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Impact of Sulfur Rates and some Foliar Applications on Broccoli

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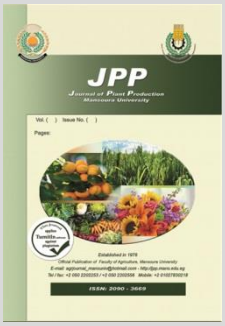

ABSTRACT

Two field experiments were conducted in a private farm at Kafr Saad district, Damietta Governorate, Egypt, during 2018/2019 and 2019/2020 seasons to study the effect of three sulfur rates (0, 125 and 250 kg/fed.) and some foliar application treatments (sulfur, selenium, chitosan) in addition tap water as a control and their interaction on broccoli growth, yield and quality. Obtained results revealed that sulfur fertilization at 125 kg/fed. gave the maximum values of No. of leaves, head diameter, total yield and head quality (chlorophyll a+b, vitamin C and total carbohydrates). Foliar application with selenium gave the highest means of No. of leaves, fresh weight of leaves, plant height, leaves area, head diameter, head compactness rate and chlorophyll a+b of head, while foliar application with sulfur gave the maximum values of leaves, head dry matter, total yield and vitamin C content, as well foliar application with chitosan gave the maximum content of total carbohydrates. Thus, it could be recommended that the combined application of 125 kg/fed. of sulfur with the foliar applications with sulfur (4ooo mg/l) or selenium (50 mg/l) or chitosan (3000 mg/l) in broccoli fields can be recommended to enhance productivity of broccoli plants and quality

Keywords: broccoli, chitosan, selenium and sulfur.

INTRODUCTION

Broccoli (*Brassica oleracea* L. var. italica) is a member of family Brassicaceae. The green color of broccoli is due to chlorophyll which is in floral buds. Broccoli is one of the most important vegetables grown all over the world which has been used for human consumption due to its highly health promoting and nutritious such as protein, carbohydrates, vitamin C, glucosinolates, phenolic antioxidants, minerals (Ca, K, Mg, P and S) and micro elements (Mølmann *et al.*, 2015). Broccoli has been deemed as anti- cancer source by American cancer society. Broccoli considered one of untraditional vegetables that started spread lately in Egypt. The total cultivated area is not exactly known. Egypt is ranking the fifteenth in the world production with a total production of 130.000 tons. China is the top world producer of broccoli.

Sulfur is one of macro elements that enhance availability of elements and decrease their deficiencies in different soils (Manesh *et al.*, 2013). Sulfur has main effect in stimulation of photosynthesis process, metabolism of carbohydrate, metabolic compounds amino acids, glutathione and protein). It is necessary for the synthesis of chlorophyll and vitamins. Foliar application with sulfur had appositive effect of insect management and enhanced total polyphenol but declined carbohydrates (Imen *et al.*, 2013). Sulfur fertilization as soil application an important for vegetative growth and quality of crops.

Selenium (Se), a metalloid mineral micronutrient, is an important element for the healthy life of humans, animals and some other microorganisms in trace amounts while excess quantities are harmful. Although the essentiality of Se for humans and animals, human intake of Se in the food is lower than the recommended daily rates which 50–70 µg (Brown and Arthur, 2001). Se is available to plants mainly as selenate or selenite. Selenate is usually the main soluble form of Se in soil.

Chitosan is an environmentally friendly product. It used to stimulate the immunity of plants to protect it against plant disease (Bautista *et al.*, 2003). Chitosan is obtained from chitin which is an important for ameliorating the growth vegetative, generative and all components of plants. Chitosan is extracted from shrimps, penfish, crabs and cramp.

Thus, the aim of the present study was to evaluate the influence of some soil additions of sulfur and foliar applications of sulfur, selenium, chitosan on vegetative growth parameters, yield and quality of broccoli.

MATERIALS AND METHODS

Two field experiments were carried out at kafr Saad district, Damietta Governorate, Egypt during the two successive seasons of 2018-2019 and 2019- 2020 to study the effect of some soil additions of sulfur and foliar applications of sulfur, selenium and chitosan on Broccoli (*Brassica oleracea* L. var. italica) c.v Matsuri.

The experimental design:

This experiment was adopted in split plot design with three replicates containing 12 treatments that were the combination between 3 sulfur rates (0, 125 and 250 kg/fed.) were assigned in main plots and 4 foliar applications (Tap water as a control, sulfur, selenium and chitosan) which were allocated in sup plots as follow:

A- First factor (sulfur rates):

1- Without sulfur addition
2- 125 kg/fed.
3- 250 kg/fed.

B- Second factor (foliar applications):

1- Control (Tap water)
2- Sulfur (4000 mg/l as micronized sulfur)
3- Selenium (50 mg/l as sodium selenite)
4- Chitosan (3000 mg/l)

Agricultural practices:

Seeds of broccoli cultivar were sown in the shading screen nursery in foam trays (209 eyes), using mixture of peat moss and sand 1:1 (v/v) (the recommended transplant production media for protected cultivation) on the 19th and 17th of September

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in first and second seasons, respectively. Transplants were planted after forty days from seed sowing at 4-5 leaf stage.

In early September of both seasons, the field was cleaned, ploughed. Seedling were planted at 29th and 27th October in first and second seasons, respectively. Plot area was 12.6 m^2 consisted of 2 rows. Each row was 90 cm width and 7 m long at 60 cm between each plant. The method of irrigation was surface irrigation system.

Sulfur fertilizers rates (0, 125, 250 kg/fed.) were added over the lines before planting then irrigated and growing transplants.

Broccoli plants were sprayed three times with foliar applications during the growth period after 4, 6 and 8 weeks from transplanting.

In both seasons, all cultural practices i.e., cultivations irrigation, fertilization and pest control according to the recommendations of the Egyptian Ministry of Agriculture.

Data recorded:

A) Vegetative growth characters:

Random samples of five plants from each experimental plot were taken after 80 days from transplanting and the following measurements were recorded:

1- **Plant height:** It was measured from the highest point of the plant down to the soil surface.
2- **Number of leaves/plant.**
3- **Leaves fresh weight and dry matter:** leaves of five plants were weighed and dried in an oven at 70°C for 48 to 72 hours until constant weight.
4- **Leaves area:** it was calculated according to Koller (1972).

B) Yield and physical quality of head:

1. Head yield/fed.

2. Head dry matter content: five heads were weighed and dried in an oven at 70°C for 48 to 72 hour until constant.

3. Head diameter: It was measured using vernier caliber.

4. Head compactness rate according to (Riad *et al.*, 2009). Where theoretically compactness rating of 1 means the head is very compact. The lower rate the more compactness.

$$\text{Compactness rate} = \frac{\text{head volume (0 .75 X 3.14 X radius}^3\text{)}}{\text{head weight}}$$

Head chemical quality:

1. Chlorophyll a+b content: It was determined according to Goodwine (1965).
2. Vitamin C: It was determined as according to the method reported in A.O.A.C (2007).
3. Total carbohydrates: Total carbohydrates were determined according to anthirone method by Sadasivam and Manickam (1991).

Statistical analysis:

Data were subjected to the analysis of variance (ANOVA). The differences among means of data were compared by LSD as found by Gomez and Gomez (1984). The Statistical analyses were conducted according to the procedure outlined by (Sneddecor and Cochran, 1976).

RESULTS AND DISCUSSION

Result

1- Vegetative growth parameters:

Obtained results in Table 1 show that vegetative growth characters, *i.e.,* No. of leaves, leaves fresh weight, dry matter, plant height and leaves area were significantly affected by sulfur fertilization except No. of leaves, leaves fresh weight and leaves area in the first season. Increasing sulfur rates up to 250 kg/fed. increased leaves fresh weight, dry matter and leaves area. On the other hand, increasing sulfur rates decreased plant height, while adding sulfur fertilization at 125 kg/fed. gave the highest number of leaves.

Table 1. Number of leaves, fresh weight of leaves, dry matter of leaves, plant height and leaves area as affected by sulfur fertilization rates and foliar applications as well as their interaction during 2018/2019 and 2019/2020 seasons.

Characters		No. of leaves/plant		Fresh weight of leaves (kg)		Leaves DM (%)		Plant height (cm)		Leaves area (m^2)	
Treatments		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Sulfur fertilization:											
zero		15.70	14.91	1.24	1.36	2.44	2.68	76.20	90.67	0.566	0.679
125 kg		16.01	18.73	1.25	1.5	3.17	3.81	75.25	87.28	0.561	0.560
250 kg		15.42	19.12	1.30	1.69	3.55	4.61	72.69	82.14	0.593	0.652
LSD at 5%		NS	0.66	NS	0.07	0.11	0.13	0.96	1.08	NS	0.049
B- Foliar applications:											
Control		14.92	16.69	1.13	1.36	2.67	3.28	70.32	81.62	0.522	0.573
Sulfur (4000 mg/l)		15.64	17.50	1.26	1.52	3.43	4.19	76.47	88.80	0.584	0.644
Selenium (50 mg/l)		16.33	18.27	1.32	1.59	3.02	3.65	76.37	88.66	0.599	0.659
Chitosan (3000 mg/l)		15.95	17.90	1.33	1.60	3.08	3.68	75.67	87.73	0.587	0.644
LSD at 5%		0.51	0.59	0.03	0.05	0.12	0.15	0.51	0.58	0.018	0.021
C- Interaction:											
zero	Control	15.00	14.25	1.13	1.24	2.20	2.42	72.00	85.68	0.483	0.580
	Sulfur	15.60	14.82	1.30	1.43	2.40	2.64	79.00	94.01	0.606	0.728
	Selenium	16.66	15.83	1.30	1.43	2.53	2.78	79.80	94.96	0.616	0.740
	Chitosan	15.53	14.75	1.23	1.35	2.63	2.89	74.00	88.06	0.556	0.668
125 kg	Control	15.40	18.01	1.13	1.36	1.53	1.84	71.80	83.28	0.516	0.516
	Sulfur	16.66	19.5	1.2	1.44	3.36	4.04	80.00	92.8	0.550	0.550
	Selenium	15.86	18.56	1.26	1.52	3.20	3.84	75.70	87.81	0.583	0.583
	Chitosan	16.13	18.87	1.40	1.68	4.60	5.52	73.50	85.26	0.593	0.593
250 kg	Control	14.36	17.81	1.13	1.47	4.30	5.59	67.16	75.90	0.566	0.623
	Sulfur	14.66	18.18	1.30	1.69	4.53	5.89	70.43	79.59	0.596	0.656
	Selenium	16.46	20.41	1.40	1.82	3.33	4.33	73.63	83.20	0.596	0.656
	Chitosan	16.20	20.09	1.36	1.77	2.03	2.64	79.53	89.87	0.610	0.671
LSD at 5%		0.88	1.02	0.06	0.07	0.21	0.26	0.88	1.02	0.031	0.035

As for the effect of foliar applications, results in the same table clear that all used foliar applications (sulfur, selenium and chitosan) increased aforementioned vegetative traits. Plants sprayed with selenium at 50 mg/l gave the highest values of No. of leaves, leaves fresh weight, plant height and leaves area, while foliar application with sulfur at 4000 mg/l gave the maximum values of leaves dry matter.

Concerning the interaction between sulfur rates and foliar applications, data in the same table illustrate that fertilized broccoli plants with 250 kg/fed. of sulfur combined with foliar application of selenium (50 mg/l) and sulfur (4000 mg/l) gave the highest values of leaves fresh weight and dry matter of leaves, respectively. On the other hand, foliar application with selenium at 50 mg/l without sulfur fertilization addition increased plant height and leaves area. These results are true in both seasons. As for number of leaves, data in the same table show that interaction between sulfur rates at 125 kg/fed. and foliar application with sulfur at 4000 mg/l gave superiority of other treatments in the first season, while the fertilization with sulfur at 250 kg/fed. and foliar application with selenium at 50 mg/l gave the maximum values in the second season.

2- Yield and physical quality:

Data presented in Table 2 illustrate that there were significant differences on head diameter, dry matter, compactness rate and head yield. The maximum values of head diameter and head yield were recorded at 125 kg/fed. of sulfur application, as well increasing sulfur fertilization rates increased head dry matter, this results are true in both seasons. Head compactness index increased in the second season with increasing sulfur rates, while it decreased in the first season.

Table 2. Head diameter, head dry matter, compactness rate and total yield as affected by sulfur fertilization rates and foliar applications as well as their interaction during 2018/2019 and 2019/2020 seasons.

Characters / Treatments		Head diameter (cm)		Head DM (%)		Compactness rate (%)		Total yield (ton/fed.)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Sulfur fertilization:									
zero		23.83	21.45	7.25	7.98	9.23	7.48	3.54	3.19
125 kg		24.2	26.62	6.33	5.70	7.93	8.79	4.10	4.92
250 kg		23.38	25.72	7.33	8.80	8.19	9.91	3.61	3.98
LSD at 5%		0.52	0.61	0.68	0.69	0.49	0.56	0.11	0.10
B- Foliar applications:									
Control		23.08	23.90	5.22	5.55	7.69	8.01	3.68	3.95
Sulfur (4000 mg/l)		23.75	24.61	8.22	8.75	8.12	8.70	3.85	4.09
Selenium (50 mg/l)		24.55	25.19	6.55	7.15	9.69	9.47	3.75	4.07
Chitosan (3000 mg/l)		23.82	24.68	7.88	8.50	8.30	8.73	3.73	4.01
LSD at 5%		0.40	0.42	0.72	0.81	0.46	0.45	0.04	0.05
C- Interaction:									
zero	Control	22.46	20.22	5.33	5.86	7.88	6.38	3.30	2.97
	Sulfur	22.80	20.52	5.33	5.86	6.35	5.14	4.27	3.84
	Selenium	27.26	24.54	5.33	5.86	14.96	12.12	3.10	2.79
	Chitosan	22.80	20.52	13.00	14.3	7.75	6.28	3.50	3.15
125 kg	Control	23.20	25.52	5.33	4.80	7.28	8.07	3.93	4.71
	Sulfur	24.40	26.84	9.33	8.40	8.23	9.13	4.04	4.84
	Selenium	24.60	27.06	5.33	4.80	7.67	8.5	4.45	5.34
	Chitosan	24.60	27.06	5.33	4.80	8.53	9.46	3.99	4.80
250 kg	Control	23.60	25.96	5.00	6.00	7.91	9.58	3.80	4.18
	Sulfur	24.06	26.47	10.00	12.00	9.78	11.84	3.26	3.58
	Selenium	21.80	23.98	9.00	10.80	6.44	7.79	3.69	4.06
	Chitosan	24.06	26.47	5.33	6.40	8.63	10.45	3.69	4.06
LSD at 5%		0.69	0.72	1.24	1.39	0.81	0.79	0.07	0.08

Regarding the effect of foliar applications on yield and head physical quality, data in the same table clear that foliar application with selenium at 50 mg/l gave the maximum values of head diameter and compactness percentage, while foliar application with sulfur at 4000 mg/l increased dry matter of head and head yield, it increased total yield by (4.62 and 3.54%) in the first and second season, respectively.

Combination between sulfur rates and foliar applications significantly affected on yield and physical quality. Fertilization with 125 kg/fed. of sulfur combined with foliar spraying with selenium at 50 mg/l gave the highest total yield (4.45 and 5.4 ton/fed.) in the first and second seasons, respectively. Figure 1 clear a positive correlation between leaves fresh weight and head yield.

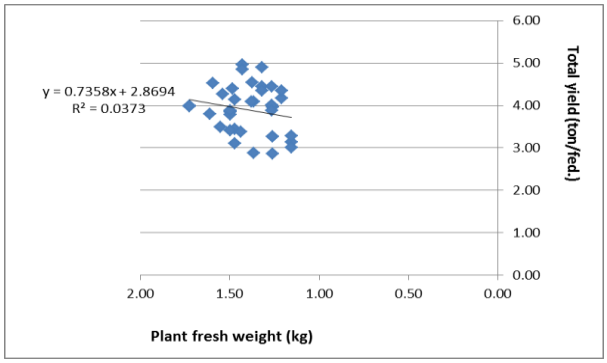

Fig. 1. Linear analysis of leaves fresh weight and head yield (ton/fed.) of broccoli grown under sulfur rates and foliar applications (average of the two seasons).

3- Head chemical quality:

Data tabulated in Table 3 cleared that there were significant differences between sulfur rates on quality of head (chlorophyll a+b, vitamin C and total carbohydrates), increasing sulfur fertilization up to 125 kg/fed. gave the highest values of head quality then decreased at 250 kg/fed. As for foliar applications, selenium at 50 mg/l, sulfur at 4000 mg/l or chitosan 3000 mg/l gave the maximum values of chlorophyll a+b, vitamin C and total carbohydrates, respectively.

Concerning to combination between sulfur rates and foliar applications, the maximum values of chlorophyll a+b and total carbohydrates were recorded by sulfur application at 125 kg/fed. combined with foliar spraying with selenium at 50 mg/l in both seasons. As for vitamin C, interaction between sulfur at 250 kg/fed. and foliar application with sulfur at 4000 mg/l gave the highest values in the first season, while fertilization with 125 kg/fed. combined with foliar spraying with sulfur at 4000 mg/l gave the maximum values in the second season.

Table 3. Chlorophyll a+b, vitamin C and total carbohydrates as affected by sulfur fertilization rates and foliar applications as well as their interaction during 2018/2019 and 2019/2020 seasons.

Characters / Treatments		Chlorophyll a+b (mg/g F.W)		Vitamin C (mg/100 g)		Total carbohydrates (%)	
		1st	2nd	1st	2nd	1st	2nd
A- Sulfur fertilization:							
zero		0.487	0.529	234.33	140.60	22.98	25.27
125 kg		0.829	0.867	254.46	231.55	36.61	32.96
250 kg		0.697	0.751	236.56	191.61	34.86	27.89
LSD at 5%		0.028	0.076	0.58	1.22	0.58	0.64
B- Foliar applications:							
Control		0.612	0.686	201.01	156.36	26.60	24.79
Sulfur (4000 mg/l)		0.674	0.727	262.56	207.71	31.80	29.21
Selenium (50 mg/l)		0.701	0.737	251.85	195.53	32.97	29.78
Chitosan (3000 mg/l)		0.697	0.714	251.71	192.08	34.56	31.03
LSD at 5%		0.023	NS	0.89	0.68	0.41	0.38
C- Interaction:							
zero	Control	0.355	0.518	188.04	112.83	25.57	28.13
	Sulfur	0.503	0.556	206.11	123.66	27.23	29.94
	Selenium	0.566	0.553	255.52	153.31	14.77	16.25
	Chitosan	0.525	0.491	287.65	172.58	24.34	26.77
125 kg	Control	0.814	0.784	201.35	183.22	28.65	25.78
	Sulfur	0.816	0.895	283.94	258.38	31.48	28.33
	Selenium	0.842	0.896	282.47	257.04	57.83	52.04
	Chitosan	0.843	0.894	250.08	227.57	28.51	25.66
250 kg	Control	0.668	0.757	213.62	173.03	25.58	20.46
	Sulfur	0.703	0.729	297.65	241.09	36.70	29.36
	Selenium	0.696	0.763	217.56	176.23	26.33	21.06
	Chitosan	0.722	0.757	217.40	176.09	50.85	40.68
LSD at 5%		0.040	NS	1.55	1.17	0.72	0.66

Discussion

The superior effect of sulfur amendments on broccoli vegetative growth, yield and quality are mainly due to decrease soil pH by sulfur additions which enhances elements availability in soil (Hilal and Abd El-fattah, 1987). Sulfur is a part structure of cysteine and methionine thus it increases proteins, hence it enhances synthesis of chlorophyll and vitamins (Marschner, 1995). Foliar application with sulfur enhanced leaves area by enhancing cell division and light interception, hence improve vegetative growth and photo-assimilation to growing sinks (Garg *et al.*, 2006). The obtained results are in harmony with those obtained by Elwan and Abd El-Hamed (2011), Shukry *et al.* (2015), Correa *et al.* (2016) and Slosar *et al.* (2016) on broccoli.

The improvement of selenium on broccoli growth and yield may be due to enhance antioxidant activity of plants (Xu *et al.*, 2003), and its ability to encourage hormone and antioxidant balance in the plant (El-Shalakany *et al.*, 2010). Selenium ameliorate synthesis of glucosinolates, paramount subaltern metabolites found mainly in brassicaceae plants, by substituting sulfur nutrient and developing some enzymes activity (Barickman *et al.*, 2013 and Avila *et al.*, 2014). Se enhanced leaf thickness thus enhance surface that expose to light hence increase photo assimilation thus enhance vegetative growth and yield as shown in Fig. 1 that there was a positive correlation between leaves fresh weight and total yield. Pedrero *et al.* (2007) on broccoli investigated that the foliar spray with selenium significantly produced the highest values of chlorophyll concentration on head compared to control plants. Similar results were confirmed by Mechora *et al*. (2011) on cabbage leaves, Poldma *et al.* (2013) on onion and Shalaby *et al.* (2017) on lettuce.

The remarkable enhancement effects of chitosan on growth parameters of broccoli plants may be attributed to its serious function in transmission of water and nutrients in addition to increase activities of key enzyme of nitrogen metabolism thus enhanced photosynthesis that increased plant growth (Mondal *et al.*, 2012) and yield, also stimulate synthesize of hormones such as gibberellins and auxin (El-Bassiony *et al.*, 2014) hence improve vegetative growth. In addition, enhance availability of water and essential elements through regulate cell osmotic pressure (Guan *et al.*, 2009). These findings are in the same line with those obtained by Farouk *et al.* (2011) on radish, Metwaly and El-Shatoury (2017) on cabbage, Abd El-Hady and Abd-Elhamied (2018) on cucumber and Bondok *et al.* (2019) on broccoli seed sprouts.

CONCLUSION

This study demonstrate that it is possible to enhance growth, yield and quality of broccoli plants cultivated under similar condition at Damietta governorate by applying sulfur amendment at 125 kg/fed. in combination with foliar application of sulfur at (4000 mg/l) or selenium at (50 mg/l) or chitosan at (3000 mg/l).

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تأثير معدلات الكبريت وبعض معاملات الرش الورقى على البروكولى

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أجريت تجربتان حقليتان خلال موسمي 2019/2018 و2020/2019 بمزرعة خاصة بناحية كفر سعد، محافظة دمياط، مصر وذلك لدراسة تأثير بعض معدلات إضافة الكبريت (صفر، 125، 250 كجم/فدان) والرش الورقي بالكبريت والسيلينيوم والشيتوزان وكذلك التفاعل بينهم على النمو والمحصول وصفات الجودة لنبات البروكلي. وكانت أهم النتائج ما يلي: أدي التسميد بالكبريت بمعدل 125 كجم/فدان إلى الحصول على أعلى القيم فيما يخص عدد الأوراق وقطر الرأس والمحصول الكلى وجودة الرأس (كلوروفيل أ+ب، فيتامين سي، الكربوهيدرات الكلية). أدي الرش الورقي بالسيلينيوم إلى الحصول على أعلى المتوسطات لعدد الأوراق ووزنها وطول النبات والمساحة الورقية وقطر الرأس، وكذلك معدل اندماج الرأس ومحتوى الرأس من كلوروفيل أ+ب. أدي الرش الورقي بالكبريت إلى الحصول على أعلى القيم بالنسبة للمادة الجافة للأوراق والرأس والمحصول الكلى والمحتوى من فيتامين سي. بينت الدراسة أن الرش الورقي بالشيتوزان قد أعطى أعلى القيم فيما يخص محتوى الرأس من الكربوهيدرات الكلية. وعليه توصي هذه الدراسة بتسميد نباتات البروكلي بالكبريت بمعدل 125 كجم/فدان مع الرش الورقي بأي من الكبريت بتركيز 4000 مليجرام/اللتر أو السيلينيوم بتركيز 50 مليجرام/ التر أو الشيتوزان بتركيز 3000 مليجرام/التر وذلك للحصول على أعلى معدلات للنمو والمحصول وجودة البروكلي المنزرع تحت ظروف ناحية كفر سعد، محافظة دمياط.