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RESPONSE OF CABBAGE (*BRASSICA OLERACEA* VAR. CAPITATA) AND CAULIFLOWER (*BRASSICA OLERACEA* VAR. BOTRYTIS) CROPS TO SULPHUR FERTILIZATION LEVELS.

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ABSTRACT

Two separate field experiments were conducted at Qaha Experimental Farm of Horticultural Research Institute, Qalyoubia Governorate, on cabbage and cauliflower during the two winter seasons of 2005/2006 and 2006/2007 respectively, to study the effect of 5 sulfur fertilization levels on growth, yield, quality and chemical constituents in cabbage head and cauliflower curds. The sulfur levels there were without, 25, 50, 100 and 150 kg S/fed. The experimental design for each crop was complete randomized blocks .The obtained results indicated, in general, that increasing the application of sulfur levels from 0 up to 100 kg significantly improved all vegetative growth parameters (plant height, number of leaves, total plant fresh weight, head weight, total, marketable and edible head yield of cabbage and cauliflower curds)as was well as total chlorophyll in leaves, head cabbage and curd cauliflower quality (length, diameter and compactness) and the chemical constituents, i.e., N, P, k and S contents. Moreover, Vit-C, sinigrin and glucoraphanin contents in heads and curds were also increased by S application . Furthermore, there is a positive correlation was found between sulphur levels and each of sinigrin and glucoraphanin contents in both cabbage and cauliflower crops. In this respect, it could be recommended that application of sulphur at the rate of 100 kg S /fed. for both cabbage and cauliflower gave the best vegetative growth, high yield and quality as well as higher content of Vit-C, sinigrin and glucoraphanin as anticancer substances in heads and curds.

INTRODUCTION

Cabbage and cauliflower are two of the most important cole crops grown in Egypt. They have a high nutritive value due to their content of Vit-C., Vit-B_1 (thiamin), B_7 (Niacin) and moderate content of Ca and Mg. In addition, cole crops are considered as anti-cancer and antioxidant. Farnham *et al.* (2005) on broccoli found that the concentration of glucoraphanin compound associated with vegetables cancer-inhibiting abilities is influenced more by genetics than by environment. Fahey (2005) on broccoli and some cole crops mentioned the cancer protective effects of broccoli and other cruciferous vegetables.

Sulphur application plays an important role in soils, it is used as a soil amendment to improve the availability of nutrients such as P, Fe, Zn, Mn and Cu. (Heter, 1985). Moreover, Abd El-Fattah *et al.* (1990) found that the addition of sulfur element decreased the pH and conversed the unavailable phosphorus to available form for plant absorption.

Bhagavantagoudra and Rokhad (2001) on cabbage mentioned that application of sulphur with 40 kg/ha gave the highest yield (43.71 ton/ha),number of inner leaves, head diameter and chemical contents of ascorbic acid, protein, dry matter production and S uptake. However, Sanderson (2003) on broccoli and cauliflower studied the effect of sulphur and calcium and found gypsum increased yield by 14% for broccoli and 25% for cauliflower, increased S content of tissue and decreased soil pH.

Vallejo *et al.* (2003) on broccoli found that cultivars grown under high fertilization level of S (150 kg/ha) resulted in a higher vitamin -C content and total glucosinolates than those grown under the low level of S (15 kg/ha). Also, Rangkadilok *et al.*, (2004) Studied the application of varying amounts of sulphur as gypsum at (0, 23 and 92 kg/ha) on three cultivars of broccoli. They found that during the early vegetative phase increased S uptake and glucoraphanin content in each plant organ, a large increase in S and glucoraphanin content was found in the green head of broccoli and mature seeds, S presented in glucoraphanin accounted for only 4-10% of total S content in broccoli heads. However, S presented in glucoraphanin in mature seeds accounted for 40-46% in the seeds, as well as the partitioning of S into glucoraphanin also increased of with gypsum application. Morever, Lee *et al.* (2005) on broccoli, mentioned that higher total glucosinolate contents were observed in the sprouts cultivated on 80 mg S/liter, with the increase of some major glucosinolates (progoitrin, glucoraphanin, gluconasturtin and 4-methoxy-glucbrassicin).

Rosen *et al.* (2005) found that sulfur application at 110 kg/ha gave the highest significant increase of cabbage yield in the second season only and total glucosinolates and glucoraphanin were maximized at the low N and high S application rates, and sinigrin in one of the two seasons.

Therefore, this experiment aimed to study the effect of sulphur application on growth, yield and quality as well as its chemical components of glucoraphanin or sinigrin and the relationship of these compounds and sulphur content of cabbage and cauliflower.

MATERIALS AND METHODS

Two separate experiments on cabbage (*Brassica oleracea* var. capitata) and cauliflower (*Brassica oleracea* var. botrytis) were carried out at Qaha Experimental Farm, Horticulture Research Institute, during the two winter seasons of 2005/2006 -2006/2007, to study the effect of five levels of sulfur application, i.e., 0, 25, 50, 100 and 150 kg/fed on plants of both crops. The amounts allocated for each plot were divided to three equal parts; the first portion was added during soil preparation while the second and third portions were added at 3- week intervals, starting after transplanting. Seed of both crops were sown in the nursery on 1st and 3^{ed} of Aug. in both seasons, respectively. Each experimental plot was consisted of 4 rows each of 80 cm in width and 4 m in length. The transplants were set up at 70 cm apart on one side of the rows after 45 days from seed sowing in the nursery in both seasons. The rate of NPK fertilizer was applied at the recommended rate of NPK fertilizer for such crops, i.e.,80 kg N, 60 kg P_2O_5 and 48 kg K_2O/fed., for all treatments. The mentioned amounts for each plot were divided in to two equal parts. The first part was applied after 4 weeks and the second part was added after 8 weeks from transplanting. The sources of fertilizers used were ammonium nitrate (33.5% N), calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O). Other cultural practices were carried out according to the recommendation for such crop. Some physical and chemical characteristics (according to Jackson, 1965) of the soil used in this study are presented in Table (1).

The experimental design for each crop was complete randomized blocks with three replicates. The treatments were arranged randomly in each replicate. At harvesting time (after 110 days from transplanting of cabbage cv. Balady and 95 days of cauliflower cv. Snowball), five plants were randomly taken from each experimental plot and the following characters were measured.

Vegetative growth:

Plant height, total number of leaves per plant plant fresh weight were recorded.

Yield and its components:

Total yield was recorded and the harvested plants were prepared for local market then the marketable yield was determined. The edible part weight of cabbage heads and cauliflower curds were determined and the net head or curd yield were calculated

Table (1): The physical and chemical analysis of the experimental soil samples from Qaha Farm before transplanting.

Depth (cm)	Texture class	pH in 1:2.5 soil:water suspension	Organic matter %	E.C. m mohos/cm at 1:5 soil:water	$CaCo_3$ %	Available mineral content			
						N%	P%	K%	SO_4^{--} %
0-30	Clay loam	8.4	2.0	0.66	1.79	0.32	0.61	4.3	0.53

Physical characteristics:

Height (H) and diameter (D) of head or curd were recorded and head or curd index (H/D) was calculated. Compactness of head or curd were estimated according to the following scale: 1, compact to 5, un compact.

Chemical constituents of head or curd:

Chlorophyll content of leaves were determined, total chlorophyll was extracted by acetone and then colorimetrically determined as mentioned in the A.O.A.C. (1970) . Total nitrogen was determined according to Pregl (1945) using micro-Kjildahl apparatus. Phosphorus was estimated calorimetrically according to the methods described by Murphy and Riley (1962). Potassium content was estimated according to the methods described by Brown and Lilleland (1946).Sulfur was determined calorimetrically as reported by Cohenie *et al.* (1982). Vitamin-C content was estimated in fresh samples by titration with 2,6 dichloride phenol indophenols as described in A.O.A.C. (1970). Sinigrin and glucoraphanin as thioglucoside content in head and curd were estimated at the Chemical Analysis Laboratory of General Organization for Agriculture Equalization Fund of Ministry of Agriculture. according to McGhee *et al.* (1965).

Association of sulphur levels and sinigrin or glucoraphanin contents in cabbage heads and cauliflower curds was determined by calculating simple correlation and regression of these variables using the following formula according to Nageswara (1983):

$$r = \frac{Cov.x1\ x2}{\sqrt{(Variance\,X1)\,(Variance\,X2)}}$$

r = the correlation coefficient.
Cov. = covariance.
X1=measurement of one variable.
X2= measurement of the other variable.
Linear regression between the two variables was done.

Statistical analysis:

All recorded data were statistically analyzed according to the method described by Gomez and Gomez (1983).

RESULTS AND DISCUSSION

1- Vegetative growth:-

Data presented in Table (2) show that there the values of plant height, number of leaves, total fresh weight and head weight of cabbage plants were gradually increased,in general, as the level of S increased up to 100 kg S / fed. in both seasons.

Regarding the effect of sulphur levels on cauliflower data presented in Table (2) also show the same trend of response as mentioned in cabbage. These results could be due to the acidic effect of S-fertilization on soil- pH which increase the availability of phosphorus and most of micronutrients and consequently reflected on the uptake of these nutrients by plant which in turn increased plant vegetative growth parameters. These results agree with those reported by those of Bhagovantagoudia and Rokhad (2001) on cabbage.

2- Total and marketable head or curd yield:-

Data in Table (3) show that increasing levels of S application from 0 up to 100 kg. S/fed gradually and significantly increased total, marketable and net head weight (edible part) of cabbage without significant differences between 100 and 150 kg S/fed in the first season only.

However, in the second season 150 kg. S/fed of sulphur significantly decreased all yield components than 100 kg S/ fed. These results are in agreement with those reported by Bhagavantagoudra and Rokhad (2001) on cabbage.

Table (2): Vegetative growth characteristics of cabbage and cauliflower as affected by levels of sulphur application.

Season	2005/2006							
Sulphur Kg/fed.	Cabbage plants				Cauliflower plants			
	Plant height (cm)	No. of leaves/ plant	Total fresh weight (kg/plant)	Head wt. (kg/plant)	Plant height (cm)	No. of leaves/ plant	Total fresh weight (kg/plant)	Curd wt. (kg/plant)
0	60.2 d	31.2 c	5.530 e	3.810 c	53.1 d	25.0 c	2.540 c	1.473 c
25	70.0 c	35.0 b	6.513 d	4.443bc	57.0 c	30.1 b	2.790 c	1.616bc
50	75.3 b	38.0 a	7.210 c	5.110 b	60.0 b	31.2 b	3.590 b	2.146ab
100	77.0 b	40.0 a	9.970 a	7.150 a	70.3 a	35.0 a	3.940 a	2.483 a
150	80.4 a	38.1 a	8.940 b	6.930 a	62.2 b	30.0 b	3.460 b	2.246 b
	2006/2007							
0	55.1 d	28.1 c	5.110 e	3.410 c	57.0 c	23.1 b	2.670 c	1.520 c
25	65.2 c	34.2 b	5.850 d	4.093bc	59.1 c	31.0 a	2.893 c	1.707bc
50	72.0 b	41.0 a	6.790 c	4.953 b	62.2ab	34.0 a	3.410 b	2.113ab
100	79.0 a	43.0 a	9.170 a	6.947 a	68.0 a	35.1 a	3.810 a	2.473a
150	78.0 a	40.0 a	8.140 b	6.283 a	64.0 b	32.1 a	3.600ab	2.180a

Table (3): Total, marketable and net yield (ton/fed.) of cabbage and cauliflower as affected by levels of sulphur application.

Season	2005/2006					
Sulphur Kg/fed.	Cabbage plants			Cauliflower plants		
	Total yield (ton /fed.)	Marketable yield (ton/fed.)	Net Head yield (ton/fed.)	Total yield (ton /fed.)	Marketable yield (ton/fed.)	Net curd yield (ton/fed.)
0	34.510 c	27.060 d	22.860 d	15.850 d	9.581 d	8.895 b
25	40.620 bc	32.580 c	26.640 c	17.410 c	10.710 c	9.709 b
50	44.990 b	36.300 b	30.660 b	22.400 b	14.430 b	12.920 a
100	62.220 a	48.669 a	42.800 a	24.590 a	17.490 a	14.890 a
150	55.780 a	47.881 a	41.580 a	21.590 b	14.530 b	13.470 a
	2006/2007					
0	31.890 e	23.400 e	20.490 e	16.660 c	10.530 d	9.120 c
25	36.500 d	26.700 d	24.602 d	18.030 c	11.440 c	10.230 c
50	43.490 c	32.230 c	29.734 c	21.280 b	13.910 b	12.480 b
100	57.220 a	44.230 a	41.649 a	23.770 a	16.460 a	14.900 a
150	50.826 b	41.860 b	37.840 b	21.590 b	14.530 b	13.080 ab

Values followed by the same letters in the same column is not significant according to Duncan's multiple range test at 0.05.

Concerning the effect of various levels of sulphur application on total, marketable and net curd yield of cauliflower, data in Table (3) show that the same responses were detected as previously mentioned in cabbage, except for edible part of curd yield in the first

season where no significant differences were observed among 50,100 and 150 kg S/fed. These results may be due to the role of S element in increasing the availability of phosphorus as reported by kashirad and Bazaragni (1972) and Heter (1985). These results are in agreement with those reported by Sanderson (2003) on broccoli and cauliflower and Rangkadilok *et al.* (2004) on broccoli.

3- Physical characteristics:

Data in Table (4) show that increasing levels of S-fertilizer from 0 up to 100 kg S/fed. significantly increased values of head length, diameter and compactness of cabbage heads in both seasons. However, addition of 150 kg S/fed gave the highest values of head shape index in the second season only.

Regarding the effect of S- application on curd quality of cauliflower, data presented in Table (4) show the same effect on curd length, diameter and compactness as that mentioned in case of cabbage. Except for, curd index the application of all 5 treatments gave the highest values as compared with the control treatment in the second season and without significant differences among treatments in the first season . This result may be due to the role of S- application on the availability of macro and micro elements in the soil. Moreover, these results are similar with those reported by Hunashikatti et *al,*. (2000) who found that increasing S levels from 0 up to 25 kg. S/ha increase the number of inner leaves and diameter of cabbage heads. Also, Sanderson (2003) on broccoli and cauliflower reported similar results.

4- Chemical constituents:-

Data presented in Table (5) show that, the values of Vit-C and P% content in cabbage heads were gradually increased as the levels of sulphur were increased up to 100 kg. S/ fed. However, 50 kg. S/ fed gave the highest values of total chlorophyll, N and K content of cabbage heads in both seasons .

Regarding the effect of sulphur levels on cauliflower curd content of total chlorophyll, Vit-C, N, P and K data presented in Table (5) also show the same response as previously mentioned in cabbage. Except for K content of cauliflower curds where there were no significant differences among the S levels from 25 to 150 kg/fed in both seasons These results are in agreement with those reported by Bhagavantagoudra and Rokhad (2001) on cabbage and Vallejo *et al.* (2003) on broccoli

Table (4): Physical characteristics of cabbage and cauliflower as affected by levels of sulphur application.

Season	2005/2006							
Sulphur Kg/fed.	Cabbage head				Cauliflower curd			
	Head length (cm)	Head diameter (cm)	Head index (H/D)	Head compac-tness (1-5)	Curd length (cm)	Curd diameter (cm)	Curd index (H/D)	Curd compac-tness (1-5)
0	20.4 c	29.7 c	0.82 a	2.9 d	10.7 c	24.9 d	0.44 a	2.4 c
25	25.4 b	31.7 c	0.80 a	2.0 c	11.7abc	26.5 c	0.44 a	1.5 b
50	26.1 b	34.2 b	0.76 b	1.9bc	12.4ab	28.1ab	0.44 a	1.3 b
100	30.0 b	38.9 a	0.81 a	1.1 a	12.7 a	29.1 a	0.43 a	1.0 a
150	28.0ab	36.0 b	0.82 a	1.7 b	11.4 bc	27.5ab	0.41 a	1.5 b
Season	2006/2007							
0	21.1 d	28.3 d	0.84 b	2.7 d	9.3 c	25.5 c	0.36 b	3.0 d
25	22.4 d	32.2 c	0.67 c	2.0cd	10.9 b	27.4 b	0.39ab	2.1 c
50	25.7c	35.9 b	0.80 b	1.7 c	11.7ab	28.1 b	0.41 a	1.5 b
100	29.1 b	39.9 a	0.81 b	1.1 a	12.3 a	30.4 a	0.43 a	1.0 a
150	31.0 a	36.4 b	0.95 a	1.4 b	11.3 b	28.7 b	0.41 a	1.5 b

Values followed by the same letters in the same column are not significant according to Duncan's multiple range test at 0.05.

Table (5): Total chlorophyll, Vit-C, N, P and K content of cabbage and cauliflower as affected by levels of sulphur application.

Season	2005/2006									
	Cabbage head					Cauliflower curd				
Sulphur Kg/fed.	Total chloro-phyll (mg/100mg F.W)	Vit-C (mg/ 100mg F.W)	N %	P %	K %	Total chloro-phyll (mg/100mg F.W)	Vit-C (mg/ 100mg F.W)	N %	P %	K %
0	194.6 d	31.7 d	2.69 c	0.564c	2.41c	205.1 c	53.1 d	2.91 b	0.595e	2.72 b
25	245.6 c	39.9 c	2.9 5b	0.689b	2.64b	220.0 b	61.4 c	2.99 b	0.690d	2.79ab
50	269.2ab	47.1 b	3.21a	0.736b	2.81a	235.6 a	69.1 b	3.19 a	0.789c	2.84ab
100	273.8 a	58.7 a	2.97b	0.840a	2.85a	241.8 a	76.2 a	2.94 b	0.950a	2.90 a
150	264.4 b	58.9 a	2.99b	0.890a	2.80a	237.3 a	78.4 a	2.90 b	0.875b	2.91 a
	2006/2007									
0	196.5 c	35.4 d	2.87c	0.510d	2.70b	193.0 b	59.1 b	2.47 c	0.601c	2.64 b
25	246.5 b	41.1 c	3.11b	0.640c	2.84a	199.2 b	64.4 b	2.64 b	0.790b	2.79 a
50	274.0 a	49.4 b	3.44a	0.748b	2.87a	215.1 a	67.9 b	2.99 a	0.884b	2.84 a
100	282.1 a	58.7 a	2.91c	0.895a	2.91a	230.4 a	78.9 a	2.61 b	0.930a	2.89 a
150	273.6 a	59.1 a	2.88c	0.840ab	2.89a	221.3 a	66.9 b	2.69 b	0.910a	2.87 a

Values followed by the same letters in the same column is not significant according to Duncan's multiple range test at 0.05.

As for the effect of sulphur levels on sulphur, sinigrin and glucoraphanin contents, Data presented in Table (6) show that increasing levels of sulphur application from 0 up to 150 kg /fed. gradually increased significantly the values of sulphur, sinigrin and glucoraphanin content in both cabbage heads and cauliflower curds in both seasons.

These results indicate the fact that sulphur plays an important role in cole crops as it is an essential element presented in these crops, moreover it enters in the formation of sinigrin and glucoraphanin which they are important contents of cabbage heads and cauliflower curds. These results agree with those reported by Rangkadilok *et al.* (2004) on broccoli and Rossen *et al.* (2005) on cabbage.

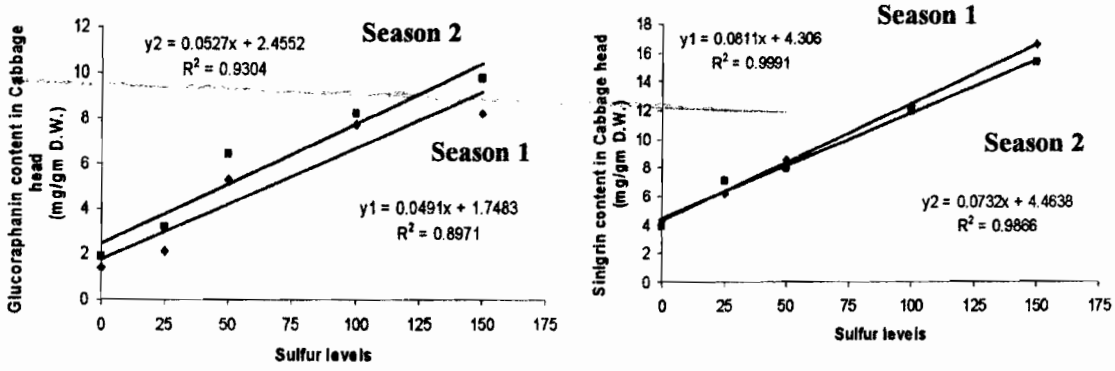
Table (6): Sulphur, sinigrin and glucoraphanin content of cabbage and cauliflower as affected by levels of sulphur application.

Season	2005/2006					
	Cabbage head			Cauliflower curd		
Sulphur Kg/fed.	Sulphur (%)	Sinigrin (mg/g D.W)	Glucoraphanin (mg/g D.W)	Sulphur (%)	Sinigrin (mg/g D.W)	Glucoraphanin (mg/g D.W)
0	0.290 e	4.3 e	1.4 d	0.540 d	3.1 e	2.4 e
25	0.510 d	6.2 d	2.1 c	0.610 c	5.2 d	5.2 d
50	0.590 c	8.6 c	5.3 b	0.650 c	7.3 c	8.4 c
100	0.740 b	12.3 b	7.7 a	0.790 b	9.3 b	10.0 b
150	0.810 a	16.5 a	8.2 a	0.890 a	11.5 a	11.9 a
Season	2006/2007					
0	0.210 d	3.9 e	1.9 e	0.520 e	2.7 d	2.2 e
25	0.500 c	7.1 d	3.2 d	0.630 d	4.8 c	5.7 d
50	0.600 b	7.9 c	6.4 c	0.710 c	7.1 b	9.4 c
100	0.790 a	11.9 b	8.2 b	0.850 b	8.4 a	11.0 b
150	0.850 a	15.3 a	9.7 a	0.950 a	8.3 a	12.7 a

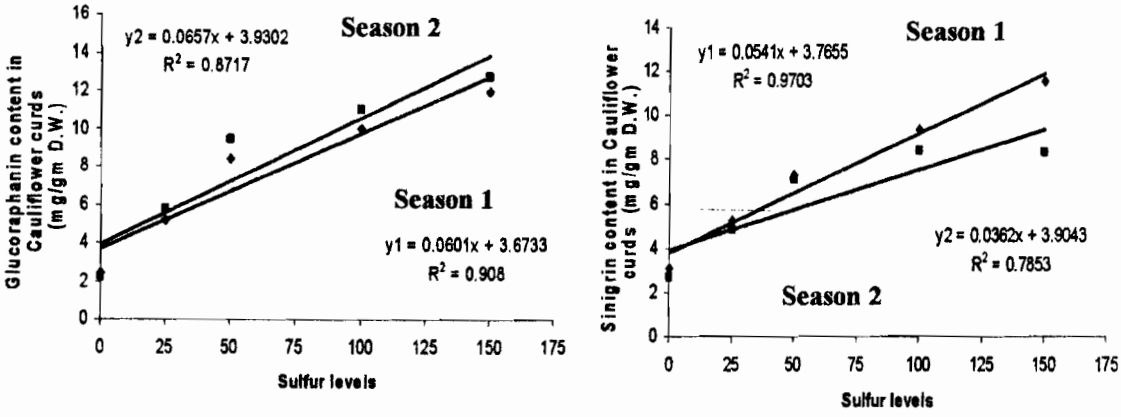
Values followed by the same letters in the same column is not significant according to Duncan's multiple range test at 0.05.

From the obtained results on the effect of sulphur levels on sinigrin and glucoraphanin content in cabbage and cauliflower it is worthy to mention that there was a positive correlation between sulphur levels and these two substances which is clearly noticed from the linear regression presented in the Figs. (1 and 2) for cabbage and Figs. (3 and 4) for cauliflower.

Finally, it could be concluded that addition of 100 kg. S/fed. gave the best values of yield, quality and chemical contents of both cabbage heads and cauliflower curds and there was a positive correlation between sulphur levels and each of sinigrin and glucoraphanin contents in both cabbage and cauliflower crops



Figs. (1 and 2): Linear regression between sulphur levels and each of glucoraphanin and sinigrin content in cabbage heads.



Figs. (3 and 4): Linear regression between sulphur levels and each of,glucoraphanin and sinigrin content in Cauliflower curds.

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إستجابة محصولى الكرنب والقنبيط لمستويات من التسميد بالكبريت

حاتم محمد عبد العال

قسم بحوث الخضر – معهد بحوث البساتين – مركز البحوث الزراعية – الجيزة – مصر

أجريت تجربتان حقليتان منفصلتان بمحطة البحوث الزراعية بقها، محافظة القليوبية ،على محصول كل من الكرنب والقنبيط خلال العروة الشتوية ٢٠٠٥/٢٠٠٦ و ٢٠٠٦/٢٠٠٧ وذلك لدراسة تأثير مستويات من التسميد بالكبريت على النمو والمحصول والجودة والمحتوى الكيماوي من النتروجين والفوسفور والبوتاسيوم والكبريت وكذلك محتوى الكرنب والقنبيط من فيتامين ج والسنجرين والجلوكورافنين.

وكانت مستويات الكبريت كالتالى: بدون، ٢٥، ٥٠، ١٠٠ و١٥٠ كجم كبريت/فدان. وقد استخدم تصميم القطاعات كاملة العشوائية لكل محصول.

تبين من الدراسة أن إضافة مستويات الكبريت من صفر حتى ١٠٠ كجم / فدان أعطت بوجه عام نتائج معنوية لجميع صفات النمو الخضرية. وهى طول النبات، عدد الأوراق، وزن النبات الطازج، متوسط وزن الرأس او القرص لكل من الكرنب والقنبيط.

كما زاد معنوياً كلا من المحصول الكلى والقابل للتسويق لرؤوس الكرنب وأقراص القنبيط وكذلك محتوى الأوراق من الكلوروفيل الكلى وصفات الجودة فى الرؤوس والأقراص (الإرتفاع – القطر – الإندماج) وكذلك أيضاً محتوى الرؤوس والأقراص من النتروجين – الفوسفور – البوتاسيوم والكبريت وذلك بالإضافة إلى فيتامين ج والسنجرين والجلوكورافنين وذلك فى كل من الكرنب والقنبيط. كما أظهرت النتائج وجود ارتباط موجب بين مستويات الكبريت ومحتوى كل من السنجرين والجلوكورافنين فى المحصولين.

تحت ظروف هذه الدراسة. يمكن أن نوصى بتسميد نباتات الكرنب والقنبيط بالكبريت بمعدل ١٠٠ كجم / فدان لكى يعطى أعلى نمو ومحصول وجودة وكذلك أعلى محتوى من فيتامين ج والسنجرين والجلوكورافنين كمضاد للسرطان.