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EFFECT OF SOIL AMENDMENTS AND ANHYDROUS AMMONIA APPLICATION AND THEIR INTERACTIONS ON SOME SOIL PROPERTIES AND WHEAT PRODUCTIVITY UNDER SALT AFFECTED SOILCONDITIONS

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ABSTRACT

Rehabilitation of saline–sodic soils is governed by a lot of management schemes which involve mainly addition of chemical ameliorates as gypsum and sulphuric acid "SA". The recent studies recommended the use of practices package that lead to improve soil health and reduce production costs besides increasing soil-water-fertilizer unit uses. Therefore, under saline-sodic soil conditions the current study was planned to compare the effect of gypsum application (75% of gypsum requirements) and sulphuric acid (20% of the applied gypsum) under three levels of N-fertilizer, 70, 90, 110 kg N/fed., in form of anhydrous ammonia "AA" on soil salinity-sodicity status and wheat (*Triticum aestivum L.*, Sakha 93) production. A split block experimental design with three replications was used to evaluate the tested treatments and their interactions. Irrigation water amount during winter growing season was measured to assess water productivity (WP) of wheat crop under various soil treatments. Results showed almost significant effect of soil amendments application and different N-levels and their interactions on the studied soil parameters (EC_e & SAR), wheat yield and its attributes, nitrogen use efficiency (NUE), as well as water productivity. In general, *Results revealed also that, effect of the concerned amendments on ECe, SAR values, plant characters, NUE and WP was higher than those of N-levels.* However, sulphuric acid application resulted in an increase of wheat grain yield, NUE & WP, by about 56% and 25 %, respectively as compared to un-amended and gypsum treatments. With regard to the interaction effect of the applied treatments on the tested parameters results indicated that the highest values of plant parameters, grain yield production, WP and the lowest values of soil salinity/sodicity parameters were recorded with the 110 kg N/fed + SA applications, while, the highest value of NUE was obtained with the combined effect of 70 kg N/fed and SA applications.

Keywords: Salt affected soils, soil amendments, anhydrous ammonia, soil salinity and sodicity parameters, wheat grain yield, nitrogen use efficiency, water productivity.

INTRODUCTION

Productivity enhancement of salt affected soils is a national target to overcome the gap between food demands and production. Therefore, intensive efforts should be made to minimize the chances of developing secondary salinity and sodicity by controlling the improper use and management of land and water resources and to transform them from *environmental burdens into economic opportunities (Qadir et al., 2008).* For this reason, several strategies and techniques have been applied to ameliorate characteristics of salt affected soils as well as improve their productivity, e.g. increasing Ca^{2+} concentration in every step of a successive diluted–leaching series (Muhammed *et al.*, 1969, and Misopolinos, 1985), different leaching schemes under suitable drainage system to reduce salinity level for barley production.

(Khosgoftarmanesh and Shariatmadarih, 2002), phytoremediation for coarse to medium textured soils that are moderately sodic or saline–sodic (Qadir *et al.*, 2005). Also, combination of tillage implements, amelioration material and farmyard manure

(FYM) along with salinity tolerant plants cultivation produced acceptable grain yield and ameliorate saline- sodic soil (Milani *et al.*, 2011).

Various soil chemical amendments such as Ca^{2+} source materials as well as acids and acid formers have been and are being applied to salt affected soils of different texture classes, particularly those containing lime, (Ghafoor *et al.*, 2001 and Abdelhamid *et al.*, 2013) due to its economical efficiency on crop yield production (Zia *et al.*, 2006) and amelioration of salt affected soils circumstances in various parts of world wide (Iqbal *et al.*, 2010 and Ağar, 2011). Several authors declared that increasing Ca^{2+} concentration in soil solution, which is derived either from direct solubility of Ca^{2+} materials or indirectly from acid reaction with $CaCO_3$, has an improvement effect on soil physical characteristics' such as increases of infiltration rates and hydraulic conductivity (Prather *et al.*, 1978), water permeability (Hussain *et al.*, 2001) and reduce dispersion and swelling of clays (Naseri and Rycroft, 2002), resulting in a decrease in soil EC and SAR as well as pH parameters (Kahlon *et al.*, 2012). Also, Amezketa *et al.* (2005) highlighted the effect of Ca^{2+} amendments for preventing soil surface crust formation and protect surface aggregates against raindrop impact besides reducing their wetting rate by decreasing their susceptibility to slaking.

Results of numerous studies stated that reclamation of salt affected soils by chemical amendments applications is highly effective, bringing significant increases in the productivity of the cultivated plants (Hammad, *et al.*, 1989; Zia *et al.*, 2006; Ağar, 2012 and Awaad, *et al.*, 2012).

The relative impact of various amendments such as, (H_2SO_4, $CaCl_2.2H_2O$, $CaSO_4.2H_2O$) or (HCl, $CaSO_4.2H_2O$, OM) and (H_2SO_4, $CaCl_2.2H_2O$, ,$CaSO_4.2H_2O$, FeSO4, $Al_2(SO4)_3$) as well as (H_2SO_4, and three types of gypsum materials) on soils properties were tested, under laboratory condition, by Prather *et al.* (1978), Ahmed *et al.* (1988), Miyamoto and Enriquez (1990) and Amezketa *et al.* (2005), respectively. They found that all applied amendments have an enhancement effect on soil properties, particularly those of acid treatments. Under field experiment trials, several authors pointed out the capability of acid treatments, even at low rates individually or in combination with other soil practices, for improving soil quality, plant growth and crops productivities when compared to other soil ameliorates (Hussain *et al.*, 2001; Kahlown & Mushtaq, 2004 ; Iqbal *et al.*, 2010 and Milani *et al.*, 2011).

Wheat crop is considered one of the most dominant winter crops in the cropping system of Egypt, particularly under salt affected soil conditions. Successful wheat production under such environment depends on, beside the optimum agronomic practices, N fertilization that effectively encourages plants to cope with salinity stress (Shen *et al*., 1994), resulting in increases of plant growth (Barhoumi *et al*., 2010) and yield and yield attributes as well as grain protein content (Zeidan *et al*.,2009). Increasing N level up to 1.5 times of the recommended N dose, in terrace salt affected soil of Sudan, led to increase wheat grains of Debeira and Wadielneel varieties by 24.5 and 18 %, respectively. Also, under salt affected soil, in Egypt, increasing N level up to 125% from the recommended dose (90 N/fed.) recorded the highest grains yield of wheat variety Sakha 93 (Awaad *et al*., 2012).

Anhydrous ammonia (AA) uses, has increased rapidly during last decade as an alternative effective N-material (El-Mneasy, 2002) and inexpensive N fertilizer than other commercial ones (Abdel Kader, 2002). Therefore, it is widely used effectively for fertilizing different crops such as cereal, fiber and field crops as well as vegetable crops grown in soils widely different in their physical and chemical features even those planted in salt affected soils (Ali-Nadia, *et al*.,2002; kineber, *et al*., 2004 and El-Masry *et al*., 2006).

There have been no studies evaluating the combined effect of acid amendment application following anhydrous ammonia (AA) injection and their effects on soil and plant characteristics. Therefore, the objectives of the current work were to highlight the relative impact of gypsum and low rate of sulphuric acid applications and their interactions with different rates of anhydrous ammonia on some soil properties and the response of wheat (Sakha-93) yield and its attributes under salt affected soils conditions.

MATERIALS AND METHODS

A field experiment was conducted in a salt affected farmer's farm at El- Moghtaribeen village, South of El-Husainia plain, El-Sharkia Governorate during the winter season of (2008/2009) to evaluate the impact of two soil amendments namely, gypsum and sulphuric acid, under anhydrous ammonia injected at different rates on some soil characters and wheat productivity. Initial soil samples from the top 0-15cm were collected to determine some physical and chemical properties (Table 1) as described by Richards (1954) and Jackson (1973). Gypsum requirements (GR) of top 0.15m soil layer was also calculated.

Before the experimental set up took place, some practices such as conventional plough (≈ 0.2m depth) followed by sub-soiling at 0.5m, plowing twice at 0.2m depth and finally land leveling were conducted. The experimental area was divided equally into three parts (main plots) by open filed ditches (0.6 - 0.7m depth) to facilitate soil drainage. The spacing between drainage ditches were 20m.

The experiment was laid out in a spilt block design with three replicates having net plot size of 8m x 16m. Before anhydrous ammonia (AA) injections, gypsum treatment at equivalent rate of 75% GR was spread with hand on the sub-plot surface and all tested plots were subjected to mechanical rotovator to maintain good gypsum mixing as well as obtaining fine seed bed. All other agronomic practices were kept uniformly according to farmer practices.

Anhydrous ammonia (82% N), at rates of 70 (NL1), 90 (NL2) and 110 (NL3) kg N/fed (main plots), was injected into a moist soil (20% moisture content) at 0.2m depth using ammonia injector. After one week, wheat seeds (Sakha-93) were sown by drilling at rate of 70 kg/fed. Sulphuric acid (SA) treatment, equivalent to 20% of the applied gypsum, was mixed in two equal doses with irrigation water applied in the 1^{st} and 2^{nd} irrigations. Also, to assess the effect of the tested treatments on water productivity, amounts of irrigation water during wheat growing season were measured by cut-throat flume (10 x 90cm) and calculated as m^3/fed (Early, 1975).

At harvest, plant samples from one m^2 were randomly selected from each plot to measure spikes number/m^2 (Sp/m^2), spike length (SpL, cm), plant height (PLH, cm), and 1000 grain weight (10^3 GW) beside grain weight/m^2 (GW/m^2). Also, soil samples of the surface layer of each plot were collected and analyzed again to evaluate the impact of the studied treatments on soil chemical properties. Moreover, nitrogen use efficiency (NUE) and water productivity (WP) were calculated as described by Dobermann (2007) and Jehangir *et al.* (2007), respectively as follows:

$$\text{Nitrogen use efficiency (NUE)} = \frac{\text{Grain yield (kg/fed)}}{\text{Applied nitrogen (kg N/ fed)}}$$

$$\text{Water productivity (WP kg.m}^{-3}\text{)} = \frac{\text{Grain yield (kg/fed)}}{\text{Applied water (m}^3\text{/fed)}}$$

The collected data were statistically analyzed according to Snedecor, and Cochran (1989).

Table1. Some physical and chemical properties of the examined soil

A:- Physical characteristics.

Particle size distribution			Texture class	Bulk density
Sand %	Silt %	Clay %		
15.0	28.4	56.6	Clay	1.37

B:- chemical analysis

EC_e (dSm^{-1})	pH (1:2.5)	Soluble ions of saturated soil paste extract (mmolc L^{-1})							SAR	$CaCO_3$ %	CEC cmolc kg-1	Avail-N mg kg^{-1}
		Na^+	K^+	Ca^{2+}	Mg^{2+}	HCO_3^-	Cl^-	SO_4^{2-}				
9.7	8.4	68.24	1.77	12.55	26.6	2.15	78.9	28.11	15.42	6.47	42	10

RESULTS AND DISCUSSION

1- Effect of the applied soil treatments on some soil chemical properties after wheat harvesting.

Electrical conductivity (EC_e, dS/m) and sodium-adsorption-ratio (SAR) as sensitive indicators of soil chemical properties expressing changes of soil salinity and sodicity status were used to assess the effect of tested treatments. The initial analysis of soil properties revealed that the soil was saline-sodic with EC_e = 9.7dS/m, SAR =15.42, and pH = 8.4 (Table 1). Figure (1a) illustrates the effect of the applied soil amendments on reducing soil EC_e and SAR values as percentage of their initial soil values. Results showed that, the highest reduction of 43.2% (from 9.7 to 5.51 dS/m) and 31.8% (from 15.42 to10.52) in EC_e and SAR values, respectively, were observed with sulfuric acid treatment, followed by 28.49, 12.51% reduction in EC_e and 22.29, 8.78% in SAR values of gypsum and un-amended treatments, respectively. These findings clearly show that the reduction in EC_e and SAR values of the un-amended treatment may be attributed to the pre-soil tillage practices and applied AA treatments beside the continuous leaching process. Xia *et al.* (2012) stated that chemical characters of the soil were significantly enhanced by soil amendments application. The obtained results were also similar to that obtained by Chaudhry *et al.*, (1989) and confirmed by Milani *et al.* (2011) who reported that more reduction in EC_e and particularly SAR values in the amended plots is due to the replacement of sodium with the added calcium or H_2SO_4 and leaching of soluble salts from amended soil layer. On the other hand, the effect of the applied N-treatments (including the effect of soil amendments) on the reduction percentage of EC_e and SAR values, as compared to their pre-soil analysis, were 32.47, 28.11, and 22.34% as well as 23.61, 21.08 and 18.18%, for N-L_3, N-L_2 and N-L_1 treatments, respectively (Fig. 1b). The obtained results may be a resultant of the combined effect of the plowing practices before the experimental set-up, soil amendment treatments along with AA injection which seemed to stimulate plant growth to be reflected on the concerned properties. These findings came in line with those of Niazi *et al.* (2001) and Ağar (2011)

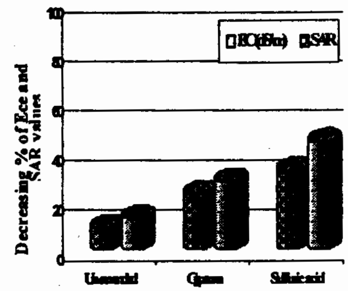


Figure 1a Effect of amendment types on soil EC_e (dS/m) and SAR values.

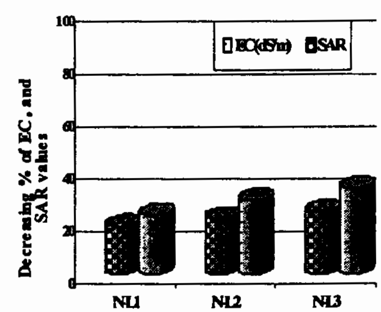


Figure 1b Effect of N levels on soil EC (dS/m) and SAR values.

who indicated that roots of growing plants play a vital role in soil reclamation through its penetrating physical effects in addition to the decay of organic matter present in the soil beside their activities to enhance the solubility of Ca^{2+} sources including natural gypsum and $CaCO_3$ in soil.

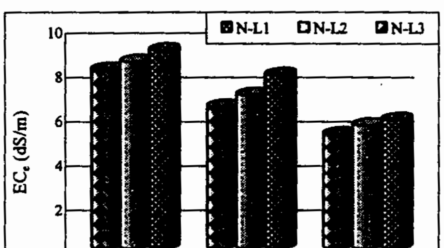
Table (2) Effect of applied soil treatments and their interactions on EC_e (dS/m) and SAR values

Treatments	EC_e (dS/m)	SAR
2-A. Effect of the applied soil amendments		
Unamended (U)	8.49 a	14.07 a
Gypsum (G)	7.06 b	11.98 b
Sulfuric acid (SA)	5.51 c	10.52 c
2-B. Effect of the applied anhydrous ammonia levels		
N-L1	7.53 a	12.61 a
N-L2	6.97 b	12.17 b
N-L3	6.55 c	11.78 c
2-C. Interactions effects of applied soil amends & nitrogen levels		
T1 (N-L1& U)	8.95 a	14.29 a
T2 (N-L2&U)	8.43 b	14.10 bc
T3 (N-L3&U)	8.08 bc	13.81 c
T4 (N-L1&G)	7.84 c	12.56 ab
T5 (N-L2&G)	6.93 d	11.83 d
T6 (N-L3&G)	6.40 e	11.56 e
T7 (N-L1&SA)	5.81 f	11.00 f
T8 (N-L2&SA)	5.56 f	10.58 fg
T9 (N-L3&SA)	5.16 g	9.97 g

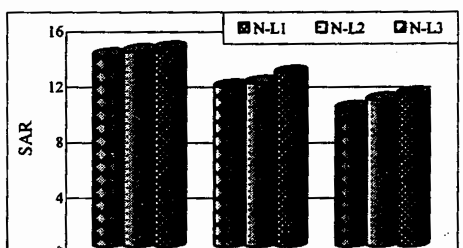
A comparison between the effect of soil amendments and application of different N levels on the studied soil properties revealed that EC_e and SAR values were significantly decreased (Table 2). The SAR values being reduced approximately by 25 and 15% with the ECe values were greatly reduced by 35 and 17% with sulfuric acid and gypsum application, respectively, as compared with the un-amended soil treatment. Whereas, the EC_e and SAR values were significantly decreased by 13 and 7% as well as 7 and 4%, respectively, with the N-L_3 and N-L_2 treatments, respectively, as compared to the low N-rate (N-L_1) treatment. These results may be again declaring the vital role of applied amendments and their capability on reclamation of saline-sodic soils (Chaudhry *et al.*, 1989). Results indicated also that the highest reduction in EC_e and SAR values were recorded with sulfuric acid treatment (SA) as compared with the same values under gypsum treatment as a comparing amendment. These results are confirmed by those of Yahia *et al.* (1975), who reported that sulfuric acid (SA) was more effective than gypsum, especially for soil having higher ESP values, to dissolve soil $CaCO_3$ which in turn enhanced water penetration. Again, such pattern could be explained by the low dissolution rate of gypsum (Richard, 1954), besides decreasing of gypsum dissolution rate as a result of the increasing delay in the Na leached from soil, than that produced from sulfuric–calcite reaction which seemed to encourage the development of CO_2 escaping channels, that could also serve as preferential channels for water infiltration (Amezketa *et al.*, 2005).

Figures 1c&1d represent the interaction effect of the applied soil amendments at different N-levels on the studied soil parameters. Results showed that both EC_e and SAR values of the tested treatments were greatly affected and gradually decreased by increasing AA injection rates along with amendments application. The maximum reduction of EC_e and SAR values was obtained with highest AA application rate of 110kg N/fed in presence of sulfuric acid (T9), while the lowest reduction was obtained with un-amended treatment (T1), which received low AA injection rate of 70kg N/fed. The effect of the studied treatments on EC_e and SAR reductions followed the sequence: $N\text{-}L_3$ + SA (T9) > $N\text{-}L_2$ + SA (T8) > $N\text{-}L_1$ + SA (T7) > $N\text{-}L_3$ + G (T6) > $N\text{-}L_2$ + G (T5) > $N\text{-}L_1$ + G (T4) > $N\text{-}L_3$ (T3) >$N\text{-}L_2$ (T2) > $N\text{-}L_1$ (T1). These results partly are in agreement with those reported by Turner (2004), who found that sodium adsorption ratio at 0-15cm depth decreased linearly with increasing annual applications rates of nitrogen fertilizer (0, 56, 168 and 504 kg N/ha) of anhydrous ammonia (AA). While, EC values increased at the high AA loading rate.

In spite of the aforementioned results, the interaction effect between different soil treatments (amendments & N-levels) on EC_e reduction was almost significant among the concerned treatments, whereas insignificant effect was observed with SAR reduction. However, the differences between this finding and those reported by Turner (2004) should be a resultant of differences in the irrigation technique as well as the experimental set up conditions along with applied amendments which seemed to modify leaching process that significantly contributed for more EC_e reductions.



Figuer 1c. Effect of different soil treatments on soil EC_e (dS/m) values.



Figuer 1d. Effect of different soil treatments on soil SAR values.

2- Effect of applied soil treatments and their interactions on wheat attributes.

Results in Table 3 (A & B) show the effects of soil amendments applications and levels of anhydrous ammonia injection on plant height, number of spikes/m^2, spike length (cm), and 1000 grain weight (g). Applying soil amendments significantly resulted in increasing the aforementioned parameters with corresponding values of 4.42, 15.83, 12.87 and 5.53% as well as 9.8, 40.44, 20.52 and 11.32%, for the gypsum and sulfuric acid treatments, respectively, as compared to un-amended treatment (Table 3-A). Similar results were achieved by Rashid *et al.* (2009) and were confirmed by Abdel Hamid *et al.* (2013).

Table (3) Effect of applied soil treatments and their interactions on some growth parameters of wheat plant.

Treatments	Plant height (cm)	% increase	Number of spikes /m2	% increase	Length of spike (cm)	% increase	1000 grain weight (g)	% increase
3-A. Effect of the applied soil amendments								
Unamended	79.29 c	----	353.98 c	----	9.89 c	----	42.56 c	----
Gypsum	82.80 b	4.42	410.04 b	15.83	11.17 b	12.87	44.91 b	5.53
Sulfuric acid	87.07 a	9.80	497.11 a	40.44	11.92 a	20.52	47.38 a	11.32
3-B. Effect of the applied anhydrous ammonia levels								
N-L_1	79.16 c	----	371.00 c	----	9.95 c	----	43.90 b	----
N-L_2	83.42 b	5.38	420.10 b	13.23	11.03 b	10.89	45.11 ab	2.76
N-L_3	86.58 a	9.37	469.99 a	26.68	12.00 a	20.60	45.83 a	4.40
3-C. Interactions effects of applied soil amends & nitrogen levels								
T1	76.68 a	----	324.33 f	----	8.45 a	----	41.35 a	----
T2	79.53 a	4	358.30 e	10	10.10 a	20	42.72 a	3
T3	81.67 a	7	379.30 de	17	11.13 a	32	43.61 a	5
T4	78.20 a	2	355.67 ef	10	10.23 a	21	44.01 a	6
T5	83.53 a	9	405.67 d	25	10.97 a	30	45.07 a	9
T6	86.67 a	13	468.67 b	45	12.30 a	46	45.66 a	10
T7	82.60 a	8	433.00 c	34	11.17 a	32	46.35 a	12
T8	87.20 a	14	496.33 b	53	12.03 a	42	47.55 a	15
T9	91.40 a	19	562.00 a	73	12.57 a	49	48.23 a	17

They reported that soil amendments significantly improved plant characters compared to un-amended treatment.

Regarding the effect of N-fertilizer, it was clear that increasing N-doses of anhydrous ammonia resulted in a significant increase in the studied wheat parameters (Table 3-B). The increasing percentage in the concerned parameters were 5.4, 13.2, 10.9 and 2.8% with N-L_2 (90 kg N/fed), whereas those obtained with N-L_3 (110 kg N/fed) were 9.4, 26.7, 20.6 and 4.4% as compared with the low N-rate of 70 kg N/fed (N-L_1) in same sequences.

These findings come in line with those early reported by Novoa and Loomis (1981) and recently confirmed by Zeidan *et al.* (2009), who found that raising N-fertilizer level from 60 to 90 and doubling N level from 60 to 120 kg N/fed was accompanied by a significant increase in wheat yield and yield attributes. They ascribed these findings to the promotion effect of N on vegetative growth which favored the metabolic process, hence, increased number of spikes/m^2, spike characters, number of grains/spike and 1000-grain weight. They also added that, increasing N-level led to increase merismatic regions and stimulate auxiliary buds (crown) of wheat plant to initiate more tillers per plant.

With regard to the interaction effect of soil amendments and anhydrous ammonia levels (Table 3C), except for number of spikes/m^2 parameter which exhibited significant differences among the combined effect of studied treatments (T1:T9), no significant differences were observed between the other plant characters. Results showed that, the highest increasing percentage of 19, 73, 49 and 17% for plant height, number of spikes/m^2, spike length (cm) and 1000 grain weight (g), respectively, was obtained from the combined effect of 110 kg N/fed + sulfuric acid treatment (T9). Whereas the lowest values of the aforementioned characters were recorded with the un-amended treatment with low AA dose of 70 kg N /fed (T1).

The obtained results revealed also that, the examined plant characters exhibited different responses to the interaction effect of AA injection levels and applied soil amendments which in turn were reflected on crop yield production (Table 3C). The interaction effect on wheat height followed the following sequence: T9 > T8 > T6 > T5 > T7 > T3 > T2 > T4 > T1 corresponding to the highest values of 91.4, 87.2, 86.67, 83.53, 82.6, 81.67, 79.53, 78.29 and 76.68cm, respectively. A relatively similar trend was obtained for the number of spikes/m^2 parameter, exception being observed with T7 (70 kg N /fed + SA) where number of spikes/m^2 values were significantly higher than those recorded with T5 (90 Kg N/fed + gypsum). As for the spike length (cm) parameter, the tested treatments followed a descending order that differed with those attained with plant height & number of spikes/m^2. The obtained order was as follows: T9 > T6 > T8 > T7 > T3 > T5 > T4 > T2 > T1. Also, this trend was observed with the 1000 grain weight (g) parameter except for T6 which was inferior to T7 as well as T3 which was also lower than T4. The previously mentioned results may be summarized as:

1- The examined plant parameters were positively improved by increasing N- levels and in presence of soil amendments particularly with sulfuric acid (SA) application. These results are supported by the findings of Zeidan *et al.* (2009) and Abdelgadir *et al.* (2010) who found that increasing N-levels led to increase plant growth parameters as well as biomass yield of different wheat varieties. Also, under alkali soil conditions, El-Masry *et al.* (2006) found that application of anhydrous ammonia at rate of 100 % of barley N-requirement & sulfur as soil amendment enhanced barley quantity and quality compared to the same N rate in the presence of gypsum.

2- Low rate of AA in presence of SA(T7) seemed to be more effective than application of high rate of anhydrous ammonia (T3) alone and had relatively comparable effect to that attained with T5 (90 Kg N/fed + gypsum) for the studied plant characters. This may be due to the relatively favorable conditions such as decreasing EC_e and SAR of soil values as well as pH, as a result of SA application which seemed to be more retardant for ammonification process (Yusuff *et al.*, 2009) compared to gypsum, hence, more chances for N assimilation by plant.

3- Effect of applied soil treatments and their interactions on wheat grain yield, nitrogen use efficiency (NUE) and water productivity (WP).

The results in Table 4 revealed that grain yield (kg/fed) and NUE (kg grain per kg N supplied) as well as WP kg grain/m^3 were significantly affected by the tested treatments.

Table (4) Effect of applied soil treatments and their interactions on wheat grain yield, NUE and WP.

Treatments	Grain yield kg / fed	NUE	WP
A. Main effect of the applied soil amendments			
Unamended	1822 c	20.52 c	0.83 c
Gypsum	2254 b	25.38 b	1.03 b
Sulfuric acid	2836 a	31.90 a	1.30 a
B. Main effect of the applied anhydrous ammonia levels			
N-L1	1989 c	28.42 a	0.91 c
N-L2	2291 b	25.46 b	1.05 b
N-L3	2631 a	23.92 c	1.20 a
C. Interactions effects of applied soil amends & nitrogen levels			
T1	1589 g	22.69	0.73 h
T2	1791 f	19.90	0.82 g
T3	2085 de	18.96	0.95 ef
T4	1955 ef	27.93	0.89 fg
T5	2230 d	24.78	1.02 de
T6	2577 c	23.43	1.18 c
T7	2424 c	34.63	1.11 cd
T8	2853 b	31.70	1.30 b
T9	3230 a	29.37	1.48 a

NUE: Nitrogen use efficiency WP: Water productivity

The highest increases of about 55.7% in the aforementioned parameters were observed with the SA treatment followed by an increase of 23.7% with the gypsum treatment as compared with the un-amended treatment. This could be attributed to the more favorable soil conditions, the enhancement of soil physiochemical and biological properties besides increasing availability of other nutrients with the application of sulfuric acid than with gypsum treatment. This improvement was reflected on the plant growth parameters (Ryan *et al.*, 1975; Prather *et al.*, 1978; Chaudhry *et al.*, 1989; Milani *et al.*, 2011, and Hussain *et al.*, 2012).

With respect to the applied N fertilizer levels, grain yield and consequently water productivity values were significantly increased with increasing N-levels, while the NUE values decreased with increasing N-levels. The obtained results may be explained according to Zeidan *et al.* (2009) and Moreau *et al.* (2012), who related the increase to the promotion of nitrogen effect on meristematic and photosynthetic activities which directly reflected on plant architecture, carbon acquisition, and finally on grain yield and protein concentration. On the other hand, NUE values seemed to increase significantly with decreasing grain yield at low ammonia injection level. Dawson *et al.* (2008) and Hirel *et al.* (2011) reported similar findings.

As for the interaction effect of the applied treatments (Table 4C) results showed that, both grain yield and WP (kg grain/m^3 of applied irrigation water) were significantly affected by the combined effect of the tested treatments and followed the same trend that was attained with plant growth parameters. The highest values of grain yield (3230 kg/fed) and WP (1.48 kg/m^3) were recorded when AA (anhydrous ammonia) was applied at rate of 110 kg N/fed combined by sulfuric acid application (T9). These findings came in line with those of Jehangir *et al.* (2007) who reported that average field-scale of WP (grain yield per unit of applied water) was estimated at 1.48 kg/m^3 for wheat crop indicating that about 0.675 m^3 of applied water was used to produce one kilogram of wheat grains.. There were no significant differences between grain yield and WP values obtained with T7 (70 kg N / fed + SA) and T6 (110 kg N/fed + gypsum), in spite of the inferiority of its NUE value as compared to that observed with T7 which could be due to the rapid improvement of soil properties (Prather *et al.*,1978, and Sadiq *et al.*, 2003), nutrition status (Ryan *et al.*, 1975, and Chaudhry *et al.*, 1989), as well as more retardant for NH_3 losses as a resultant of SA application (Yusuff, *et al.*, 2009).

Data also reveled that NUE values varied from 18.96 kg grain /kg applied N with T3 (110kg N/fed without amendment application) up to 34.63 kg grain/kg applied N with T7 treatment (70 kg N/fed + SA application).These findings agreed with those of Dobermann (2007) and Vukovic *et al.* (2008) who found that NUE values tend to decrease with increasing nitrogen fertilization levels.

Conclusion

According to the abovementioned results it could be concluded that, applying AA at the rate of 110kg N/fed with sulfuric acid (SA) as soil amendment will achieve rapid improvement of saline sodic soils and obtain

. high wheat grain yield, high NUE, and high water productivity (WP) values under the experimental conditions.

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تأثير اضافة محسنات التربة و الامونيا الغازية والتداخل بينهما على بعض خواص التربة وانتاجية محصول القمح تحت ظروف الاراضي المتأثرة بالأملاح.

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يحكمْ إعادة تأهيل الأراضى المتأثرة بالأملاح عديد من أساليب الأدارة والتى تتضمن بصفة أساسية إضافة محسنات التربة الكيميائية مثل الجبس الزراعى وحامض الكبريتيك. وتوجهت الدراسات الحديثة إلى أستخدام حزمة من التقنيات التى تهدف إلى تحسين خواص التربة وتخفيض تكاليف الأنتاج إلى جانب زيادة كفاءة أستخدام وحدة التربة والمياه والسماد.

ولذلك تحت ظروف الأراضى الملحية الصودية تم التخطيط لهذه الدراسة لمقارنة أثر إضافه كلاً من الجبس الزراعى (٧٥% من الأحتياجات الجبسية) وحامض الكبريتك (٢٠% من الجبس المضاف) تحت ثلاثة مستويات من السماد الأزوتى (٧٠ ، ٩٠ ، ١١٠ كجم نيتروجين/ فدان فى صورة أمونيا غازية) على بعض خواص الأراضى الملحية الصودية وايضاً انتاجية نبات القمح (سخا ٩٣).

أستُخدم تصميم الشرائح المنشقة في ثلاث مكررات لتقييم أثر المعاملات والتداخل بينها. وتم قياس كمية مياة الرى المضافة أثناء موسم النمو الشتوى للمحصول لتقييم كفاءة إنتاجية وحدة المياه للمعاملات المختلفة.

أظهرت النتائج ان إضافة محسنات التربة أو مستويات التسميد الأزوتى المختلفة أوالتداخل بينهما كان له تأثير معنوى على خواص التربة (درجة التوصيل الكهربى ونسبة الصوديوم المدمص) وعلى إنتاجية محصول القمح ومكوناته وكذلك على كلا من كفاءة أستخدام وحدة السماد والمياه.

بصفه عامة، اُوضحتْ النتائج ايضاً أن تأثيرإضافه المحسنات السالفة الذكرعلى قيم درجة التوصيل الكهربى ونسبة الصوديوم المدمص وخواص النبات وكذلك كلا من كفاءة أستخدام وحدة السماد والمياه كانت اعلى مقارنة بتأثير التسميد الازوتى.

وجديراً بالذكر، إن معاملة حامض الكبريتيك أدت إلى زيادة قدرها ≈ ٥٦% و ٢٥% فى إنتاج محصول الحبوب وكل من كفاءة إستخدام "وحدة المياه والسماد" مقارنة بكلا من معاملتى الكنترول والجبس"على التوالى". أما فيما يختص بالتداخل بين المعاملات،أظهرت النتائج ان أعلى القيم لخصائص النبات وإنتاجية محصول الحبوب و أقل القيم لمقاييس الملوحة والقلوية للتربة سُجلتْ مع إضافة ١١٠ كجم نيتروجين /فدان + حامض الكبريتيك. بينما اعلى قيمة لكفاءة أستخدام وحده السماد حُققتْ مع إضافة ٧٠كجم نيتروجين/ فدان + حامض الكبريتيك.

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