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Sulfur Fertilization Effects on Growth, Yield and Fruit Quality of Grand Nain Banana Cultivar

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Abstract: During two successive seasons (2004-2005), this study was carried out on banana Grand Nain cv in order to investigate the effect of different rates of sulfur fertilization on growth, yield and fruit quality. Sixty three plants, uniform in growth and in good physiological conditions as possible were selected at random. Each treatment represented by nine plants distributed in three blocks in complete randomized design. The experimental plants were subjected to the following treatments: (1) Control (without sulfur application). (2) 0.005 % S. (3) 0.0075 % S. (4) 0.01 % S. (5) 0.015 % S. (6) 0.0175 % S. (7) 0.02 % S (w/w) equivalent to zero, 50, 75, 100, 150, 175, and 200 kg S /fed. Data of the two experimental seasons revealed that soil pH and availability of macronutrients were significantly affected by S-application rates. The lowest values of pH and the highest values of macronutrients availability were obtained with 200 kg/fed for the two seasons. Leaf chemical analysis showed direct relationship between S-application rates and the leaf mineral content. Leaf N, K and S content were increased with sulfur applied as compared with the control. It is clear that adding sulfur at any dose resulted in greater bunch weight and number of fingers than the control in both seasons. Fruit total soluble solids; total sugars and vitamin C content were significantly increased with increasing S-application rates compared with the control. Generally, it could be concluded that the treatment of 200 kg sulfur/fed seems to be the promising treatment which produced the highest vegetative growth, yield and improved fruit quality under these experimental conditions due to improving soil chemical properties.

Key word: Sulfur fertilization, rates, Banana, Grand Nain, fruit quality, clay soil

INTRODUCTION

The increment in S deficiency in agriculture world can be attributed primarily to the following causes:

1. More S is removed from the soil as a result of an increase in agricultural production with increasing fertilizer use, intensifying cropping systems, high-yield crop varieties, and improving irrigation.
2. Increased use of high-analysis, S-free fertilizers, such as urea, diammonium phosphate (DAP) and potassium chloride (KCl); decreased use of traditional organic manures and S containing fertilizers, such as SSP and ammonium sulfate, and S-containing pesticides.
3. Greater control of industrial emission of S combined with the decreased use of high S fuels which reduce atmospheric S deposition, one of the important S sources for agricultural soils around industrial areas.

Sulphur (S) is one of the major essential plant nutrients like nitrogen, phosphorus and potassium and it contributes to an increase in crop yields in three different ways:

1. It provides a direct nutritive value.
2. It provides indirect nutritive value as a soil amendment, especially for calcareous and saline alkali soils.
3. It improves the efficiency use of other essential plant nutrients, particularly N and P.

Elemental S is an ideal slow release fertilizer, and elemental S-containing fertilizers are the most concentrated S carriers. However, elemental S has to be oxidized into the sulphate form before plant uptake, which limits its availability right after application to soil. The rate of biological S oxidation depends on its particle size, method and time of application, and soil conditions such as microbial population, soil moisture and temperature, etc. Blair[8], Chen Shulun[9], Donald and Fan[11] and Baijukya *et al*[6].

Banana is considered one of the most important tropical fruits grown in many countries including Egypt. Fertilization of bananas is one of the most important problems that face the growers because of the relatively high amounts of fertilizers needed by banana. However, it is difficult to suggest the program that could be recommended to apply under different conditions. The

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requirements of plant from different elements widely vary according to the species, the amount of vegetative growth produced, the yield and the environmental conditions.

Therefore, the objective of this study was to investigate the effect of several rates of sulfur on growth; leaf mineral content, yield and fruit quality of Grand Nain Banana grown in clayey soil.

MATERIALS AND METHODS

This experiment was carried out during two successive seasons of 2004 -2005 (second ratoon) and 2005-2006 (third ratoon) on Grand Nain cultivar growing in randomized block design with seven treatments in a private orchard at Kafr El-Ziat, Ghrbia Governorate, Egypt. The plants spaced at 3.5x3.5 meters apart and received the normal cultural practices recommended by the National Campaign for improving banana productivity in Egypt. Some physical and chemical properties of the orchard soil; some chemical organic manure used and irrigation water were performed according to the methods described by Black[7] and Cottenie *et al*[10] as shown in Table 1 a, b, c and d)

For this study sixty three plants uniform in growth and in good physiological conditions as possible were selected at random. Each treatment represented by nine plants distributed in three blocks in complete randomized design.

The experimental plants were subjected to the following treatments:

1. Control (without sulfur application).
2. 0.005 % S
3. 0.0075 % S
4. 0.01 % S
5. 0.015 % S.
6. 0.0175 % S.
7. 0.02 % S (w/w) equivalent to zero, 50, 75, 100, 150, 175, and 200 kg S /fed. Sulfur was added to the soil in May.

The organic fertilizer was added in one dose 30 m^3/fed and the inorganic fertilizers were added as follows:

N in seven equal applications (500 g N/plant from April to October) as ammonium sulphut 20.5% N. P in one application 250 g P_2O_5/plant in December as super phosphat15.5% P_2O_5 and K at three equal applications (200 g K_2O April, June and August) as potassium sulphut.

At bunch shooting, length and circumference of pseudostem were measured. Number of green leaves at bunch shooting was recorded. Chlorophyll a and b were determined from fresh leaves using carl-zeiss spectrocolorimeter at wave length of 662 and 644mu according to Wettstein[28]. The N, P, K and S contents

Table 1: Analytical properties of studied soil.

a- Mechanical analysis

Sand		Silt	Clay	Soil texture
Course 2000 - 200 %	Fine 200-20 µ %	20 – 2 µ %	‹2 µ %	
8.25	21.30	19.70	50.75	Clay

b- Chemical analysis

pH 1:2.5	EC dSm^{-1}	$CaCO_3$ %	OM %	Soluble cations and anions meq/100 g soil								Available ppm		
				Na^+	K^+	Mg^{++}	Ca^{++}	$CO^{=}_3$	HCO^-_3	Cl-	$SO^{=}_4$	N	P	K
8.23	0.46	2.33	1.88	1.58	0.53	0.68	1.15	--	0.39	3.52	1.21	185	25	225

c- Chemical of organic manure used

pH 1:2.5	EC dSm^{-1}	O.C %	OM %	Total solids %	C:N	Total macro nutrients %			Available macronutrients %		
						N	P	K	N	P	K
7.56	3.0	21.0	33.2	68	15:9	1.32	0.23	0.16	0.04	0.02	0.42

d- irrigation water used

Water used	pH	EC dSm^{-1}	Soluble cations (meq/l)				Soluble anions(meq/l)				Degree
			Na^+	K^+	Mg^{++}	Ca^{++}	$CO^{=}_3$	HCO^-_3	Cl-	$SO^{=}_4$	
	7.55	1.10	4.21	0.21	2.70	8.30	--	2.50	0.48	12.44	Good

were determined as the procedure of Cottenie *et al*[10] and Page *et al*[21]. Yield was recorded at maturity (around 120 days after flowering). Angulation percentage: The equatorial diameter of two different sides were measured by using the venire caliper and the angulations percent was estimated according to Abou-Aziz *et al*[3]. Total soluble solids were recorded using a hand refractometer and expressed in percentage. Total sugars and acidity was estimated in the pulp of ripe fruit A.O.A.C.[5]. The ascorbic acid content was estimated and expressed as mg of ascorbic acid/100 g pulp[12]. Data were statistically analyzed according to Snedecor and Cochran[24].

RESULTS AND DISCUSSIONS

Data presented in Table (1) showed the initial state of experimental soil indicated that soil texture was clayey with low content of $CaCO_3$ (2.3%). Soil pH is around alkalinity (8.2), the proper limit 5.5-7 for banana López and Espinoza[18] and Jetse *et al*[17]. The total soluble salts were low and available macronutrients were relatively sufficient according Angeles *et al*[4] and Tamimi, *et al*[26]. Accordingly, the investigated soil is fertile but not productive to banana. So the soil needs increasing nutrient availability, (ii) increased porosity/ improved infiltration; (iii) increased surface rooting.

Effect of S – application on the nutritional status of studied soil: Soil pH and availability of macronutrients were significantly affected by S- application rates. Data in Table (2) show that decreases in soil pH were treating the soil using studied rates of S- application to be 1.0, 2.3, 3.9, 5.5, 7.1, and 8.3 % untreated soil, respectively. Similar findings were reported by Tisdale, *et al*[25], Slaton *et al*[23] and Abd El-Fattah and Abd El-Kader[2].

S-application significantly increased available macronutrients at studied rates. Data in Table (2) show that increase in macronutrients than were untreated soil by 24.8, 26.2, 56.3, 75.5, 100.2, and 118.3 %, respectively for nitrogen; 25.3, 39.8, 45.0, 64.0, 104.9 and 155.7 % that of untreated soil, respectively of phosphorus; and 20.2, 22.8, 28.0, 35.7, 59.6 and 73.3 %, respectively for potassium. The obtained results in line with findings were reported by Slaton *et al*[23], Donald and Fan[11] and Abd El-Fattah and Abd El-Kader[2].

Sulfur application on Vegetative Growth: Pseudostem length, pseudostem circumference, number of green leaves and Chlorophyll content are presented in Table (3). Increases in vegetative growth parameters than untreated soil were 2.6, 7.0, 10.5, 14.8, 18.0, and 18.6%, respectively for the pseudostem length 5.5, 9.3, 13, 16, 19.8 and 20.4 %, respectively for the pseudostem circumference 7.6, 16.6, 18.4, 25.6, 25.6, and 26.4 %, respectively for the number of green leaves and 7.9, 12.8, 16.3, 17.9 18.4 and 21.1%, respectively for Chlorophyll content.

The application of sulfur was more effective in enhancing plant growth values of pseudostem length, circumference (cm), number of green leaves at bunch shooting and leaf chlorophyll content in both seasons. These effects might be due to enhancing nitrogen fertilizer in soil by decreasing soil pH and in plant metabolism. These results are in line with those obtained by Turner *et al*[27], Abd El-Kader *et al*[1], Abou-Aziz *et al*[3], Pertiz and Das[22], Slaton *et al*[23] and Hosam El-Dean[16].

Sulfur application on leaf mineral content: Leaf mineral content i.e. N, K and S are presented in Table (4). Increases in leaf mineral content than the untreated soil

Table 2: Effect of sulfur application on the nutritional status of studied soil.

Properties	Soil pH			Available macronutrients ppm								
	Z			N			P			K		
Treatment	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
control	8.20	8.17	8.19	180	186	182.3	27.6	25.2	26.4	216	220	218
50 kg/fed	8.12	8.10	8.11	225	230	227.5	32.6	33.5	33.1	257	266	262
75 kg/fed	8.02	8.00	8.00	225	235	230.0	35.8	38.0	36.9	266	273	270
100 kg/fed	7.98	7.85	7.87	275	295	285.0	37.0	39.5	38.3	275	282	279
150 kg/fed	7.73	7.75	7.74	310	330	320.0	41.6	45.0	43.3	294	298	296
175 kg/fed	7.66	7.55	7.61	360	370	365.0	52.0	56.2	54.1	340	356	348
200 kg/fed	7.53	7.49	7.51	396	400	398.0	66.6	68.3	67.5	375	380	378
L.S.D at 0.05	0.03	0.10	--	10.0	10.2	--	2.32	1.45	--	39.8	34.5	--

Table 3: Effect of Sulfur application on pseudostem length circumference and number of green leaves and chlorophyll content of Grand Nain Banana cultivar.

Properties	Pseudostem length (cm)			Pseudostem circumference (cm)			Number of green leaves			Chlorophyll (mg/g fresh leaves)						
										a		b		Total (a+b)		Mean
Treatment	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean	2004	2005	2004	2005	2004	2005	
Control	262	270	266.0	80	82	81.0	11.0	11.3	11.2	0.708	0.716	0.205	0.212	0.913	0.921	0.917
50 kg/fed	271	275	273.0	85	86	85.5	12.0	12.0	12.0	0.755	0.765	0.230	0.232	0.985	0.997	0.989
75 kg/fed	280	289	284.5	88	89	88.5	13.0	13.0	13.0	0.791	0.809	0.282	0.280	1.073	1.089	1.081
100 kg/fed	288	300	294.0	90	93	91.5	13.0	13.4	13.2	0.806	0.828	0.215	0.219	1.021	1.047	1.034
150 kg/fed	301	310	305.5	92	96	94.0	14.0	14.0	14.0	0.832	0.848	0.221	0.232	1.053	1.080	1.067
175 kg/fed	309	319	314.0	95	99	97.0	14.0	14.0	14.0	0.848	0.860	0.233	0.230	1.081	1.090	1.086
200 kg/fed	311	320	315.5	95	100	97.5	14.2	14.0	14.1	0.868	0.875	0.240	0.239	1.109	1.114	1.111
L.S.D at 0.05	5.6	6.1	--	4.3	3.4	--	0.8	0.7		--	--	--	--	--	--	--

Table 4: Effect of Sulfur application on leaf mineral content of Grand Nain banana cultivar.

Properties	Nitrogen %			Phosphorus %			Potassium %			Sulfur %		
Treatment	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
control	2.0	2.1	2.05	0.22	0.21	0.215	2.9	3.0	2.95	0.42	0.40	0.41
50 kg/fed	2.1	2.3	2.20	0.22	0.23	0.225	3.2	3.2	3.20	0.45	0.44	0.44
75 kg/fed	2.2	2.4	2.40	0.23	0.22	0.225	3.4	3.4	3.40	0.45	0.46	0.46
100 kg/fed	2.4	2.6	2.50	0.23	0.22	0.225	3.6	3.6	3.60	0.47	0.49	0.48
150 kg/fed	2.5	2.6	2.55	0.22	0.22	0.220	3.7	3.7	3.70	0.48	0.50	0.49
175 kg/fed	2.6	2.8	2.70	0.23	0.22	0.225	4.0	4.1	4.05	0.49	0.51	0.50
200 kg/fed	2.7	2.8	2.75	0.23	0.23	0.230	4.2	4.2	4.20	0.52	0.53	0.53
L.S.D at 0.05	0.1	0.1	--	N.S	N.S	--	0.1	0.6	--	0.18	0.18	--

7.3, 17.1, 22.0, 24.4, 31.7 and 34.1 %, respectively for nitrogen, 8.5,15.3, 22.0 , 25.4, 37.3, and 42.4 %, respectively for potassium and 7.9, 12.8, 16.3, 17.9 18.4 and21.1%, respectively for sulfur. Phosphorus percentage did not show significant differences among the treatments. Data indicated that nitrogen, potassium and sulfur content in leaves were significantly affected by different rates of S- application. These data are in agreement with those found by Turner *et al*[27], Hasan *et al*[14] and Hosam El-Deen[16].

Yield and fruit quality:

(a) Yield: Fruit yield parameters i.e. bunch weights, number of hands/bunch and number of fingers/bunch are presented in Table (5). Increases in fruit yield parameters than untreated soil were 3.0, 9.9, 18.9, 28.2, 41.2, and 46.0%, respectively for the bunch weight, 3.4, 7.9, 9.9, 15.8, 22.7 and 29.1 %, respectively for the number of hands/bunch and 4.5, 6.1, 9.9 , 16.0, 22.4 and 24.3 %, respectively for the number of fingers/bunch.

In the other word, the fruit yield was increased by increasing S-application rates during the two seasons. The highest value was recorded by plant received 200 kg sulfur in the two seasons. The yield increase could be attributed largely to higher bunch weight, more number of hands/bunch and more fingers/bunch. These results are in harmony with those obtained by Hedge, D.M.[15], Turner *et al*[27], Abd El-Kader *et al*[1], Abou Aziz *et al*[3] Goenaga and Irizarry[13] and Hosam El-Deen[16].

(b) Fruit quality: Fruit quality parameters i.e. weight, length, diameter and angulations of fingers are presented

Table 5: Effect of sulfur application on bunch weight, Number of hands/bunch and number of fingers/bunch of Grand Nain banana cultivar.

Properties	Bunch weight (kg)			Number of hands / bunch			Number of fingers / bunch		
Treatment	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
Control	23.7	23.9	23.80	10.0	10.3	10.15	156	157	156.50
50 kg/fed	24.7	25.9	25.30	10.4	10.6	10.50	161	166	163.50
75 kg/fed	25.5	26.8	26.15	10.9	11.0	10.95	163	169	166.00
100 kg/fed	27.8	28.8	28.30	11.0	11.3	11.15	172	172	172.00
150 kg/fed	30.3	30.7	30.50	11.7	11.8	11.75	181	182	181.50
175 kg/fed	33.3	33.9	33.60	12.3	12.6	12.45	190	193	191.50
200 kg/fed	35.0	34.5	34.75	13.0	13.2	13.10	192	197	194.50
L.S.D at 0.05	1.1	0.7	--	0.5	0.5	---	4.3	3.2	--

Table 6: Effect of sulfur application on finger weight, length, diameter and finger angulations of Grand Nain banana cultivar.

Properties	Finger Weight (gm)			Finger Length (cm)			Finger Diameter (cm)			Finger angulations		
Treatment	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
Control	151	152	151.50	17.9	17.9	17.9	3.3	3.3	3.30	14.9	15.8	15.35
50 kg/fed	153	156	154.50	18.2	18.3	18.25	3.3	3.4	3.35	12.8	14.0	13.40
75 kg/fed	157	159	158.00	18.5	18.7	18.60	3.4	3.5	3.45	12.2	13.0	12.60
100 kg/fed	162	168	165.00	18.8	19.0	18.90	3.4	3.7	3.55	12.4	12.0	12.20
150 kg/fed	168	169	168.50	19.2	19.4	19.30	3.5	3.7	3.60	11.3	12.5	11.90
175 kg/fed	175	175	175.00	19.6	19.6	19.60	3.5	3.8	3.65	11.9	11.4	11.65
200 kg/fed	178	176	177.00	20.0	20.2	20.10	3.5	4.0	3.75	11.0	11.2	11.10
L.S.D at 0.05	4.6	5.3	---	0.4	0.3	---	N.S	0.4	---	0.2	0.2	---

in Table (6). Weight, length and diameter were significantly increased comparing with the untreated plants. However, finger weight increment than the control was about 2.0, 4.3, 8.9, 11.2, 15.5, and 16.8 % for treatments, respectively. While as, finger length was increased by about 2.0, 4.0, 5.6, 7.8, 9.5 and 12.3 % for the treatments, respectively than the control. As for finger diameter, it was increased than the untreated plants by about 1.5, 4.5, 7.6, 9.1, 110.6 and 13.6 %, respectively. On the other hand, finger angulations were decreased by about 12.7, 17.9, 20.1, 20.5, 22.5 and 27.7 %, respectively than the control. However, there are a correlation between sulphur level treatments and the previous results. This was true in the two studied seasons. In this respect, the highest concentration of sulphur applied gave the highest increase. The obtained results are in line with those obtained by Moreau and Robin[20] Abou-Aziz *et al*[3] and Hosam El-Deen[16].

Some chemical fruit parameters i.e. total soluble solids; acidity, total sugar and ascorbic acid content of fruits are presented in Table (7). The recorded increase in total soluble solids was about 2.0, 3.3, 5.0, 5.8, 7.2, and 8.6 %, respectively than the control. Regarding total sugars, it recorded 1.0, 1.2, 4.1 , 5.0, 6.9 and 8.2 % as increment than the control, respectively. As for ascorbic acid, it was increase than the untreated plants by about 8.7, 10.1, 10.4, 14.4, 15.4 and 16.4 %, respectively during the two seasons of the study.

Acidity percentage did not show significantly differences among the treatments.

In conclusion, data of the two experimental seasons revealed that soil pH and availability of macronutrients were significantly affected by S-application rates. The lowest values of pH and the highest values of macronutrients availability were obtained with 200 kg/fed for the two seasons. Leaf chemical analysis showed direct relationship between S-application rates and the leaf mineral content. Leaf N, K and S content were increased with sulfur applications as compared with the control. It is clear that adding sulfur at any dose resulted in great bunch weight and number of fingers than the control in both seasons. Also, the different S-application rates significantly increase total soluble solids; total sugars and vitamin C content in the fruits and the increment was related to the increasing S-application rates. Generally, it could be concluded that the treatment of 200 kg sulfur/fed

Table 7: Effect of sulfur application on total soluble solids, Acidity and total sugar of grand nain banana cultivar.

Properties	TSS %			Acidity %			Total Sugar %			Ascorbic acid (mg/ 100g)		
Treatment	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
Control	18.0	18.1	18.05	0.36	0.32	0.34	15.8	16.0	15.90	15.0	14.8	14.90
50 kg/fed	18.4	18.4	18.40	0.37	0.38	0.38	16.0	16.0	16.00	16.5	15.9	16.20
75 kg/fed	18.6	18.7	18.65	0.37	0.37	0.37	16.2	16.0	16.10	16.6	16.2	16.40
100 kg/fed	18.7	19.2	18.95	0.35	0.36	0.36	16.3	16.8	16.55	16.5	16.4	16.65
150 kg/fed	18.8	19.4	19.10	0.35	0.36	0.36	16.5	16.9	16.70	17.2	16.9	17.05
175 kg/fed	19.0	19.7	19.35	0.34	0.36	0.35	17.0	17.0	17.00	17.4	17.0	17.20
200 kg/fed	19.0	20.2	19.60	0.34	0.35	0.35	16.9	17.5	17.20	17.5	17.2	17.35
L.S.D at 0.05	0.3	0.4	---	N.S	N.S	--	0.6	1.1	--	0.32	0.4	--

seems not only to be the promising treatment to produce the highest vegetative growth and yield but also to improve the fruit quality under these experimental conditions due to improving soil chemical properties.

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