PADDY RICE CULTIVATION IN IRRIGATED WATER MANAGED SALINE SODIC LANDS UNDER RECLAMATION, EGYPT[1]

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ABSTRACT
Several mega-projects are undertaken by the Government of Egypt to divert considerable amounts of drainage water to newly reclaimed areas after blending with the Nile water. One of those projects is El-Salaam Canal, which will put 620,000 feddans (650,000 acres) of new lands in the northeastern Nile Delta and northern Sinai Peninsula, under irrigation. Establishment of guidelines for drainage water reuse in agriculture and land reclamation to avoid risk on the soil-plant system, and human health is required. Accordingly, three pilot areas of approximately 1200 Feddan were selected in the El-Salam Canal command area, west of Suez Canal: which are El Rowad, Tarek Ibn Ziad, and al Eman villages to establish these guidelines.

Soils of the study areas are saline sodic soils, which need special reclamation strategies. Average soil salinity and sodicity values are 20 dS/m and 25 respectively. Infiltration rate is small and water table depth is less than 0.75 m below ground. These conditions are not ideally suitable for paddy rice cultivation or at least may decrease crop yield by 75%. But a well controlled water management system including daily surface irrigation followed by rapped field drainage could lead to high paddy rice crop yield, compared with the average rice yield in Egypt which is the highest in the world. Land reclamation experience suggested two years of salt leaching and soil amendments are required to manage crop cultivation and get positive income. The objective of this study is to describe the monitoring program, the water management and the cultivation steps which are set up to derive the guidelines that should lead to high production of paddy rice yield in such saline sodic soils.

1 BACKGROUND
El-Salaam Canal Project aims at mixing drainage water with fresh water from Damietta Branch of Nile River Delta. Equal volumes of fresh and drainage water will be mixed to irrigate an area of 620,000 acre of newly reclaimed lands (NAWQAM, 1999). Salinity of El-Salam Canal irrigation water is in a range of 0.8 to 2 dS m^{-1}. Irrigation water sodicity expressed in sodium adsorption ratio (SAR) is ranged between 8 and 11.

1.1 Study Area
The study area is El-Rowad reclamation village, which lies within the south El-Hussania plain of El-Salam Canal project area. The geodesic coordinates are 31 02 49 N Latitude and 32 00 06 E Longitude. Total reclamation area is 2000 acres. Annual rainfall approximately 33 mm. Maximum temperatures during July-August are 41-to 46 ?C and minimum temperature during December–January is 8 to 19 ?C. The land is slightly above the level of Lake Manzala (M.S.L.). Field survey was conducted in years 1999 and 2000 to establish a baseline data for the study area as a part of the National Availability and Water Quality Management project, (NAWQAM). Twenty monitoring and sampling locations were selected to make soil, water and crop surveys.

Soils are described as saline sodic soils since salinity of the top 1.0 m is more than 4 $dS.m^{-1}$ and the SAR is greater than 15-mil eq. L^{-1}. There is a clay cap, which is sometimes near to the ground surface. The soil texture in the area is loamy clay-to-clay extending to more than 2.0m. The calcium carbonate content is low and the high sodicity leads to wetness of the soil profiled at some locations. (Khalifa and Rashed, 2001). A Summery of the soil chemical analysis data is presented in Table 1.

Table 1 Summary of the soil samples chemical analysis El-Rowad area in 1999.

	pH	EC (dS/m)	Cations (mg./liter)				Anions (mq/ liter)				ESP
			Ca	Mg	Na	K	HCO_3	SO_4	CL	SAR	
Min	7.10	3.64	9.1	16.2	61.5	0.7	2.2	27.3	38.7	11.64	13.7
Avg	7.47	25.9	26.8	68.6	265.3	2.0	2.8	143.3	216.9	39.7	35.7
Max	7.80	71.04	89.7	295.0	575.0	3.3	3.9	296.7	749.1	77.5	53.1
SD	0.16	11.50	17.4	43.7	101.3	0.9	0.4	55.9	127.1	11.4	6.7

(Source: Khalifa, and Rashed , 2001])

Salinity and chemical analysis of irrigation, drainage and ground waters in winter 1999 and summer 2000 are presented in Tables 2, 3 and 4. The groundwater table depth is shallow at some locations (varies from 0.0-1.05m) with an average of 0.47 m below ground surface.

Land use of El-Rowad reclamation area during 1999 shows nearly fallow lands in winter season except few spots of barley and wheat while paddy rice cultivation was abundant in the summer. It is used during reclamation and salt leaching stages. The average rice crop yield during 1999 was 2.9 ton / acre, (Khalifa, and Rashed, 2001). The yield is not so much less than the average rice crop yield in the old lands of Nile Delta.

Table 2 Chemical parameters for El-Rowad pilot area irrigation water on 1999.

Season	pH	EC	TDS	Ca	Mg	Na	K	HCO_3	SO_4	Cl	SAR	SAR_{Adj}
Winter	7.2	1.8	1455.7	5.7	5.6	10.0	0.3	5.4	10.3	5.9	4.2	10.8
Summer	7.5	1.5	940.8	3.0	2.4	8.4	0.3	4.9	4.2	5.1	5.1	13.0

(Source: Khalifa, and Rashed, 2001)

Table 3 Chemical parameters of El-Rowad pilot area drainage water on 1999.

Season	pH	EC	TDS	Ca	Mg	Na	K	HCO_3	SO_4	Cl	SAR	SAR_{Adj}
Winter	7.3	10.3	6431.6	10.4	22.4	71.5	1.0	5.0	32.9	67.3	17.7	47.6
Summer	7.3	5.9	3776.0	11.4	7.5	35.0	0.7	5.0	13.8	35.8	11.4	32.2

(Source: Khalifa, and Rashed, 2001)

Table 4 Chemical parameters of El-Rowad pilot area groundwater on 1999.

	pH	EC	Ca	Mg	Na	K	HCO_3	SO_4	Cl	SAR	SAR_{Adj}
Min.	6.4	30.7	28.9	67.4	115.5	0.2	4.0	46.6	77.5	6.8	20.6
Avg.	6.8	72.8	90.9	245.1	872.1	0.7	6.8	387.7	813.9	68.8	201.1
Max.	7.3	109.4	148.0	488.7	1387.5	3.8	8.6	707.7	1462.5	95.3	291.1
S D	0.2	26.9	31.4	129.4	370.4	0.8	1.37	209.4	372.1	22.1	110.9

(Source: Khalifa, and Rashed, 2001)

1.2 Paddy Rice Culture

1.2.1 Climate

Paddy rice (*Oryza sativa*) needs optimum climate conditions to grow during its different growing stages. However, different varieties of rice can grow along a wide climatic range from tropical regions, subtropical to slightly moderate tempered regions (Yun, 2001). Temperature, solar radiation and precipitation influence rice yield by directly influencing the physiological processes involved in grain production.

1.2.2 Soil

Rice is growing in a soil that has a variety of water content ranging from waterlogged, poorly drained to well drained. The term, rice soil or paddy soil are not precise enough to be used to indicate the type of soil group, (USDA, 1975). Most types of soil can be used to grow rice if water conditions are favorable. For rice cultivation soils of fine to medium texture are most commonly used. Clays of floodplains and deltas and sandy textured soil are suitable for rice cultivation

1.3 Effects of Salinity and Sodicity on Soils

The suitability of soils for rice cropping depends heavily on the readiness with which they conduct water and air (permeability) and on aggregate properties, which control the friability of the seedbed (tilth). Poor permeability and tilth are often major problems in irrigated lands (FAO, 1992). Contrary, sodic soils may have greatly reduced permeability and poor tilth. Rhoades, 1982 made a relation between the SAR of the topsoil and the salinity of the irrigation water that infiltrate this topsoil. He found that there is a threshold values for SAR of topsoil and salinity of irrigation water above, which the irrigated lands may in unlikely permeability hazard (Rhoads,1982). Comparing his findings with El Salam Canal situation (EC irrigation water = 1.5 dS m^{-1} and SAR of top soil, the area is generally may suffer from permeability hazards.

1.3.1 Effects of salinity and sodicity on Rice as a plant

Excess salinity with the plant root zone has a general deleterious effect on plant growth since it causes reduction in transpiration and growth rates. Each crop has a tolerance limit in growth against salinity. Ayers and Westcot, 1976 summarized soil salinity tolerance levels for different crops including paddy rice. The salt tolerances of various crops are expressed in terms of relative yield (Y), (threshold salinity value (a), and percentage decrement value per unit increase in excess of the threshold (b), where soil

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salinity is expressed in terms of EC_e in dS/m^{-1} as in eqn (1) (Maas and Hoffman [8]). Table 4 shows Salt tolerance and relative crop yield for paddy rice.

$$Y_r = 100 - b\ (EC_e - a) \qquad (1)$$

Table 5 Some Referenced Salt tolerance and relative crop yield for paddy rice.

Soil Salinity EC_e dS/m	3	4	5	7	8	9	10	11
Relative Crop Yield % (Maas and Hoffman [8])	100	88	78	45	35	25	16	5
Relative Crop Yield % (Ayers and Westcot [7])	100	90	75	45	--	--	--	10

Mass, 1986 reported salt tolerance values for rice at emergence and during growth to maturity classifying rice as a sensitive crop. The ECe values of 3.6 dS m-1 is the tolerant soil salinity value for 100 % relative crop yield while it is 18 dS m-1 in emergent stage for 50 % relative crop yield. The soil salinity values were measured at the submerged soil in paddy rice fields which is less saline the same soil if it is dry or even partially saturated.

As for sodicity, sodic soil conditions may include calcium as well as other nutrients, deficiencies because the associated high pH and bicarbonate conditions repress the solubility of many soil minerals, hence limiting nutrient concentration solutions and, thus, availability the plant. Tolerance of paddy rice to Exchangeable-Sodium Percentage (ESP) may reach 20-40 % describing rice as a moderate sensitive crop against sodicity (James et al.,1982).

Rice does not tolerate excess salinity: rice yield is halved at 6–7 dS/m salinity in saturated soil paste extract (Mass and Hoffman [8]). However, a satisfactory yield of rice can be achieved even with 20–25 dS/m in topsoil saturated extract, if submergence is maintained throughout the crop growing season (van Alphen, 1975).

1.4 Rice Cultivation at El Salam Canal Reclamation Area

Rice is the main summer crop in El Salam Canal project area. It is the most favorable crop all the Egyptian North Delta due to several reasons. First, rice is the best summer serial crop in the local market. Second, paddy rice is efficient in salt build up protection in the arid water logged soils located at the relatively low lands in the Nile Delta and the surrounding areas. Third, rice is easier for farmers in agricultural activities such as land preparation, adding fertilizers, best management practices comparing with the other summer crops such as cotton and corn.

1.4.1 Land preparation for rice cultivation

The following steps were practiced in order to prepare farms for rice cultivation as well as salts leaching:

Land leveling is practiced at the very beginning using either non-leaser tractors or leaser-equipped tractors. The leveling time was 5 to 8 tractor hours per acre.

Each farm was divided laterally into 12 to 14 sections each section has dimensions of 100 * 15 to 100 * 12 meters. These sections are separated by field canals or field open drains which have about 0.9-m depth. The field open drains helps in the drainage of the poor permeable sodic soils.

Gypsum is added as amendment tool for sodicity problems. Small gypsum dozing rate is practiced (not more than 1 ton/acre) since gypsum is expensive for poor farmers. The required dozing rate is about 2 to 3 tons/acre for 3 years period according to the SAR and ESP of the soil. Deep bloughing is practiced after gypsum adding to introduce it at the deeper soil layers where the sodicity is dominant and forming a hard pan at the plants root zone.

Alternate or cycling salt leaching is practiced two months prior to rice cultivation. Flooding farms with 10 to 20 cm of water and leave it on farm for 2 to 5 days while the drainage outlets are blocked. Draining the field water rapidly to the field open drains and consequently to the collector drain and leaving the drainage system opened for 2 to 3 weeks. Deep wide cracks are observed at the drained fields and those cracks are developed with time passed after drainage. Repeating the leaching cycle on the coming month and leaving the field for complete drying in order to prepare for rice planting.

Rice water seeding is started on mid April, one month earlier than the transplanted rice in the Nile Delta. Precise water control must be achieved and more seeds are required than the transplanting method.

Alternate daily irrigation and drainage for rice field is practiced. Water is irrigated on the early mornings for 2 to 3 hours filed filling time. Field water is left 10 cm above ground for the whole daytime. After sunset, filed drains are opened to get rid of the field water and drainage is continued until the next morning. A new irrigation cycle started on the net day. The cyclic paddy rice irrigation continued for the 110 days of rice cultivation period.

On mid August, the irrigation-drainage cycling is stopped leaving farms to dry as a preparation for mechanical or manual rice harvesting.

2 MATERIALS AND METHODS

Twenty farms of 100 acres total area were selected of the total 2000 acres in El Rowad village to monitor rice cultivation practices. Irrigation water was measured at each plot irrigation inlet using both current meters and volume and time methods. The measurements were taken daily at noontime. Current meters were used at the irrigation inlet pipes while bucket and stopwatch was used directly with the lifting irrigation pumps. Each measurement was repeated 3 times and the average was taken in order to minimize human error. For each plot, collective irrigation quantities were calculated from multiplying the average discharge value times the irrigation period. A field survey was done at each farm in order to measure the net cultivated area which is the total farm area subtracted from the area of filed irrigation and drains canals. Water consumption (m^3/acre) was obtained by dividing total field irrigation quantities by farm net area.

The physical and chemical measurements were made for soil and irrigation water as well. Soil sampling was done just before rice seeding and just after its harvesting. Soil samples were collected from the selected 20 locations at four depths; 0-25, 25-50, 50-75, and, 70-100 cm.

Rice crop productivity measurements are used to determine the level of soil reclamation and the economics of crop production. Crop productivity parameters measured in the field include cropping pattern or the distribution of crops grown in the pilot areas is assessed during each cropping season. Yield samples are taken in the field at harvest time. Three crop samples were selected randomly at each monitoring site. An area of 3.0 * 3.5 m was harvested and fresh and oven dried weighted and then manually rice crop obtained. This area forms 1/400 of acre. Two kg of the harvested rice samples was analyzed for moisture content estimation. The fresh samples were weighted directly after harvesting, then dried at 105 C electrical oven for 24 hours to obtain the dry weight ant the moisture content.

3 RESULTS AND DISCUSSIONS

3.1 Water management at rice fields

Paddy rice water consumptions at 20 farms at El Rowad reclamation area are shown in Table 5. In addition, farm irrigation water quantities are presented. The irrigation was done daily for about 2 hours per acre for the 110 days of rice growing stages. The mean rice water consumption at El Rowad area is 5215 m^3/acre that is almost equal to the average rice water consumption at Nile Delta matured agricultural lands (5000 m^3/acre). This is attributed to using a shorted age rice variety at El Rowad area that lasts 120 days comparing with the 150 days rice variety at the Delta lands. In addition the new lands has only surface on farm drainage while the Delta lands are provided with subsurface drainage in addition to some field surface drains. Daily irrigation and drainage cycles with efficient field water management consume the same irrigation quantities in rice fields of old lands in Nile Delta. Efficient field water management is done by surrounding the field with earth ridges 10 cm higher than pounding rice water that stops surface runoff. Also well controlled drainage outlets help in water saving by preventing surface drainage. The short period between field draining and re-irrigating keeps soil in saturation phase and prevent water evaporation from field surface.

Table 5. Some Statistics parameters for farm irrigation water quantity of El-Rowad reclamation area.

N	Minimum	Average	Maximum	Standard Deviation	SD/Avg.
17	4231	5215	6583	719	0.138

3.2 Effects of Irrigation Water on soil and plant

Referring to Table 1, irrigation water salinity is 1.8 and 1.5 during winter and summer seasons receptively which classified as a permissibly irrigation water but with considered leaching fraction. Several imperial equations were used to estimate leaching fraction of planted root zone in different soil types depending mainly on irrigation salinity values. FAO, (1992) mentioned examples such as;

$$LF = EC_i / (2.2 * EC_e) \qquad (2)$$

Where LF is irrigation leaching fraction of plant root zone, EC and EC are salinity of irrigation water and average root zone soil salinity in dS/m respectively.

Applying this equation for farm 347 in El Rowad area as an example gives that required LF for 1999, 2000, and, 2001 is 4, 7, and, 11% respectively while the referenced values for leaching root zone of loamy clay soil is 30% as reported by Hoffman et al.(1983). Accordingly these equations are not suitable for estimating LF of such severs saline soils. These equations were adopted for leaching accumulated salts within plant root zone resulted from evaporation that occurred after irrigation activities (Hoffman et al.1983). Meanwhile, our case is leaching huge mount of salts accumulated at the root zone and 1 m layer beneath affected with severely shallow saline groundwater.

Water sodicity may described as low sodic irrigation water during winter season (adjustable sodium absorption Ratio, (SAR_{adj} = 10) while it has medium sodic during summer season (SAR_{adj} = 13). The summer irrigation water needs both soil amendments such as gypsum and to increase salts leaching fraction.

3.3 Soil salinity and Sodicity Improvement

Continuous paddy rice cultivation as a summer reclamation practices in addition to the alternate winter salt leaching was practiced since 1999. Figure 1 shows arithmetic average soil salinity of the selected monitoring locations of El Rowad area in 1999, 2000 and 2001. The results are by layers (25 cm apart) as well as an average of the top 50 cm and the top 100 cm of soil.

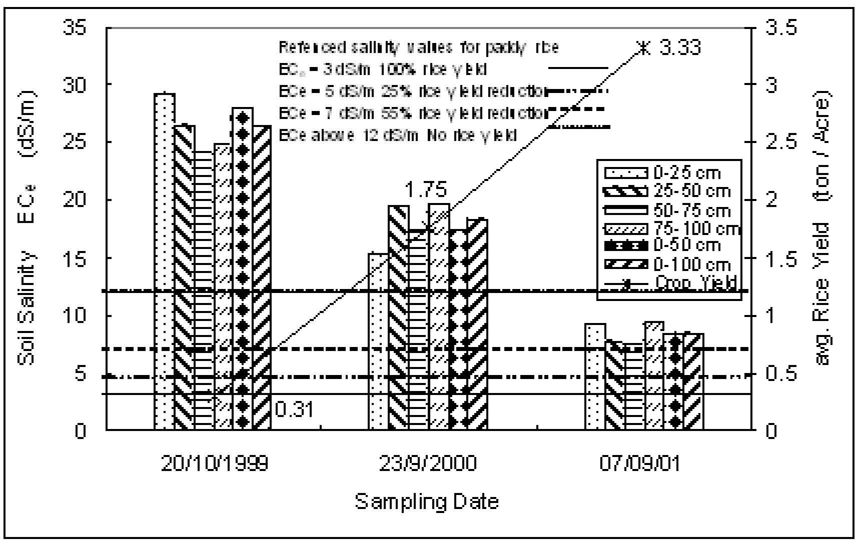

Figure 1 Average rice crop yield for El Rowad reclamation area and the corresponding soil salinity of different layers (referenced threshold salinity values and the % rice yield reduction is mentioned on top).

It is clear that there is a big improvement in the soil salinity during the past 3 years. In 2000, after the second rice season, the salinity of all layers significantly decreased comparing with the 1999 values. The salinity decrease in 0-25 and 25-50 cm layers is 93 % and 45% in 2000 comparing with 1999 respectively. In 2001, after the third rice season, the salinity decreasing continued in all layers comparing with the 1999 values. The salinity decrease in 0-25 and 25-50 cm layers by 222 % and 236% in 2000 comparing with 1999 respectively and by 63% and 136% in 2001 comparing with 2000 respectively.

Rice tolerates exchangeable sodium because it grows well in standing water, but the infiltration rate needs to be sufficient to leach out toxic substances (USDA, 1975). In addition, as rice has a shallow root system, it can grow well if sodicity is reduced in only the top few centimeters of soil. Excessive uptake of elemental sodium can be toxic at high ESP.

3.4 Rice crop yield

Results of crop yield of 11 farms of El Rowad reclamation area is shown in table 6 during three summer seasons, 1999 -2001. The corresponding soil salinity (EC_e) that was measured just after rice harvesting values is also presented against each crop yield. Results show that in 1999, rice crop yield is almost zero or rice was failed to be cultivated or to complete its growing stages. When soil salinity excesses 20 dS/m, rice seeding faced high salinity stresses during the germination stage and 2 farms of 11 manage to get rice grain at the season end.

Observations showed that about 70 % of rice seeds was died after 10 to 15 days from planting and first germination. Some farmers attempted to re-seed the died spots 3 weeks later but useless. Other farmers transplant rice at the failed spots from the dense well germinated adjacent spots and about 50 % manage to grow up. The whole rice field including the dead rice spots was continued for irrigation and drainage daily as a tool for salts leaching.

On the second season (2000), soil salinity levels decreased significantly as shown in Table 6 due to continues leaching during winter season. Eight farms of eleven manage to cultivate paddy rice with a crop yield ranged from 1.5 to 3 tons/acre with a soil salinity ranging from 7 to 18 dS/m in the top 25 cm soil layer. The other 3 farms failed to complete the growing season and rice died during germination stage and even after a rice-transplanting trail. It is obvious since soil salinity of the topsoil is still above 20 dS/m in those farms. On the third growing season (2001) all the 11 farms managed to cultivate paddy rice. The rice crop yield increased significantly comparing with the 2nd season of 2000 by a range of 40% to 270%. Some farms reach the national rice production (3.8 tons/acre) while the others have yield values of 75% of the national rice yield records. Rice yield at El Roawd reclamation area and the corresponding soil salinity measures was not comparable with the referenced threshold soil salinity limits for paddy rice.

Table 6 Average Soil Salinity of Some Farms of El Rowad Area at 0-25 and 0-50 cm Layers with the Corresponding Rice Crop Yield Shown in Brackets.

Plot No.	EC_e (0-25 cm)				EC_e (0-50 cm)		
	1999	2000	2001		1999	2000	2001
319		14 (2.5)	6(3.4)			14 (2.5)	6 (3.4)
328	23 (0.0)	7 (3.0)	6(3.8)		23 (0.0)	6 (3.0)	5 (3.8)
330	30 (0.5)	13 (1.5)	13(2.7)		31 (0.5)	16 (1.5)	15 (2.7)
332	20 (1.5)	14 (2.5)	10(3.6)		10 (1.5)	17 (2.5)	10 (3.6)
336	26 (0.0)	14 (0.0)	7(2.7)		20 (0.0)	21 (0.0)	6 (2.7)
347	20 (0.0)	18 (2.8)	6(3.8)		18 (0.0)	10 (3.8)	6 (3.8)
349	15 (0.0)	12 (2.0)	10(3.8)		17 (0.0)	15 (2.0)	8 (3.8)
351	18 (0.0)	12 (3.0)	6(4.0)		17 (0.0)	15 (3.0)	9 (4.0)
355		20 (0.0)	9(4.6)			22 (0.0)	7 (4.6)
370	17 (0.0)	11 (2.0)	9(2.8)		54 (0.0)	12 (2.0)	9 (2.8)
392	69 (0.0)	20 (0.0)	21(1.5)		63 (0.0)	32 (0.0)	19 (1.5)

A 100% relative rice yield (3.8 ton/acre) is obtained at salinity values of 6 to 9 dS/m or three times the referenced values. Also a 55 % reduction in rice yield (1.9 ton/acre) was obtained at salinity levels of a 9-17 dS/m comparing with the reference tolerance value of 7dS/m. Average rice crop yield for El Rowad reclamation area and the corresponding soil salinity of different layers are shown at Figure 1. Reduction in rice yield comparing with the national rice production is 92%, 54%, and, 12% during 1999, 2000 and 2001 respectively. This reduction is accepted since the soil salinity measures are much more the threshold values of paddy rice. Comparisons between relative rice crop yield at El Rowad area and some referenced data against soil salinity is shown in figure 2. Logarithmic trend of the percentage relative rice yield and the soil salinity shows that 60 to 70 % relative yield was achieved at 15 to 20 dS/m soil salinity comparing with 6 dS/m for both references (Ayres, and Westcot, 1976) and (Maas and Hoffmann, 1976). The relation between rice crop yield and soil salinity at El Rowad Area is:

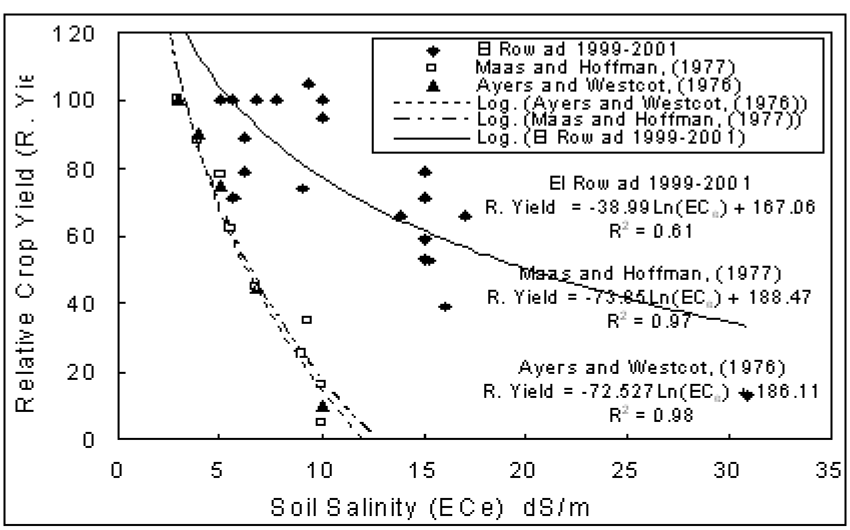

Figure 2 Comparisons between Relative Rice Crop Yield at El Rowad Area and Some Referenced Data Against Soil Salinity.

$$\textit{Relative Rice Yield} = -38.99\ Ln\ (EC_e) + 167.06 \qquad (n=20,\ R^2 = 0.61) \qquad (3)$$

The high rice yield at high salinity and sodicity levels may be attributed to many reasons. The main reason is the daily irrigation and drainage practicing for the growing period of the plant. There has been little good systematic research on the thermal properties of lowland fields and their effect on rice. The available information indicates that throughout the crop season in temperate regions of India, the ponded water in a rice field maintains soil temperature at 7.5 cm depth at about 5 ° C higher than the continuously flowing water and significantly increases the grain yield of rice (Kanwar et al, 1978).

Field preparation or puddling process is the second factor of planting rice in saline sodic soil. Puddling influences pore size distribution and thus water retention and transmission. Puddling also explains how the water consumption of paddy rice of El Rowad area is very close to the average rice water consumption of the Nile Delta old lands. In a silty clay loam soil (El Rowad area), puddling decreased transmission pores by 50%, increased storage pores by only 23% and decreased residual pores by 3% over non-puddled soil. Compaction resulted in a drastic decrease in transmission pores (95%), an increase in storage pores (48%), and a further decrease in residual pores (8%) (Acharya and Sood, 1992). This may help in decreasing water consumption by reducing vertical drainage but it has negative impact on leaching deeper soil layers below rice root zone.

4 CONCLUSIONS

Paddy rice is a suitable crop for land reclamation is saline sodic soil that has salinity values less than 20 dS/m. the crop yield is comparable with the yield of the matured lands of Nile Delta. Rice planting is not economic during reclamation stages when thee average soil salinity of root zone exceeds 20 dS/m. Alternate salt leaching is preferable up to reaching the 20 dS/m soil salinity. The obtained relation between relative rice crop yield and soil salinity of El Rowad reclamation area may be used to at similar saline sodic soil types with similar agricultural practices.

Daily irrigation-drainage cycles with controlled filed water management helps to protect rice from severe saline soil especially during early growing stages. Good field preparation such as puddling, leveling and smoothing as well as maintaining farm ridges is essential for rice cultivation in saline under reclamation soils. Condensed field drainage with 10 to 15 m spacing is essential for rapid leaching of pounded water in paddy rice fields. The referenced threshold rice crop yield values with soil salinity are not applicable of the cases of cultivation in high saline under reclamation soils.

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