RESPONSE OF WHEAT GROWN ON SANDY CALCAREOUS SOILS TO ORGANIC MANURES AND SULFUR APPLICATION

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Abstract

The aim of the present investigation was to improve the productivity of wheat grown on the sandy calcareous soil of Arab El-Awammer Experimental Station, Assiut governorate through using organic matter, elemental Sulphur application, and the suitable level of mineral N-fertilization. Three field experiments were conducted for this purpose; two in the winter season 2004/2005 and the third in season of 2005/2006. The experiments tested different forms of organic manures: Farm yard manure (FYM), chicken manure (CM) and Town wastes (TW) at rate of 100 kg N/fed and liquid Vinasse at 5 ton/fed), different levels of mineral N-fertilization (60, 90, 120, 150 kg N/fed), and Sulphur application at different rates (200, 300, 400, 600 kg/fed). Plant growth, and wheat yields (grain, straw, total) and N, P plant uptake were determined, also soil pH, EC, and available P after 30 and 60 days from sowing and at harvest of crop were measured. The obtained results showed that supplementation of organic matter, in any form, improved plant growth and induced significant or highly significant increases in wheat grain yield, 39.0, 36.1, 32.0 and 14.3 % with (TW), (FYM), (CM) and Vinasse, respectively. Sulphur application in the range of 300-400 kg/fed, alone or with organic manures had significant beneficial effects on increasing wheat growth, N and P plant uptake, and yields obtained (between 11.50 to 12.99 % increases in grain yields), and induced significant reductions in soil pH and increases in available P. The application of S with organic manures, especially (TW), had synergetic effect on increasing grain yield. The optimum economic rate of mineral N-fertilization for wheat grown on this sandy calcareous soil is 90 kg N/fed. This is in addition to an amount of TW as a soil conditioner equal to 100 kg N/fed.

INTRODUCTION

The low productivity of calcareous soils is often associated with poor plysico-chemical characteristics and with low both organic matter content and available nitrogen. Also, the high pH level results in low availability of phosphate, zinc and iron. Chlorotic symptoms are usually observed on plants grown in calcareous soils. The potential productivity of calcareous soils may be very high where adequate nutrients and water can be supplied (Fuehring, 1973).

Three approaches are often applied for improving calcareous soil physico-chemical characteristics, plant growth and productivity of planted crops: (1) Application of organic materials (2) Supplementation and management of essential nutrients (3) Application of sulfur for partially neutralizing the $CaCO_3$ present in soil.

Application of organic materials: farmyard and chicken manures are traditionally used by many investigators as soil conditioners and fertilizers for increasing growth and yield of many field crops and vegetables (Atta Allah and Mohamed, 2003, Awad *et. al.*, 2002). In addition to playing important role in improving the physical properties of soils, especially the sandy and calcareous ones, organic manures are valuable resources rich in P, N and micronutrients essential for plant growth, that are slowly released after degradation by microorganisms. Mostafa (2004) reported that the application of chicken manure or farmyard manure, at a rate equivalent to 100 kg N/fed significantly improved dry weight of wheat plants grown on soils of different textures, but response of plants to the organic manure treatments was more pronounced in sandy and calcareous soils than in the clayey ones. Also, Attia and El-Dosuky (1996) reported that the application of FYM at rates of 15 and 30 m^3/fed to wheat grown in sandy calcareous soil increased the total and grain yield, N and S contents.

In many developing countries and in newly reclaimed areas, where organic farmyard and chicken manures are not available in adequate quantities, other forms of organic matter like filter mud and vinasse of sugar-cane industry (Yassen *et. al.*, 2002), composted plant residues and town wastes (Morsy, 2002) are frequently used as soil amendments and fertilizers for supplementing major plant nutrients.

Wheat crop is known to have high nitrogen requirement, and the applied N-fertilization level greatly affect the yield produced. In Egypt, the optimum N-fertilization level for wheat varies widely depending on soil characteristics and fertility level, ranging between 80 up to 160 kg N/fed. (Atta Allah and Mohamed, 2003). Addition of N at a level of 120 kg N/fed with organic manure (15 – 30 m^3/fed) highly increased the total yield of wheat grown on sandy calcareous soil, and the highest grain yield was obtained by applying 120 kg N/fed + 30 m^3/fed of organic manure (Attia and El-Dosuky, 1996).

The application of sulfur, that is oxidized to SO_4^{--} by soil microorganisms, expectidiley lively lowers the soil pH, and consequently increases the availability of nutrients and improves physical and chemical properties of the soil. The reported changes produced by the application of elemental sulfur to calcareous soils were decreased soil pH and increased availability of P, Fe, Mn, Zn and Cu (Attia and El-Dosuky, 1996, Hilal and Abd-Elfattah. 1987).

The conjunctive use of manure and sulfur has been found beneficial in increasing productivity of many crops. In Egypt, a number of investigators reported the synergetic effect of applying Sulphur (200-500 kg/fed) or gypsum (2.67 ton/fed) with FYM, particularly in calcareous soils, on plant growth and yields obtained as well as on uptake and concentrations of macronutrients (N, P, K) and micronutrients (Fe, Zn, Mn) (Attia and El-Desouky, 1996, Awad *et. al.*, 2002). This synergetic effect is probably due to increased rates of organic matter degradation by the heterotrophic sulfur oxidizing microorganisms and uptake of mineral nutrients released.

MATERIALS AND METHODS

Three separated field experiments were conducted on wheat; two during the winter season 2004/2005, and the third experiment was conducted in winter season 2005/2006. The three conducted field experiments were designed to evaluate the use of some agricultural treatments for improving growth of wheat plants and increase the productivity of the sandy calcareous soil at Arab El-Awammer Research Station, Agric Res. Center (ARC), Assiut Governorate. The Physical and chemical characteristics of a representative composite soil sample (top 30 cm) of the site of the experimental field are shown in Table 1.

In all experiments, the soil of the experimental field was prepared by good ploughing and then divided to plots, size of each was 1/400 faddan (3 m × 3.5 m =10.5 m^2), and granular superphosphate (15.5 % P_2O_5) at rate of 300 kg/fed, and elemental Sulphur (at the tested level) were broadcasted and thoroughly mixed with soil surface layer (0 - 25cm).

Table 1. Some physical and chemical characteristics of the representative composite soil sample taken from the field experimental site.

Soil Properties	Values	Soil Properties	Values
Sand (%)	96.72	Organic matter %	0.24
Silt (%)	2.12	Total nitrogen (%)	0.003
Clay (%)	1.16	Available P (ppm)	8.30
Soil texture	Sandy	Available micronutrients (ppm):	
Total $CaCO_3$ %	35.18	Fe	1.85
EC mmhos/cm (1 : 1)	0.35	Mn	1.59
pH (1:1 water suspension)	8.65	Zn	0.33
		Cu	0.38

Wheat grains (*Triticum aestivum L.* cv. Giza 168) were sown by broadcasting at rate of 85 kg/fed (212.5 g/plot). Ammonium nitrate (33.5 % N), used as mineral N-fertilizer, was added at the tested level in four equal doses, after 20, 40, 55, and 70 days from sowing. Potassium sulfate (48 % K_2O) was added to plots at rate of 50 kg/fed in two equal doses after 20 and 40 days from sowing. Chelated Fe, Mn and Zn and boric acid, in liquid solution containing 150, 150, 150 and 50 ppm, respectively, was used as a foliar spray at rate of 0.5 L/plot (200 L/fed), sprayed twice after 50 and 85 days from sowing.

The first experiment tested the response of wheat to two levels of N-fertilizer and 4 levels of S-application. The experimental design was a split plot design with three replications, N-fertilizer rates (120 and 150 kg N/fed) were in main plots and elemental S rates (zero , 200 , 400 , 600 kg powdered S/fed) were in sub plots.

The second experiment tested the effect of supplying different types of organic materials (in addition to mineral nitrogen, 120 kg/fed) and application of powdered S on growth and grain yield of wheat. The experimental design was a split plot design with four replications. The five organic matter treatments [without O.M. – Farmyard manure (FYM), Chicken manure (CM), Vinasse (V) and Town wastes (TW)] were laid in the main plots, and elemental S treatments (zero and 600 kg powdered S/fed) were in the sub plots. Elemental sulfur was broadcasted before sowing and thoroughly mixed with soil surface layer. The air dried organic materials, except Vinasse, were applied at rate of 100 kg N/fed, and were evenly spread and mixed with soil surface layer. Liquid vinasse, at rate of 5 ton/fed (12.5 kg/plot), was applied in three doses added with irrigation water, the first dose at sowing (60%) and the second and third doses (20% and 20%) after 10 and 20 days from the first. The chemical analyses of the used organic fertilizers (FYM, CM, V and TW) are shown in Table 2 .

Table 2. Chemical analyses of organic fertilizers (FYM , CM , V and TW) that were used in field experiments.

Properties of Organic Material	Values			
	FYM	CM	V	TW
Organic matter (%)	48.58	57.76	7.28	20.99
Organic carbon (%)	28.18	33.50	4.23	12.18
Total N (%)	1.011	2.640	0.272	1.063
C/N ratio	27.87	12.69	15.55	11.46
Total P (%)	0.403	1.181	0.112	0.339
Total K (%)	1.643	1.136	0.553	0.568
Total Na (%)	1.070	0.534	0.218	0.581
Total Fe (ppm)	6474	1825	23	9138
Total Mn (ppm)	164	187	1	232
Total Zn (ppm)	54	117	3	366
Total Cu (ppm)	11	23	6	61
pH (1:10 suspension)	7.65	6.51	4.50	6.44
EC (1:10 suspension) mmhos /cm	6.61	3.15	15.35	3.40

The third experiment tested response of wheat to different mineral nitrogen fertilization levels (60, 90, 120 and 150 kg N/fed) and S-application (zero and 300 kg powdered S/fed). The experimental design was a split plot design with eight replications. N-fertilizer rates were in the main plots and elemental S treatments were in the sub plots. All plots received town wastes at rate of 100 kg N/fed, that was evenly spreaded, and thoroughly mixed with soil surface layer.

Plant sampling for growth determination was done 82 days after sowing, where 10 random plants were taken from each plot and plant height and fresh weights were immediately determined, then washed with tap and distilled water and oven dried at 70 °C, then their dry weights were determined. Concentration of N in plants (by the microkjeldahl procedure; Jackson 1973) and P (by the stannous chloride .phosphomolybdic sulfuric acid method; Jackson, 1973) were determined, and plant uptakes were calculated.

At harvest, total yield of three square meters from the center of each plot were manually harvested, dried for 5 days and weighed, and after threshing grain weights were determined, then total grain, straw yields per faddan and seed index were calculated. Number of spikes/m^2 was determined and spike average weight was calculated. Samples of grains and straw were taken from each plot for chemical analysis.

Determination of soil salinity and pH were made in soil samples, taken from the surface soil layer (top 30 cm) after 30 and 60 day from sowing and at harvest. Also, at harvest, available P in soil samples were determined (extracted with 0.5 M $NaHCO_3$ at pH 8.5 and measured colorimetrically by the stannous chloride phosphomolybdic-sulfuric acid method; Jackson, 1973).

The first experiment (2004/2005)

The MSTAT-C (version 2.10) computer program was used to perform all the analysis of variance and to compare for significant differences among treatment means, using the LSD at $p = 0.05$ and $p = 0.01$. as outlined by Steel and Torrie (1982).

RESULTS AND DISCUSSION

The first field experiment (2004/2005)

Data of the first field experiment (2004/2005) presented in Tables 3 and 4 show that, increasing N–fertilization level from 120 to 150 kg N/fed caused significant improvement in plant growth parameters and plant uptake of N and P, and resulted in significant increases in yield (straw, grain and total yield) and yield components (no. of Spikes/m^2 and wt. of 1000 grains), as well as total N and P uptake.

These results are in accordance with those of other investigators and confirm the promotive effect of increased N-fertilization level, for wheat growth and yield, especially in newly cultivated soils with low O.M. (Alromian and El-Fakhrani, 2002, Attia and El-Dosuky, 1996).

S-application at the levels 400 and 600 kg powdered S/fed caused significant or highly significant increases in plant growth and N and P uptakes (Table 3), as well as in yield and yield components (Table 4) compared with zero S or the treatment supplied with 200 kg S/fed. The application of 400 kg S and 600 kg S/fed resulted in 11.5 % and 17.8 % increases in grain yield, and 12.5 and 21 % in straw yield, respectively.

The statistical analysis of results obtained in this experiment. showed that there were no significant interactions between N-fertilization levels and S-application levels on wheat growth, yield or yield components.

Table 3. Wheat growth* in field as affected by levels of N-fertilization and S-application (2004/2005).

Tested factors	Treatments	Average plant wt. (g)		Conc. in plants (%)		Uptake/plant (mg)		Plant height
		Fresh	Dry	N	P	N	P	(cm)
N-fert. levels	120 kg N/fed	7.0	1.36	2.470	0.389	33.7	5.27	49.0
	150 kg N/fed	9.53	1.78	2.517	0.372	44.8	6.62	55.4
$L.S.D_{0.05}$		1.15	0.314	n.s	n.s	6.7	0.94	3.1
S application levels	Zero S	6.86	1.34	2.487	0.365	33.2	4.86	49.2
	200 kg S/fed	7.60	1.48	2.501	0.389	37.0	5.74	50.6
	400 kg S/fed	9.09	1.71	2.461	0.381	42.1	6.45	53.5
	600 kg S /fed	9.50	1.76	2.525	0.385	44.4	6.72	55.6
$L.S.D_{0.05}$		1.64	0.244	n.s	n.s	7.3	0.71	3.0
$L.S.D_{0.01}$		n.s	0.343	-	-	n.s	0.99	4.2

* After 82 days from sowing.

Table 4. Yield and yield components of wheat as affected by levels of N-fertilizer and S-application (2004/2005).

Tested factors	Treatments	Yield (kg/fed)			Nitrogen conc. (%)		Phosphorous conc. (%)		Total uptake (kg/fed)		No. of Spikes /m^2	Spike average weight (g)	Wt. of 1000 grains (g)
		Grain	Straw	Total	Grain	Straw	Grain	Straw	N	P			
N-fert. levels	120 kg N/fed	1248	1905	3153	2.101	0.418	0.344	0.072	34.55	5.68	384	0.789	34.42
	150 kg N/fed	1650	2386	4036	2.216	0.493	0.363	0.075	48.34	7.78	483	0.820	35.75
L.S.D $_{0.05}$		306	199	496	n.s	n.s	0.018	n.s	8.02	1.13	80.6	n.s	0.51
L.S.D $_{0.01}$		n.s	458	n.s	-	-	n.s	-	n.s	n.s	n.s	-	1.18
S* application levels	Zero S	1339	1965	3304	2.038	0.423	0.349	0.066	36.28	6.00	404	0.789	34.34
	200 kg S/Fed	1388	2030	3418	2.072	0.437	0.343	0.074	37.89	6.31	415	0.793	34.84
	400 kg S/Fed	1493	2210	3703	2.249	0.471	0.363	0.072	44.02	7.03	444	0.766	35.29
	600 kg S /Fed	1578	2377	3955	2.276	0.491	0.360	0.080	47.59	7.58	472	0.801	35.86
L.S.D $_{0.05}$		145	265	368	n.s	n.s	n.s	n.s	3.73	0.82	45.7	n.s	1.01
L.S.D $_{0.01}$		n.s	n.s	516	-	-	-	-	5.23	1.15	n.s	-	n.s

*Powdered elemental sulfur.

The improvement in plant growth and wheat yield by the S-application treatments are attributed to biological S-oxidation to sulphuric acid, causing reduction in soil pH and increase in amount of available P, and probably, other nutrients. Table 5 and Figures 1 and 2 show that the highest measured reduction in soil pH was recorded in the treatment receiving 600 kg S/fed compared with the untreated control. On the contrary, the EC of soil suspension tended to increase with S-application levels.

Table 5. Effect of S-application levels on soil pH, EC and available P in soil at wheat harvest (2004/2005).

Levels of S-application	After 30 days from sowing		After 60 days from sowing		At harvest (After 140 day)		
	pH*	EC*	pH*	EC*	pH*	EC*	Available P
Zero S	8.15	755	8.08	581	8.48	346	9.02
200 kg S/Fed	7.93	1067	7.86	716	8.25	389	10.15
400 kg S/Fed	7.87	1097	7.76	825	7.92	467	11.03
600 kg S /Fed	7.74	1550	7.65	922	7.82	524	11.80
$L.S.D_{0.05}$	0.198	309	0.129	184	0.14	35	0.63
$L.S.D_{0.01}$	0.278	434	0.181	258	0.196	49	0.88

*EC and pH measured in (1:1) suspension, EC in micromhos, and available P in ppm.

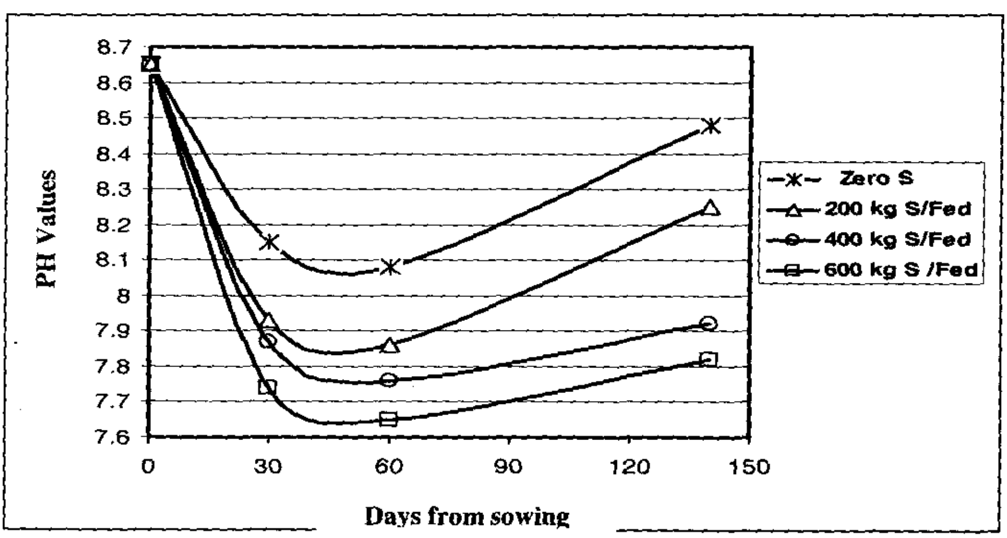

Figure 1. Changes in soil pH as affected by levels of S-application.

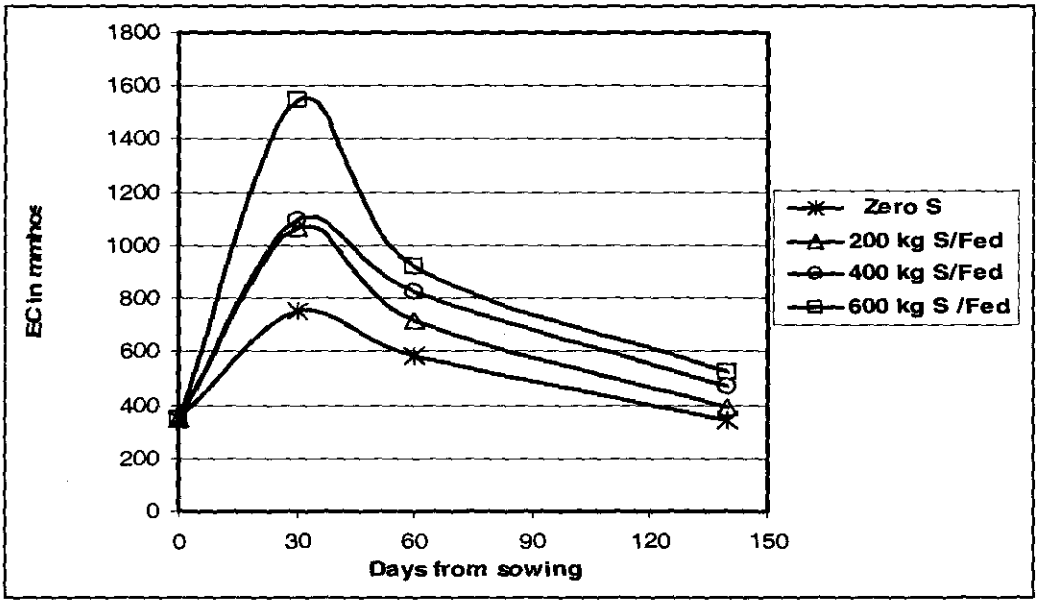

Figure 2. Changes in soil EC as affected by levels of S-application.

Figure 1 shows changes in soil pH as affected by levels of S. The reduction in soil pH were quite sharp after 30 days from sowing and reached its minimum after 60 days, but pH gradually increased again by the end of the experiment at harvest The pH values were still lower than at the beginning or when compared with the control treatment (Figure 1). It should be noted that the reduction in soil pH induced by the S-application levels were associated with the increase in soil available P determined at harvest (Table 5 and Figure 1) and with the increases in EC of soil suspension (Figure 2).

The increments in wheat yield scored by S-application in the present investigation are in agreement with those obtained by other investigators (Alromian and El-Fakhrani, 2002; Attia and El-Dosuky, 1996).

The second experiment (2004/2005)

Data of the second experiment (Tables 6 and 7) show that, with the exception of vinasse, the vegetative growth of wheat and plant uptake of N and P were significantly or highly significantly improved by the applied organic matter (FYM, CM and TW). The highest improvements in wheat growth, yield and yield components were recorded in the TW treatment, followed by FYM and CM without significant differences among them (Tables 6 and 7).

The application of vinasse (5 ton/fed) induced the lowest increases in wheat yields (total, straw and grain) and N and P uptakes, but they were still significantly higher than those of the untreated control (Table 7). Compared with the untreated control, the increases in grain yield were 39.0, 36.1, 32.0 and 14.3 %, for the application of TW, CM, FYM and V, respectively; while the increases in straw yield were 62.3, 44.9, 52.9 and 27.9 %, respectively. These recorded increases in plant growth and wheat yields are due to supplementation of N and other nutrients from the degradation of added organic matter.

S-application alone, at the rate of 600 kg/fed, induced significant improvement in all growth parameters and nutrients uptake of wheat during the vegetative stage (Table 6), and were reflected in significantly higher yields (grain, straw, and total) and total N and P uptakes at harvest (Table 7). Also, S-application to soil before sowing (600 kg/fed) with either TW or FYM significantly increased grain yield and no. of spikes/m^2, as well as total P uptakes (Table 8). The increases in grain yield by S-application with TW and FYM were 21.9% and 29.0%, respectively, compared with the untreated plots.

The significant positive interactions of TW and FYM with S-application on wheat yield may be attributed to supplying of suitable digestable carbon sources that stimulated the heterotrophic S-oxidizing microbes, thus resulting in increasing available P (and probably other nutrients) and consequent increases in plant growth, no. of spikes and grain yield. The stimulated S-oxidation by organic matter application to soil was reported by (Gallardo-Lara *et. al.*, 1990). The Town Waste compost was found to produce significantly greater increase in SO_4^{--} in two soils than did either of two agricultural wastes (Gallardo-Lara *et. al.*, 1990).

Table 6. Wheat growth* as affected by applied organic matters and S-application (2004/2005).

Tested factors	Treatments	Average plant wt. (g)		Conc. in plants (%)		Uptake/plant (mg)		Plant height (cm)
		Fresh	Dry	N	P	N	P	
Applied O.M.	No O.M. (control)	7.42	1.32	2.53	0.408	33.53	5.43	46.9
	FYM	8.54	1.47	2.827	0.433	41.90	6.37	54.5
	CM	8.51	1.50	2.648	0.447	39.78	6.68	58.4
	V	7.67	1.32	2.632	0.385	34.83	5.09	53.2
	TW	9.95	1.57	2.656	0.427	41.88	6.72	55.5
$L.S.D_{0.05}$		1.04	0.18	n.s	n.s	6.22	0.82	3.9
$L.S.D_{0.01}$		1.46	n.s	-	-	n.s	1.15	5.51
S Application	Zero S	7.89	1.35	2.582	0.400	35.07	5.42	52.4
	600 kg S/fed	8.95	1.52	2.735	0.439	41.70	6.69	55.0
$L.S.D_{0.05}$		0.55	0.07	0.146	0.023	3.11	0.43	1.98
$L.S.D_{0.01}$		0.76	0.098	-	0.031	4.31	0.60	n.s

* After 82 days from sowing.

FYM= farmyard manure, CM= chicken manure, V= Vinasse, TW= town wastes, applied at rate of 100 kg N/fed, except Vinasse at rate of 5 ton /fed.

All plots received mineral nitrogen in the form of ammonium nitrate (33.5 % N) at rate of 120 kg N/fed.

Table 7. Effects of applied* Orgnic matter types and S-application on yield and yield components of wheat (2004/2005).

Tested factors	Treatments	Yield (kg/fed)			Nitrogen conc. (%)		Phosphorous conc. (%)		Total uptake (kg/fed)		No. of Spikes /m²	Spike average weight (g)	Wt. of 1000 grains (g)
		Grain	Straw	Total	Grain	Straw	Grain	Straw	N	P			
Applied O.M.	No O.M.	1414	1934	3348	1.920	0.428	0.309	0.073	35.45	5.79	345	0.979	36.27
	FYM	1867	2957	4824	2.107	0.456	0.351	0.080	52.99	8.98	431	1.042	37.97
	CM	1924	2803	4727	2.190	0.504	0.337	0.075	56.47	8.62	451	1.014	39.57
	V	1616	2474	4090	2.054	0.463	0.315	0.062	44.59	6.60	354	1.087	39.17
	TW	1965	3139	5104	2.143	0.473	0.378	0.066	57.04	9.54	419	1.115	38.57
$L.S.D_{0.05}$		142	288	322	n.s	n.s	0.034	0.0046	4.46	0.88	22.2	0.073	1.74
$L.S.D_{0.01}$		199	403	451	-	-	0.048	0.0065	6.25	1.24	31.1	n.s	n.s
S - Application	Zero S	1657	2567	4224	2.049	0.450	0.326	0.069	45.70	7.19	382	1.035	37.62
	600 kg S/fed	1858	2756	4614	2.117	0.480	0.350	0.074	52.92	8.62	418	1.060	39.00
$L.S.D_{0.05}$		113	148	224	n.s	0.021	0.014	0.0045	3.87	0.55	12.9	n.s	1.02
$L.S.D_{0.01}$		n.s	205	310	-	0.029	0.02	n.s	5.35	0.76	17.8	-	n.s

*FYM= farmyard manure, CM= chicken manure, V= Vinasse, TW= town wastes applied at rate of 100 kg N/fed, except Vinasse at rate of 5 ton /fed.

All plots received mineral nitrogen in the form of ammonium nitrate (33.5% N) at rate of 120 kg N/fed.

Table 8. Interaction effects of applied organic matters and sulfur application on yield and yield components of wheat (2004/2005).

Tested factors*		Yield (kg/fed)			Nitrogen conc. (%)		Phosphorous conc. (%)		Total uptake (kg/fed)		No. of Spikes /m^2	Spike average weight (g)	Wt. of 1000 grains (g)
Applied O.M.	S-application	Grain	Straw	Total	Grain	Straw	Grain	Straw	N	P			
No O.M.	Zero S (control)	1392	1911	3303	1.887	0.410	0.300	0.071	34.15	5.53	342	0.971	36.00
	600 kg S/fed	1436	1958	3394	1.953	0.445	0.318	0.075	36.76	6.04	347	0.986	36.55
FYM	Zero S	1630	2772	4402	2.028	0.433	0.323	0.080	45.01	7.46	370	1.048	37.25
	600 kg S/fed	2104	3142	5246	2.186	0.478	0.379	0.080	60.98	10.51	492	1.036	38.70
CM	Zero S	1905	2744	4649	2.135	0.487	0.329	0.072	54.27	8.25	451	1.011	38.35
	600 kg S/fed	1943	2861	4804	2.245	0.522	0.346	0.079	58.66	9.00	451	1.016	40.80
V	Zero S	1588	2432	4020	2.053	0.461	0.311	0.062	43.71	6.45	350	1.081	38.18
	600 kg S/fed	1642	2516	4158	2.055	0.465	0.318	0.062	45.46	6.75	357	1.094	40.15
TW	Zero S	1772	2974	4746	2.140	0.458	0.367	0.060	51.36	8.28	397	1.064	38.33
	600 kg S/fed	2160	3305	5465	2.146	0.488	0.389	0.073	62.71	10.80	441	1.166	38.82
L.S.D$_{0.05}$		253	n.s	n.s	n.s	n.s	n.s	n.s	n.s	1.229	28.8	n.s	n.s

FYM= farmyard manure, CM= chicken manure, V= Vinasse, TW= town wastes, applied at rate of 100 kg N/fed, except Vinasse at rate of 5 ton /fed.
All plots received mineral nitrogen in the form of ammonium nitrate (33.5% N) at rate of 120 kg N/fed.
Each value is a mean of 4 replicates.

S-application to soil as shown from the results presented in Table 9, in addition to inducing significant reduction in soil pH, resulted in significant increase in soil available P at harvest.

The increasing in available P in untreated control may be attributed to the exudation of organic anions and protons and their effect on P bioavailability, whereas little has been done on the effect of the release of inorganic ligands such as bicarbonate ions. All these processes will possibly result in a build-up of P concentration in the soil solution and, hence in an increase in bioavailability of P to plants (Hinsinger, 2001).

The reduction in soil pH values after 30 and 60 days from sowing in the different organic matter treatments (Table 9), show that the lowest recorded soil pH values were in the TW and FYM treatments. Even at harvest, the soil pH of the TW treatment was still the lowest recorded of all organic matter types (Table 9).

These results are similar to those reported by other investigators recording decreased soil pH and increased availability of P and other micronutrients (Fe, Mn, Zn and Cu) by S application in calcareous soils (Alromian and El–Fakhrani, 2002, Attia and El-Dosuky, 1996, Hilal and Abd-Elfattah. 1987).

Table 9. Effects of applied organic matters and S-application on soil pH, EC and available P in soil at harvest of wheat (2004/2005)*.

Tested factors	Treatments	After 30 days from sowing		After 60 days from sowing		At harvest (After 140 days)		
		pH*	EC*	pH*	EC*	pH*	EC*	Ava.P
Applied O.M.	No O.M.	8.10	1226	7.92	769	8.16	373	11.91
	FYM	7.84	1731	7.79	896	8.08	392	16.68
	CM	7.92	1415	7.84	735	8.00	380	16.79
	V	7.90	990	7.92	737	8.10	332	13.98
	TW	7.83	1015	7.78	912	7.84	487	16.15
$L.S.D_{0.05}$		0.183	307	0.119	115	0.19	69.7	1.25
$L.S.D_{0.01}$		n.s	431	n.s	161	n.s	97.8	1.76
S Application	Zero S	8.04	1181	7.97	629	8.19	331	14.00
	600 kg S/fed	7.79	1369	7.73	991	7.88	454	16.21
$L.S.D_{0.05}$		0.068	88	0.076	71	0.101	27.5	0.87
$L.S.D_{0.01}$		0.094	122	0.105	98	0.14	38.1	1.20

* EC and pH measured in (1:1) soil suspension, EC in micromhos, available P in ppm.
FYM= farmyard manure, CM= chicken manure and TW= town wastes were applied at rate of 100 kg N/fed, and Vinasse (V) at rate of 5 ton /fed.

The third experiments (2005/2006)

It is found that increasing the N-fertilization level from 60 up to 150 kg/fed resulted in additive increases in plant growth, (fresh and dry weights) N and P uptakes by wheat plants (Table 10), as well as in yield and yield components (Table 11). However, the statistical analysis of the yield results indicates that 90 kg N/fed with 100 kg TW/fed is the optimum fertilization level for wheat grown on this calcareous sandy soil (Table 11). The application of more than 90 kg N/fed (120 or 150 kg N/fed), although increased growth and yields yet, the recorded increases were non-significant compared with those of the 90 kg N treatment, and resulted in only 42 kg and 159 kg/fed grain yield, and 154 kg and 454 kg/fed straw yield, over those obtained at the 90 kg N level (Table 11). Economically, these increases in grain and straw yields are less beneficial to the farmer compared with the costs of the excess amounts of N-fertilizer added (30 or 60 kg N/fed). Therefore, we consider that the 90 kg N/fed is the recommended economic level of mineral N for wheat production in the sandy calcareous soil of Arab El-Awammer, particularly when organic matter is applied to soil as amendment and nutrient supply.

S-application to wheat at 300 kg/fed induced highly significant improvement in plant growth (fresh and dry wt.), N and P uptakes (Table 10), and resulted in highly significant increases in yield and yield components (Table 11). The increases in grain, straw and total yields, by S-application at rate of 300 kg/fed, were 231, 222 and 453 kg/fed, respectively (Table 11), compared with the respective values: 201, 189 and 390 kg/fed obtained by application of 600 kg S/fed in the second field experiment of (2004/2005) (Table 7). These results indicate that 300 kg S/fed is the beneficial economic level of S-application to Arab El-Awammer sandy calcareous soil. The higher tested level (600 kg S/fed) in 2004/2005 season did not induce excessive increases, neither in plant growth, nor in yields.

This is probably because of the slow biological oxidation of elemental S, especially during the cool winter season of wheat growth, which result in leaving residual elemental S to be oxidized during the growth of the succeeding crops (Attoe and Olson, 1966).

Table 10. Wheat growth* as affected by levels of mineral N-fertilizer and S-application (2005/2006).

Tested Factors	Treatments**	Average plant wt. (g)		Concentration (%)		Uptake/plant (mg)		Plant height
		Fresh	Dry	N	P	N	P	(cm)
Levels of Mineral N	60 kg N/fed	6.76	1.63	1.804	0.357	28.8	5.89	60.3
	90 kg N/fed	8.25	1.92	2.015	0.370	37.0	7.08	64.2
	120 kg N/fed	8.68	1.88	2.231	0.394	40.6	7.43	65.5
	150 kg N/fed	10.65	2.08	2.729	0.398	56.1	8.27	65.9
L.S.D $_{0.05}$		0.78	0.158	0.131	n.s	5.16	0.74	1.89
L.S.D $_{0.01}$		1.06	0.215	0.179	-	7.02	1.01	2.58
S Application	Zero S (Control)	7.92	1.74	2.134	0.373	36.7	6.52	63.1
	300 kg S/fed	9.24	2.02	2.255	0.385	44.5	7.81	64.9
L.S.D $_{0.05}$		0.57	0.107	n.s	n.s	3.52	0.51	1.42
L.S.D $_{0.01}$		0.76	0.144	-	-	4.74	0.68	n.s

* After 82 days from sowing.

**All plots received 100 kg N/fed in organic matter form (TW) during soil preparation.

Table 11. Yield and yield components of wheat as affected by levels of mineral N-fertilizer and S-application (2005/2006)*.

Tested factors	Treatments	Yield (kg/fed)			Nitrogen conc. (%)		Phosphorous conc. (%)		Total uptake (kg/fed)		No. of Spikes /m^2	Spike average weight (g)	wt. of 1000 grains (g)
		Grain	Straw	Total	Grain	Straw	Grain	Straw	N	P			
Level of Mineral N**	60 kg N/fed	1695	2327	4022	1.732	0.405	0.390	0.096	38.70	8.86	351	1.17	37.63
	90 kg N/fed	1892	2753	4645	1.911	0.432	0.395	0.102	48.08	10.27	395	1.148	37.89
	120 kg N/fed	1934	2898	4832	2.004	0.473	0.381	0.102	52.53	10.34	392	1.176	39.27
	150 kg N/fed	2051	3207	5258	2.497	0.549	0.381	0.115	68.99	11.51	416	1.189	39.95
L.S.D $_{0.05}$		165	188	312	0.108	0.046	n.s	0.007	4.09	1.03	25	n.s	1.06
L.S.D $_{0.01}$		225	256	425	0.147	0.062	-	0.010	5.55	1.40	34	-	1.44
S Application	Zero S (Control)	1778	2685	4463	1.984	0.445	0.375	0.103	47.59	9.44	364	1.171	37.99
	300 kg S/fed	2009	2907	4916	2.088	0.485	0.398	0.105	56.56	11.05	413	1.171	39.38
L.S.D $_{0.05}$		75	163	202	0.068	0.021	0.016	0.004	2.39	0.4	21	n.s	0.8
L.S.D $_{0.01}$		102	220	272	0.092	0.029	0.021	0.006	3.22	0.54	28	-	1.08

*All plots received 100 kg N/fed organic matter, in form of town wastes, during soil preparation.

** Mineral nitrogen fertilization in the form of ammonium nitrate 33.5% N.

The significant improvements in wheat growth and yield by S-application are due to the reduction in soil pH and consequently to the increase in nutrient availability. This is indicated from the high increase in soil available P at harvest of wheat by S-application (Table 12), which was associated with highly significant reduction in soil pH.

Table 12. Effects of nitrogen fertilization levels and S-application on soil pH, EC and available P in soil at harvest of wheat (2005/2006).

Tested factors	Treatments**	After 60 days from sowing		At harvest (After 140 day)		
		pH*	EC*	pH*	EC*	available P*
N-levels	60 kg N/Fed	8.28	485	8.28	471	13.84
	90 kg N/Fed	8.16	523	8.18	504	14.91
	120 kg N/Fed	8.04	529	8.14	516	15.33
	150 kg N/Fed	8.03	528	8.14	524	15.84
$L.S.D_{0.05}$		0.113	27	0.086	24	1.42
$L.S.D_{0.01}$		0.154	37	0.117	32	n.s
S Application	Zero S	8.24	497	8.26	487	14.09
	300 kg S/fed	8.02	535	8.11	520	15.87
$L.S.D_{0.05}$		0.070	16	0.061	18	0.59
$L.S.D_{0.01}$		0.095	22	0.083	24	0.80

* EC and pH measured in (1:1) suspension, EC in micromhos, available P in ppm.

**All plots received 100 kg N/fed in organic matter form (town refuses) during soil preparation.

The results presented in Table 13 indicate that S-application at rate of 300 kg/fed significantly interacted with levels of mineral N-fertilization (60, 90, 120 and 150 kg/fed), and this was reflected as significant increases in grain yield and total N-uptake. The calculated excess increase in grain yield in the treatment 90 kg N/fed + 300 kg S/fed was 16.7 %, and in the treatment 150 kg N + 300 kg S/fed was 18.9 %.

The high correlation and interaction of N-fertilization rates and sulfur supply in plant nutrition and protein synthesis are known to be interdependent (Alromian and El–Fakhrani, 2002, Attia and El-Dosuky, 1996).

In summary, the results of the present investigation on wheat grown on Arab El-Awammer sandy calcareous soil show that organic matter application in any form (FYM, TW, CM, or vinasse) induced significant or highly significant increases in wheat growth and yield. Such increases are attributed to supplementation of nitrogen and other nutrients released from organic matter degradation, as well as to improvements in soil chemical, physical, nutritional and biological properties. Similar conclusions were reported by other investigators (Hammad, *et. al.*, 2007, Hegazi, 2007, Morsy, 2002).

Also, in accordance with the results obtained in the present investigation on wheat growth (field experiments 1, 2, and 3), other investigators reported that the conjunctive use of S with organic manures has been found beneficial in increasing productivity of many crops (Attia and El-Dosuky, 1996, Awad *et. al.*, 2002). The synergetic effect of applied S (or gypsum) with compost or FYM, particularly in calcareous soils, was mainly attributed to increased rates of organic matter degradation by the heterotrophic S-oxidizing microorganisms and the release of nutrients in organic forms, in addition to the increased availabilities of P and micronutrients induced by the reductions in soil pH.

Table 13. Interaction effects of levels of mineral N-fertilizer and sulfur application on yield and yield components of wheat (2005/2006)*.

Tested factors		Yield (kg/fed)			Nitrogen conc. (%)		Phosphorous conc. (%)		Total uptake (kg/fed)		No. of Spikes $/m^2$	Spike average weight (g)	wt. of 1000 grains (g)
Interactions		Grain	Straw	Total	Grain	Straw	Grain	Straw	N	P			
60 kg N/fed	Zero S (Control)	1577	2226	3803	1.689	0.394	0.385	0.094	35.30	8.15	335	1.136	37.06
	300 kg S/fed	1814	2428	4242	1.775	0.416	0.396	0.098	42.11	9.57	367	1.204	38.19
90 kg N/fed	Zero S	1747	2623	4370	1.885	0.416	0.384	0.100	43.78	9.28	359	1.164	37.59
	300 kg S/fed	2038	2883	4921	1.936	0.449	0.405	0.104	52.38	11.26	431	1.133	38.18
120 kg N/fed	Zero S	1915	2881	4796	1.929	0.441	0.366	0.097	49.68	9.79	379	1.204	38.87
	300 kg S/fed	1954	2914	4868	2.079	0.505	0.396	0.108	55.38	10.88	406	1.148	39.68
150 kg N/fed	Zero S	1874	3010	4884	2.432	0.529	0.366	0.122	61.60	10.54	382	1.179	38.44
	300 kg S/fed	2228	3404	5632	2.561	0.570	0.396	0.108	76.39	12.47	450	1.2	41.46
$L.S.D_{0.05}$		151	n.s	n.s	n.s	n.s	n.s	n.s	4.77	n.s	n.s	n.s	n.s

* All plots received 100 kg N/fed organic matter, in form of town wastes, during soil preparation. Each value is a mean of 8 replicates.

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استجابة القمح المزروع في الأرض الرملية الجيرية للأسمدة العضوية وإضافة الكبريت الزراعي الناعم

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الهدف من هذه الدراسة هو تحسين إنتاجية القمح المزروع في الأرض الرملية الجيرية بمحطة تجارب عرب العوامر، محافظة أسيوط وذلك من خلال إضافة الأسمدة العضوية، الكبريت الزراعي الناعم، ومستويات التسميد النيتروجينى المعدني المناسبة. وقد تم تنفيذ ثلاث تجارب زراعيه لهذا الغرض ، اثنتان في شتاء ٢٠٠٥ والثالثة في شتاء ٢٠٠٦.

وقد اختبرت هذه التجارب استجابة القمح لإضافة، أنواع مختلفه من الأسمده العضوية (بدون مادة عضوية – سماد الماشية – سماد الدواجن – سماد القمامة بمعدل ١٠٠ كجم نيتروجين/فدان وسماد الفيناس السائل بمعدل ٥ طن/فدان)، مستويات مختلفه من التسميد النيتروجينى المعدني (٦٠ – ٩٠ – ١٢٠ – ١٥٠ كجم/فدان)، ومعدلات مختلفه من الكبريت الزراعي الناعم (صفر– ٢٠٠ – ٣٠٠ – ٤٠٠ – ٦٠٠ كجم/فدان). وتم قياس نمونباتات القمح و تقدير المحصول (حبوب – قش – المحصول الكلى) وكذلك تقديرالنيتروجين، الفوسفور الممتص ، كذلك ال EC, pH و الفوسفور الميسر بعد ٣٠ و٦٠ يوم من الزراعة و عند الحصاد.

وأظهرت النتائج ان اضافة السماد العضوى فى اى صوره ادت الى زياده فى نمو النباتات والى زياده معنويه او معنوية جدا فى محصول الحبوب ٣٩,٠، ٣٦,١، ٣٢,٠ و ١٤,٣% على التوالي نتيجة إضافة سماد القمامة، سماد الدواجن، سماد الماشية و القيناس. كما أظهرت النتائج ان أضافة الكبريت الزراعى الناعم بمعدل ٣٠٠ :٤٠٠ كجم/فدان، منفردا أو مع إضافة السماد العضوى ادى الى زياده معنويه فى نمو نباتات القمح، ومقدار النيتروجين و الفوسفور الممتص والمحصول الناتج (وقد تراوحت الزياده فى محصول الحبوب بين ١١,٥ و ١٢,٩٩ %)، بالأضافه الى حدوث انخفاض معنوى فى pH التربه وزياده فى الفوسفور الميسر. وكان لاضافة الكبريت الزراعى الناعم مع الأسمده العضويه، خصوصا سماد القمامه، تأثير ايجابي Synergetic effect على زياده محصول الحبوب.

و قد وجد أن المعاملة ٩٠ كجم نيتروجين/فدان هي المستوى الاقتصادي المثالي للتسميد النيتروجينى المعدني لمحصول القمح في الاراضى الرمليه الجيرية بعرب العوامر وذلك مع إضافة المادة العضوية كمصلح ومصدر إضافي للعناصر الغذائية (بمعدل ١٠٠ كجم نيتروجين عضوى/فدان فى صورة سماد القمامه).