsy *et al*. (2001), Ali (2002) and El-Naggar (2004) on tomato.

Effect of chitosan foliar spray

Spraying sweet potato plants with chitosan had significant effect on N, P, and K contents and its uptake in sweet potato shoot in both seasons, except P and K contents in shoot in the 1st season (Table 8).

The increases in nitrogen uptake by shoot were about 17.1 and 25.8% for sprayed plants with chitosan than unsprayed plants in the 1st and 2nd seasons, respectively.

The increment in N uptake by shoots may be brought about by the amino components in chitosan and or higher ability of the plant to absorb N from the soil when chitosan was degraded. Also the higher uptake of K explains the higher quality of the fruits due to the presence of K which acts on photosynthate translocation from the leaves to the storage organs (**El-Tanahy *et al*., 2012**).

Effect of interaction between sulphur and FYM rates

Results presented in Table 9 show that the interaction between sulphur and FYM rates had significant effect on all mineral contents and its uptake by shoot in both seasons, except P content in shoot in the 1st season.

The interaction between sulphur application and FYM at 4 ton/fad., recorded the highest values of N, P and K contents and its uptake by shoot in the two seasons.

These increases in nitrogen uptake by shoot were about 166.6 and 159.3% for the interaction between sulphur at 150 kg/fad., and FYM at 4 ton/fad., than untreated plants with sulphur or FYM in the 1st and 2nd seasons, respectively.

Effect of Interaction between sulphur and chitosan

The interaction between sulphur andchitosan reflected significant effect on of N,P and K contents and its uptake by shoot in the two season, except P content in shoot in the 1st season than untreated plants (Table 9).

The increases in nitrogen uptake by shoot were about 64.5 and 66.5% for the interaction between sulphur application and chitosan sprayed than without sulphur and without chitosan in the 1st and 2nd seasons, respectively.

Effect of Interaction between FYM and chitosan

Plants fertilized with FYM 4 ton/fad., and sprayed with chitosan, had significant effect on N, P and K contents and its uptake by shoot in the two seasons (Table 9).

The increases in nitrogen uptake by shoot were about 112.4 and 138.0% increases for the interaction between FYM at 4 ton/fad., and sprayed plants with chitosan than unfertilized plants with FYM and unsprayed with chitosan in the 1st and 2nd seasons, respectively.

Effect of triple interaction

The triple interaction among sulphur application, FYM 4 ton/fad., and sprayed plants with chitosan had significantly increased all mineral contents and its uptake by shoot in both seasons (Table 10). The increases in nitrogen uptake by shoots were about 213.0 and 235.4% regarding the triple interaction among sulphur application at 150 kg/fad., FYM 4 ton/fad. and sprayed plants with chitosan than plants untreated with sulphur, FYM and chitosan in the 1st and 2nd seasons, respectively.

It could be concluded that, the interaction between 150 kg/fad., sulphur application, fertilized plants with FYM at 4 ton/fad., and sprayed plants with 150 ppm chitosan were the best interaction treatments for enhancing plant growth and chemical constituents of sweet potato under clay soil.

Table 9. Effect of dual interaction between sulphur and FYM, sulphur and chitosan as well as FYM and chitosan on N,P and K contents and its uptake by shoots of sweet potato plants at 110 DAP in 2014 and 2015 seasons

Treatment		Contents (%)						Uptake (mg/plant)						Relative increases in N uptake (%)	
		N		P		K		N		P		K			
		2014 season	2015 season	2014 season	2015 season	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**	3.76e	3.73d	0.331a	0.339f	3.48 c	3.58 f	2096.3f	2054.5f	184.3e	186.4e	1942.5e	1972.7e	100.0	100.0
	2 ton/fad.	4.01d	4.14c	0.355a	0.359e	3.69 bc	3.80 d	3115.7e	2980.6e	276.4d	258.6d	2867.8d	2739.5d	148.6	145.1
	4 ton/fad.	4.09bc	4.27b	0.380a	0.370d	3.79 b	3.99 b	4279.9c	4242.4b	397.5 b	366.4b	3967.6b	3964.4b	204.2	206.5
150 kg/fad.	**Without**	4.04cd	4.13c	0.386a	0.375c	3.86 b	3.76 e	3352.6d	3007.5d	318.4 c	272.6c	3199.9c	2738.7d	159.9	146.4
	2 ton/fad.	4.13b	4.29b	0.376a	0.400b	3.90 b	3.96c	4365.1b	3932.3c	397.5b	366.6b	4123.2b	3624.4c	208.2	191.4
	4 ton/fad.	4.49a	4.63a	0.396a	0.412a	4.14 a	4.16 a	5588.6a	5327.9a	493.8 a	474.0a	5161.0a	4783.1a	266.6	259.3
Sulphur	**Chitosan**	**Sulphur and chitosan foliar spray**													
Without	**Without**	3.91d	3.96d	0.351a	0.355d	3.61 c	3.72c	2901.4d	2735.3d	261.6 d	245.6 d	2677.3d	2569.8d	100.0	100.0
	150 ppm	3.99c	4.14c	0.359a	0.357c	3.70 bc	3.87 b	3426.5 c	3449.6c	310.5c	295.3 c	3174.6c	3214.6c	118.1	126.1
150 kg/fad.	**Without**	4.13b	4.22b	0.391a	0.386b	3.96 ab	3.87 b	4098.3b	3624.9b	384.0b	331.0 b	3914.9b	3323.5b	141.3	132.5
	150 ppm	4.30a	4.48a	0.381a	0.405a	3.98 a	4.05 a	4772.6a	4553.6a	422.6a	411.1 a	4407.8a	4107.3a	164.5	166.5
FYM	**Chitosan**	**FYM and chitosan foliar spray**													
Without	**Without**	3.86f	3.86e	0.370ab	0.355e	3.70 bc	3.60 f	2477.9 f	2253.9f	241.2 f	207.2f	2388.6f	2095.7f	100.0	100.0
	150 ppm	3.93e	4.01d	0.346b	0.359d	3.64 c	3.74 e	2970.9 e	2808.2e	261.6 e	251.8e	2753.8e	2615.7e	119.9	124.6
2 ton/fed.	**Without**	4.03d	4.13c	0.361ab	0.372c	3.75 bc	3.82d	3416.0d	3102.6d	307.2 d	281.6 d	3192.4d	2873.8d	137.9	137.7
	150 ppm	4.12c	4.30b	0.371ab	0.387b	3.84a-c	3.94 c	4064.8 c	3810.2 c	366.8 c	343.6c	3798.6c	3490.2c	164.0	169.0
4 ton/fad.	**Without**	4.18b	4.28b	0.382ab	0.385b	3.91 ab	3.96 b	4605.6b	4183.9b	420.1 b	376.2 b	4307.4b	3870.5b	185.9	185.6
	150 ppm	4.39a	4.63a	0.394 a	0.397a	4.03 a	4.19 a	5262.9 a	5386.4 a	471.2 a	464.1 a	4821.3a	4876.9a	212.4	239.0

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.

Table 10. Effect of triple interaction between sulphur, FYM and chitosan foliar spray on N,P and K contents and its uptake by shoots of sweet potato plants at 110 DAP in 2014 and 2015 seasons

Treatments			Contents (%)						Uptake (mg/plant)						Relative increases in N uptake (%)	
			N		P		K		N		P		K			
			2014 season	2015 season	2014 season	2015 season	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**	3.72 i	3.65 g	0.331 c	0.336 j	3.45 f	3.51 j	1902.1k	1800.3k	169.2 h	165.7l	1767.4 j	1734.6j	100.0	100.0
		150 ppm	3.80 h	3.82 f	0.331 c	0.342 i	3.51ef	3.65 i	2290.4j	2308.7 j	199.4 g	207.1 k	2117.5i	2210.8i	120.4	128.2
	2 ton/fed.	**Without**	3.97 g	4.08 e	0.350bc	0.351 h	3.64d-f	3.73 g	2814.8i	2655.2 i	247.8 f	228.6 j	2577.7h	2429.6h	148.0	147.5
		150 ppm	4.05 e	4.21 c	0.361a-c	0.367 f	3.74 c-f	3.88 e	3416.6g	3306.0g	305.1 e	288.7 h	3157.9fg	3049.5g	179.6	183.6
	4 ton/fed.	**Without**	4.04 ef	4.14 d	0.373a-c	0.378 d	3.74 c-f	3.91d	3987.3e	3750.5e	367.9 d	342.7 e	3686.7de	3545.2e	209.6	208.3
		150 ppm	4.14 d	4.41 b	0.386ab	0.363 g	3.84b-d	4.08b	4572.4d	4734.2b	427.0 c	390.0 d	4248.5 c	4383.5b	240.4	263.0
150 kg/fad.	**Without**	**Without**	4.00fg	4.07 e	0.410 a	0.374e	3.94a-c	3.69h	3053.7h	2707.4h	313.2 e	248.8 i	3009.7 g	2456.8h	160.5	150.4
		150 ppm	4.07 e	4.20 c	0.361a-c	0.377d	3.78b-e	3.84f	3651.4f	3307.6g	323.7 e	296.5 g	3390.1ef	3020.6g	192.0	183.7
	2 ton/fad.	**Without**	4.08 e	4.18 c	0.372a-c	0.394c	3.86b-d	3.90de	4017.1e	3550.1 f	366.6 d	334.6 f	3807.1d	3318.0 f	211.2	197.2
		150 ppm	4.19 c	4.40 b	0.381a-c	0.407b	3.94a-c	4.01c	4713.0c	4314.5d	428.5c	398.6 c	4439.4c	3930.9d	247.8	239.7
	4 ton/fad.	**Without**	4.32b	4.42 b	0.391ab	0.392 c	4.08ab	4.01c	5223.9b	4617.2c	472.2 b	409.8 b	4928.0b	4195.9c	274.6	256.5
		150 ppm	4.65 a	4.85 a	0.402ab	0.432 a	4.21 a	4.31 a	5953.3a	6038.6a	515.5 a	538.2 a	5394.1a	5370.4a	313.0	335.4

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

١- النمو الخضري والمكونات الكيماوية

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أجريت تجربتان حقليتان خلال موسمي صيف ٢٠١٤ ، ٢٠١٥ وذلك بمزرعة البحوث الزراعية بالجميزة ، محافظة الغربية، مصر، وذلك لتقييم تأثير إضافة الكبريت ومستويات السماد البلدى والرش بالشيتوزان والتفاعل بينهم على النمو الخضري والمكونات الكيماوية للبطاطا صنف بيوروجارد النامية في الأرض الطينية، ازداد معنويا كل من طول الفرع الرئيسي، عدد الأفرع والأوراق/نبات، الوزن الجاف للعرش، محتوى العرش من كلورفيل أ، الكلورفيل الكلى، المحتوى من النيتروجين، الفوسفور والبوتاسيوم والممتص منهم بواسطة العرش، وكانت الزيادة معنوية بمعاملة التفاعل الثلاثي بين إضافة الكبريت بمعدل ١٥٠ كجم/فدان، السماد البلدي بمعدل ٤ طن/فدان والرش بالشيتوزان بتركيز ١٥٠ جزء في المليون، وعلى الجانب الأخر فقد سجلت أقل القيم لكل الصفات السابقة بمعاملة التفاعل الثلاثي بين بدون كبريت وبدون سماد بلدي وبدون شيتوزان في كلا الموسمين.

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