Tagungsbeitrag zu: Jahrestagung der DBG, Kommission VIII
Titel der Tagung: Unsere Böden – Unser Leben
Veranstalter: DBG
Termin und Ort der Tagung: 5. – 10. September 2015, München
Berichte der DBG (nicht begutachtete online Publikation)
http://www.dbges.de

Can potassium fertilization, soil amendments and land leveling ameliorate rice production under salt affected soils conditions?

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Abstract

The significance of nutrient and water and its sustainability was and still one of the most emerging issues in agriculture. Therefore, it should be considered the maintenance, improvement and efficiently utilization of nutrient and water resources. In present work, the effect of land leveling, soil amendments including gypsum and/or compost application and K- fertilizer on rice production under salt affected soils conditions have been studied. The results showed that the highest yield of grain and straw of rice was obtained with using K-fertilization, land levelling rate 0.05 % of surface slope in the presence of gypsum plus compost application. Furthermore, this study suggests that, the efficiency of irrigation application increased from about 60 (for control) to 65 and 78 % for land leveling with 0.0 and 0.05 % slope, respectively. That means, the water loss rate from irrigation were 43, 36 and 32 %, respectively using the previous land leveling treatments. Thus, about 17 % from the applied water for irrigation could be saved under 0.05 % slope. On the other hand, the highest decrease rate in soil salinity (EC, dS m^{-1}) and alkalinity (sodium absorption ratio, SAR) was 26 and 20 %, respectively for the traditional land leveling or the farmers' practices. Therefore, sustainable rice crop production should be managed to overcome the soil salinity and alkalinity under low land rice cultivation, improving soil quality and its fertility.

Key words: *Rice, potassium, gypsum compost, land leveling*

I. Introduction

In arid and semi-arid regions, soil salinity and sodicity are common problems under these conditions. Moreover, in these soils, there are increased potentials for hazardous accumulation of salts and the productivity of crops and plants is severely limited under such conditions. Therefore, the reclamation process of salt affected soils may be achieved by using different practices such as tillage, water, crop and chemical and/or fertilizer amendments. These previous practices are increasingly important tools for improving crop productivity in many these regions **(1,2,3)**. Whereas, it is reported that salt affected soils represent about one billion hectare in more than 100 countries **(4,5)**. In general, the crop production may be adversely affected by salt toxicity, poor soil physical/chemical properties and nutritional imbalances under salt-affected soils conditions **(6,7)**. There are several reports focused on the practices concerning salt affected soils including management **(8,9)**, using compost **(10,11)**, land leveling **(12),** gypsum **(4,13)** and potassium fertilization **(1,13)**. It is worth to mention that, the salt affected soils represent 9.1 % from the total area in Egypt **(9)**. Therefore, the aim of this study was to highlight on the ameliorative effects of potassium fertilization, soil amendments including gypsum and/or compost and land leveling on the rice production under salt affected soils in Kafr El-Sheikh, Egypt.

II. Materials and Methods

A field experiment was carried out in Sedi Salem city, Kafr El Sheikh Governorate (31° 27- latitude and 30° 78- longitude).

During 2013 and 2014 seasons, the effect of land leveling, soil amendments and K-fertilization on production of rice as well as their effect on water and salt balance and productivity of salt affected soils (**Table 1**). This experiment was conducted in split – split plot design, with four replicates. The main plots were land leveling including the traditional land leveling, dead level (0.0 %) and 0.05 % slope. Whereas, the sub plots were soil amendments (i.e., without addition, 12 Mg gypsum ha^{-1}, 24 Mg compost rice straw and 12 Mg gypsum plus 12 Mg compost rice straw and sub-sub plots were for potassium fertilizer (without application and 120 kg K_2O ha^{-1}). The plot area was 200 m^2 (20 m in length and 10 m width). The previous cultivated crop was wheat. Rice (variety: Sakha 104) was planted in the nursery in the 1st week of May, transplanted on June, 10 and harvested on October, 5 2013 and 2014, respectively. The soil characterization was clayey texture and **saline sodic soil** (EC, pH, SAR and ESP were **6.36 dS m^{-1}, 8.6, 13.35 and 15.85 %**, respectively). Yield of rice crop was determined by for each plot using a 1 m x 1 m sampling frame in the experiment. Ten plants were chosen randomly from this frame to determine the grain and straw yield and weight of 1000 grain.

Table1: The experimental design

Treatments	
Land leveling	
L1	Traditional land leveling
L2	Dead level (0.0%) slope
L3	0.05% ground surface slope
Soil amendments	
Control	Without application
Gypsum, G	12 Mg (ton) gypsum ha^{-1}
Compost, C	24 Mg compost rice straw ha^{-1}
G + C	12 Mg gypsum plus 12 Mg compost ha^{-1}
K – application	
K0	0 kg K_2O ha^{-1} (without application)
K120	120 kg K_2O ha^{-1} (50 kg K_2O fed^{-1})

Soil samples were air-dried crushed and passed through 2 mm sieve for the chemical analyses according to **Page et al. (14)**. The results were analyzed statistically by a General Linear Model procedure and 2 way analysis of variance (ANOVA) using Cohort computer program according to **Gomez and Gomez (15)**. All calculations were made on a dry weight basis.

III. Results and Discussion

It could be remediated salt affected soils using chemical agents, including gypsum (**$CaSO_4$. $2H_2O$**), calcium chloride (**$CaCl_2$. $2H_2O$**), calcite (**$CaCO_3$**) and organic matter or amendments (farmyard manure, compost, green manure and municipal solid waste). These previous materials are successful approaches that have been implemented worldwide, being simple, low cost, and effective **(16)**. In a field experiment, some chemical (gypsum) and organic (compost) amendments as well as K-fertilization were applied for rice cultivated under land leveling practices. The addition of K-fertilizer significantly increased both of grain and straw yields of rice comparing with control (**Table 2**). The highest values of these yields **(8.23 and 8.28 Mg ha^{-1}, respectively)** were recorded under the application of soil amendments (compost + gypsum). Under land leveling treatments, the highest values of grain and straw yields were achieved using slope of 0.05 % in ground surface. On the other hand, using of the precision land leveling (0.0 and 0.05 % slope) may be contributed to save amount of irrigation water. Thus, about 17 % from the applied water for irrigation could be saved under 0.05 % slope. It is found that the efficiency of irrigation application increased from about 60 (for control) to 65 and 78 % for land leveling with 0.0 and 0.05 % slope, respectively (**Fig. 1**). That means, the water loss rate from irrigation were 43, 36 and 32 %, respectively using the previous land leveling treatments. Concerning the ameliorative effects of soil amendments, it is found that, the addition of soil amendments (compost and gypsum) can be reduced the soil salinity and its alkalinity. Whereas, the highest decrease rate in soil salinity (EC, dS m^{-1}) and its alkalinity (sodium absorption ratio, SAR) was 26 and 20 %, respectively for the traditional land leveling or the farmers' practices (**Table 3**).

The current study concludes that, the land leveling practice can be used successively to save irrigation water amount under rice cultivation for a heavy clayey texture in Kafr El-Sheikh (about 50 % clay content). It could be saved till 17 % from applied irrigation water by using land leveling 0.05% ground surface slope (unpublished data). On the other hand, compost amendments can be used to provide essential nutrients (such as N, P and K; 1.89, 1.57 and 1.19 %, as a total content respectively) to rebuild soil physico-chemical properties, and re-establish microbial populations and activities **(10,17)**. The conjunctive uses of compost with gypsum significantly can improve soil physico-chemical properties of salt affected soils as compared to their alone application **(18)**. Therefore, the combined application of organic (like compost) and inorganic (like gypsum) amendments as well as K-fertilizer can be played a significant and ameliorative role in improvement and management of salt affected soils. This combined application could induce an increase in the humus content, nitrogen, and available P and K levels **(19)**. The SAR values were higher for 15–30 cm (13.7) compared to 0–15 cm soil depth (13.3), indicating the migration of exchangeable Na^+ from the top soil layer and accumulated in the lower depth with application of gypsum and compost **(20)**. Under paddy rice growth conditions, the anaerobic conditions with compost also provided higher CO_2, which could increase the amount of soluble Ca^{2+} for soil reclamation **(21)**. Therefore, gypsum application is proven to decrease SAR of salt affected soils (8% alone) but its effect could be enhanced with application of organic amendments like compost **(**about 20 **%; 21)**.

Therefore, it could be recommended that, optimizing reclamation of salt affected soil strategies for high rice crop production and water use efficiency should be followed using K-fertilization, compost and gypsum under land leveling practice to conserve water resource, especially in water limited regions. Furthermore, it could be improved the physical, chemical and biological properties of salt-affected soils by the application of organic and/or inorganic amendments, leading to enhanced plant growth and development. Therefore, the application of these previous amendments for salt affected soils remediation is important for sustainable land use and crop productivity **(16)**.

IV. Acknowledgments

Authors thank the outstanding contribution of STDF research teams (Egypt) and MBMF/DLR (Germany), (Project ID 5310) for their help. Great support from this German-Egyptian Research Fund (GERF) is gratefully acknowledged.

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Table 2: Effect of land leveling, soil amendments, K-application on **rice** yield and its production (mean of two seasons)

Treatments	Grain yield (Mg ha^{-1})	Straw yield (Mg ha^{-1})	1000 grain weight (g)
Land Leveling			
L1	7.29 c	7.56 c	57.9 c
L2	7.70 b	7.89 b	58.0 b
L3	8.01 a	8.02 a	58.2 a
Soil amendments			
Control	7.15 d	7.42 d	57.8 c
Gypsum (G)	7.51 c	7.68 c	58.1 b
Compost (C)	7.75 b	7.89 b	58.2 a
G + C	**8.23 a**	**8.28 a**	**58.1 a**
K-application			
K0	7.22 b	7.46 b	57.9 b
K120	8.11 a	8.18 a	58.2 a

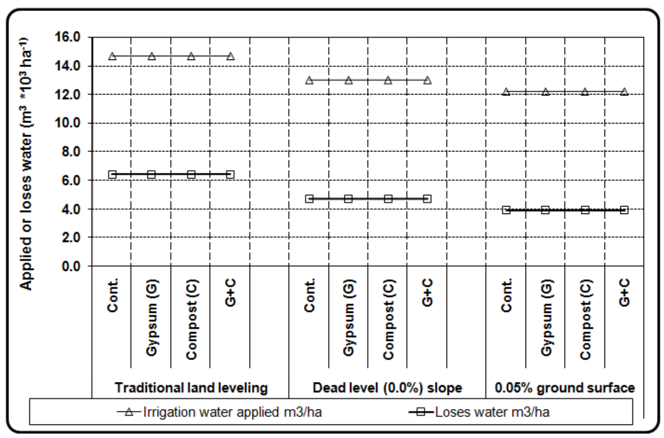

Fig. 1: Effects of land leveling and soil amendments on applied and loses of irrigation water under **rice** cultivation in salt affected soils

Table 3: Soil salinity (EC, dS m^{-1}) and sodium adsorption ratio (SAR) as affected by different treatments before cultivation and after harvesting of rice crop under salt affected soils conditions (mean of two seasons)

Treatments		**Soil salinity (EC, dS m^{-1})**			**Sodium adsorption ratio (SAR)**		
Land leveling	Soil amendments	Before cultivation	After harvesting	Change rate (%)	Before cultivation	After harvesting	Change rate (%)
L1	Control	6.54	6.00	8.26	13.53	12.07	10.79
	Gypsum (G)	6.54	5.10	22.02	13.53	11.17	17.44
	Compost (C)	6.54	5.48	16.21	13.53	11.57	14.49
	G + C	6.54	4.83	**26.15**	13.53	10.83	**19.96**
L2	Control	6.54	6.28	3.98	13.53	12.37	8.57
	Gypsum (G)	6.54	5.63	13.91	13.53	11.67	13.75
	Compost (C)	6.54	6.09	6.88	13.53	12.17	10.05
	G + C	6.54	5.15	**21.25**	13.53	11.20	**17.22**
L3	Control	6.54	6.47	1.07	13.53	12.13	10.35
	Gypsum (G)	6.54	6.06	7.34	13.53	12.43	8.13
	Compost (C)	6.54	6.35	2.91	13.53	12.57	7.10
	G + C	6.54	5.68	**13.15**	13.53	11.73	**13.3**

Where: L1 represents the Traditional land leveling, whereas **L2** and **L3** represent the slope in soil surface with 0.0 and 0.05 % (0 and 5 cm for each 100 m, respectively).