Combined Effects of Farmyard Manure (FYM) and Elemental Sulfur (S)on Soil Chemical Properties, Growth, Yield, Leaf Water and Nutrient Contents of Corn Plant Grown on Sandy Clay Loam Soil

A.H.A. Hussein[1]

ABSTRACT

A field experiment was conducted in the Agricultural and Veterinary Training and Research Station of King Faisal University (KFU), Al-Hassa region during 2006 growing season of corn (*Zea mays*, L.). The objective of this work was to investigate the combined ffect of farmyard manure (FYM) and elemental sulfur (S) on soil chemical characteristics, growth, yield, and leaf water and nutrients contents of corn. The experimental soil has a sandy clay loam texture. All plots (17.5 m²) cultivated with corn received 78.5 kg N/ha in the form of ammonium nitrate (33.5% N), 150.0 kg K_2O/ha in the form of potassium sulfate (48% K_2O) and 88.0 kg P/ha in the form of calcium-superphosphate (15.5% P_2O_5). Farmyard manure was applied to the soil at rates of 0, 14.0, 28.0 and 56.0 ton/ha and elemental sulfur (S) at rates of 0, 360, 720 and 1440 kg/ha. The farmyard manure and elemental sulfur were mixed with the 30 cm top layer of the soil before planting. The obtained results revealed that applications of both FYM and elemental sulfur significantly altered the chemical properties of soil. The electrical conductivity (EC) was significantly increased, while the soil pH and exchangeable sodium percentage (ESP) were decreased as a result of FYM and S applications. Also, the results showed a significant effect of FYM and S in improving the available soil nutrients (N, P, K, Fe, Mn, Cu and Zn) in which significantly increased with FYM and S applications at all rates. The results also showed that plant fresh weight significantly increased as a result of both FYM and S applications. Also, FYM and S applications, especially at highest levels had significant effects on increasing the grain yield and its components (weight of 100 kernels and grain protein content). Grain yield increased by about 5.34 and 6.20% over the control treatment, respectively. Leaf water contents were improved as a result of FYM and S applications. In the same time leaf total chlorophyll content was significantly increased. Applications of FYM and S significantly improved the leaf contents of macro- and micro-elements.

INTRODUCTION

Sulfur (S), like nitrogen, phosphorus, potassium and calcium is needed in relatively large amounts for optimal plant growth. It has important metabolic functions for plant, it is a component of amino acids and proteins and the SH (sulphydryl or thiol) group plays an important role in many physiological reactions; also it is a constituent of CoA and of the vitamins biotin and thiamine (Mengel and kirkby, 1987).

Acid forming sulfur compounds such as elemental sulfur and gypsum ($CaSO_4$) has been used for many years in the reclamation and improvement of alkaline soils. In this process, sulfur oxidized by soil microorganisms to sulfuric acid, which in turn lowers soil pH, improves soil structure and increases the availability of certain plant nutrients notably P, K and several of micro-nutrients (Hassan and Olson, 1966). Stromberg and Tisdale (1979) stated that the undesirable properties of sodic soils can be corrected by the use of several acid-forming sulfur compounds, which increase water penetration, lower soil pH and consequently increase nutrients availability (Abdel-Nasser and Harhash, 2000). As S is oxidized to SO_4^{-2} and sulfuric acid, $CaCO_3$ undergoes dissolution and Ca^{+2} ions are released to the soil solution which can replace exchangeable Na, thereby lowering the exchangeable sodium percentage (ESP), (Abdel-Nasser and El-Shazly, 2000). Also, Electrical conductivity (EC) was affected by elemental S applications (Abdel-Nasser and El-Shazly, 2000).

Several investigators reported the importance of S in increasing growth and yield of fruit trees; Abo-Rady *et al.* (1988) on date palm, Kassem *et al.*(1995) on guava, Hening *et al.* (1991) on pecan, El-Shazly and Abdel-Nasser (1999) on Balady Mandarin and Abdel-Nasser and El-Shazly (2000) on Balady orange.

One of the practical solutions of N pollution is using the organic manures in plant fertilization, so called organic farming or Eco-agriculture (U.S.D.A., 1980 and Blake, 1990). The organic manures were used after increasing the objection against the chemical agriculture as a main source of soil and water pollution as well as food products.

Abdel-Naim *et al.* (1986) with maize, Laila and Abdel-Aziz (1992) with wheat, Abdel-Aziz *et al.* (1996) with sunflower, Abdel-Nasser and Harhash (2000) with grapevine and Hussein and Abdel-Nasser (2001) with

[1]Water Studies Center, King Faisal University
P.O.Box 420 - Al-Hassa 31982, Saudi Arabia
Email: ahahmed_61@yahoo.com
Received September 9, 2008, Accepted September28, 2008

sunflower found a successive increase in the yields with increasing the rates of farmyard manure.

Also, changes in soil chemical properties have been found as a result of using of organic manure, but in different magnitude due to differences in climate, crop rotation, soil type or length of time that soil has been under organic management (Clark *et al.*, 1998). In the same time, organic manures considered as a source of essential nutrients for plant growth (Chen and Avnimelech, 1986). Therefore, the present study was carried out to clarify the combined effect of farmyard manure (FYM) and elemental sulfur (S) rates on soil chemical properties, growth, yield, and leaf water and nutrients contents in leaves of corn.

MATERIALS AND METHODS

A field experiment was conducted, in the Agricultural and Veterinary Training and Research Station of King Faisal University (KFU), Al Hassa region, during 2006 growing season of corn (*Zea mays*, L.).Some physical and chemical characteristics were determined at the beginning of the growing season before application of farmyard manure (FYM) and elemental sulfur. The analysis of soil samples collected from the plough layer (0-30 cm) was done according to the methods outlined in Carter (1993) and the results obtained are shown in Table(1). Soil application of farmyard manure was at rates of 0, 14.0, 28.0 and 56.0 ton/ha and elemental sulfur (S) at rates of 0, 360, 720 and 1440 kg/ha. The farmyard manure and elemental sulfur were mixed with the 30 cm top layer of the soil before planting. Some characteristics of FYM used in the study are shown in Table(2).

Corn (*Zea mays*, L.) seeds variety Hageen were used in this study. Planting took place on September 2nd, 2006 and harvesting was done at June 20th, 2007. The experimental plot consisted of 5 rows; 5 m long and 0.7 m wide making an area of 17.5 m^2. Seeds were planted at 0.3 m apart within each row. The experiment was conducted in a Split Plot Design with 3 replicates. The main plots contain Farmyard manure (FYM) treatments, while the subplot was devoted to the elemental sulphur treatments. All plots had received the 88.0 kg P_2O_5/ha before planting in the form of calcium-superphosphate (15.5% P_2O_5). Nitrogen fertilization as ammonium nitrate (33.5% N) at a rate of 78.5 kg N/ha was divided into two equal doses, the first dose was applied with the first irrigation and the second dose was applied one month later. Potassium fertilization was applied in the form of potassium sulphate (48%K_2O) at a rate of 150.0 kg/ha at two equal doses, the first dose was applied with the first irrigation and the second dose was one month later.

Table1. The main physical and chemical characteristics of the experimental soil

Soil character	Values
Particle size distribution,%	
sand	69.7
silt	10.1
clay	20.2
Texture	sandy clay loam
EC, dS/m (soil saturated paste)	2.38
pH (soil saturated paste)	8.31
Organic matter,%	0.83
CaCO3,%	22.85
Exchangeable Sodium, %	24.40
Soluble Nitrate, mg/L	17.3
Soluble Cations, meq/L	
Na^+	1.43
K^+	1.83
Ca^{++}	13.01
Mg^{++}	7.76
Soluble Anions, meq/L	
$CO_3^=+HCO_3^-$	1.53
Cl^-	10
$SO_4^=$	11.99
Available nutrients, mg/kg soil	
N	109.53
P	12.1
K	312
Fe	3.45
Mn	2.33
Cu	1.10
Zn	1.55
B	2.28

At harvest, ten plants were randomly collected from the three central rows to determine leaf water content and elemental composition. Each sample was divided into two portions; the first portion had washed with tap water, distilled water, air-dried, oven dried at 65C° for 72 hrs, and then ground in a stainless steel mill and stored for elemental analysis. The second portion of leaf sample (fresh sample) was used to determine leaf water content and total chlorophyll. Total chlorophyll was determined according to the method of Moran and Parath (1980). Total water content (TWC), free water content (FWC), bound water content (BWC), and relative water content (RWC) were determined according to (Weathrely, 1950 and Abdel- Rasoul *et al*, 1987).

The ground plant material was digested with concentrated sulphuric acid +30% hydrogen peroxide according to the method of Wolf (1982). Total nitrogen was determined by using the micro-kjeldahl method (Jackson, 1973). In the digest, total phosphorus was determined colorimetrically according to the method of

Murphy and Riley (1962). Total potassium was determined by flame photometery according to Jackson (1973). Total calcium and magnesium were determined by atomic absorption spectrophotometer according to Carter (1993). Fe, Mn, Cu and Zn were determined by inductively coupled plasma optical emission spectrometer (Carter, 1993). Grain protein percentage was calculated using suitable constant (N% x 6.25).

Table2. The main physical and chemical characteristics of the farmyard manure (FYM)

Parameters	Values
Bulk density, Mg/m^3	0.86
Moisture content, %	10.2
Organic carbon, %	20.22
Total nitrogen, %	1.24
C/N ratio	16.31
Organic matter, %	34.86
EC (1:10 water extract), dS/m	5.24
pH (1:10 water suspension)	6.78
Total Macro-nutrients, %	
P	0.55
K	0.94
Ca	1.31
Mg	0.54
Total Micro-nutrients, mg/kg soil	
Fe	1653
Mn	338
Cu	68
Zn	59

At harvest, soil samples (0-30cm) were collected, air-dried, ground, mixed thoroughly and sieved through a 2mm mesh screen for chemical analysis. Electrical conductivity (EC) was measured in soil saturated paste using a conductivity meter (Rhoades, 1982). Soil pH was measured in soil saturated paste using pH meter (Rhoades, 1982). Exchangeable sodium percentage (ESP) was calculated according to the method described in Richards (1972). Soil available nutrients; N, P and K were extracted using a 0.5 M $NaHCO_3$ solution (Schoenau and Karamanos, 1993) and determined spectophotometrically (Carter, 1993). The Fe, Mn, Cu and Zn were extracted using DTPA-extraction method (Lindsay and Norvell, 1978), and measured by inductively coupled plasma optical emission spectrometer (Carter, 1993).

The obtained data were tabulated and subjected to statistical analysis according to Steel and Torrie (1982). Correlation coefficient was done using the method described in Draper and Smith (1981).

RESULTS AND DISCUSSIONS

1. Soil pH

Table (3) showed that the soil pH significantly decreased as a result of increasing FYM or S application. The reduction in pH was more pronounced at high rates of application of FYM or S. With regard to FYM, the decrease in soil pH is due to organic acids produced during FYM decomposition. Similar results were obtained by Tester (1990), Abdel-Nasser and Harhash (2000) and Abdel-Nasser and Hussein (2001). Also, with regard to S, the reduction in soil pH may be attributed to acidification resulted from S oxidation (El-Shazly and Abdel-Nasser, 1999, Abdel-Nasser and El-Shazly, 2000, Abdel-Nasser and Hussein, 2002 and Yanshan *et al*., 2004). Similar trend was obtained with S sources but the elemental sulfur was relatively more effective than gypsum (Hassan and Olson, 1966).

2. Soluble salts

Soluble salts in soil solution as expressed by electrical conductivity (EC) were significantly increased as FYM or S rate increased. The higher values of EC were related with higher rates of FYM or S materials. Such increase may be attributed to the high salt content of FYM as shown in Table(2). The present results are in agreement with those reported by Abdel-Nasser and Hussein, (2001). Relative higher values of EC for soil receiving sulfur application could be attributed to acidity produced through oxidation of S by microorganisms. This acidity was an efficient solvent (Abdel-Nasser and Hussein, 2002).

3. Exchangeable Sodium Percentage (ESP)

With regard to Exchangeable Sodium Percentage (ESP), it is noticed that both FYM and S materials significantly decreased the ESP, but S was more effective than FYM. Such reduction in ESP values may be attributed to the acidity produced by FYM decomposition. This acidity is effective in solubilizing the native soil calcium carbonate that produced Ca^{2+} ions which replace adsorbed Na on soil complex, thus reduce the ESP values (Richards, 1972). Similar results were obtained by Abdel -Nasser and Harhash (2000) and Abdel-Nasser and Hussein, (2001). This point is very important in reclamation of sodic soils (ESP> 15%). Thus, organic manures such as FYM can be used in reducing the exchangeable sodium percentage (ESP) in sodic soil, that contain amount of calcium carbonate sufficient to produce Ca^{2+} ions replacing the Na adsorbed on soil complex.

Also, such result can be explained on the basis that S when applied to soil exposed to oxidation through the activity of microorganisms. It produces free Ca^{2+} ions which replace adsorbed Na on soil complex, thus reduced the ESP by about 24.01 and 56.82% relative to FYM and S, respectively (Richards, 1972). The present results are in agreement with those reported by Abdel-Nasser and Hussein, (2002). The results also showed that increasing S rate significantly decreased the ESP to the critical limit of sodicity (15%). The higher reduction in ESP was correlated with high S rate of 1440 kg/ha.

4. Available nutrients

Table(3) revealed that both FYM and S have a significant effect on soil available nutrients (N, P, K, Fe, Mn, Cu and Zn) but S is more effective than FYM. Table(3) revealed that application of FYM significantly increased the level of available nutrients in soil. The more availability of soil nutrients due to FYM application may be attributed to the acidity produced by organic manure decomposition and its effects on solubility of some soil minerals or due to releasing the nutrients through organic manure decay by micro-organisms activity. Also, increasing of the soil available nutrients may be attributed to the high content of such elements in organic manures (Table, 2). However, the magnitude of increase in soil available nutrients differed according to the source of organic manure and its elemental content. The present results are in agreement with those reported by Abdel-Nasser and Hussein (2001).

Also, increasing S rate significantly increased the available nutrients contents. The high values were attained at higher S rate. The obtained results can be explained on the basis that the oxidation of sulfur applied to soil by microorganisms to $SO_4^=$ ions. The $SO_4^=$ ions can dissolve some minerals and release these nutrients or due to the reduction in the soil pH, which affect the solubility and availability of soil nutrients (Mengel and Kirkby, 1987).

Acidification due to sulfur application significantly increased the extractable soil N. The increase in extractable soil N was 21.86% by increasing S rate up to 1440 kg/ha. This result may by explained on the fact that $SO_4^=$ formed due to S oxidation can markedly reduce the NO_3^- losses from soil and simulated the

Table 3. Chemical properties and nutritional status of soil as affected by farmyard manure and sulfur applications

FYM Ton/ha	S rate kg/ha	pH	EC dS/m	ESP %	Available Macronutrients, mg/kg			Available Micronutrients, mg/kg			
					N	P	K	Fe	Mn	Cu	Zn
0	0	8.39	2.35	24.4	92.9	12.1	307.2	3.0	2.7	0.7	1.5
	360	8.28	2.40	22.0	98.1	13.5	321.8	3.3	3.0	0.7	1.6
	720	8.13	2.43	18.7	103.8	14.6	341.3	3.7	3.3	1.0	1.8
	1440	8.00	2.46	13.0	111.8	16.9	361.2	4.0	3.8	1.4	2.0
14	0	8.30	2.38	24.3	96.9	12.7	317.0	3.3	2.9	0.7	1.6
	360	8.19	2.42	20.0	102.2	13.8	330.4	3.6	3.3	1.0	1.9
	720	8.09	2.44	16.4	108.3	15.6	354.6	4.1	3.7	1.3	2.0
	1440	7.92	2.48	11.2	117.6	18.0	376.4	4.4	4.3	1.5	2.4
28	0	8.23	2.42	24.1	101.1	13.5	328.4	3.5	3.1	0.9	1.7
	360	8.11	2.46	18.2	108.8	14.9	342.6	3.9	3.6	1.1	2.0
	720	8.03	2.48	14.1	118.7	16.6	370.5	4.3	4.1	1.5	2.3
	1440	7.88	2.49	9.5	122.2	19.6	391.1	4.6	4.8	1.7	2.6
56	0	8.15	2.44	23.1	104.2	14.5	335.4	3.6	3.4	1.0	1.9
	360	8.01	2.47	16.1	114.9	15.7	352.4	4.2	3.8	1.4	2.1
	720	7.94	2.48	12.2	121.0	17.7	379.6	4.5	4.3	1.7	2.4
	1440	7.66	2.53	7.8	130.0	20.8	412.8	5.2	5.3	1.9	2.8
Main effect of farmyard manure, ton/ha											
0		8.20	2.41	19.5	101.6	14.3	332.9	3.5	3.2	0.9	1.7
14		8.13	2.43	18.0	106.3	15.0	344.6	3.8	3.5	1.1	2.0
28		8.06	2.46	16.5	112.7	16.2	358.1	4.1	3.9	1.3	2.1
56		7.94	2.48	14.8	117.5	17.2	370.1	4.4	4.2	1.5	2.3
LSD (0.05)		0.03**	0.03**	0.24**	2.05**	0.29**	1.39**	0.30**	0.09**	0.15**	0.20**
Main effect of sulfur, kg/ha											
0		8.27	2.40	24.0	98.8	13.2	322.0	3.3	3.0	0.8	1.7
360		8.15	2.44	19.1	106.0	14.5	336.8	3.8	3.4	1.0	1.9
720		8.05	2.46	15.3	112.9	16.1	361.5	4.2	3.8	1.4	2.1
1440		7.87	2.49	10.4	120.4	18.8	385.4	4.5	4.5	1.6	2.4
LSD (0.05)		0.02**	0.02**	0.16**	1.76**	0.33**	1.86**	0.23**	0.28**	0.15**	0.23**
Interaction FYM x S											
LSD (0.05)		0.04**	NS	0.32**	NS	0.67*	3.72**	NS	NS	NS	NS

reduction of NO_3^- to NH_4^+ (Kowalenko,1979), decreasing N losses in soil led to increase N availability and plant uptake, Table(3).

Increasing S rate substantially increased extractable soil P. Such result may be due to that, increasing S rates resulted in an increase of soluble $SO_4^=$, which lowered the soil pH, and consequently increased the extractable P. In addition, in soil containing $CaCO_3$, the H^+ ions increased as a result of S application, the unavailable P react with H^+ and become more extractable and available to plant uptake (Yousry *et al.*, 1984). Moreover, the lower extractable P in S-untreated soil could be attributed to that, when P fertilizers are applied to soil containing high $CaCO_3$ content, PO_4^{3-} ions can be adsorb to $CaCO_3$ granules and precipitate to a form of unavailable P (Mattingly, 1975).

The amount of extractable K was increased significantly as the rate of S application increased. The increase in extractable K in soil was about 19.69% over the control treatment. Such results may be attributed to the fact that S application can broke down the K-bearing minerals in soil, consequently release more available K (Ali, 1974).

Also, extractable soil micronutrients (Fe, Mn, Cu, and Zn) were increased due to S applications (Table, 3). Such results could be attributed to that, when soil treated with S, the soil pH is lowered which permits the increase of micronutrients availability, thus, raising the plant tissue contents of these elements. These results are in accordance with Wainwright (1984), Abdel-Nasser and Hussein (2002) and Yanshan *et al*., (2004).

The interaction between FYM and S showed a significant effect only on soil pH, ESP, available P and K.

5. Leaf water contents

The data of leaf water contents i.e. free water content (FWC), bound water content (BWC), total water content (TWC) and relative water content (RWC) of corn as affected by the application of both FYM and S are presented in Table (4).

Table 4. Leaf water contents and total chlorophyll of corn as influenced by farmyard manure andelemental sulfur applications

FYM Ton/ha	S rate kg/ha	Free water Content (%)	Bound water Content (%)	Total water Content (%)	Relative water Content (%)	Total chlorophyll Mg/100g FW
0	0	18.88	38.7	57.6	81.23	272
	360	19.28	38.9	58.2	81.50	285
	720	19.43	39.3	58.7	81.90	293
	1440	19.63	39.5	59.1	82.20	305
14	0	18.98	38.9	57.9	81.50	284
	360	19.31	39.2	58.5	81.90	293
	720	19.73	39.5	59.2	82.30	307
	1440	20.03	39.5	59.5	82.50	312
28	0	19.18	39.3	58.5	81.90	291
	360	19.61	39.5	59.1	82.30	302
	720	20.13	39.5	59.6	82.70	319
	1440	20.63	39.7	60.3	82.90	331
56	0	19.48	39.5	59.0	82.40	301
	360	20.01	39.5	59.5	82.70	315
	720	20.63	39.6	60.2	83.00	329
	1440	21.23	39.7	60.9	83.20	341
Main effect of farmyard manure, ton/ha						
0		19.31	39.10	58.41	81.71	288.75
14		19.51	39.28	58.79	82.05	299.00
28		19.89	39.50	59.39	82.45	310.75
56		20.34	39.58	59.91	82.83	321.50
LSD (0.05)		NS	NS	NS	0.17**	7.88**
Main effect of sulfur, kg/ha						
0		19.13	39.10	58.23	81.76	287.00
360		19.55	39.28	58.83	82.10	298.75
720		19.98	39.48	59.46	82.48	312.00
1440		20.38	39.60	59.98	82.70	322.25
LSD (0.05)		0.86*	NS	0.90**	0.22**	3.38**
Interaction FYM x S						
LSD (0.05)		NS	NS	NS	NS	NS

The data showed that application of FYM insignificantly increased FWC, BWC and TWC. The RWC significantly increased as a result of application of FYM. Also, the results showed that application of S significantly increased leaf water contents (FWC, TWC and RWC) especially at the highest application rates. BWC insignificantly increased as a result of application of S. These results could be due to the effect of both FYM and S applications on improving soil structure and water penetration (Stromberg and Tisdale, 1979) or may be due to the increase in root growth, which means an increase of water absorption and translocation to leaves. Also, increasing the leaf water contents of corn plants due to FYM application may be attributed to the beneficial effects of FYM in improving the water-holding capacity of soil (Buschiazzo *et al.,* 1991 and Abdel-Nasser and Harhash, 2000). Also, increased the availability of soil water for plant absorption, such conditions improve the plant growth and increased the absorption of soil water and nutrients. Increasing water absorption by plants led to improve the plant water status (Harhash and Abdel-Nasser, 2000 and Hussein and Abdel-Nasser (2001).

The interaction between FYM and S showed insignificant effect on all leaf water contents (FWC, BWC, TWC and RWC). This indicates that both FYM and S could be able to improve the water status of corn plants.

6. Leaf chlorophyll content

Table(4) clearly indicates that application of both FYM and S significantly increased the leaf total chlorophyll content which increased by 3.55, 7.62 and 11.34% over the control treatment for FYM at rates of 14.28, 58.56 and 57.12 ton/fed., respectively. While, the increases due to S applications were 4.10, 8.71 and 12.28%, over the control treatment at rates of 360, 720 and 1440 kg S/ha, respectively. These increases may be explained on the basis that both FYM and S applications enhanced the plant uptake of N, Mg, and Fe; such elements have a close association in chlorophyll biosynthesis (Hall and Rao, 1996). Hening *et al.* (1991) reported that chlorophyll content increased in pecan seedlings as a result of S soil application. Also, these results are in agreement with those reported by Hussein and Abdel-Nasser (2001 and 2002) who found that chlorophyll content increased in leaves of sunflower plant as a result of FYM and S soil application. The interaction between FYM and S showed insignificant effect on leaf total chlorophyll content in leaves of corn.

7. Leaf elemental content

Table (5) showed that application of both FYM and S significantly increased the corn leaf elemental content, except for P where it was decreased by increasing S application rate. The data showed that both macronutrients (N, K, Ca and Mg) and micronutrients (Fe, Mn, Cu and Zn) contents increased gradually with increasing levels of both FYM and S application. Such increases in leaf nutrients contents may be attributed to the increases of nutrients availability in the root zone (Abd El-Naim *et al*., 1986). These results agree with those obtained by Awad *et al.* (1996), Hussein and Abdel-Nasser (2001 and 2002) and Rehana *et al*., (2008). The interaction between FYM and S showed a significant effect only on Mn and Zn contents of corn leaves.

8. Growth, yield and yield parameters

Table(6) showed that addition of FYM and S significantly increased the plant fresh weight, grain yield and yield components. Plant fresh weight increased gradually as the application rate of FYM increased. It is increased by 6.10, 9.57 and 12.42%, for rates of 14, 28 and 56 ton/ha, respectively, relative to the control treatment. The highest values of grain yield, weight of 100 kernel and grain protein content were attained at the highest level of FYM (56 ton/ha). The increases in grain yield were 2.27, 3.73 and 5.34%, respectively relative to the control treatment. The corresponding values for grain protein content were 1.99, 5.52 and 6.70%, respectively. Also, the weight of 100 kernel, behaved the same trend because of the total seed yield is correlated with weight of seed. Concerning the effect of S, the highest values of fresh weight, weight of 100 kernel and grain protein content were attained at the highest level of S (1428 kg/ha). Plant fresh weight was increased by 2.19, 4.85 and 6.68%, for 360, 720 and 1440 kg S/ha, respectively, over the control treatment. The S application increased grain yield of corn by about 1.71, 5.09 and 6.20% for rates of 360, 720 and 1440 kg S/ha, respectively over the control treatment. The corresponding values for grain protein content were 12.47, 24.60 and 34.25%, respectively.

Farmyard manure as organic manures are considered as a source of essential nutrients for plant growth (Chen and Avnimelech, 1986). Many investigators such as Laila and Abdel-Aziz (1992) with wheat, Abdel-Aziz *et al*. (1996) with sunflower and Rehana *et al.*, (2008) with maize found successive increases in the yields with increasing the rates of farmyard manure. Also, Hussein and Abdel- Nasser (2001) found that application of farmyard manure significantly increased the growth (fresh weight, disk weight and disk diameter) and the yield (seed yield, weight of 100 seeds, oil seed percent and oil yield) of sunflower. Soil properties such as plow layer thickness, organic matter and clay content affect crop productivity (Rogaski and Smukalski, 1988 and Diaz-zorita *et al.* 1999). Organic matter content has been found to be a reliable index of crop productivity (Pierce *et al.*, 1983), because it positively affects soil water-holding capacity (Buschiazzo *et al.*, 1991).

Such increases in plant growth parameter (fresh weight of corn) due to the S applications could be attributed to its positive effect on solubilizing some elements making them more readily available for plant, and consequently growing shoot and the associated soil micro-organism activity that responsible for organic matter decomposition and release its content of available nutrients (Alexander, 1977). In addition, lowering the soil pH may be enhancing the solubility of soil nutrients (Alawi *et al.*, 1980 and Yousrey *et al.*, 1984). Also, the increase in vegetative growth as a result of S application may be due to the improvement of nutrient availability and uptake, consequently increasing plant growth. Similar results were found by Peterson *et al.* (1987), Hening *et al.* (1991), Kassem *et al.* (1995) and Abdel-Nasser and El-Shazly (2000). They noticed that S application increased vegetative growth of Blueberry, pecan, guava and Balady orange trees, respectively. In addition, Kowalenko (1979) stated that S application enhanced N availability and uptake by reducing nitrate losses and stimulated the reduction of NO_3^- to NH_4^+ thereby, increasing N uptake and consequently increasing plant growth. On the other hand, Spires and Braswell (1992) reported that application of S at rates up to 1120 kg/ha was not detrimental to tree vigor and had no effect on tree growth.

The increase of corn yield as a result of S application may be attributed to the effect of S in decreasing soil pH (Kassem *et al.*, 1995) and consequently increasing the nutrient uptake and translocation (Stromberg and Tisdale, 1979, Shadfan and Hussen, 1985 and Hening *et al.*, 1991), thereby improving tree condition and increasing the total yield.

The interaction between FYM and S showed insignificant effects on plant fresh weight, grain yield and yield components of corn plant.

Table 5. Corn leaf elemental contents as affected by farmyard manure and elemental sulfur applications

FYM	S rate	Macronutrients content, %					Micronutrients content, mg/kg			
Ton/ha	Kg/ha	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
	0	2.12	0.33	1.25	2.33	0.91	265.0	57.0	11.0	24.0
	360	2.21	0.25	1.40	2.39	1.01	276.0	70.0	16.0	29.0
0	720	2.26	0.23	1.46	2.48	1.04	291.0	91.0	19.0	36.0
	1440	2.52	0.18	1.51	2.76	1.09	303.0	98.0	26.0	43.0
	0	2.31	0.35	1.30	2.36	1.00	286.0	72.0	15.0	29.0
	360	2.35	0.29	1.45	2.43	1.07	293.0	87.0	18.0	37.0
14	720	2.4	0.27	1.56	2.59	1.11	315.0	101.0	27.0	46.0
	1440	2.62	0.22	1.66	2.84	1.17	327.0	105.0	34.0	50.0
	0	2.37	0.41	1.35	2.43	1.12	295.0	83.0	20.0	33.0
	360	2.49	0.35	1.51	2.51	1.19	299.0	96.0	31.0	38.0
28	720	2.57	0.31	1.64	2.66	1.23	310.0	108.0	37.0	44.0
	1440	2.73	0.25	1.77	2.81	1.29	324.0	115.0	42.0	52.0
	0	2.53	0.45	1.49	2.46	1.18	301.0	96.0	26.0	34.0
	360	2.6	0.41	1.68	2.57	1.24	312.0	110.0	31.0	37.0
56	720	2.75	0.36	1.78	2.74	1.28	331.0	129.0	39.0	54.0
	1440	2.92	0.32	1.92	2.89	1.39	348.0	153.0	48.0	62.0
Main effect of farmyard manure, ton/ha										
0		2.28	0.25	1.41	2.49	1.01	283.75	79.00	18.00	33.00
14		2.42	0.28	1.49	2.56	1.09	305.25	91.25	23.50	40.50
28		2.54	0.33	1.57	2.60	1.21	307.00	100.50	32.50	41.75
56		2.70	0.39	1.72	2.67	1.27	323.00	122.00	36.00	46.75
LSD (0.05)		0.19**	0.05**	0.07**	0.03**	0.07**	9.05**	3.64**	3.79**	4.90**
Main effect of sulfur, kg/ha										
0		2.33	0.39	1.35	2.40	1.05	286.75	77.00	18.00	30.00
360		2.41	0.33	1.51	2.48	1.13	295.00	90.75	24.00	35.25
720		2.50	0.29	1.61	2.62	1.17	311.75	107.25	30.50	45.00
1440		2.70	0.24	1.72	2.83	1.24	325.50	117.75	37.50	51.75
LSD (0.05)		0.10**	0.07**	0.07**	0.08**	0.05**	7.88**	4.82**	2.60**	1.67**
Interaction FYM x S										
LSD (0.05)		NS	NS	NS	NS	NS	NS	9.64*	NS	3.35**

Table 6. Plant growth, yield and yield components of corn as influenced by farmyard manure and elemental sulfur applications

FYM ton/ha	S rate Kg/ha	Fresh weight g/plant	Grain yield kg/ha	Weight of 100 kernel, g	Grain protein content, %
	0	604.1	**3596.63**	20.48	10.99
	360	610.1	3648.99	22.17	12.29
0	720	616.3	3755.64	22.47	13.79
	1440	620.5	3786.58	23.65	14.59
	0	628.6	3670.53	21.37	11.20
	360	640.4	3732.13	22.37	12.56
14	720	656.3	3848.46	23.77	14.16
	1440	675.3	3872.26	24.04	14.77
	0	639.6	3703.28	21.62	11.46
	360	660.4	3765.99	22.49	13.06
28	720	688.1	3917.48	23.99	14.27
	1440	697.4	3953.18	24.44	15.72
	0	663.8	3758.02	21.89	11.75
	360	680.7	3833.75	22.67	13.15
56	720	698.5	3956.92	24.23	14.35
	1440	712.4	4029.34	24.87	15.87
Main effect of farmyard manure, ton/ha					
	0	612.8	3696.96	22.19	12.92
	14	650.2	3780.84	22.89	13.17
	28	671.4	3834.98	23.14	13.63
	56	688.9	3894.51	23.42	13.78
	LSD (0.05)	8.17**	50.59*	NS	0.93**
Main effect of sulfur, kg/ha					
	0	634.0	3682.12	21.34	11.35
	360	647.9	3745.22	22.43	12.77
	720	664.8	3869.62	23.62	14.14
	1440	676.4	3910.34	24.25	15.24
	LSD (0.05)	5.41**	33.13*	1.43**	0.66*
Interaction FYM x S					
	LSD (0.05)	NS	NS	NS	NS

CONCOLUSION

The important outcome of this study is to clarify the role of combined application of FYM and elemental S in improving the chemical properties of sodic soil. It can be recommended that in case of sodic soils, the addition of S with FYM is advisable to improve soil properties that reflected in improving the growth, yield and utilization of soil nutrients by plant.

REFERENCES

Abdel-Aziz, S.M., M.E. El-Fayoumy, M.H. Gomaa and H.M. Ramadan (1996). Soil and crop responses to applied soil conditioners. Alex. Sci. Exch., 17 (3): 261-270.

Abd-El-Naim., E.M., M.E. El-Shal., R. Abbas, R.M. El-Awady and A.E. Ibrahim (1986). Effect of Agrosoke (soil conditioner) on sandy soil characteristics and sunflower plant growth. Agric. Res. Rev. 64 (4): 681-689.

Abdel-Nasser, G and A.H.A. Hussein (2001). Effect of different manure sources on some soil properties and sunflower plant growth. 1. Soil physical and chemical properties. Alex. J. Agric. Res. 46(1): 227-251.

Abdel-Nasser, G and A.H.A. Hussein (2002). Influence of superphosphate and elemental sulfur on soil physical properties, growth, yield and nutrients status of sunflower.1. Soil physical and chemical characteristics and fertility status. J. Adv. Agric. Res. 7(2):469-490.

Abdel-Nasser, G. and M.M. Harhash (2000). Effect of organic manures in combination with elemental sulphur on soil physical and chemical characteristics, yield, fruit quality, leaf water contents and nutritional status of flame seedless grapevine I. Soil Physical and Chemical Characteristics . J. Agric. Sci. Mansoura Univ., 25 (6): 3541-3558.

Abdel-Nasser, G. and S.M. El-Shazly. (2000). Effect of sulphur application on soil physical and chemical characteristics, nutrient status, yield and fruit quality of

Balady orange trees J. Agric. Res., Tanta Univ., 26(1): 72-92.

Abdel-Rasol, M., M.T. El-Saidi, A.l. Gabr, and H.A. El-zeiny. (1987). Effect of CCC and B-9 at different water regimes on water relations in Maize leaves. Annals Agric. Sci., Fac. Agric., Ain Shams Univ., Cairo, Egypt, 32 (2): 941-955.

Abo-Rady, M.D.K., O. Duheash, M. Khalil and M.A. Turjoman. (1988). Effect of elemental sulphur on some properties of calcareous soil and growth of date palm seedlings. Arid Soil Research and Rehabilitation, 2 (2):121-130.

Alawi, B. J., J.L. Stroehlein, E.A. Hanlon, and F. Turner. (1980). Quality of irrigation water and effects of sulpheric acid and gypsum on soil properties and Sudan grass yield. Soil Sci. 129 : 315-319.

Alexander, M. (1977). "Introduction to Soil Microbiology". 2 nd ed., John Wiley and Sons. Inc., New York.

Ali, O.M. (1974). Potassium supplying power of the soils in Egypt Ph. D. Thesis. Fac. of Agric., Al. Azhar Univ. Cairo. Egypt.

Awad, A. M., H. M. Ramadan, and M. E. El-Fayoumy. (1996). Effects of sulphur, phosphorus and nitrogen fertilizers on micronutrients availability, uptake and wheat production on calcareous soil. Alex. J. Agric. Res., 41 (3): 311-327.

Blake, F. (1990). Organic Farming and Growing. The Crowood Press. New York.

Buschiazzo, D.E., A.R. Quiroga and K. Stahr. (1991). Patterns of organic matter accumulation in soils of the semiarid Argentinean Pampas. Zeitschr. Pflanzenernaehr. Bodenk. 154 : 437-441.

Carter, M.R. (1993). Soil Sampling and Methods of Analysis. Canada Society of Soil Science, Lewis Publishers.

Chen, Y. and Y. Avnimelech (ed.). (1986)." The role of organic matter in modern agriculture". Development in plant and soil sciences V. 25. Marthinus Nijhoff Publishers, Dordrecht, Boston, Lancaster.

Clark, M.S., W.R. Horwath, C. Shennan and K.M. Scow. (1998). Changes in soil chemical properties resulting from organic and Low-Input Farming Practices. Agron. J. 20: 622-671.

Diaz-Zorita, M., D.E. Buschiazzo and N. Peinemann. (1999). Soil Organic Matter and Wheat Productivity in the Semiarid Argentine Pampas. Agron. J. 91 : 276-279.

Draper, N.R. and H. Smith. (1981). Applied Regression Analysis". 2nd ed. John Wiley, New York.

El-Shazly, M. and G. Abdel- Nasser. (1999). Efficiency of phosphorus fertilizers as affected by soil sulphur application in Balady Mandarin plants. J. Agric. Sci. Mansoura Univ., 24(12): 7623-7638.

Hall, D.O. and K.K. Rao (1996). Photosynthesis. 5th ed., Cambridge University Press, Cambridge, UK.

Harhash, M.M. and G. Abdel-Nasser, (2000). Effect of organic manures in combination with elemental sulphur on soil physical and chemical characteristics, yield, fruit quality, leaf water contents and nutritional status of flame seedless grapevine. II. Yield, fruit quality, leaf water contents and nutritional status. J. Agric. Sci. Mansoura Univ., 25 (5): 2819-2837.

Hassan, N. and R.A. Olson (1966). lnfluence of applied sulfur on availability of soil nutrients for com (Zea mays L.) nutrition. Soil Sci.Soc.Amer. Proc. Vol. 30:284-268.

Hening, H.; D. Sparks and J.J. Evans. (1991). Sulphur deficiency influence vegetative growth, chlorophyll and element concentrations and amino acids of pecan. J. Amer. Soc. Hort. Sci., 116 (6):974-980.

Hussein, A.H.A. and G. Abdel-Nasser (2001). Effect of different manure sources on some soil properties and sunflower plant growth. 2. Growth , yield, leaf water contents and nutrients status. Alex. J. Agric. Res. 46(1):205-225.

Hussein, A.H.A. and G. Abdel-Nasser (2002). Influence of superphosphate and elemental sulfur on soil physical properties, growth, yield and nutrients status of sunflower. 2. Growth , yield, leaf water and nutrients contents. J. Adv. Agric. Res. 7(2):491-508.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice-Hall, Inc. India.

Kassem, A.A., H.A. Kassem, and H.M. Kamal. (1995). The influence of sources, level of nitrogen fertilizers and/or sulphur application on guava trees grown in alkaline sandy soil. Menofiya J. Agric. Res., 20 (3):1223-1235.

Kowalenko, C. G. (1979). Rapid analysis of soil nitrate with sulphur. Can. J. soil Sci., 59: 221-223.

Laila, H. A. and S.B.M. Abdel-Aziz (1992). Effect of organic manure on some physical properties of a sandy soil and on crop production. Egypt. J. Appl. Sci. 7 (6): 299-305.

Lindsay, W.L. and W.A. Norvell (1978). Development of DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Amer. J., 42: 421-428.

Mattingly, C. (1975). Labile phosphate in soil. Soil Sci., 119: 369-375.

Mengel, K. and E.A. Kirkby (1987). Principles of plant Nutrition. 4th Ed., International Potash Institute, Bern, Switherland.

Moran, R. and D. Parath. (1980). Chlorophyll determination in instact tissues using N-N-dimethyl formamide. Plant Physiol., 65: 478-479.

Murphy, J. and J.P. Riely (1962). A modified single solution method for the determination of phosphorus in natural water. Anal. Chem. Acta. 27: 31-36.

Peterson, P.V., C.A. Mullins, D.A. Lietzke and D.E. Deyton (1987). Effect of soil applied elemental sulphur, aluminum sulfate and sawdust on growth of rabbitege blueberries. J. Amer. Soc. Hort. Sci. 112: 612-616.

Pierce, F.J., W.E. Larson, R.H. Dowdy and W.A.P. Graham. (1983). Productivity of soils: Assessing long-term changes due to erosion. J. Soil Water Conserv., 38 : 39-44.

Rehana, R., S.S. Kukal and G.S. Hira. (2008). Soil organic carbon and physical properties as affected by long-term application of FYM and inorganic fertilizers in maize – wheat system. Soil and Tillage Research, Volume 101, Issues 1-2,:31-36.

Rhoades, J.D. (1982). Soluble salts P. 167-185. In A.L. Page et al. (ed.) Methods of soil analysis Part 2. Chemical and microbial methods.. 2nd ed. Agron. Monogr 9. ASA and SSA. Madison, WI.

Richards, L.A. (ed.) (1972). Diagnosis and Improvement of Saline and Alkaline soils. U.S. Dept. of Agric., Agric. Handbook No. 60.

Rogaski, J. and M. Smukalski (1988). Boden fruchtbarkeit und winter-weizenertage auf Morunenstandoren. Tag. Bert. Akad. Landwirtsch. Wiss. 269: 383-390.

Schoenau, J.J. and R.E. Karamanos. (1993). Sodium Bicarbonate-Extractable P, K and N. Chapter 7 in M.R. Carter, Soil sampling and Methods of Analysis, Lewis Publishers, 823 pp.

Shadfan, H. and A.A. Hussen. (1985). Effect of sulphur application on the availability of P, Fe, Mn, and Cu in Selected Saudi Soils. In. Proc. 2nd Arab regional Conf. On sulphur and its usages, P. 3-23.

Spiers, J.M. and J.H. Braswell. (1992). Applied Sulphur additions on growth, yield and leaf nutrient content of rabbiteye blueberry.T.Amer. Soc. Hort. Sci., 117(2): 230-233.

Steel, R.G. and J.H. Torrie. (1982). Principles and Procedures of Statistics. 2nd Ed., McGraw Hill Book Company, New York, USA.

Stromberg, L.K. and S.L. Tisdale. (1979). Treating irrigated arid-land soils with acid-forming sulphur compounds. The sulphur Institute Technical Bulletin, 24, p. 2.

Tester, C.F. (1990). Organic amendment effects on physical and chemical properties of a sandy soil. Soil Sci. Soc. Amer. J. 58: 827-831.

U.S.D.A. (1980). Report and recommendations on organic farming. U.S. Dept. of Agriculture, U.S. Gov. Print Office, Washington D.C.

Wainwright, M. (1984). Sulphur oxidation in soils. Adv. Agron., 37: 349-396.

Weatherly, P.E. (1950). Studies in the water relations of the cotton plants. 1-field measurement of water deficits leaves. New Phytolog., 50: 36-51.

Wolf, B. (1982). A comprehensive system of leaf analysis and its use for diagnosing crop nutrient status. Commu. Soil Sci., Plant Anal., 13, pp. 1035-1059.

Yanshan, C., Y. Dong, H. Li and Q. Wang. (2004). Effect of elemental sulphur on solubility of soil heavy metals and their uptake by maize.
Environment International, Volume 30, Issue 3,:323-328.

Yousry, M., A. El-Leboudi, and A. Khater. (1984). Effect of Sulphur and petroleum by-products on soil characteristics. I. Availability of certain nutrients in a calcareous soil under intermittent leaching. Egypt J. Soil Sci., 24 (3): 185-194.

الملخص العربي

التأثير المشترك لسماد المزرعة والكبريت الزراعي على الخواص الكيميائية للتربة، النمو، والمحصول ومحتوى الأوراق من الماء والعناصر الغذائية لنبات الذرة النامي في أرض رملية طينية لومية

عادل حسين أحمد حسين

أجريت تجربة حقلية في محطة التدريب والأبحاث الزراعية والبيطرية بجامعة الملك فيصل بمنطقة الإحساء خلال موسم النمو 2006 على محصول الذرة. الغرض من هذه الدراسة هو معرفة التأثير المشترك لكلا من سماد المزرعة والكبريت الزراعي على الخواص الكيميائية للتربة، النمو، المحصول والحالة المائية ومحتوى العناصر الغذائية لمحصول الذرة. جميع القطع التجريبية لأرض التجربة (17.5م2) تم زراعتها بالذرة وقد تم إضافة 78.5 كجم نيتروجين/هكتار في صورة نترات أمونيوم(33.5%ن) و150 كجم% بو2أ /هكتار في صورة سلفات بوتاسيوم(48% بو2أ) و88 كجم فوسفور/هكتار في صورة سماد السوبر فوسفات (15.5% فو2أ5). وقد تم إضافة سماد المزرعة بمعدلات صفر، 14، 28، 56 طن/هكتار والكبريت الزراعي بمعدلات صفر، 360 ،720 ، 1440 كجم/هكتار. كلا من سماد المزرعة والكبريت تم خلطهما مع الطبقة السطحية للتربة(30سم) قبل الزراعة. أوضحت النتائج المتحصل عليها أن إضافة كلا من سماد المزرعة والكبريت قد أدت إلى إحداث تغيير جوهري في الصفات الكيميائية للتربة فقد أدى ذلك إلى زيادة الأملاح الكلية الذائبة بينما قيم تفاعل التربة ونسبة الصوديوم المتبادل نقصت معنويا نتيجة إضافة كلا من سماد المزرعة والكبريت المعدني. وأن هناك تأثير معنوي لكلا من سماد المزرعة والكبريت المعدني في تحسين حالة العناصر الغذائية الميسرة بالتربة مثل النيتروجين- الفوسفور- البوتاسيوم- الحديد- المنجنيز- النحاس والزنك حيث أنها زادت معنويا. أيضا أوضحت النتائج المتحصل عليها أن الوزن الأخضر زاد معنويا مع زيادة معدلات كلا من سماد المزرعة والكبريت المعدني. كما أن سماد المزرعة والكبريت كان لهما تأثير معنوي خصوصا عند المعدلات العالية على محصول الحبوب ومكوناته(وزن100حبة ونسبة البروتين في الحبوب). وقد كانت الزيادة في محصول الحبوب5.34 و6.20% عن معاملة الكنترول على التوالي. أيضا تشير النتائج إلى تحسن محتوى الأوراق من الماء نتيجة لإضافات سماد المزرعة والكبريت. في نفس الوقت فان محتوى الأوراق من الكلوروفيل الكلي زاد معنويا وقد كانت الزيادة مرتبطة بالمعدلات العالية من الإضافة. إضافة سماد المزرعة والكبريت أدى إلى تحسن محتوى الأوراق من العناصر الغذائية.