J. Agric. Sci. Mansoura Univ., 30 (7): 4337 - 4353, 2005

RESPONSE OF POTATO GROWN ON CLAY LOAM SOIL TO SULFUR AND COMPOST APPLICATION

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ABSTRACT

Two field experiments were conducted on clay loam soil at Battera village, Talkha district, Dakahlia Governorate, Egypt, during the two successive growing seasons of summer 2003 and winter 2003/2004 to study the effect of tow sources of sulfur application rates (0, 150kg S fed^{-1} as elemental sulfur 99.5%S and as gypsum 18.60% S) under rice straw compost application (0, 6, 12 ton fed^{-1}) on potatoes (*Solanum tuberosum*, L.) cultivar Spunta and some soil properties. The experimental design was a split plot design with three replicates.

The obtained results showed that:

- Addition of sulfur (S) and Compost (C) and their interactions significantly increased plant height (cm), leaf area (m^2 $plant^{-1}$), total chlorophyll and fresh and dry tuber yield (t fed^{-1}) both seasons.
- Soil physical properties were markedly affected with both of sulfur and compost applications whereas, bulk density decreased and increased total porosity %. Saturation percentage increased significantly with compost but it was not affected by sulfur application.
- Application of sulfur and compost significantly increased available (NH_4^+-N, NO_3^--N), P and K as compared with control in both seasons.

Finally, from the present study we can recommended that application of 150 kg S fed^{-1} as element + 12 ton compost fed^{-1} of rice straw with the constant background of recommended doses of (NPK) for improving the production of potato under similar experimental conditions.

INTRODUCTION

Potato (*Solanum tuberasum* L.) as a member of the family solanaceae is one of the most important food crops all over the world including Egypt. It ranks the first export and the second vegetable crop in acreage.

Adding sulfur to soil has an important role not in correcting many of the soil and plant nutrition problems. Many researchers studied the effect of sulfur addition on growth and yield of potato, among of them (Radwan,1997; Saha, *et al.*, 2001; Terans, *et al.*, 2001) they found that application of sulfur increased number of leaves, number of secondary stems $plant^{-1}$, plant height, leaf area, chlorophyll content in leaves, fresh and dry weight $plant^{-1}$, crop growth rate and tuber bulking rate. It was also found that total tuber yield, yields of vegetable crops and other yield related parameters increasing with sulfur applicaitn (Omprakash *et al.*, 1997; Radwan, 1997; Terans, *et al.*, 2001). Also sulfur element can use as soil amendment would increase the availability of nutrient elements through the reduction in pH (El-Fayoumy and El-Gamal, 1998 and Makary, 2002) and evoke a plant response. Also, sulfur can be added into the soils through gypsum application as a soil amendment which can improve many soil properties (Sansom, *et al.*, 1998 on soil sodicity and pH value and Math, *et al.*, 1999 on soil pH and EC)

Egyptian soils are very poor in their organic matter content which fluctuates between 0.1 – 2.5 % due to the climate arid conditions which is reflected on the high decomposition rate of organic matter.

The effect of organic manure and other residues on plant behavior is not just a matter of nutrients supply, but it influence the physical, chemical and biological characteristics of soil which in turn influence development of plants (Mahmoud, 2000; El-Fayomy and Hammad 2001; El-Ghamry and El-Naggar 2001 and Abdelhamid, *et al.*, 2004).

Because of the high fertilizer prices and transport costs in the hills, there is a need to supplement a part of N needs of potato with organic fertilizer. The rice straw residue is about 6.5 million tons year^{-1}. The large quantity of it is disposal by burning the straw in the field and this way for removal straw caused air pollution, this is the actual reasons for the problem of black cloud which appeared and that pollution is dangerous and harmful for human health which caused a lot of diseases. So this problem should be faced. The positive effects of organic fertilizers or residues which are added into different soil types on various plants are reported by many workers (Abdulla, 1999; Arisha and Bardisi, 1999; and Krishnamurthy *et al.*, 2001 on potato.

Therefore, the present investigation was carried out to clarify the influence of two sources of sulfur under compost "rice straw" application on (1) growth and yield and its characters of potatoes plant and **(2)** improving some physical and chemical properties of the soil after potatoes harvest.

MATERIALS AND METHODS

Location of experiment: Two field experiments were conducted on clay loam soil at Battera village, Talkha district, Dakahlia Governorate, Egypt, during the two successive growing seasons of summer 2003 and winter 2003/2004 to study the effect of sulfur under rice straw compost application on potatoes (*Solanum tuberosum*, L.) cultivar Spunta. The following materials and methods were applied.

Soil used: The experimental soil was clay loam in texture (39.75% sand, 28.34% silt and 32% clay). This clay loam texture was reflected on the physical characteristics of soil where, saturation percentage 65%, bulk density 1.2 g cm^{-3} and real density 2.65 g cm^{-3}. Soil pH 7.6 and the soil is non saline where electrical conductivity (EC) 3 dS m^{-1}. Soil organic matter content (1.20%). $CaCO_3$ 3.2%. The soil before planting was low to medium in available nitrogen (44-35 ppm), where the soil is high in both available phosphorus (15-20 ppm), and potassium (640-990 ppm).

Seed Tubers: Potatoes (*Solanum tuberosum*, L.) c.v. spunta were chosen to this study.

Soil amendments:

Rice straw compost: Rice straw compost was prepared before each season at the same sites of present study. Rice straw was collected from Battra village. It was composted at this place according to method described by Abou El-Fadl (1960). The composting process was continued up to 90 days to obtain C/N ratio less than 25:1 which is considered suitable according to Cooke (1982). Some chemical properties of the compost samples are shown in Table (1).

Table (1): Some chemical analysis of the used compost.

Compost	pH	EC	Total C%	Total N%	C:N ratio	Total P%	Total K%
1st season	6.40	2.26	27.40	1.44	19: 1	0.44	0.18
2nd season	6.40	2.18	26.68	1.50	18: 1	0.38	0.20

Sulfur: Sulfur was used from different sources as gypsum (60.5% purity) and elemental sulfur (99.5%S) as a soil amendment and in the same time as a fertilizer.

Treatments:

- Three levels of rice straw compost were applied as follows: (C_0): Zero compost (control without application), (C_1): 6 ton compost fed^{-1}, and (C_2): 12 ton compost fed^{-1}.
- Three treatments of sulfur was applied at two rates 0 and 150 kg S fed^{-1} from two sources as: (S_0): 0 kg sulfur (control without application), (S_E): 150 kg S fed^{-1} as an element sulfur (99.5% S) and (S_G): 150 kg S fed^{-1} as a gypsum (1.3 ton gypsum fed^{-1}).

Experimental Design: The experimental design was a split plot design with 3 replicates. The main plots were assigned to the three levels of compost (C) while, the sub-plots were assigned to the three treatments of sulfur (S).

Planting and Harvesting: Potato tuber pieces (c.v. spunta) were planted in January 8th 2003 in the 1st season and harvested in April 28th 2003, while the 2nd season planted in October 2nd 2003 and harvested in January 22nd 2004.

Application of Fertilizers and Irrigation: The rate of nitrogen fertilizers (ammonium nitrate 33.5% N) of recommended dose 150 kg N fed^{-1} were divided into 2 doses the 1st dose was added with the 1st irrigation and the 2nd dose with the 2nd irrigation after sowing. Calcium super-phosphate (15.5% P_2O_5) was applied before planting irrigation at the rate of recommended does 75 kg P_2O_5 fed^{-1} for all treatments. Potassium sulfate (48.0% K_2O) was applied at rate of 96 kg K_2O fed^{-1} (recommended does) for all treatments, as a one dose with the third irrigation. Potatoes were irrigated after planting where 5 irrigations were done at first season and 4 irrigations at second season.

Rice straw compost analyses: pH value was determined in 1: 5 suspension for compost using a Gallenkamp pH meter (Jackson, 1967). Electrical conductivity (EC) measurements were run in (1: 5) compost: water extract , total carbon (C%) content of compost was determined by Walkly & Black method as described by Hesse (1971). Total nitrogen (%) in compost was determined using the conventional method of Kjeldahal (Jackson, 1967). C/N ratio was calculated molecularly by dividing each determination on its molecular weight e.g. C/12 and N/14, then the obtained values of both C and N were divided (C/N).

Soil analyses: were carried out according to (Piper, 1950) for mechanical analysis, $CaCO_3$% - (Dewis and Freitas, 1970) for bulk density and real density - Hillel, (1972), for porosity- Hesse (1971) for EC, pH, OM, available N and K – and (Jackson, 1967) for available K.

Plant Measurements and Analysis:

Plant height (cm). Leaf area m^2 $plant^{-1}$. It was calculated using the following equation according to (Koller, 1972):

$$\text{Leaf area} = \frac{\text{Dry weight of leaves x disk area x No. of disks}}{\text{Dry weight of disks}}$$

Total chlorophyll content: leaf chlorophyll contents were measured by a Minolta SPAD chlorophyll meter (Yadava, 1986). The reading of chlorophyll meter was taken on 2nd leaf from the top of plant.

Yield and Yield Components:

Potatoes were harvested after 110 days from planting date and the following parameters were recorded: Fresh tuber yield (t fed^{-1}) and Dry tuber yield (t fed^{-1}).

Statistical Analysis:

The statistical analysis of the obtained data was done according to the methods described by **(Gomez and Gomez, 1984)** using LSD to compare the means of treatments values.

RESULTS AND DISCUSSION

Effect of sulfur and compost on vegetative growth:

- **Plant height.**

Data presented in Table (2) illustrate that sulfur addition significantly increased plant height in the 1st and 2nd seasons. The means of plant height at sulfur treatments S_0 (without S addition), S_E (150 kg S fed^{-1} as elemental S) and S_G (150 kg S fed^{-1} as gypsum) were 29.20, 32.17 and 32.39 cm, and 57.55, 64.00 and 60.78 respectively in both seasons. The elemental sulfur (S_E) could be more active than gypsum (S_G) in 2nd. season. This effect of sulfur on plant height may be due to increasing the availability of different nutrient elements. These results are agreeable with those obtained by El-Radwan (1997) where, he illustrated that S application significantly increased plant height as compared with the control. It is noticed that the application of S as an element was more effective than the application as a gypsum. This may be attributed to the high activity of sulfur than gypsum.

Data in the same Table reveal that compost application increased plant height, significantly in both seasons. The mean values of plant height were 29.67, 30.70 and 33.39 cm and 55.55, 62.89 and 63.89 at the applied rates of C_0 (control), C_1 (6 t fed^{-1}) and C_2 (12 t fed^{-1}), respectively in both seasons. These results may be related to compost content of nutrients which increase with increasing application rates and consequently increase plant height. In addition, the effect of compost on vegetative growth may be due to improving the soil structure. These are in agreement with those obtained by Jung Bae, *et al.*, (1996) where they observed in a greenhouse experiment that application of 1 ton rice straw / ares (are = $100m^2$) increased plant height compared with chemical fertilizer. Also, Arisha and Bardisi (1999) found that plant height was significantly increased with increasing FYM up to 30 m^3 ha^{-1}.

Finally, the effect of interaction CxS on plant height was insignificant at 1st season and significant at 2nd season as shown in Table (2). Generally, the mean values of plant height in 1st season was differ than its value in 2nd season. This may be related to differences in condition growth.

Table (2): Effect of Sulfur and compost on vegetative growth of potatoes.

Treatments		Plant height (cm)		Leaf area (m^2 $plant^{-1}$)		Total chlorophyll (reading)	
		1st	2nd	1st	2nd	1st	2nd
Compost levels							
C_0		29.67 b	55.55 b	0.48 a	0.50 b	46.77 a	54.62 a
C_1		30.70 ab	62.89 a	0.51 a	0.60 a	45.80 c	56.71 a
C_2		33.39 b	63.89 a	0.52 a	0.65 a	46.43 b	58.33 a
LSD 5%		2.855	2.308	NS	0.079	0.087	NS
Sulfur treatments							
S_0		29.20 b	57.55 c	0.48 a	0.56 a	45.92 c	54.53 b
S_E		32.17 a	64.00 a	0.53 b	0.59 a	46.77 a	58.01 a
S_G		32.39 a	60.78 b	0.51 a	0.60 a	46.31 b	57.12 a
LSD 5%		1.472	1.391	0.022	NS	0.048	1.148
Interaction CxS							
C_0	S_0	27.00 d	54.33 d	0.46 b	0.47 c	45.50 d	53.23 c
	S_E	30.50 bc	57.33 d	0.48 b	0.50 bc	47.80 a	55.10 bc
	S_G	31.50 abc	55.00 d	0.50 b	0.53 abc	47.00 b	55.53 bc
C_1	S_0	28.93 cd	57.33 d	0.50 b	0.58 abc	45.20 f	54.37 c
	S_E	31.33 abc	67.33 a	0.53 b	0.62 a	47.10 b	57.87 b
	S_G	31.83 abc	64.00 b	0.51 b	0.60 ab	45.10 g	57.90 b
C_2	S_0	31.67 abc	61.00 c	0.48 b	0.64 a	47.07 b	56.00 bc
	S_E	34.67 a	67.33 a	0.57 a	0.66 a	45.40 e	61.07 a
	S_G	33.83 ab	63.33 bc	0.51 b	0.66 a	46.83 c	57.93 b
LSD 5%		NS	2.409	0.039	NS	0.084	NS

- **Leaf area of potatoes.**

Data presented in Table (2) indicate that leaf area increased significantly with S application in 1st and insignificant in 2nd seasons, the means of leaf area increased from 0.48 to 0.53 and 0.51 m^2 $plant^{-1}$ and from 0.56 to 0.59 and 0.60 m^2 $plant^{-1}$ at S treatments, S_0, S_E and S_G respectively in both seasons. These results are confirmed with those obtained by Saha, *et al.*, (2001).

Data in the same Table reveal that compost application increases leaf area insignificantly in 1st season and significantly in 2nd season. The means of leaf area (m^2 $plant^{-1}$) were 0.48, 0.51 and 0.52 m^2 $plant^{-1}$ in 1st season and 0.50, 0.60 and 0.65 in 2nd season at rates of compost application C_0 (control), C_1 (6 t fed^{-1}) and C_2 (12 t fed^{-1}), respectively. This effect of compost application on leaf area may be related to positive effect of compost in improving soil properties and availability of nutrients which reflected on increasing leaves number plant^{-1} and leaf area. Similar finding was obtained by Abdulla (1999) and Abdel-Kader (2002).

As shown in the same Table the effect of interaction between S and C on leaf area (m^2 plant^{-1}) CxS was significant in 1st season and insignificant in 2nd season.

❖ **Total chlorophyll of potatoes.**

Also, sulfur addition increases T.Chlo. significantly as compared with control (without addition) in both seasons. Almost the elemental S (S_E) gave a higher Chlo. content than gypsum S (S_G) in both seasons. The maximum mean of total Chlorophyll. as affected by S addition was 46.77 in 1st season and 58.01 in 2nd season at treatment S_E (150 kg S fed^{-1} as elemental sulfur). These may be due to that sulfur is an essential element for vitamins and hormones formation, protein synthesis and structure cells, all of this play an important role in increase vegetative growth and then chlorophyll. These results are in harmony with those obtained by El-Gamal, *et al.*, (1990), Radwan (1997), Terans, *et al.*, (2001) and Mohamed (2002) where they reported that S application increased total chlorophyll in plants.

As shown in Data of Table (2) compost application led to significant increases of T.Chlo. in 1st season and insignificant in 2nd season. The mean values of T.Chlo. were 46.77, 45.80 and 46.43 in 1st season, whereas, were 54.62, 56.71 and 58.33 in 2nd season at the applied rates of C_0 (without addition), C_1 (6 t fed^{-1}) and C_2 (12 t fed^{-1}), respectively. This effect of compost on T.Chlo. might be related to compost content of essential nutrients such as N, P and micro nutrients which are important for photosynthesis process, respiration, carbohydrate metabolism, protein synthesis and chloroplasts formation, that leads to an increase in chlorophyll.

The effect of interactions CxS on total chlorophyll were significant in 1st season, while it was insignificant in 2nd season. These may be due to the difference in conditions of growth between two seasons where, 1st season was at winter-spring season while 2nd season was at autumn-winter season. As clearly, there is a different in conditions growth, whereas autumn-winter season improve vegetative growth more than winter-sprig season. Generally, the effect of C and S on total chlorophyll may be due to those roles in supplying plants with essential elements for growth.

Effect of Sulfur and compost on yield of potatoes:

❖ **Fresh tuber yield of potatoes.**

Data presented in Table (3) reveal that S application increases total fresh tuber yield significantly in both seasons. The fresh tuber yield (t fed^{-1}) increased by 15.13 and 11.78 % in 1st season with applied S treatments S_E and S_G respectively. While, yield increased by 16.06 and 12.46% in 2nd season. The maximum mean of total fresh tuber yield as affected by S addition was 17.23 t fed^{-1} in 1st season and 13.39 t fed^{-1} in 2nd season at the applied rate S_E in both seasons. These may be due to that elemental S (S_E) is more active than gypsum (S_G). Effect of S on tuber yield may be related to sulfur effect on reducing soil pH and then, increased the availability of nutrients to plant uptake which reflected on vegetative growth and consequently on the tuber yield. In addition, sulfur plays the importance role for plant growth. Similar results are reported by Mohamed (2002), where he reported that S application at 250 kg fed^{-1} increased total tuber yield. Also, Sud, *et al.*, (1996) pointed out that elemental S gave significantly higher yield than $(NH_4)_2SO_4$ and $CaSO_4$ with increasing levels of S up to 40 kg ha^{-1}.

As show In the same Table data illustrate that compost addition increased fresh tuber yield (t fed^{-1}) significantly in both seasons. The means of fresh tuber yield increased by 8.42 and 12.08% with applied compost rates C_1 (6 t fed^{-1}) and C_2 (12 t fed^{-1}), respectively in 1st season. Whereas in 2nd season it increased by 10.84 and 31.32%, respectively. These effect of compost on total fresh tuber yield may be due to its effect on improving physical, chemical and biological properties of the soil where are reflected on the encourage of vegetative growth and root development, which lead to higher yield of plant. These results are in accordance with those obtained by Kotbe, *et al.*, (1995) where observed that continued organic fertilizer application led to about 10 to 20% higher tuber yield. Also, Singh, *et al.*, (1996) found that the application of 15 t FYM + 100 kg P_2O_5 ha^{-1} gave the highest tuber yield of (38.5 – 40.0 t ha^{-1}).

With respect to the effect of interaction CxS, data in Table (3) reveal that on tuber yield was insignificant in both seasons.

Table (3): Effect of sulfur and compost on yield of potatoes.

Treatments		Fresh tuber yield (t fed^{-1})		Dry tuber yield (t fed^{-1})	
		1st	2nd	1st	2nd
Compost levels					
C_0		15.00 b	10.47 c	3.58 a	2.33 c
C_1		16.38 ab	11.75 b	3.86 a	2.68 b
C_2		17.06 a	15.25 a	4.08 a	3.52 a
LSD 5%		**1.534**	**0.651**	**NS**	**0.297**
Sulfur treatments					
S_0		14.63 b	11.24 b	3.49 b	2.55 b
S_E		17.23 a	13.39 a	4.10 a	3.05 a
S_G		16.58 a	12.84 a	3.92 a	2.93 a
LSD 5%		**0.771**	**0.808**	0.202	**0.237**
Interaction CxS					
C_0	S_0	13.86 c	9.460 e	3.33 c	2.12 d
	S_E	15.55 bc	11.49 cd	3.76 abc	2.56 cd
	S_G	15.59 bc	10.47 de	3.64 bc	2.30 d
C_1	S_0	14.03 c	10.17 de	3.32 c	2.19 d
	S_E	17.95 a	12.66 bc	4.25 a	2.97 bc
	S_G	17.16 ab	12.41 bc	4.02 ab	2.89 bc
C_2	S_0	15.99 b	14.09 b	3.83 abc	3.33 ab
	S_E	18.20 a	16.02 a	4.30 a	3.63 a
	S_G	16.99 ab	15.64 a	4.11 ab	3.59 a
LSD 5%		**NS**	**NS**	**NS**	**NS**

❖ **Dry tuber yield of potatoes.**

Also, data presented in Table (3) reveal that sulfur (S) application increases dry tuber yield significantly in both seasons. Moreover, addition of

150 kg S fed^{-1} as elemental sulfur (S_E) gave the highest mean of dry tuber yield 4.10 t fed^{-1} in 1st season and 3.05 t fed^{-1} in 2nd season as compared with S_0 (control) and S_G (150 kg S fed^{-1} as gypsum). The positive effect of S addition on dry tuber yield may be due to joined among plant growth, weight of shoot, fresh tuber yield and dry matter % in tuber. These results are agreeable with those obtained by Omprakash, *et al.*, (1997).

Data in Table (3) indicate that dry tuber yield increases insignificantly with compost (C) addition as shown for the 1st season and significantly in 2nd season. The mean of dry tuber yield increased by 7.42 and 12.34% in 1st season with C_1 and C_2 addition respectively, and by 13.29 and 33.83% in 2nd season. This effect of compost addition may be due to the same reasons at increase fresh tuber yield in addition to effect of compost in increase dry matter % in tuber.

Finally, the interaction effects of CxS, on dry tuber yield were similar to itself on total fresh tuber yield in both seasons. Similar observation are obtained by Rana, *et al.*, (2001).

Effect of sulfur and compost on soil physical properties after harvesting of potatoes.

- **Bulk density (BD)**

Data in Table (4) reveal that sulfur application significantly decreased BD of the soil in 1st season and insignificantly in 2nd season. The differences between S_E and S_0 was insignificant where, the difference between (S_G&S_0) and (S_G&S_E) were significantly at 5% in the 1st season. It is obvious that treatment S_G (150 kg S fed^{-1} as gypsum) improved soil properties where BD reduced. This may be attributed to Ca^{+2} produced from the solubility of gypsum which enhanced the formation of large soil aggregates and caused the soil volume, and then decrease BD of soil. In this concern Shainberg, *et al.*, (1989) reported that gypsum treated soil has a lower BD compared with untreated soil. Also, El-Emshaty (2002) observed that gypsum addition decreased soil bulk density.

Also, data presented in Table (4) show that the application of compost levels decrease the values of bulk density significantly as compared with control in both seasons. The mean values of BD decreased from 1.19 to 1.15 and 1.13 g cm^{-3}in 1st season and from 1.19 to 1.15 and 1.13 g cm^{-3} in 2nd season with applied rates of compost C_1 and C_2 respectively. The difference between C_2 and C_1 was significant in both seasons where the high application of 12 t fed^{-1} compost (C_2) gave the lowest BD in both seasons. Thus application of 12 t fed^{-1} compost resulted in improving soil properties. The positive effect of compost on BD of soil may be related to its effect on aggregate soil particles together which reflected on improving soil structure and reducing the BD of soil. These results are in accordance with those reported by Mahmoud (2000), El-Fayomy and Hammed (2001), El-Ghamry and El-Naggar (2001) and El-Sedfy, *et al.*, (2003).

The effect of interactions CxS on bulk density of soil after harvesting was insignificant in both seasons. Generally, the values of BD were decreased with interactions as compared with control (zero of each sulfur and compost). Where, the lowest values of BD were 1.13 and 1.12 g cm^{-3} with interaction between C_2 (12 t compost fed^{-1}) + S_G (150 kg S fed^{-1} as gypsum) in both seasons, respectively. This effect was similar with the obtained effect by Zein, *et al.*, (1996) where he found that application of FYM with gypsum decreased bulk density of the soil.

Table (4): Effect of Sulfur and compost on soil physical characteristics after harvesting of potatoes.

Treatments		Bulk density ($g\ cm^{-3}$)		Total porosity % (TP)		SP	
		1st	2nd	1st	2nd	1st	2nd
Compost levels							
C_0		1.191 a	1.191 a	46.92 c	46.22 c	65.083 c	65.527 c
C_1		1.151 b	1.148 b	49.84 b	49.39 b	66.610 b	67.140 b
C_2		1.134 c	1.127 c	51.11 a	51.02 a	69.780 a	70.333 a
LSD 5%		0.014	0.006	1.019	0.191	1.184	0.763
Sulfur treatments							
S_0		1.163 a	1.157 a	48.96 b	48.77 a	67.137 a	67.610 a
S_E		1.157 b	1.154 a	49.36 ab	48.92 a	67.280 a	67.833 a
S_G		1.156 b	1.154 a	49.54 a	48.94 a	67.057 a	67.557 a
LSD 5%		0.005	NS	0.416	NS	NS	NS
Interaction CxS							
C_0	S_0	1.20 a	1.19 a	46.52 d	46.06 c	65.08 ef	65.58 e
	S_E	1.19 a	1.19 a	47.23 d	46.53 c	64.67 f	65.33 e
	S_G	1.19 a	1.19 a	47.00 d	46.07 c	65.50 def	65.67 e
C_1	S_0	1.16 cd	1.15 b	49.42 c	49.22 b	67.33 c	67.58 c
	S_E	1.15 cd	1.15 b	49.92 c	49.48 b	66.50 cd	67.17 cd
	S_G	1.15 d	1.15 b	50.17 bc	49.47 b	66.00 de	66.67 d
C_2	S_0	1.14 b	1.13 c	50.94 ab	51.02 a	69.00 b	69.67 b
	S_E	1.14 b	1.13 c	50.94 ab	50.76 a	70.67 a	71.00 ab
	S_G	1.13 bc	1.12 c	51.46 a	51.29 a	69.67 b	70.33 a
LSD 5%		NS	NS	NS	NS	0.885	0.736

❖ Total Porosity % (TP)

Data in the previous Table indicate that the percentage of total porosity of soil increases by sulfur application where, these increases are significantly in 1st season and insignificantly in 2nd season. Application of S at 150 kg S fed^{-1} as gypsum (S_G) increased TP% from 48.96% to 49.54% at 1st season and from 48.77% (control) to 48.94% at 2nd season. This may be attributed to reducing soil pH and ESP and increasing exchangeable Ca and Mg in soil (Patel and Sing, 1991) which reflected on particles aggregates and finally total porosity. In this concern, El-Emshaty (2002) found that application of gypsum increased total porosity.

Also, data obtained reveal that compost addition increase total porosity of soil significantly in both seasons. Compost addition at 6 and 12 t fed^{-1} increases TP% from 46.92% (control) to 49.84 and 51.11%, respectively in 1st season, and from 46.22 % to 49.39 and 51.02%, respectively in 2nd season. The highest value of TP% are with the level of compost C_2 (12 t fed^{-1}) in both seasons. This raise in TP% may be due to improving structure of soil. This results are in agreement with that obtained by El-Fayomy and Hammed

(2001), El-Ghamry and El-Naggar (2001); El-Emshaty (2002) and El-Sedfy, *et al.*, (2003).

Also, data in the Table indicate that the effect of interactions CxS on TP% are insignificant in both seasons. Similar observations were obtained by Zein, *et al.*, (1996) and El-Naggar, *et al.*, (2002).

The results reveal that the effect of interaction between compost and sulfur was insignificant at 1st and 2nd seasons. Generally, the maximum value of available NH_4^+-N (172.67 ppm in 1st season and 171.97 ppm in 2nd season) was obtained by the interaction among C_2 (12 t compost fed^{-1}) + S_E (150 kg S fed^{-1} as element) in both seasons. Similar observations are obtained by Alromian and El-Fakharani (2002) and El-Naggar, *et al.*, (2002).

❖ Available NO_3^--N (ppm)

As show in Table (5) the sulfur application at rates S_E (150 kg S fed^{-1} as elemental S) and S_G (150 kg S fed^{-1} as gypsum) significant increase available soil NO_3^-- N in both seasons. The means of NO_3^-- N increased from 96.36 ppm to 111.76 and 105.61 ppm in 1st season and from 89.94 ppm to 105.46 and 99.34 ppm in 2nd season, respectively. The difference between S_E and S_G was significant in 1st and 2nd seasons, however the maximum values were at elemental S (S_E). These obtained results could be related to the effect of sulfur on reducing soil reaction (pH), ESP and EC which accelerate nitrification processes. Kriem (1991); Patel and Sing (1991) and Math, *et al.*, (1999).

Also, data in Table (5) indicate that the means of available N as NO_3^- significant increase in both seasons with increasing levels of compost application. The mean of NO_3^--N concentration increased from 89.52 ppm to 108.13 and 116.23 ppm in 1st season and from 83.12 ppm to 101.72 and 109.90 ppm in 2nd season at rates of compost C_1 and C_2, respectively. Results show that difference between C_2 and C_1 was highly significant in both seasons where the maximum values were at the application of 12 t fed^{-1} compost. The increases may be due to the NO_3^--N contents of compost which increased with increasing the rate of application. Also, may be due to the high positive charge of compost (anion exchange capacity, AEC) of which related with NO_3^- anions and protect it's for leaching. In this concern, Sood, *et al.*, (1994) found that application of FYM improved total NO_3^--N status of the soil.

The results also reveal that the effect of interaction CxS on available soil NO_3^- was significant in both seasons. The reason for this may be due to compost which relate with NO_3^- in its exchangeable surface. Generally, the maximum concentration of available NO_3^--N in soil was 124.8 ppm in 1st season and 118.7 ppm in 2nd season which were recorded with the interactions among S_E (150 kg S fed^{-1} as elemental) and C_2 (12 ton compost fed^{-1}) in both seasons. These results are in accordance with those reported by Alromian and El-Fakharani (2002).

❖ Soil available P (ppm)

Data presented in the same Table reveal that sulfur addition increases the concentration of available P in soil under potato but, these increases are insignificant in 2nd season. The mean values of available P were increased from 43.03 ppm to 44.04 and 45.94 ppm in 1st season and from 44.58 ppm to 50.43 and 48.91 ppm in 2nd season with treatments of S_E and S_G. These effect of S application may be attributed to reducing soil reaction (pH). In these concern, Makary (2002) stated that the use of sulfur as a soil amendment would increase the availability of nutrients elements.

Data obtained in the same Table clearly show that available phosphorus (P) increases with increasing the applied rates of compost significant in 1st season and insignificantly in 2nd season as compared with control (without addition). The highest values of available P as affected by compost application were 54.17 and 49.49 ppm with C_2 level in both seasons, respectively. Those results may be due to the role of organic fertilization in improving physical and chemical properties of the soil, (Mahmoud, 2000 and Abdel-Hamid, *et al.*, 2004). These results are in accordance with those reported by (Mulder, 1976; El-Fayoumy and Hammad 2001 and Mohamed, 2003). The results also reveal that the effect of interaction CxS on available P was insignificant in 1st season and significant in 2nd season. In these concern, Alromian and El-Fakharani (2002) found that available soil P was increased significantly with increasing S application rates during two seasons.

❖ **Soil available K (ppm)**

Data presented in the same Table reveal that application of sulfur increase in available K in both seasons compared with control. The significant effect of S application on availability of K in soil may be due to the effect of S on reducing soil pH and ESP and increasing available potassium. The mean values of available K increased form 1143 ppm to 1258 and 1245 ppm in 1st season and from 1105 ppm to 1221 to 1186 ppm in 2nd season with application of S_0, S_E and S_G, respectively. As clear that highest concentrations was recorded with S_E in both seasons. This difference may be related to that element sulfur (S_E) which more active than gypsum (S_G). In this concern, Math, *et al.*, (1999) found that the application of gypsum to soil decreased the soil pH. Finally, Makary (2002) stated that the use of S as a soil amendment led to increase the availability of nutrients elements.

Data Table (5) indicate that available K in soil was increased significantly in both seasons by the application of compost. The mean values of available K increased from 1135 ppm (control) to 1240 and 1272 ppm in 1st season, and from 1080 ppm to 1120 and 1312 ppm in 2nd season at the applied rates of C_1 and C_2, respectively. Data also, show that the difference between C_2 and C_1 was significant in both seasons. This results may be due to organic acids which are produced from compost decomposition in soil and influence on soil pH and consequently nutrients availability. These obtained results are in agreement with El-Fayoumy and Hammad (2001).

Data also, show that the effect of interactions CxS on available K was significantly in 1st and 2nd seasons.

CONCLUSION

Finally, the present study is recommended that the application of 150 kg S fed^{-1} as element + 12 ton compost fed^{-1} of rice straw with the constant background of recommended doses of (NPK) was considered the optaimum for improving the tested potatoes characters and the soil under this study.

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إستجابة البطاطس النامية في أرض طميية طينية لإضافة الكبريت والكمبوست

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أجريت تجربتان حقليتان بأرض قرية بطرة مركز طلخا، محافظة الدقهلية، مصر، وذلك خلال عروتين متتاليتين (العروة الأولى في الموسم الصيفي لعام ٢٠٠٣ و العروة الثانية في الموسم الشتوي لعام ٢٠٠٣/٢٠٠٤) لدراسة تأثير إضافة الكبريت وكمبوست قش الأرز مع إضافة المعدل الموصى به من NPK على البطاطس صنف اسبونتا وعلى بعض خواص التربة. استخدم كمبوست قش الأرز بثلاث مستويات: (C_0 بدون إضافة كمبوست كنترول"– C_1 ٦ طن كمبوست/فدان – C_2 ١٢ طن كمبوست/فدان) والكبريت بمستويين من مصدرين (S_0 بدون إضافة كبريت "كنترول" – S_E ١٥٠ كجم كبريت/ فدان في صورة كبريت معدني "٩٩,٥% كبريت" – S_G ١٥٠ كجم كبريت/ فدان في صورة جبس "١٨,٦% كبريت"). وقد صممت التجربة في صورة تصميم قطع منشقة "مرة واحدة" مع ثلاث مكررات. حيث أستخدم ثلاث مستويات من الكمبوست كقطع رئيسية، بينما ثلاث معاملات من الكبريت كقطع منشقة.

وتتلخص النتائج المتحصل عليها فيما يلي:

- إضافة كل من الكبريت والكومبوست أدت إلى زيادة في صفات النمو والإنتاج لمحصول البطاطس (ارتفاع النبات ،المساحة الورقية ،الكلوروفيل الكلي ، المحصول الطازج والجاف للدرنات "بالطن/الفدان" في كلا الموسمين).
- أوضحت النتائج أن تأثير إضافة الكبريت والكمبوست أدت إلى تحسين بعض الخواص الفيزيائية للتربة حيث انخفضت الكثافة الظاهرية معنويا مقارنة بالكنترول ، زيادة المسامية الكلية بالتربة في كلا العروتين بينما لم يكن للكبريت تأثير على نسبة التشبع في كلا العروتين. إضافة الكمبوست أدت إلى زيادة معنوية في نسبة التشبع في كلا الموسمين.
- إضافة الكبريت ، الكمبوست، والتفاعل بينها أدت إلى زيادة معنوية في نسبة النيتروجين الصالح الأمونيومي بالتربة مقارنة بالكنترول في كلا الموسمين. كما زاد متوسط النيتروجين الميسر في صورة نترات بالتربة زيادة معنوية في كلا الموسمين مع إضافة الكبريت ، الكمبوست وكذا التفاعل بينهم أيضا لوحظ زيادة الفوسفور الميسر بالتربة بزيادة معدلات إضافة الكبريت، الكمبوست في كلا الموسمين. كما لوحظ زيادة البوتاسيوم الميسر في التربة في كلا الموسمين مع إضافة الكبريت، الكمبوست وكذلك التفاعل بينهم.

وتوصي الدراسة بأن إضافة ١٥٠ كجم كبريت/فدان في صورة معدنية + ١٢ طن كمبوست/فدان في صورة قش الأرز مع إضافة المعدلات الموصى بها من النيتروجين ،الفوسفور والبوتاسيوم يعتبر المعدل الأكل لتحسين كلا من صفات البطاطس وصفات التربة تحت الدراسة الحالية.