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Influence of sulphur,potassium humate and their interactions on growth, flowering and chemical constituents of roselle plant (*Hibiscus sabdariffa*)

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ABSTRACT

This study was achieved during the two successive summer seasons of 2017 and 2018 at the Experimental Farm of Faculty of Agriculture, Fayoum University, Fayoum. The main target of this study was to examin the influence of four rates (0, 50, 100 and 150 kg fed^{-1}) of sulphur and potassium humate (0, 10, 20 and 30 kg fed^{-1}) as soil application and their interactions on vegetative growth, flowering and chemical compositions of roselle (*Hibiscus sabdariffa*) plant. The obtained results referred that using sulphur at the highest rate (150 kg fed^{-1}) significantly increased growth parameters (plant height and number of branches/plant), some flowering and fruits characters (number of fruits plant^{-1} and fresh and dry weight of sepals plant^{-1}) and chemical constituents (N, P and K%, chlorophyll a+b, charbohydrate %, Anthocyanins % and sepals acidity) compared with control. Plants treated with potassium resulted in the highest significant values of all the above mentioned studied parameters. Also, the interaction effect between sulphur and potassium shown, that the highest values of vegetative growth and flowering parameters as well as and chemical composition were resulted from 100 or 150 kg fed^{-1} sulphur combined with 30 kg fed^{-1} potassium humate compared with control treatment.

Key Words: Roselle , Sulphur, Potassium humate, Growth, Yield, Chemical constituents.

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.), a member of *Malvaceae* family, is an annual tropical and sub-tropical herbaceous plant. Calyces (sepals) are the main commercial organ in roselle, which, because of their unique brilliant red color and flavor, are commonly used in food industry for production of beverages, juices, jams, and syrup **(Borrás-Linares et al., 2015**). Roselle is also used as human food or roasted as a substitute for coffee. Moreover, many medicinal applications have been developed for roselle around the world **(Mohd-Esa et al., 2010).** Red calyces of roselle are a source of anthocyanins (about 1.5 g/100 g dry weight), vitamin C and other antioxidants, such as flavonoids (gossypetin, hibiscetine, and sadderetine) (**Ghavam et al., 2019).** Roselle fruit is highly acidic, with low sugar content. Succinic acid and oxalic acid are the two main organic acids in roselle, whereas glucose is the major sugar present in its fruits **(Wong et al., 2002).**

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Sulfur is a major plant nutrient for crop production after nitrogen, phosphorus and potassium **(Jamal et al., 2005 and Jamal et al., 2010).** Sulfur has many physiological roles in plants such as formation of amino acids methionine (21% S) and cysteine (27% S), synthesis of proteins and chlorophyll **(Lakkineni and Abrol, 1992 and Scherer, 2001).**

Potassium humate can be used as an organic potash fertilizer to supply the plants with high levels of soluble potassium in a readily available form. Combined with humic acid, potassium can be rapidly absorbed and incorporated into plants. Potassium humate increases photosynthesis, chlorophyll density and plant root respiration, which resulted in greater plant growth and yield (**Yang et al., 2004 and Hassanpanah, 2009**).

The overall aim of this research is to improve understanding of the influences of sulphur and humic acid on vegetative growth, flowering and chemical constituents of *Hibiscus sabdariffa* L plant.

MATERIALS AND METHODS:

These field trails were carried during out the two successive seasons of 2017 and 2018 at the Experimental Farm of Faculty of Agriculture, Fayoum University, Fayoum, to study the effect of rates of sulphur and potassium humate as soil application and their interactions on vegetative growth, flowering and chemical composition of roselle (*Hibiscus sabdariffa*) plant.

The mechanical and chemical analysis of used soil was carried out according to the standard procedures **(Wilde et al., 1985)** and the results were presented in Table 1.

Table 1 : Physical and chemical characteristics of the experimental farm soil.

Physical properties %			
Coarse sand	**Silt**	**Clay**	**Soil texture**
6.5	13.9	56.9	**Clay**

Chemical properties

Organic matter %	EC mmhos/cm	pH	Total nitrogen %	Available p mg/g	Calcium carbonate %	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCo_3^{-}	Cl^{-}	So_4^{--}
1.21	1.56	7.63	0.17	23	5.43	5.57	2.35	7.04	0.42	2.05	8.48	4.55

Seeds: Seeds of roselle plant were obtained from the Research Center of Medicinal and Aromatic Plants in Giza, Egypt. Seeds were sown on 20th April during each season in plots (3×1.5) containing 3 rows (50 cm width) every row had five hills (50 cm apart) and one month later, the plants were thinned by leaving only one seedling/ hill. Plants were irrigated and hand weeded regularly according to its needs.

Sulphur: Sulphur was added with organic manure at the rates of 0, 50, 100 and 150 kg. $fed.^{-1}$ one month before planting.

Potassium humate: Potassium humate at the rates of (0, 10, 20 and 30 $kg.fed^{-1}$) was applied two times as a soil drench, the first applies was 45 days and the second one was 75 days after planting.

The experimental design: The experimental design split arranged in a split-plot, with three replicates. The sulphur levels were represented the main plots, meanwhile rates potassium humate represented the sub-plot.

Different measurements:

From each experimental unit, five plants from the two outer rows were randomly chosen for morphological characters and chemical composition assessment, while the middle row was chosen to fruit yield and its components determination.

1- Vegetative growth characters:

Plant height (cm) and number of main branches/ plant at the end of growing season were estimated.

2-Yield and its Components

Number of days from sowing dates to flowering, number of fruits/plant, yield of fresh calyces/ plant (gm) and yield of dry calyces/ plant (gm) were determined.

3- Chemical analysis:

Chlorophylls (a & b) and carotenoids concentrations (mg g^{-1} fresh weight of leaf) were determined using colorimetric method as described by **Moran (1982).** Total carbohydrates were colorimetrically determined according to the method described by **Herbert et al. (1971).** Nitrogen % was colorimetrically determined by using the orange G dye according to the method of **Hafez and Mikkelsen (1981)**. Phosphorus % was determined according to method described by **A.O.A.C. (1995).** Potassium % was determined by flame-Photometer Parkin-Elmer model 52 with acetylene burner according to **Wilde et al. (1985).** Anthocyanin concentration (mg g^{-1}) was determined according to the method described by **Fahmy (1970).** The acidity (pH) was determined according to **Diab (1968).**

RESULTS AND DISCUSSION

1- Vegetative growth characters;

Table 2 show that utilizing sulphur increased all vegetative growth parameters of roselle plant . Moreover, increasing of sulphur level was concomitant with improving of these parameters. This result was in parallel with those obtained **Ali et al. (2017)** on roselle. This effect may be attributed to the fact that sulphur may be used as a nutrient and as soil acidifier which gave it an importance in agricultural production (**Scherer et al., 2008**). Sulphur is an essential nutrient for plant to help formation of plant proteins, chlorophyll and improve growth (**Abdallah et al., 2010).**
Low level of potassium humate did not significantly enhance both vegetative growth parmeters, while medium and high levels could eleveted these parameters, This enhancing effect of potassium humate on morophological characters of roselle plant can be explained based on the physiological fact that humic acid stimulated plant growth, which might be attributed to the role of potassium humate which can be used as growth regulate-hormone improves plant growth **(Albayrak and Camas, 2005).** It also acts an in direct role for stimulating plant growth through its interactions with plant membrane transporters responsible for nutrients uptake and membrane associated signal transduction cascades which regulate growth and development (**Canellas and Olivares, 2014).** Many other reports support our obtained results such as **Fahmy and Hassan (2019)** on roselle and **El-Serafy, Rasha (2018)** on roselle.

The increased growth parameters observed following the combined treatment with S and HA may be attributed to their combined positive effects on the soil, which led to an increase in organic matter content and bio-available nutrients, as a result of a reduction in soil pH. These results are in line with **Osman and Rady (2012)** on pea.

Table 2 : effect of sulphur and potassium humate on plant height and number of branches of roselle plants during the two seasons of 2017 and 2018.

Humic /(kg.fed^{-1}) S / (kg.fed^{-1})	Plant height (cm)									
	First Season (2017)					Second Season (2018)				
	0	10	20	30	Mean	0	10	20	30	Mean
0	156.01	156.47	152.67	170.50	158.66	153.83	150.27	155.53	168.23	154.47
50	158.03	159.00	159.36	170.50	161.72	158.03	156.50	155.83	177.33	161.92
100	160.40	161.07	163.53	177.57	165.64	161.53	160.40	163.07	176.53	165.38
150	162.80	161..07	174.37	175.20	168.36	162.80	162.20	174.37	184.20	170.89
Mean	159.33	159.40	162.48	173.44		159.05	157.34	162.10	174.57	
L.S.D 5%										
S			**2.24**					**3.39**		
H			**2.03**					**3.07**		
S X H			**3.03**					**4.05**		
	Number of branches plant^{-1}									
0	9.27	9.40	9.47	9.53	9.42	8.13	8.27	8.27	8.40	8.27
50	9.53	9.92	9.65	10.17	9.82	8.47	8.40	8.48	9.23	8.65
100	9.72	10.33	10.23	10.10	10.10	8.53	8.58	8.53	9.27	8.73
150	10.40	10.13	10.93	11.67	10.78	9.40	9.33	9.93	10.67	9.83
Mean	9.73	9.95	10.07	10.37		8.65	8.65	8.80	9.39	
L.S.D 5%										
S			**0.35**					**0.37**		
H			**0.48**					**0.50**		
S X H			**0.51**					**0.44**		

2 – Flowering and fruits characters:

2 – 1- Number of days from sowing to flowering:

It is evident from data recorded in Table (3) that soil additions with sulphur fertilizer at 0, 50, 100 and 150 kg.fed^{-1} caused a decrement in the time required from sowing to flowering as comparing with control in the two seasons. In this respect, 150 kg.fed$^{-1.}$ application with sulphur occupied the first rank for early flowering during the two successive seasons. This influence might be due to the fact that sulphur which might have participated in higher protein synthesis and thus improved the vegetative growth responsible for more dry matter accumulation and partitioning of nutrient toward the developing flowering attributes (**Kumar and Misra, 2003).** 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 **(Diriba et al., 2014).**

Regarding the influence of potassium humate, data devoted that the general effect of potassium humate rates on number of days from sowing to flowering was significant (induced earlier flowering). Furthermore, addining potassium humate at 30 kg. fed^{-1} gave shortened number of days from sowing to flowering followed by 20 kg.fed^{-1} and the same trend was apparent in two successive seasons.

The data in the same Table (3) indicate that the minimum number of days (139.33 and 137.33) were obtained from the combined treatment 150 kg. fed^{-1} of sulphur and 30 kg.fed^{-1} of potassium humate in the first and second seasons, respectively, as compared with control *i.e.* induced earlier flowering.

Table 3 : effect of sulphur and potassium humate on number of days from sowing to flowering of roselle plants during the two seasons of 2017 and 2018.

Humic (kg.fed^{-1})	Number of days from sowing to flowering									
	First Season (2017)					Second Season (2018)				
S /(kg.fed^{-1})	0	10	20	30	Mean	0	10	20	30	Mean
0	146.67	144.00	143.67	142.33	144.16	145.67	145.00	145.33	144.00	145.00
50	146.00	142.67	143.00	143.00	143.68	143.67	142.67	142.57	143.00	142.08
100	145.67	144.00	142.00	142.00	143.42	144.67	142.33	140.67	142.33	142.50
150	146.00	144.00	139.67	139.33	142.25	142.67	140.67	139.33	137.33	140.00
Mean	146.08	143.67	142.08	141.66		144.76	142.68	141.99	141.67	
L.S.D 5%										
S	**0.06**					**0.01**				
H	**0.01**					**0.04**				
S X H	**0.08**					**0.37**				

2-2- Number of fruits plant

The results arranged in Table (4) clear that any rate of sulphur fertilizer led to significant increase in number of fruits plant^{-1} as compared with control in both seasons. Furthermore, soil application of sulphur fertilizer at 150kg. fed^{-1} gave greater value significantly of number of fruits plant^{-1}(119.58 and 108.75) in the first and second season, respectively. The role of sulphur in soil is very important for plant to optimize crop yield and quality **(Abd El-Fattah et al., 1992** and **Jez, 2008**). Sulphur is needed for all important plant functions and processes, including protein biosynthesis and hormonal control, which in addition to influencing growth and cell differentiation, indirectly interferes with crop productivity **(Malavolta and Moraes, 2007).**

As for the effect of potassium humate levels, indicated that increasing in number of fruits plant^{-1}occurred due to adding potassium humate up to 30 kg.fed^{-1}as compared to control. The improving effect of potassium humate on flowering and fruits characters can be discussed on the ground that humic acid influences on plant yield through its effect on respiration, photosynthesis as well as dry matter accumulation in plants (**Turkmen et al. 2004).** Numerous investigators came to similar conclusions on roselle such as **Youssef et al. (2014)** and **El-Serafy, Rasha (2018)** on roselle.

Significant interaction effect between the two studies factors on number of fruits plant^{-1} was obvious in both seasons. Therefore, the treatment combination of 150 kg fed^{-1}sulphur and 30 kg.fed^{-1} in the first season and 100 kg fed^{-1} sulphur and 30 kgfed^{-1} in the second season recorded the greatest number of fruits plant^{-1} (135.44 and 121.22) comparing to control. These results are in agreement with **Osman and Rady (2012)** on pea.

Table 4 : effect of sulphur and potassium humate on number of fruits plant $^{-1}$ of roselle plants during the two seasons of 2017 and 2018.

Humic (kg.fed^{-1}) / S / (kg.fed^{-1})	No. of fruits plant^{-1}									
	First Season (2017)					Second Season (2018)				
	0	10	20	30	Mean	0	10	20	30	Mean
0	74.00	101.78	94.22	114.89	96.22	69.11	94.22	99.22	100.89	90.86
50	86.78	99.56	103.67	122.67	103.17	86.78	95.67	105.44	102.67	97.64
100	101.00	110.56	110.56	126.78	112.23	100.11	98.89	109.11	121.22	107.33
150	110.78	109.11	123.00	135.44	119.58	104.11	104.11	116.22	110.56	108.75
Mean	93.14	105.25	107.86	124.95		90.03	98.22	107.50	108.84	
L.S.D 5%										
S			**1.28**					**1.02**		
H			**3.09**					**2.18**		
S X H			**3.45**					**4.01**		

2 – 3- Sepals fresh and dry weight plant^{-1} (gm):

The results arranged in Table (5) show that soil application of sulphur at the rates of 50, 100 and 150 kg fed^{-1}, in 2017 season significanty resulted in higher mean values of sepals fresh and dry weight plant^{-1} than the control. The same influence was obvious in 2018 season. These positive results may be attributed to the fact that the added S significantly improved leaf contents of chlorophyll, ascorbic acid, and reduced glutathione. In turn, this may have led to an increase in photosynthetic efficiency, and subsequently to higher plant DWs and crop yields **(Anjum et al., 2008).**

Also, soil application of potassium humate at the rates of 10, 20 and 30 kg fed^{-1} reflected positive effects on fresh and dry weight of sepals plant^{-1}in comparison with the standard treatment, in 2017 and 2018. We can notice that sepals fresh and dry weight increased as the rates of potassium humate increased in two season. Generally, soil application of potassium humate at 30 kg fed^{-1}was responsible for the heaviest fresh and dry weight of sepals plant^{-1}. Our results are in accordance with the results of **Fahmy and Hassan (2019)** on roselle, clarified that addition 4 l fed^{-1} humic acid significantly increased the yield components (fruit number/ plant, sepals yield per plant and per fed^{-1})

Statistical analysis showed the interaction effect between the four sulphur rates and four potassium humate rates on fresh and dry weight of sepals plant^{-1}in 2017 and 2018 seasons was significant. Comparisons among the sixteen combination treatments indicated that the dual application of sulphur either at 100 or 150 kg fed^{-1}and potassium humate at 30 kg fed^{-1} in the first season while, with 20 kg fed^{-1}in the second season recorded the highest mean values of fresh and dry weight of sepals plant^{-1}.

Table 5 : effect of sulphur and potassium humate on fresh and dry weight of sepals of roselle plants during the two seasons of 2017 and 2018.

Humic (kg.fed^{-1})	Sepals fresh weight plant^{-1}(gm)									
	First Season (2017)					Second Season (2018)				
S / (kg.fed^{-1})	0	10	20	30	Mean	0	10	20	30	Mean
0	297.22	298.89	349.89	411.44	339.36	256.67	298.89	322.22	360.89	309.67
50	329.56	413.00	377.22	420.56	385.09	329.56	357.67	377.22	396.33	365.20
100	405.00	431.11	447.00	451.11	433.56	376.67	373.00	405.89	391.33	386.72
150	400.78	435.22	403.11	471.11	427.56	377.44	388.67	441.22	405.67	403.25
Mean	358.14	394.56	394.31	438.56		335.09	354.56	386.64	388.56	
L.S.D 5%										
S			**9.01**					**8.03**		
H			**12.08**					**6.01**		
S X H			**13.97**					**9.35**		
	Sepals dry weight plant^{-1}(gm)									
0	28.99	35.75	39.24	40.76	36.19	25.18	28.41	31.00	30.86	28.86
50	31.69	36.01	40.10	46.95	38.69	30.00	31.69	35.38	40.10	34.29
100	37.65	41.76	43.02	46.27	42.18	33.17	33.16	37.82	41.80	36.49
150	42.87	46.88	44.81	49.12	45.92	35.42	38.48	43.88	41.17	39.74
Mean	35.30	40.10	41.79	45.78		30.94	32.94	37.02	38.48	
L.S.D 5%										
S			**1.08**					**1.04**		
H			**1.01**					**1.19**		
S X H			**0.78**					**0.82**		

3 - Chemical constituents

3. 1- Leaf elemental content

fact that the addition of potassium humate lowered the soil PH value through production of organic acid as well as increasing the activity of soil organisms and preventing nutrients ions from leaching (**Mady, 2009**). Other investigators reported similar results such as **Youssef et al. (2014), El-Serafy, Rasha (2018)** and **Fahmy and Hassan (2019)** on roselle.

3.2 Leaf pigments content:

Soil application of sulphur, irrespective of the level used, increments in leaf chlorophyll a, b, a+b and carotenoids content compared to control, in the two experimental seasons Table (7). The difference between any applied level of sulphur and control content was insignificant. Generally, comparisons among the mean values of photosynthetic pigments content show that soil application of sulphur at 150 kg fed^{-1} recorded the best mean values of leaf

The results on leaf N, P and K contents as influenced by sulphur, potassium humate levels and their interactions are presented in Table (6). The macronutriens *i.e:* N, P and K in roselle leaves were significantly increased due to the soil application of sulphur at 50, 100 and 150 kg fed^{-1} in comparison with the stander treatment.This influence might be due to the fact that higher S doses provide greater N absorption by the plants, indicating a positive interaction between these elements **Haneklaus et al.** (**2014**), **Chattoo et al.** (**2019**) it was observed that application of sulphur enhancing nutrient uptake by crop.

Also, addition potassium humate on leaf N and K contents was significant in two seasons, except the level 10 kg fed^{-1}was insignificant. Soil application of potassium humate at 20 and 30 kg fed^{-1}attained higher mean values of leaf N and K content than the control can be explained on the physiological

Similar reports were published by **Osman and Rady (2012)** on pea and **Al-Mohammad and Al-Taey (2019)** on arugula. chlorophyll a, b, a+b and carotenoids content. Sulphur is necessary for enzymatic action, chlorophyll formation **(Diriba et al., 2014).**

Table 6 : effect of sulphur and potassium humate on percentage of N, P and K of roselle plants during the two seasons of 2017 and 2018.

Humic /($kg.fed^{-1}$) S / ($kg.fed^{-1}$)	First Season (2017) 0	10	20	30	Mean	Second Season (2018) 0	10	20	30	Mean
					N %					
0	2.37	2.32	2.52	2.38	2.40	2.33	2.32	2.38	2.52	2.39
50	2.56	2.52	2.77	2.69	2.64	2.53	2.52	2.57	2.63	2.56
100	2.69	2.70	2.61	2.76	2.69	2.69	2.73	2.76	2.77	2.74
150	2.76	2.94	2.79	2.89	2.85	2.76	2.79	2.95	2.92	2.86
Mean	2.60	2.62	2.67	2.68		2.58	2.59	2.67	2.71	
L.S.D 5%										
S			**0.12**					**0.11**		
H			**0.05**					**0.06**		
S X H			**0.09**					**0.11**		
					P %					
0	0.37	0.42	0.43	0.45	0.42	0.34	0.40	0.41	0.45	0.40
50	0.46	0.47	0.47	0.52	0.48	0.42	0.46	0.48	0.51	0.47
100	0.49	0.53	0.50	0.53	0.51	0.46	0.50	0.51	0.53	0.50
150	0.50	0.52	0.53	0.53	0.52	0.46	0.51	0.53	0.53	0.51
Mean	0.46	0.49	0.49	0.51		0.43	0.47	0.49	0.51	
L.S.D 5%										
S			**0.08**					**0.07**		
H			**NS**					**NS**		
S X H			**0.09**					**0.08**		
					K %					
0	1.11	1.12	1.23	1.18	1.16	1.03	1.13	1.08	1.12	1.09
50	1.17	1.20	1.25	1.27	1.22	1.18	1.15	1.20	1.54	1.27
100	1.37	1.33	1.30	1.54	1.39	1.17	1.30	1.29	1.16	1.23
150	1.31	1.58	1.66	1.73	1.58	1.26	1.31	1.62	1.77	1.49
Mean	1.24	1.31	1.36	1.43		1.16	1.22	1.30	1.40	
L.S.D 5%										
S			**0.11**					**0.15**		
H			**0.08**					**0.09**		
S X H			**0.14**					**0.16**		

Also, data show that addition of potassium humate achieved the heaviest the content of leaf chlorophyll a, b, a+b and carotenoids content where the content of leaf was significantly as compared to control, in two seasons. Whereas the highest leaf chlorophyll a, b, a+b and carotenoids content were recorded by 30 kg fed^{-1} followed by 20 kg fed^{-1} treatment, in the first and second seasons. Humic acid enhanced the quantitative and qualitative traits due to its positive role in raising respiration, photosynthesis rate and more accumulation of total chlorophyll content in plants as found **Turkmen et al. (2004)** and **Cangi et al. (2006**). These observations and findings were in harmony with **Youssef et al. (2014)**, **El-Serafy, Rasha (2018)** and **Fahmy and Hassan (2019)** clarified that application of humic acid at higher rates of 2 and 4 l fed^{-1} increased total chlorophyll content in roselle plants compared to control during the two seasons.

The interaction between the two studied factors show the highest means of leaf pigments content were obtained mostly when. roselle plants were fertilized with the high level of sulphur 100 or 150 kg fed^{-1}

combined with high level of potassium humate 20 or 30 kg fed^{-1} in the first and second season. Likewise, **Osman and Rady (2012),** working on pea plants and found that application of humic acid to- gether with sulfur significantly increased leaf chlorophylls and carotenoids content

Table 7 : effect of sulphur and potassium humate on leaf photosynthetic pigments content of roselle plants during the two seasons of 2017 and 2018.

Humic ($kg.fed^{-1}$)/	First Season (2017)					Second Season (2018)				
S/ ($kg.fed^{-1}$)	**0**	**10**	**20**	**30**	**Mean**	**0**	**10**	**20**	**30**	**Mean**
					Chlorophyll a (mg g-1 FW)					
0	1.10	1.20	1.70	2.00	1.50	1.00	1.30	1.50	1.80	1.40
50	1.20	1.40	1.80	2.10	1.60	1.00	1.40	1.70	1.90	1.50
100	1.20	1.40	1.90	2.40	1.70	1.10	1.50	1.80	2.10	1.60
150	1.30	1.70	2.10	3.10	2.10	1.20	1.50	1.90	2.10	1.70
Mean	1.20	1.40	1.90	2.40		1.10	1.40	1.70	2.00	
L.S.D 5%										
S			**NS**					**NS**		
H			**0.30**					**0.30**		
S X H			**0.50**					**0.40**		
					Chlorophyll b (mgg^{-1} FW)					
0	1.40	2.00	2.20	2.40	2.00	1.60	2.00	2.30	2.70	2.20
50	1.70	2.40	2.60	2.80	2.40	1.80	2.30	2.50	2.80	2.40
100	2.00	2.50	2.80	3.00	2.60	2.20	2.30	2.70	3.10	2.60
150	2.20	2.80	3.10	3.60	2.90	2.30	2.70	2.80	3.60	2.90
Mean	1.80	2.00	2.70	3.00		2.00	2.30	2.60	3.10	
L.S.D 5%										
S			**NS**					**NS**		
H			**0.30**					**0.40**		
S X H			**0.40**					**0.50**		
					Chlorophyll (a+b) (mg g^{-1} FW)					
0	2.50	3.20	3.90	4.40	3.50	2.60	3.30	3.80	4.50	3.60
50	2.90	3.80	4.40	4.90	4.00	2.80	3.70	4.20	4.70	3.90
100	3.20	3.90	4.70	5.40	4.30	3.30	3.80	4.50	5.20	4.20
150	3.50	4.50	5.20	6.70	5.00	3.50	4.20	4.70	5.70	4.60
Mean	3.00	3.80	4.60	5.40		3.10	3.70	4.30	5.10	
L.S.D 5%										
S			**0.50**					**0.40**		
H			**0.60**					**0.50**		
S X H			**0.80**					**0.90**		
					Carotenoids (mg g^{-1} FW)					
0	0.50	0.80	0.90	1.10	0.80	0.30	0.55	0.70	0.90	0.60
50	0.60	0.80	0.80	1.20	0.90	0.50	0.60	0.80	1.10	0.80
100	0.60	0.90	1.10	1.40	1.00	0.50	0.60	0.90	1.20	0.80
150	0.70	0.90	1.60	1.60	1.20	0.70	0.80	1.40	1.50	1.10
Mean	0.60	0.85	1.10	1.40		0.55	0.60	1.10	1.20	
L.S.D 5%										
S			**NS**					**NS**		
H			**0.30**					**0.30**		
S X H			**0.40**					**0.30**		

3-3- Total carbohydrates percentage:

Soil application of sulphur fertilizer rates (Table 8), obtained results show that sulphur fertilizer at 150 kg fed^{-1} produced the highest significant values of total carbohydrates (29.83 and 28.92 %) followed by sulphur fertilizer at 100 kg fed^{-1} (28.20 and 27.94 %) in the first and second season, respectively.

Application of potassium humate at 20 kg fed^{-1}in the first season and 30 kg fed^{-1}in the second season was pronounced and recorded the best significant mean values of carbohydrates content in sepals (28.75 and 27.02 %) in the first and second season, respectively.

Furthermore, the highest mean values of total carbohydrates (34.32 %) was recorded when sulphur rate at 150 kg fed^{-1} and potassium humate level at 20 kg fed^{-1} in first season while, was (31.92 %) when sulphur rate at 150 kg fed^{-1} and potassium humate level at 30 kg fed^{-1} in second season. This result may due to increase chlorophylls and carotenoids content may as mentioned above table (7) be enhanced photosynthesis efficiency and that is a good explain to the increasing of dry matter production.

Table 8 : effect of sulphur and potassium humate on carbohydrates percentage in sepals of roselle plants during the two seasons of 2017 and 2018.

Humic kg.fed^{-1})	Total Charbohydrate %									
	First Season (2017)					Second Season (2018)				
S/ kg.fed^{-1})	0	10	20	30	Mean	0	10	20	30	Mean
0	24.11	26.18	25.94	25.55	25.45	23.62	24.28	24.41	24.11	24.11
50	26.14	26.62	27.68	26.68	26.78	26.18	25.55	26.55	25.64	25.98
100	26.55	27.50	27.05	31.68	28.20	26.94	30.70	27.08	27.05	27.94
150	27.28	28.63	34.32	29.08	29.83	28.63	26.68	29.08	31.29	28.92
Mean	26.02	27.23	28.75	28.25		26.34	26.80	26.78	27.02	
L.S.D 5%										
S			**0.77**					**0.68**		
H			**0.47**					**0.37**		
S X H			**0. 43**					**0.74**		

3-4 - Anthocyanins percentage:

The results in Table (9) show that anthocyanin percentage was significantly increased in the sepals, when compared with control in the two seasons as a result of soil application of sulphur fertilizer rates. The highest percentage (2.49 and 2.38 %) produced from the rate of 150 kg fed^{-1} followed by 100 kg fed^{-1} (2.38 and 2.37 %) in the first and second season, respectively. These results are in harmony with those obtained by **Abdel Bagi et al. (2002)** on roselle.

The impact of addition potassium humate on anthocyanin percentage in sepals was significant in two seasons, except the level 10 and 20 kg fed^{-1}was insignificant in the first season as compared to control. Soil application of potassium humate at 30 kg fed^{-1} attained higher mean value of anthocyanin than the control. These finding were in agreement with those of **Youssef et al. (2014)** and **El-Serafy, Rasha (2018)** on roselle found that anthocyanins percentage significantly increased by using any level of humic acid relative to control plants.

The highest value of anthocyanin content was obtained from addition of sulphur at rate 150 kg fed^{-1} with potassium humate at levels 30 kg fed^{-1} in the first season (2.84 %) and at rate 100 kg fed^{-1} with potassium humate at levels 30 kg fed^{-1} in the second season (2.57 %).

Table 9 : effect of sulphur and potassium humate on anthocyanin percentage in sepals of roselle plants during the two seasons of 2017 and 2018.

kg.fed⁻¹)/ Humic /Kg S / kg.fed⁻¹)	Anthocyanins % First Season (2017) 0	10	20	30	Mean	Second Season (2018) 0	10	20	30	Mean
0	2.19	2.15	2.25	2.31	2.23	2.13	2.22	2.29	2.20	2.21
50	2.22	2.28	2.27	2.53	2.33	2.19	2.26	2.38	2.25	2.27
100	2.31	2.35	2.32	2.54	2.38	2.25	2.35	2.30	2.57	2.37
150	2.37	2.32	2.42	2.84	2.49	2.32	2.38	2.38	2.44	2.38
Mean	2.27	2.28	2.32	2.56		2.22	2.30	2.34	2.37	
L.S.D 5%										
S			**0.03**					**0.05**		
H			**0.09**					**0.06**		
S X H			**0.17**					**0.13**		

3-5. Sepals acidity (pH value):

Table (10) reveal that all the combinations between sulphur and potassium humate succeeded in increasing the pH values in sepals of roselle plant in both seasons. However, the combined treatment between 150 kg fed^{-1} sulphur and 30 kg fed^{-1} potassium humate gave the highest pH values in sepals (3.24) in the first season, while, the treatment 150 kg fed^{-1} sulphur and 20 kg fed^{-1} potassium humate gave the highest pH values in sepals (3.25) in the second season. The differences in pH values in sepals two combined treatments were so small to reach the significant level in both seasons.

The results indicated that increase in pH values in sepals occurred with increasing the sulphur rates Table (10) and Fig (3), the heaviest pH values in sepals (3.06 and 3.11) resulted from treatment 150 kg fed^{-1} sulphur as compared to control in the first and second seasons, respectively.

Also, data showed that addition of potassium humate significant increased pH values in sepals, especially, with the rates 20 and 30 kg fed^{-1} as compared to control, in two seasons. This result was in agreement with **Youssef et al. (2014)** on roselle.

As for the interaction effect between sulphur and potassium humate, data in the same

Table 10 : effect of sulphur and potassium humate on acidity level in sepals of roselle plants during the two seasons of 2017 and 2018.

Humic kg.fed⁻¹) S /Kg	Sepals acidity (Ph value) First Season (2017) 0	10	20	30	Mean	Second Season (2018) 0	10	20	30	Mean
0	2.70	2.81	2.89	2.98	2.85	2.83	2.83	2.90	2.98	2.89
50	2.87	2.90	2.90	3.00	2.92	2.79	2.90	2.94	2.97	2.90
100	2.87	2.93	2.97	3.05	2.96	2.87	2.97	2.93	3.06	2.96
150	2.98	2.99	3.03	3.24	3.06	2.97	3.03	3.25	3.20	3.11
Mean	2.86	2.91	2.95	3.07		2.87	2.93	3.01	3.05	
L.S.D 5%										
S			**0.05**					**0.07**		
H			**0.04**					**0.06**		
S X H			**0.14**					**0.12**		

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تأثير الكبريت وهيومات البوتاسيوم والتفاعل بينهم على النمو والإزهار والتركيب الكيماوى لنبات الكركديه

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نفذت هذه الدراسة خلال موسيمين صيفيين متتاليين 2017 و 2018 بمزرعة التجارب بكلية الزراعة جامعة الفيوم بهدف دراسة تأثير أربع معدلات من الكبريت (صفر , 50 , 100 , 150كيلوجرام للفدان) وهيومات البوتاسيوم (صفر , 10 , 20 , 30 كيلوجرام للفدان) كتطبيق أرضى و ومعاملات التفاعل بينهم على النمو الخضرى والأزهار والتركيب الكيماوى لنبات الكركدية. أشارت النتائج المتحصل عليها أن أستعمال الكبريت عند المعدل المرتفع (150كيلوجرام للفدان) زود معنويا صفات النمو الخضرى (أرتفاع النبات وعدد الفروع للنبات) وصفات المحصول (عدد الثمار للنبات والوزن الطازج والجاف للسبلات) والتركيب الكيماوى (نسبة النيتروجين والفوسفور والبوتاسيوم وكلوروفيل أ+ب ونسبة الكربوهيدرات والأنثوسيانين وحموضة السبلات) بالمقارنة بالكنترول.ادت معاملة النباتات بهيومات البوتاسيوم للحصول علي أعلى قيم معنوية من الصفات سابقة الذكر المدروسة. ايضاًمعاملة التفاعل بين الكبريت وهيومات البوتاسيوم زيادة معنوية لمعظم الصفات سابقة الذكر وأعلى قيم لصفات النمو الخضرى والزهرى والتركيب الكيماوى وتم الحصول علي اعلي من تفاعل المعدلات 100 أو 150 كيلوجرام للفدان كبريت مع 30 كيلو جرام للفدان هيومات البوتاسيوم بالمقارنة مع الكنترول.