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On- Farm Soil Management Practices for Improving Soil Properties and Productivity of Rice and Wheat under Salt-Affected Soils at North Delta, Egypt

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FIELD TRAILS were conducted at Sakha Agricultural Research Station (El-Hamrawy Farm), Kafr El-Sheikh Governorate in salt affected soils. Growth cycle included rice and wheat. Rice was applied for three successive seasons (2013-2013/2014 and 2014).The soil was treated with gypsum, mole drain, farmyard manure and biofertilizer combined with different sources of nitrogen (urea, ammonia gas and ammonium sulphate). The highest rates of salt leaching were achieved with the application of gypsum combined with the injection of ammonia gas followed by the application of gypsum plus urea or gypsum plus urea and biofertilizer. The soil sodicity decreased after three seasons with all treatments combined with different nitrogen sources. Application of gypsum combined with the construction of mole drain at 4 m spacing, ammonia gas, farmyard manure and biofertilizer had the highest value of infiltration rate at the end of the growth cycle compared with the values before starting the experiment, while the application of gypsum plus biofertilizer and urea produced the lowest infiltration rate. The bulk density and total porosity were positively affected by the application of gypsum, mole drain combined with ammonia gas, farmyard manure and biofertilizer. The application of gypsum plus farmyard manure and ammonia gas or mole drain at 4 m spacing combined with biofertilizer, farmyard manure and ammonia gas increased the yield and irrigation water use efficiency of rice and wheat.

Keywords: Salt-affected soils, Kafr El-Sheikh Governorate, Biofertilizer, Mole drain, Rice, Wheat

Introduction

Soil salinity and sodicity are the major problems in the arid and semi arid regions. In these areas there are increased potentials of low productivity of crops. The old cultivated land especially the low lying lands adjacent to the irrigation canals are subjected to secondary salt accumulation attributed to shallow saline groundwater caused by flooding irrigation system, without adequate drainage system (Pessarakli, 2010). Adverse physical properties, low water permeability, osmotic effect, ionic imbalance and specific ion toxicity are the main harmful salinity and sodicity effects which inhibit plant growth and development (Chen et al., 2010). Improving salt affected soils may be achieved using different practices such as sub soiling, mole drain, soil amendments, farm manure and biofertilizer. These previous practices are important tools for improving crop productivity and soil properties in salt affected soils at the North Delta.

Mole drain is considered as an intermediate system between surface drainage and subsurface drainage. Many researches have reported positive effects of applying mole drain system especially at heavy clay salt affected soils (El-Sabry et al., 1992 and Walter & Bishay, 1992). The mole drains network filled back with sand and application of gypsum and farm manure were the best combination treatments to obtain favorable physical and chemical properties since they improved the infiltration characteristics of soil better than empty moles and led to the lowest values of salinity and sodicity in all sites at EL-Hamol District, Kafr El Sheikh Governorate. Constructed mole drains perpendicular to open drain accelerated downward water movement to the depth of mole plow (Moukhar et al., 2000 and Antar et al., 2008). Also, subsurface tillage treatments seemed to be effective in lowering soil salinity, sodicity and bulk density (Aiad et al., 2012). Sub soiling at 2 m spacing with addition

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of 110 kg N /fed., gave the highest production of wheat and maize crops (El-Sanat, 2012). The installation of sandy moles at 3m spacing was more effective in leaching of soil salts comparing with that with or without sub soiling.

However, application of gypsum and sub soiling under tile drainage of 25 m spacing reduced the soil salinity value of soil surface with the percentage of 20 and 55.36% of the initial state during two successive seasons , respectively (El-Shnawany et al., 2000). The best amelioration processes used in salt affected soils at the north Delta for reducing soil salinity and bulk density and increasing the infiltration rate, hydraulic conductivity, aggregation parameters, as well as, dry matter of sorghum crop were application of gypsum requirements and organic manure at the rate of 20 m^3 /fed. under sub soiling to 60 cm depth (El –Sanat, 2003). Also, application of organic manure tends to increase the grain yield of maize. This effect is probably determined by the initial yield and / or the organic C effect that may cause gradual improvements in soil organic carbon and its physical properties (Zhang et al., 2009). Inoculation with *Bacillus bolymxya* increased total aggregates and the aggregate size distribution, possibly due to exopolysaccharides (Mohamed et al., 2011). Agricultural production in salt affected soils to a large extent suffers from insufficient organic matter. It is well established that the growth inhibition and the adverse effects induced by salinity can be alleviated by proper fertilization and water management (Chen et al., 2010). Global fertilizers prices doubled by 2007 as farmers applied more fertilizer to maximize production and to replenish nutrient depleted soils. This fact encouraged the researchers to use other forms of fertilizers, such as anhydrous ammonia, that are efficient and cost effective. Darusman et al. (1991) observed that the comparisons of anhydrous ammonia, ammonium nitrate, urea and urea – ammonium nitrate solution in four Kansas soils at N rates 112 – 224 kg ha^{-1}showed no differences among N fertilizers on soil acidification . Also, no effects on soil physical properties were observed after 20 years of annuals application of these N sources. Also, Tisdale et al. (1999) reported that several long - term studies have shown no differences among N sources included anhydrous ammonia on soil physical properties. Siam et al (2012) found that the plant height of maize and dry weight per plant were positively affected with applied ammonia gas levels in combination with micronutrients mixture treatments as foliar application. The objective of this study is to investigate the effect of different field soil amendments on yield of rice and wheat, some soil properties and irrigation water use efficiency in salt affected soils at the North Delta, Kafr El-Sheikh Governorate.

Materials and Methods

Field trails were conducted at Sakha Agricultural Research station (EL-Hamrawy Farm) Kafr EL-Sheikh Governorate in salt affected soils. Growth cycle included rice, wheat and rice was applied for three successive seasons (2013-2013/2014 and 2014). The soil was treated by gypsum, mole drain, farmyard manure and biofertilizer combined with different sources of nitrogen (urea, ammonia gas and ammonium sulphate). The main objectives of the study were to develop and asses on farm interventions that improve soil quality, crop production of diverse farming system and increase crop productivity under salt affected soils. The experimental area is 1.76 ha and located at 31 05 13.8 latitude and 30 56 10.6 longitude. Soil samples were collected before cultivation of the experiments, and some physical, chemical properties and some characteristics of the tested farmyard manure were determined according to page (1982) and the data are presented in Tables 1, and 2.

The design of the experiments is a randomized complete block design with four replications.

The treatments were as follows:

1- Control, fertilized by urea (C+U).
2- Gypsum+ ammonia gas (G+AG)
3- Gypsum + biofertilizer +urea (G+B+U)
4- Gypsum +ammonium sulphate (G+AS)
5- Gypsum + Urea (G+U)
6- Gypsum + Farm manure +ammonia gas (G+F+AG)
7- Gypsum +mole drain+ ammonia gas+ farm manure + biofertilizer (G+M+AG+F+B)
8- Gypsum +mole drain+ ammonia gas (G+M+AG)
9- Gypsum +mole drain +urea (G+M+U)
10- Mole drain + Urea (M+U)

The field trails were started by rice variety Giza 177 in 2013 (summer season), followed by wheat variety Giza 168 in 2013/2014 (winter season) and rice variety Giza 178 in 2014 (summer season) in the same experimental area. The dates of cultivation for three crops were on June, 19, 2013, Nov. 22, 2013 and June 25, 2014. The dates of harvesting were on the end of October, 2013, beginning of May 2014 and end of October 2014. Before transplanting the rice crop , some plots were plowed, mole drain was established at 4m spacing and 50 cm depth, gypsum requirements (3ton/fed.) were incorporated with soil surface. Also, all experimental area was leveled by laser land leveling. All plots were fertilized by Ca superphosphate (15.5% P_2O_5) at a rate of 100kg/fed and received nitrogen fertilizer in different forms at a rate of 70 kg N/fed . All agricultural practices were carried out as recommended by the Ministry of Agriculture. Anhydrous ammonia was obtained from Soils, Water and Environment Research Institute (Ammonia Injection Unit, Kafr El-Sheikh). Ammonia gas was injected at 10-15 cm depth from soil surface. The rice and wheat plants were removed and separated into grain and straw yield in (ton/ha).

Irrigation water applied

The water discharge was measured using a weir installed in the main irrigation canal and calculated according to the following equation: $Q = 1.84\ LH^{1.5}$

where: Q is the water discharge (m^3/sec.), L is the weir width and H is the head above the weir.

Rice was irrigated every 4-6 days, while wheat was irrigated when 60% of available water was depleted.

Irrigation Water Use Efficiency (IWUE)Was calculated according to the following equation:

$$IWUE = \frac{\text{Grain yield (Kg/ha)}}{\text{Amount of water applied } (m^3/ha)}$$

TABLE 1. Mean physical properties of the studied soil before conducting the experiment

Soil depth cm	Particle size distribution (%)			Texture	Bulk density (Mg/m^3)	Total porosity (%)	Soil moisture characteristics (%)		
	Sand	Silt	Clay	clayey			FC	PWP	Aw
0-15	17.7	27.1	55.1	clayey	1.27	52.00	45.66	24.27	21.39
15.30	18.4	283	53.3	clayey	1.35	48.91	44.17	22.92	21.25
30-45	18.5	294	52.1	clayey	1.37	48.34	39.42	21.42	18.00
45-60	20.2	30.3	49.5	clayey	1.39	47.74	37.17	21.26	15.91

TABLE (2-1). Mean chemical properties of studied soil before conducting the experiment

Soil depth (cm)	pH	ECe (dS/m)	Soluble cations (meq/L)				Soluble anions (meq/L)				SAR
			Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	
0-20	8.76	7.02	14.7	8.4	47.7	0.67	-	7.28	33.37	30.82	14.04
20-40	8.8	8.55	17.92	10.27	58.05	0.82	-	5.1	40.65	41.32	15.46
40-60	8.94	6.07	12.75	7.28	41.25	0.6	-	4.43	28.87	28.58	13.03
mean	8.83	7.21	15.12	8.65	49	0.7	-	5.6	34.3	33.57	14.21

TABLE (2-2). Some characteristics of the tested Farmyard manure

EC (1:10, dS/m)	pH (1: 10)	Organic matter (%)	Organic carbon (%)	C/N ratio	Total N (%)	Available nutrients (mg/kg)		
						N	P	K
3.46	6.15	46.50	27.09	20.33	1.49	1571.6	164.07	874

Some soil physical and chemical properties

Soil samples were collected from different layers , *i.e.,* 0-15, 15-30, 30-45, 45-60 cm before and after harvesting each crop to determine soil physical properties and from different layers ,*i.e.* 0-20, 20-40 and 40-60 cm before and after harvesting each crop to determine soil chemical analysis according to Richards (1954) and Jackson (1967). All data statistically analyzed according to the method described by Gomez and Gomez (1984).

Results and Discussions

Effect of soil management practices on yield of rice and wheat

Effect of different soil management practices in combination with different nitrogen sources on yield of rice and wheat grown in salt affected soils were given in Table 3. Data indicated that application of either G+F+AG or G+M+ AG +F+B, to the soil had a marked effect on rice grain and straw yield and wheat grain and straw. This increment in yield may be due to the positive effects can be mitigated by incorporation of gypsum or other amendments that liberate calcium at the upper portion of the soil profile .Whereas, the lowest values were obtained from the control treatment. The decrease in the yield of different crops may be due to variation in soil salinity along the studied area since rice plants are very sensitive and wheat are moderate sensitive to salinity. It is worthy to mention that the increment of yield due to application of G+AG+F may be attributed to significant increases in available P and K content which had a higher positive effect on microbial biomass, and soil health (Dutta et al., 2002). These results are consistent with those obtained by Yadav and Chhipa (2007), they found that higher grain and straw yields were obtained under combined application of 20 ton /ha farmyard manure + 50% gypsum requirements . Also, these findings are consistent with Siam et al. (2012) who found that maize yield was significantly affected with application of ammonia gas levels in combination with foliar application micronutrients which had superiority than the other treatments. It can be concluded that the application of gypsum requirements, establishing mole drain at 4 m spacing with 50 cm depth combined with farm manure, ammonia gas and biofertilizer enhanced the productivity of salt affected soils at North Delta.

TABLE 3. yield of rice and wheat as affected by soil management practices in salt affected soils of El-Hamrawy farm, Kafr El-Sheikh, Egypt

Treatments	Rice (ton/ha) 2013 season		Wheat (ton/ha)		Rice (ton/ha) 2014 season	
	Grain	Straw	Grain	Straw	Grain	Straw
C+U	5.12cd	8.59ab	5.8d	8.00bc	6.61f	8.85c
G+AG	3.59g	6.76c	4.41f	7.38e	6.93cde	10.00c
G+B+U	5.28c	8.35b	6.00bc	8.21b	7.00c	9.90c
G+AS	4.93de	8.21b	5.23e	7.77cd	6.78c	10.02c
G+U	4.64e	8.43b	4.64f	7.62d	6.82d	9.33d
G+F+AG	6.81a	8.26b	6.59a	8.48a	8.44a	11.14a
G+M+B+AG+F	5.78b	9.42a	6.11b	8.33ab	7.31b	10.31b
G+M+AG	4.19f	7.26c	4.44f	7.48de	6.96cd	9.50d
G+M+U	4.83de	8.66ab	4.46f	7.57d	7.38b	10.12bc
M+U	5.07cd	8.38b	5.72d	7.86c	7.43b	9.92c

Effect of soil management practices on amount of water applied:

The data in Table 4 indicate that the application of G+AG received the lowest amount of irrigation water applied compared with the control and another treatments under cultivation of rice followed by wheat and rice. Also, the stated treatments save the highest amount of water applied under cultivation of three crops.

The treatments can be arranged in the following descending order according to water saving under cultivation of three crops; G+AG > G+B+U > G+U > G+As > M+U > G+F+AG > G+M+AG > G+M+U > G+M+AG+F+B.

Effect of soil management practices on irrigation water use efficiency

Average values for irrigation water use efficiency of rice, wheat and rice as affected by soil management practices are presented in Table 5.

It was noticed that either application of G+F+AG or application of G+M+AG+F+B gave the highest value of irrigation water use efficiency compared to other treatments. It is worthy to mention that the values of irrigation water use efficiency for wheat were higher than those under rice. The values of irrigation water use efficiency could be arranged in the following descending order as; G+F+AG > G+M+AG+F+B > G+B+U>M+U > G+AS > G+U = G+M+U > C+U > G+M+AG> G+AG.

TABLE 4. Effect of soil management practices on amount of water applied (m^3/ha)

Treatments	Rice 2013	Water saving (%)	Wheat 2013/2014	Water saving (%)	Rice 2014	Water saving (%)
C+U	11063.2	-	5539.30	-	13501.7	-
G+AG	9635.91	12.9	4829.30	12.82	10929.1	19.05
G+B+U	9858.9	10.88	4902.40	11.50	10681.6	21.11
G+AS	9984.1	9.75	4830.00	12.8	11317.6	16.18
G+U	9916.3	10.37	4827.40	12.85	11388.4	15.65
G+F+AG	10216.1	7.65	4901.20	11.82	12033.6	10.87
G+M+B+AG+F	10659.1	3.65	5025.20	9.28	12427.1	7.96
G+M+AG	10316.6	6.75	4922.40	11.14	11851.6	12.22
G+M+U	10356.8	6.39	5077.95	8.33	12263.5	9.17
M+U	10189.3	7.90	4917.00	11.23	11497.6	14.84

TABLE 5. Irrigation water use efficiency (kg/m^3) of Rice and Wheat as affected by soil managements practices

Treatments	Rice 2013		Wheat 2013/2014		Rice 2014	
	grain	straw	grain	straw	grain	straw
C+U	0.46	0.78	1.04	1.44	0.49	0.66
G+AG	0.37	0.70	0.91	1.53	0.63	0.91
G+B+U	0.54	0.85	1.22	1.68	0.66	0.93
G+AS	0.49	0.82	1.10	1.61	0.60	0.89
G+U	0.47	0.85	0.96	1.58	0.60	0.82
G+F+AG	0.67	0.81	1.34	1.73	0.70	0.93
G+M+AG+F+B	0.54	0.88	1.22	1.66	0.59	0.83
G+M+AG	0.41	0.70	0.90	1.52	0.59	0.8
G+M+U	0.47	0.84	0.88	1.49	0.60	0.83
M+U	0.50	0.82	1.16	1.16	0.65	0.86

Effect of soil management practices on soil properties

Bulk density and total porosity

As shown in Table 6 , the soil management practices positively affected the soil bulk density and the total porosity in the soil layers (0-60 cm). The greatest total soil porosity was found in the soil treated with M+AG+F+B cultivated with rice - wheat – rice rotation .The decrease in the bulk density and the increase in the total porosity may be due to improving soil aggregates. Also, the soil with rotation improves the soil physical quality. On the other hand, the application of G + M +F led to increase bulk density and decrease the total porosity. This effect is probably determined by the initial yield and – or the organic carbon effect that may cause gradual improvement in soil organic carbon and its physical properties (Zhang et al., 2009). Also, Mahamed et al. (2011) added that the inoculation with *bacillus bolymxya* increased total aggregates and the aggregate size distribution, possibly due to exopolysaccarides.

Basic infiltration rate

For an efficient soil water management information on infiltration characteristics is of vital importance. Soil infiltration rate can be reduced by compaction or by surface sealing . It decreases rapidly with the time and after few hours becomes near constant, then called basic infiltration rate. Referring to the data in Table 7, it could be observed that the application of G+M+AG+F+B had the highest value of basic infiltration rate (1.8cm/hr) after harvesting the last crop compared to the obtained value before the experiment. It is worthy to mention that under salt affected soils, the excess salts keep the clay in saline soils in a flocculated state so that these soils generally have good physical properties. Structure is generally good and tillage characteristics and permeability to water are even better than those of non-saline soils. However, when leached with low salt water, some saline soils tend to disperse resulting in low permeability to water and air, particularly when soils are heavy clays.

Soil salinity and sodicity

Data in Tables 8 and 9 illustrated that, after three seasons it could be observed that the highest rate of salt leaching was achieved with application of G+AG followed by application of G+U+B. It is worthy to mention that soil salinity has significantly decreased as affected by different soil amendments and nitrogen sources. The data also reveal that the values of soil sodicity after three seasons were decreased with all soil amendments in combined with different nitrogen sources. Moreover, the application of G+M+U had a great effect in decreasing the soil sodicity by 50 % compared to initial value.

TABLE 6. Effect of soil management practices on Soil bulk density (Mg/m^3) and total porosity (%) after cultivation

	After rice, 2013		After wheat, 2013/2014		After rice, 2014	
Treatments	**Bulk density**	**Total porosity**	**Bulk density**	**Total porosity**	**Bulk density**	**Total porosity**
C+U	1.31	50.66	1.24	53.4	1.26	52.64
G+AG	1.29	51.23	1.18	55.66	1.29	51.32
G+B+U	1.27	52.17	1.2	54.62	1.27	52.07
G+AS	1.34	49.34	1.18	55.57	1.31	50.57
G+U	1.33	49.91	1.16	56.14	1.28	51.7
G+F+AG	1.29	51.51	1.12	57.65	1.22	54.15
G+M+AG+F+B	1.19	55.09	1.14	56.89	1.2	54.72
G+M+AG	1.26	52.45	1.14	56.89	1.3	50.94
G+M+U	1.39	47.55	1.26	52.36	1.27	52.26
M+U	1.32	50.1	1.24	53.12	1.23	53.68

TABLE 5. Irrigation water use efficiency (kg/m³) of Rice and Wheat as affected by soil managements practices

Treatments	Rice 2013		Wheat 2013/2014		Rice 2014	
	grain	straw	grain	straw	grain	straw
C+U	0.46	0.78	1.04	1.44	0.49	0.66
G+AG	0.37	0.70	0.91	1.53	0.63	0.91
G+B+U	0.54	0.85	1.22	1.68	0.66	0.93
G+AS	0.49	0.82	1.10	1.61	0.60	0.89
G+U	0.47	0.85	0.96	1.58	0.60	0.82
G+F+AG	0.67	0.81	1.34	1.73	0.70	0.93
G+M+AG+F+B	0.54	0.88	1.22	1.66	0.59	0.83
G+M+AG	0.41	0.70	0.90	1.52	0.59	0.8
G+M+U	0.47	0.84	0.88	1.49	0.60	0.83
M+U	0.50	0.82	1.16	1.16	0.65	0.86

TABLE 8. Effect of Soil managements practices on soil salinity (dS/ m) at depth (0-60 cm) after cultivation

Treatments	Before Experiment	After rice,2013	After wheat ,2013/2014	After rice,2014	Rate of change %
C+U	7.21	4.18	5.54	2.92	-
G+AG		5.58	5.35	3.91	45.80
G+B+U		5.50	4.98	4.39	39.10
G+AS		5.40	5.14	5.07	29.70
G+U		6.42	5.79	4.34	39.80
G+F+AG		4.84	5.11	4.92	31.80
G+M+AG+F+B		5.31	5.08	4.57	36.62
G+M		6.19	5.65	5.33	26.10
G+M+U		5.21	5.07	4.47	38.00
M+U		6.08	5.05	4.69	34.90

TABLE 9. Effect of soil management practices on SAR at depth (0-60 cm) after cultivation

Treatments	Before Experiment	After rice,2013	After wheat ,2013/2014	After rice,2014	Rate of change %
C+U	17.34	11.75	8.88	7.65	-
G+AG		12.38	8.56	12.12	45.8
G+B+U		10.72	8.56	9.04	39.1
G+AS		10.34	7.54	10.62	29.7
G+U		10.6	8.5	11.01	39.8
G+F+AG		9.42	7.02	11.58	31.8
+F+B G+M+AG		9.88	8.72	10.75	36.62
G+M		11.44	9.83	8.95	26.1
G+M+U		9.26	10.12	8.67	38
M+U		12.69	10.34	9.27	34.9

Conclusion

Improving the salt affected soils through different practices such as sub-soiling, mole drain, water management and addition of soil amendments had become important for salt affected soils in the north Delta. Application of gypsum, construction of mole drain at 4m spacing and 50 cm depth combined with ammonia gas, farmyard manure and biofertilizer significantly increased the yield of some field crops. Under different types of salt affected soil, some soil properties were positively affected by construction of mole drain at 4m spacing combined with soil amendments. Also, the construction of mole drain combined with soil amendments had a great effect on irrigation water use efficiency under condition of salt affected soils in North Delta.

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