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Bio-mass and Tuberization of Potato Influenced Via Addition of Sulphur

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ABSTRACT

Two field experiments were carry out during the two sequential fall seasons of 2012/2013 and 2013/2014 in sandy soil at Taba Farm, Sadaat city, EL-Menofyia Governorate, Egypt to examine the effect of agricultural sulphur levels (0, 150 and 300 kg/fed.) on the potato plant growth, tubers yield and nutritional values of potatoes. The obtain results indicated that the supplement of sulphur fulfill in a significant notability in plant growth such as plant height, number of leaves/plant and shoots/plant, fresh and dry weight, leaf area, leaf area index, relative growth rate and Net assimilation rate if compared with plants without sulphur. But the variation between the extension of 150 and 300 Kg/fed., were not significant divergence. The biggest tubers yield of potato expressed as tons/fed. and marketable yield recorded with plants which received 300 kg sulphur/fed. pursue in decreasing order by plants received 150 kg sulphur/fed. Whereas, the plants received zero sulphur perform in the heaviest un-marketable tuber yield. The preferable physical characters as expressed by average weight and number of tubers/plant, length and diameter as well as specific gravity, all composed data recorded their highest values with that plants received the highest rate of sulphur. The highest nutritional values, i.e. starch, carbohydrates, total sugar, N, P, K, Ca, Fe, Zn, Mn, and Cu were evaluated with that plants received the highest rate of sulphur (300 Kg/fed.).

Keywords: Sulphur, Potato, Growth, Yield, Nutritional values.

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is renowned as one of the extreme important vegetable crops for local consuming and exportation and is famous as the fourth most important world crop, after rice, wheat, and maize.

Sulphur is one of sixteen essential nutrient elements and is the fourth major nutrient after N, P and K desired by plants for suitable growth and yield as it is known to take part in many response in all living cells [1]. Sulphur minus had poor utilization of nitrogen, phosphorus and potassium and a significant lowering of catalase activities at all age [2]. Sulphur has a direct effect on soil royaltys as it may reduce soil pH which ameliorate the availability of microelements such as Fe, Zn, Mn and Cu as well as crop yield and its regarding characteristics [3]. Moreover, [4, 5 and 6] on potato notified that all level of sulphur extension acquired the best plant growth characters if compared with the no sulphur extension. on potato plants found that addition of agricultural sulphur acquired the highest values of tuber yield and its components. The sulphur play a great role in improving the chemical harmonious of potato yield, whereas it may be increase the starch, protein, carbohydrate, sugar, N, P, K, Zn, Fe, Cu [7 and 8].

Therefore, the present investigation was engage to find out the beneficial effect of different levels of agricultural sulphur on the output and quality of potato plants.

MATERIALS AND METHODS

Two field experiments were carried out in sandy soil at Taba farm, Sadaat city, EL-Menofyia Governorate during the two successive fall seasons of 2012/2013 and 2013/2014. The physical and chemical characteristics of experimental soils are presented in Table (1). These experiments were conducted to investigate the effect of different sulphur rates on potato productivity. Certified potato seed tubers of cultivar Diamante (locally produced and cold stored), obtained from Union of Producers and Exporters of Horticultural Crops (UPEHC), Cairo, Egypt, were used in two seasons. The tubers were planted on the first week of October during the two seasons on one side of the ridge at distance of 25 cm between tubers and 75 cm within rows. This experiment included 3 treatments of agricultural sulphur, i.e. 0, 150 and 300 kg/fed. All experimental plots received their sulphur levels during soil preparation.

Experimental design

A complete randomized design with four replicates was used. However, the three levels of sulphur, i.e. 0, 150 and 300 kg/fed. were arranged randomly in plots. Each plot contained 5 rows each was 6 m in length and 0.75 m width and plot area was 22.5 m^2. The normal agricultural practices were used for the potato production i.e. irrigation, weed control as well as diseases and pest control, where followed according to the recommendations of the Egyptian Ministry of Agriculture.

Table (1): Physical properties and chemical analysis of the experimental soil.

Properties	Values
Physical	
Sand %	90
Silt %	5
Clay %	5
Texture	Sandy
Available nutrient	
N %	Traces
P %	0.443
K %	0.575
Chemical properties (meq/L)	
pH	8.20
EC ds/m	1.50
$CaCO_3$ %	5.50
Ca^{++}	2.65
Mg^{++}	2.40
Na^{+}	4.34
CO_3^{-}	Zero
HCO_3^{-}	3.85
Cl^{-}	53.00
SO_4^{-}	55.65

Recorded data

A. Vegetative growth

A random samples of 3 plants were taken at 70, 80 and 90 days after planting for the determination of the following characters of potato plant vegetative growth:

Plant height (cm), number of leaves/plant, number of shoots/plant, fresh and dry weight of whole plant and its leaves and shoots. Moreover, leaf area (m^2/plant), net assimilation rate (g/m^2/day) and relative growth rate (mg/g/day) were measured according to the method described by Gardner *et al.* [9].

B. Tubers yield and its categories

1- Tuber yield

Weight of tubers g/plant, number of tubers/plant, average weight of tubers g/tuber, average weight of tuber yield (tons/fed., marketable tuber yield (yield of good shapes and healthy) and unmarketable tuber yield (off shape, blemished, green and diseased) all recorded. Also at harvesting date the total tubers yield of each experimental plot was divided into three categories i.e. large (weight more than 200 g/tuber), medium (weight within 100-200 g/tuber) and small (weight less than 100 g/tuber) and the percentage of each category was calculated.

2- Physical properties of tubers yield

Samples of tuber yield were taken randomly at harvesting stage for determination of physical properties as following: diameter of tuber (cm), length of tuber (cm), volume of tuber (cm^3/tuber) and specific gravity (g/cm^3). Where the average specific gravity of the tuber was determined by dividing the tuber weight by its volume.

C. Chemical values

Dry matter percentage was calculated according to A.O.A.C. [10]. Total carbohydrates and total sugars were determined according to the method described by Dobbis *et al*. [11]. Starch content was determined using the method of Somogi [12]. Total nitrogen and phosphorus content were determined according to the procedures described by Cottenie *et al*. [13]. Potassium and Calcium contents were measured as described by Chapman and Pratt [14], whereas, Fe, Zn, Mn and Cu were determined as described by Chapman and Pratt [14], and Sulphur was determined using the modified colorimetric method using spectrophotometer (SPECTRONIC 200, Milton Roy Co., Ltd, USA).

Statistical Analysis

Obtained data were subjected to the analysis of variance procedure and means were compared to the L.S.D. test at 5 % level according to **Gomez and Gomez [15].**

RESULTS AND DISCUSSION

1. Vegetative growth characters

Table (2) showed clearly that increasing sulphur levels from 0 to 300 kg S/fed. significantly increased all measured vegetative parameters. The highest values of (plant length, leaves and shoot number as well as fresh and dry weight of plant) were recorded when potato plant provide the highest rate of sulphur fertilization (300 kg S/fed.). The obtained data revealed that, the differences within the levels of sulphur were significant only between the highest and the lowest values of the measured characters. However, in most cases both 300 kg and 150 kg sulphur /fed. acquired no significant variation. These findings were true in both seasons. Generally, it means that the interest rate of agricultural sulphur for potato plant may be within the range 150 to 300 Kg/fed. These results are in the same line with those of **[1 and 4]** on potato.

Results in Table (2) showed also that the sulphur extension as soil dressing at rate of 300 Kg/fed. had a significant effect on fresh weight and dry weight of whole plant and its leaves and shoots if compared with plants that no received sulphur (control treatment).

In other words, the lowest plant growth was observe with plants that received no sulphur. Data revealed that no significant divergence was found between the supplement both of 150 and 300 Kg/fed. specially at early plant stages i.e. 70 and 80 days. Generally, it could be stated that supplement of sulphur within rates 150 and 300 Kg/fed. performed in the vigor plant growth. [4 and 6] observed that sulphur application in potato showed significant influence on fresh and dry weight of whole plant and its different organs. Also [16] on potato had the same trend of results, all of these reports support the obtained data.

From the previously mention plant growth parameters it could be concluded that the sulphur catalyzed the tested plant growth measurements. This may attributed to that sulphur is one of sixteen essential nutrient elements and is the fourth major nutrient after N, P and K, required by plants for proper growth and yield as it is known to take part in many response in all living cells [1].

2. Photosynthetic attributes

It's clear from data shown in Table (3) and Fig. (1) that the soil addition of agricultural sulphur as dressing caused an increase in the photosynthetic adjective as expressed by leaf area LA, relative growth rate RGR and net assimilation rate NAR of potato plant, if compared with plants which did not receive sulphur (control). Moreover, increasing the addition rate of sulphur resulted in higher value of photosynthetic attributes. It means the lowest values resulted from that plants received no sulphur. Also the data reveals that the differences between sulphur rates recorded significant value during the two seasons, except leaf area at 90 days old, and NAR at period of 80 - 90 days (in 1st season) and RGR at period of 80 - 90 days (in both seasons); as well as RGR and NAR at periods of 70 - 80 days (in 2nd seasons). It could be concluded that, the increasing in values of LA, LAI, RGR and NAR due to the sulphur addition may be attributed to the increasing in number, total area and dry weight of leaves which led to more active photosynthesis and in turn more dry mater accumulation. The findings of [4, 7 and 16] agree with the obtained results.

It could be concluded that applying sulphur to potato plants had an enhancement on the vegetative growth characters (the tallest plants which carried the largest leaves and shoots number as well as their heaviest fresh and dry weight of whole plants and its leaves and shoots). Moreover, the best growth was connected with increasing amount of sulphur. Sulphur is commonly used to reduce soil pH which was carried out by increasing the rate of sulphur addition. This decrease in the pH consequently led to increase the solubility and availability of macro and microelements and therefore, increase the plant uptake of mineral and finally enhance plant growth consequently improved the photosynthetic attributes [3 and 17]. Moreover, [2] reported that sulphur generally increased the plant to adsorb nutrients. This might be attributed to the reduction of soil alkalinity due to the oxidization of sulphur to sulphoric acid that led to an increase of the available of nutrient elements, consequently, these condition favor photosynthetic attributes.

The obtained results are in good accordance with previous investigators such as [6 and 16] on potato, [5] on sweet pepper and [7] on artichoke.

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Table (2): Effect of agricultural sulphur levels on some vegetative growth characters at different growth stages of potato plant during 2012/2013 and 2013/2014 seasons.

Characters	0 kg/fed.			150 kg/fed.			300 kg/fed.			L.S.D. at 5 % level		
	Days after planting											
	70	80	90	70	80	90	70	80	90	70	80	90
First season 2012/2013												
Plant height	71.50	72.17	72.50	74.58	75.29	75.75	75.50	76.17	76.67	3.89	3.160	2.865
Number of leaves/plant	67.58	68.17	69.08	76.83	77.50	78.75	80.75	81.42	82.58	3.94	4.369	2.926
Number of shoots/plant	5.50	5.50	5.83	7.00	7.33	7.50	7.17	7.42	7.67	0.774	0.717	0.358
Fresh wt. of leaves	329.49	334.99	342.41	424.45	432.45	441.37	449.50	460.97	466.97	31.20	21.261	14.361
Fresh wt. of shoots	184.71	188.71	192.81	238.54	245.96	251.71	248.92	257.34	263.25	19.67	20.871	18.108
Total fresh weight	514.21	523.71	535.22	662.99	678.41	693.07	698.42	718.31	730.23	50.31	N.S.	29.096
Dry wt. of leaves	45.48	49.04	52.48	55.72	60.72	64.27	56.87	62.31	66.76	2.91	6.01	5.30
Dry wt. of shoots	20.07	20.96	22.29	23.33	24.55	26.44	24.16	26.27	28.49	0.76	0.64	1.47
Total dry weight	65.55	70.00	74.78	79.04	85.26	90.71	81.03	88.58	95.25	2.96	5.93	4.42
Second season 2013/2014												
Plant height	67.83	69.17	70.75	74.00	75.00	76.67	76.50	77.08	77.50	1.224	1.681	1.372
Number of leaves/plant	60.50	64.92	66.25	66.42	71.25	73.00	70.33	73.58	75.50	1.133	1.133	2.209
Number of shoots/plant	4.50	4.50	4.67	6.50	6.67	6.75	6.75	6.83	7.00	0.801	0.717	0.774
Fresh wt. of leaves	307.92	316.40	322.44	371.62	382.98	393.78	408.73	424.58	437.21	17.922	22.092	20.211
Fresh wt. of shoots	179.54	192.62	207.30	228.56	241.05	247.38	238.95	250.79	250.79	9.941	35.231	28.820
Total fresh weight	487.46	509.03	529.74	600.18	624.03	641.16	647.68	675.37	688.01	10.343	24.550	17.926
Dry wt. of leaves	37.14	40.54	47.95	50.54	55.22	64.59	54.09	58.67	68.25	1.02	5.56	2.32
Dry wt. of shoots	18.45	20.04	24.59	21.20	24.17	35.00	23.26	28.09	45.05	0.76	2.17	2.86
Total dry weight	55.59	60.58	72.55	71.74	79.39	99.59	77.35	86.77	113.29	0.96	4.55	4.44

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Table (3): Effect of agricultural sulphur levels on leaf area, leaf area index, relative growth rate and net assimilation rate at different growth stages of potato plant during 2012/2013 and 2013/2014 seasons.

Sulphur levels kg/fed.	Leaf area (m^2/plant)			Relative growth rate (mg/g/day)		Net assimilation rate (mg/m^2/day)	
	Days after planting						
	70	80	90	70-80	80-90	70-80	80-90
First season 2012/2013							
0 kg/fed.	1.37	1.50	1.69	4.15	6.41	0.17	0.26
150 kg/fed.	1.52	1.65	1.81	5.27	7.23	0.23	0.34
300 kg/fed.	1.62	1.83	1.91	5.53	7.98	0.24	0.37
L.S.D. at 5 % level	**0.126**	**0.102**	**N.S.**	**1.416**	**N.S.**	**0.053**	**N.S.**
Second season 2013/2014							
0 kg/fed.	1.39	1.55	1.69	4.47	5.65	0.17	0.22
150 kg/fed.	1.51	1.65	1.81	4.49	5.97	0.20	0.28
300 kg/fed.	1.62	1.78	1.91	5.19	7.24	0.22	0.34
L.S.D. at 5 % level	**0.085**	**0.072**	**0.168**	**N.S.**	**N.S.**	**N.S.**	**0.083**

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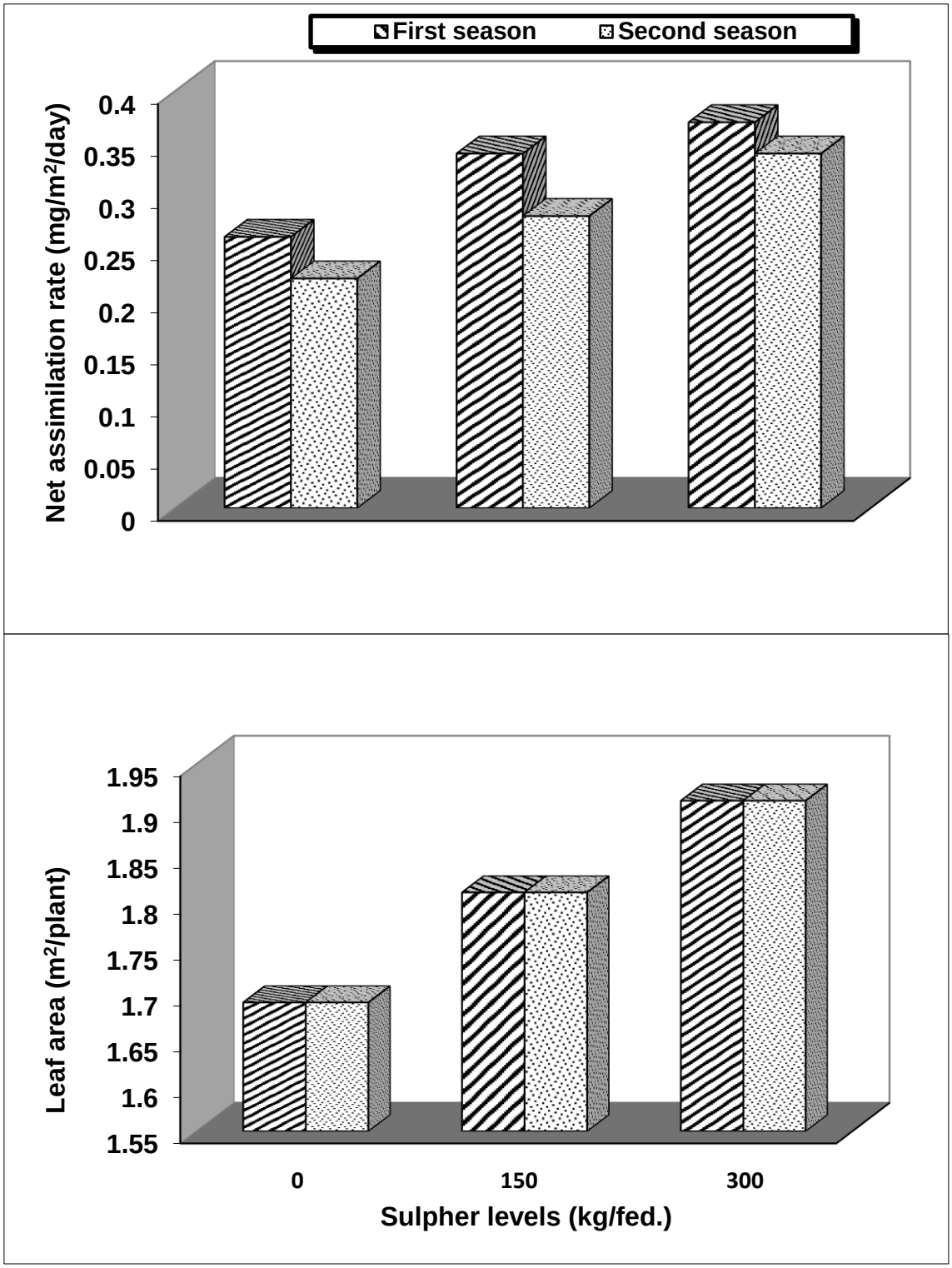

Fig.1: Effect of sulphur addition on the net assimilation rate and leaf area of potato plants during both seasons.

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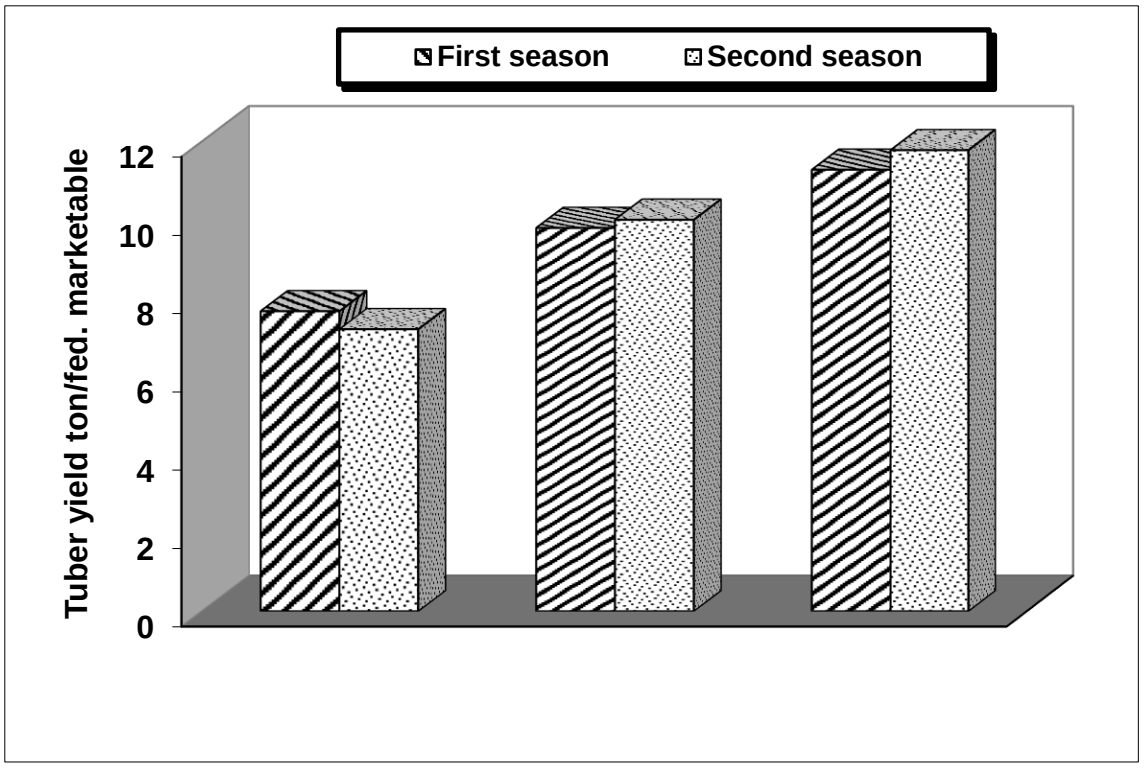
3. Tubers yield

It is clear from data in Table (4) and Fig. (2) that the total yield and its marketable yield were increased by increasing agricultural sulphur addition to reach their highest weights i.e. 12.45 and 11.28 tons/fed., respectively, in 1st season, and 12.84 and 11.78 tons/fed., for the same respective in 2nd season. The lowest total and marketable tubers yield, i.e. 9.14 and 7.66 respectively in 1st season and 8.55 and 7.20 tons/fed., for the same respective in 2nd season were obtained plants that were not supplied with sulphur. The superiority of sulphur addition at rate of 300 kg/fed., over the no sulphur addition amounted to 36.2 and 50.1 % for total tubers yield respectively in 1st and 2nd seasons. For the marketable tubers yield this increases amounted to 47.2 and 63.6 % for the same above respective. Moreover, the obtained data indicated the differences between the two sulphur addition, i.e. 150 and 300 kg/fed., were in significant. These findings were true in both two seasons. The average number and weight of tubers/plant as well as average tuber weight showed similar response to agricultural sulphur addition as those above mentioned. The unmarketable potato yield followed an opposite, trend, where, the lowest unmarketable yield was recorded with that plants received the highest rate of sulphur. These were similar in both seasons. These results are in the agreement with those of [7] on artichoke and [8] on potato.

The total tuber yield is a resultant of the integration of metabolic reaction in the plant consequently and any factor influenced the metabolic activity of the plant of any period of its growth may affects the yield. Therefore, the S treatment influenced the yield of potato through its effect on the growth components. The marketable tuber yield depend on high tuber quality, so if any factor affect one or more of tuber characters, it well stimulate amorously affect this quality. However, among these factors sulphur which improve length, diameter, size and specific gravity of tuber. It means that sulphur increased the proportion of the larger tubers which are preferable for marketing.



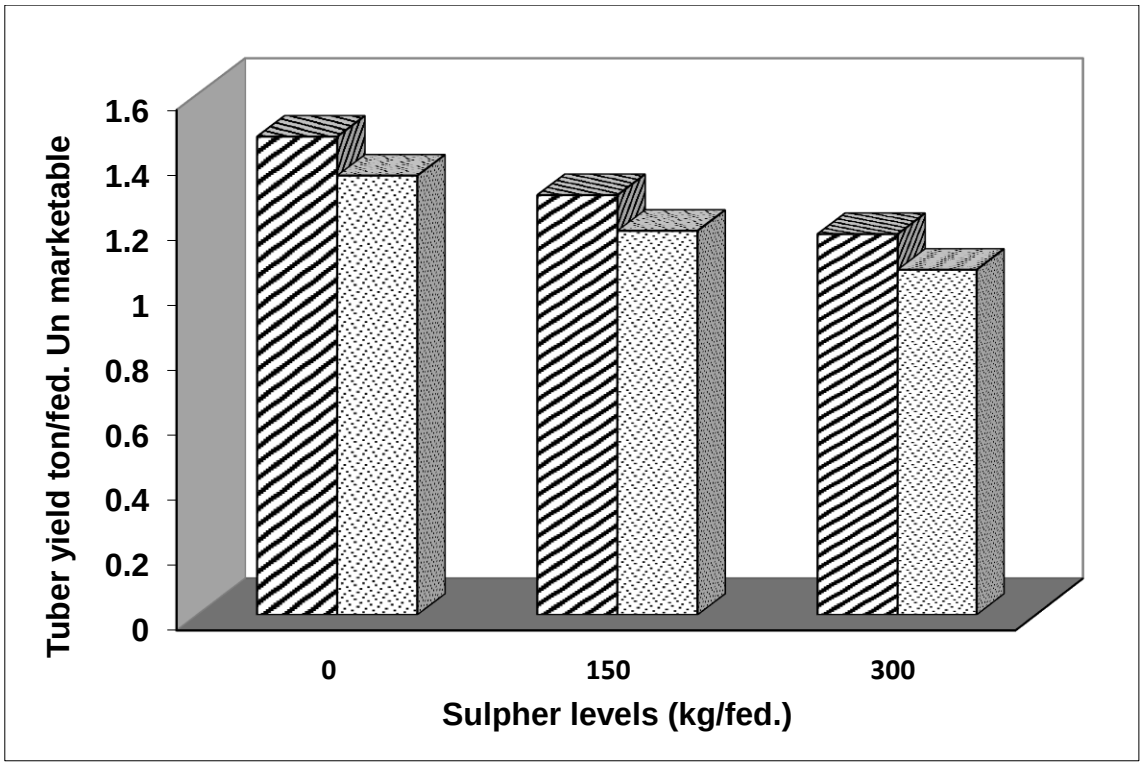


Fig.2: Effect of sulphur addition on total tubers yield, marketable and un marketable of potatoes during both seasons.

Generally it could be concluded that plants received sulphur application gained more tubers yield. These results might be attributed to the favorable effect of sulphur on reducing soil pH, increasing soil particles flocculation, thereby improving soil structure and increase the availability of certain plant nutrients to the soil. Another possibility could be due either to the fact that sulphur is required with greater supplies for the synthesis of co-enzyme and amino acid for protein elaboration and for the formation of certain disulphide linkages that have been associated with structural characteristics of plant protoplasm [17]. Also, the influence of S on the yield of potato could be attributed to an important role of sulphur in plant protein and some hormone, also sulphur is necessary for enzymatic action, chlorophyll formation, synthesis of certain amino acids and vitamins, hence it help to have a good vegetative growth leading to get high yield [18].

4. Physical properties

Data presented in Table (5) and Fig. (3) clearly showed that the addition of sulphur at rates of 150 or 300 kg/fed., caused an increase in the values of diameter, length, volume and specific gravity if compared to the control treatment (without sulphur addition). Moreover, the highest sulphur rate gained a superiority in the value of above mentioned parameter. However, the obtained data showed in some cases that there was no significant difference between the added agricultural sulphur rates. These results were true in both two seasons. It means, that the bad physical properties of tuber was significantly recorded by that potato plants which were not supplied with sulphur addition. These results might be attributed to the favorable effect of sulphur on reducing soil pH increasing soil particles flocculation, thereby improving soil structure and increasing the availability of certain plant nutrients in the soil which needs to improve the physical properties of yield. Similar results with sulphur fertilization have been reported by [4 and 6] on potato.

Addition of sulphur caused a reduction in the percentage of small potato tubers but caused an increase in medium (1st season) and large tubers (both two seasons) as shown in Table (5). In spite of that the differences were not significant for small and medium sizes in both seasons. It could be concluded that sulphur addition at 300 Kg/fed. is more effecting for getting the highest percentage of large potato size compared for the lowest sulphur levels. However, the difference was not significant in the first season. The obtained results are in harmony with those found by [4] on potato.

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Table (4): Effect of agricultural sulphur levels on tubers yield components of potato plant during seasons of 2012/2013 and 2013/2014.

Sulphur levels kg/fed.	Tubers/plant		Average tuber Wt. (g)	Average tuber Wt. (ton/fed.)	Tuber yield (ton/fed.)	
	Wt. (g)	No.			Marketable	Un marketable
First season 2012/2013						
0 kg/fed.	571.03	6.42	88.42	9.14	7.66	1.47
150 kg/fed.	692.50	7.17	96.08	11.08	9.79	1.29
300 kg/fed.	777.67	7.75	99.92	12.45	11.28	1.17
L.S.D. at 5 % level	**191.487**	**N.S.**	**5.862**	**3.06**	**3.139**	**N.S.**
Second season 2013/2014						
0 kg/fed.	534.25	6.08	87.58	8.55	7.20	1.35
150 kg/fed.	698.83	7.17	97.17	11.18	10.00	1.18
300 kg/fed.	802.50	7.92	101.25	12.84	11.78	1.06
L.S.D. at 5 % level	**135.761**	**0.585**	**14.770**	**2.172**	**2.204**	**0.100**

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Table (5): Effect of agricultural sulphur levels on physical tuber quality of potato plant during seasons of 2012/2013 and 2013/2014.

Sulphur levels kg/fed.	Physical tubers quality				The percentages of various grades of tuber		
	Diameter (cm)	Length (cm)	Volume (cm^3/tuber)	Specific Gravity (g/cm^3)	Small <100 g.	Medium 100-200 g.	Large > 200g.
First season 2012/2013							
0 kg/fed.	6.03	6.54	180.00	0.65	55.56	44.44	0.00
150 kg/fed.	7.20	7.68	210.00	0.69	39.98	50.28	9.74
300 kg/fed.	7.35	8.12	222.50	0.78	39.29	41.40	19.31
L.S.D. at 5 % level	**0.344**	**0.377**	**0.293**	**0.078**	**N.S.**	**N.S.**	**11.832**
Second season 2013/2014							
0 kg/fed.	5.19	6.88	177.5	0.51	46.87	53.13	0.00
150 kg/fed.	6.46	8.00	195.00	0.67	40.03	46.58	13.39
300 kg/fed.	7.00	8.83	230.00	.078	25.21	51.50	20.90
L.S.D. at 5 % level	**N.S.**	**N.S.**	**0.293**	**0.039**	**N.S.**	**N.S.**	**3.205**

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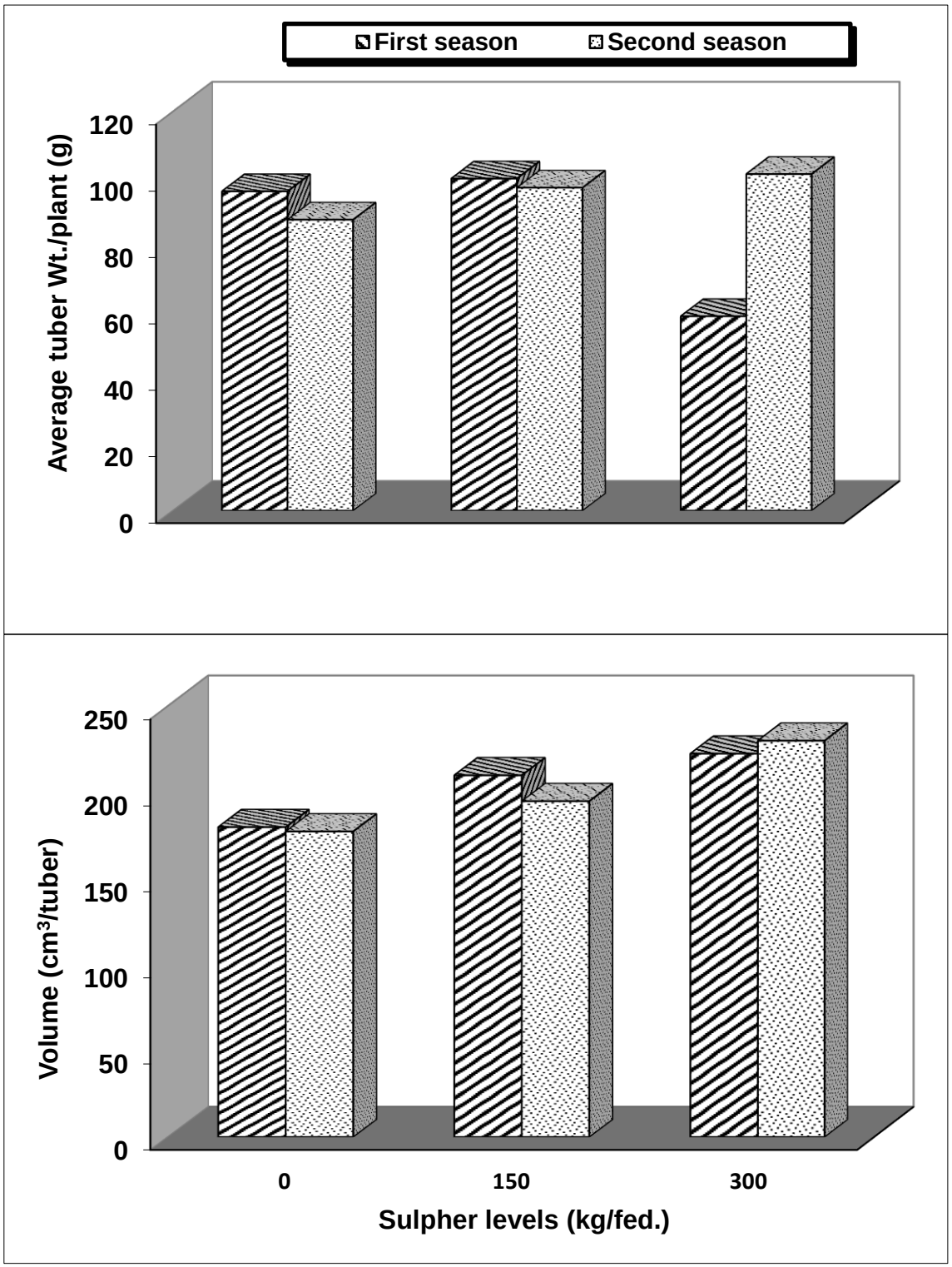

Fig.3: Effect of sulphur addition on the average tuber weight (g/tuber) and size of tuber (cm^3/tuber) of potato during both seasons.

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Table (6): Effect of agricultural sulphur levels on nutritional values of potato tubers during seasons of 2012/2013 and 2013/2014.

Sulphur levels kg/fed.	%									ppm			
	Dry matter	Starch	Carbo hydrates	Total sugars	N	P	K	Ca	S	Fe	Mn	Zn	Cu
First season 2012/2013													
0 kg/fed.	14.49	52.40	52.65	0.605	1.39	0.549	2.87	0.92	0.16	221	24.34	30.56	19.15
150 kg/fed.	16.63	55.56	56.07	0.644	1.47	0.623	3.63	1.29	0.33	358	43.66	34.27	37.30
300 kg/fed.	17.27	58.88	60.29	0.657	1.61	0.645	4.03	1.43	0.37	450	50.86	36.95	42.22
L.S.D. at 5 % level	**0.66**	**N.S.**	**1.34**	**N.S.**	**0.06**	**0.08**	**0.42**	**0.18**	**0.02**	**26.63**	**4.16**	**2.72**	**5.64**
Second season 2013/2014													
0 kg/fed.	14.88	50.53	54.12	0.607	1.42	0.65	3.09	0.95	0.17	232	25.34	31.25	22.86
150 kg/fed.	16.75	55.74	57.48	0.648	1.53	0.74	4.21	1.35	0.35	365	44.60	35.53	39.57
300 kg/fed.	17.51	58.21	61.98	0.656	1.65	0.79	4.39	1.54	0.38	461	52.67	37.79	43.45
L.S.D. at 5 % level	**1.32**	**7.31**	**0.58**	**N.S.**	**0.09**	**0.04**	**0.29**	**0.12**	**0.10**	**N.S.**	**3.43**	**0.51**	**4.23**

Chemical contents:

Data presented in Table (6) clearly showed that the sulphur addition caused an encouragement in all chemical contents of tubers (starch, carbohydrates, sugars, and protein, N, P, K, Ca, S, Fe, Mn, Zn and Cu) over that plants without sulphur addition. Moreover, with increasing levels of sulphur the higher nutritional values increased. However the differences between 150 and 300 kg sulphur/fed. were not significant in many cases.

It is well known that adding sulphur to the soil encouraged and raised the solubility and availability of macro and micro-elements in soil solution which favorable the absorption of nutritional elements and hence increased their concentrations in tuber tissues. However, [6] reported that the superiority in chemical contents of potato tubers with addition of sulphur might be attribute to the favorable positive effect of sulphur to increase plant growth parameters, consequently increasing the uptake of N, P, K, Fe, Mn, Cu, S and Zn by root system, which might have influenced the synthesis and translocation of stored materials. The results which previous carried out by many investigators are in good harmony with that obtained herein. Whereas, the sulphur supplying caused an increase in the content of dry matter, starch, total carbohydrates, total sugars and elemental values in tubers tissues [4]. Moreover, they added that the increase in total carbohydrates may be due to the increase in leaves dry matter, leaves number and area, chlorophyll which led to more active photosynthesis and in turn more carbohydrates, starch and sugar accumulation.

REFERENCES

[1] Sud K.C. and Sharma R.C. 2002. Sulphur needs of potato under rain fed conditions in Shimla hills. In: Potato Global Research and Development, Khurana, S.M.P., G.S. Shekhawat, S.K. Pandey and B.P. Singh (Eds.). Vol. 2. Indian Potato Association, Shimla, pp: 889-899.

[2] Nasreen S. and Imamul Huq S.M. 2005. Effect of sulphur fertilization on yield, sulphur content and uptake by onion. Indian J. Agric. Res., 39(2): 122-127.

[3] Tantawy E., El-Beik E.M. and El-Beik A.K. 2009. Relationship between growth, yield and storability of onion (*Allium cepa* L.) with fertilization of nitrogen, sulphur and copper under calcareous soil conditions. Res. J. Agric. Biological Sci., 5: 361-371.

[4] Sharma D.K., Kushwah S. and Rathore S.S. 2011. Effect of sulphur on yield and quality of potato. Inter. J. Agric. Res., 6(2): 143-148.

[5] Shafeek M.R., Nagwa M.K. Hassan, Awatef G. Beheiry and Fatma A. Rizk 2012. Productivity of sweet pepper plant (*Capsicum annuum* L.) as affected by sources of nitrogen and sulphur fertilizers under newly reclaimed soil. J. Appl. Sci. Res., 8(11): 5365-5371.

[6] Shaheen A.M., Fatma A. Rizk, Awatef G. Behairy and Y.I. Helmy 2013. The role of sulphur and bio-phosphorus in potato plant growth and its productivity in newly soil. Res. J. Agric. & Biol. Sci., 9(3): 119-126.

[7] Saleh S.A., Shehata S.M., El-Desuki M. and Shaheen A.M. 2006. Response of artichoke plants to agriculture sulphur and chicken manure application. J. Agric. Sci. Mansoura Univ., 31(11):7287-7304.

[8] Klikocka H. 2011. The effect of sulphur kind and dose on content and uptake of micro-nutrients by potato tubers (*solanum tubersosum* L.). Acta Sci. Pol., HortorumCultus 10(2): 137-151.

[9] Gardner F.P., Pearce R.B. and Mitchell R.L. 1985. Physiology of Crop Plants. Iowa State University Press, USA, pp.186–208.

[10] A.O.A.C., Association of Official Analytical Chemists, 1990. Official Methods of Agriculture Chemists. 17th Ed. Pub. A.O.A.C., Washington, D. C., U.S.A.

[11] Dubois, M., Gilles K.A., Hamilton J.K., Rebers P.A. and Smith F. 1956. Colourimetric method for determination of sugars and related substances. Ann. Chem.., 28: 350.

[12] Somogyi M. 1952. Colourimetric method for determination of sugars and related substances. J. Bio Chem., 200: 245.

[13] Cottenie A., Verloo M., Kickens L., Velghe G. and Camerlynck R. 1982. Chemical analysis of plants and soils. Laboratory of Analytical and Agro-chemistry. State University, Ghent Belgium, pp: 63.

[14] Chapman H.D. and Pratt P.F. 1982. Methods of Plant Analysis, I. Methods of Anaylsis for Soil, Plant and Water. Chapman Publishers, Riverside, California, USA.

[15] Gomez K.A. and A.A. Gomez 1984. Statistical procedures for Agriculture Research. Second Ed. Wiely Interscience Publ. John Willey and Sons, New York.

[16] Rabbani M.G., Rahman M.S., Islam M.J. and Hogue A.R. 2001. Effect of zinc, boron, sulphur and magnesium on the growth and yield of potato. Pakistan J. Biological Sci., 4 (9): 1090-1093.
[17] Marschner H. 1996. Mineral nutrition of higher plants. Academic press, London, England.
[18] El-Shafie, Fattma S. and Eida E. El-Gamaily 2002. Effect of organic manure, sulphur and microelements on growth, bulb yield, storability and chemical composition of onion plants. Minufiya J. Agric. Res., 27(2): 407-424.