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Chemical Compositions and Salinity Development in Paddy Soil as Affected by Irrigation Intervals of Mixed Water under Saline Soil

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Abstract: The northern Nile Delta, in Egypt, is an area with extensive saline soils with high ESP and EC. It was necessary to study the behavior of soil chemical compositions and soil salinity development under different irrigation intervals of mixed water (50% fresh + 50% drainage water). Two field experiments were carried out through two seasons. Four irrigation intervals viz; 3, 6, 9 and 12 days were applied under saline soil. The soil was chemically analyzed both before sowing and at the end of the season. Electrical conductivity, pH, Na, Cl, K, Ca, Mg, SO_4, Na/K ratio and Na/Ca ratio as well as grain yield and its components were determined. The irrigation intervals significantly affected all the above mentioned characters except pH and Na/Ca ratio. Prolonging irrigation intervals markedly increased soil salinity, Na, Cl, K, Ca, Mg, SO_4, Na/K ratio and SAR. Continuous irrigation succeeded in improving soil salinity and reducing its soluble salts. At the same time, grain yield was dramatically affected by prolonging irrigation interval in parallel with soil deterioration. The rice grain yield significantly decreased as irrigation intervals were prolonged up to 12 days. The data collected on salinity development during three months indicated that the prolonging irrigation intervals up to 12 days significantly increased the salinity level, particularly during July. High temperature and high evaporation during July led to high salts concentration in the soil. These results confirmed that the prolonging irrigation interval (12 days) under saline soil is unfavorable for rice growth. Looking at the rising of rice yield and soil chemical composition, it can be observed that flooding every 3 or 6 days should be followed to prevent the soil chemical composition from degenerating and unbalance nutrients.

Key words: Salinity development, saline soils, prolonging irrigation, rice grain yield

INTRODUCTION

Soil salinity and water shortage are two of the major obstacles to rice production in the tropics and subtropics areas. The Northern Nile Delta, in Egypt, is an area with an extensive saline soil with high exchangeable sodium percentage, which may reach 70% and EC of more than 8 dS m^{-1}. Total potential of water resources in the Northern Nile Delta is less than that required meeting domestic, urban and industrial use. Recycled wastewater or drainage water is the only source of additional water for agriculture to compensate the lack of normal irrigation water (Haytham *et al.*, 2005).

Salt-affected soils are major reason for low agricultural productivity in irrigated areas of Egypt and elsewhere in the world. Salinity problems arise when excessive concentrations of sodium chloride, sodium carbonate, sodium sulfate or salts of magnesium are presented. The excessive root zone salts affect on either a number of plant physiological processes through its effect on soil properties or osmotic pressure. This excessive of salts effects of high ionic concentration and their toxic effects within the plant tissue (Chapman, 1974). Moreover, soil salinity modifies plant nutrient status by 1) lowering Ca/Na; 2) inducing Ca deficiency; and 3) deficiencies of phosphorus, zinc, manganese and other minerals due to the restricted solubility of these ions under alkaline conditions. Under saline environments, plants take up excessive amounts of Na at the cost of K and Ca (Aslam *et al.*, 1996). Low Ca/Na in the saline environments in turn impair selectivity of root membranes, which results in passive accumulation of Na in root and shoot (Ahmad and Wyn Jones, 1985). Saline-sodic soils are specifically known to differ widely in Ca/Na, which require Ca in the external growth medium for maintaining selectivity and integrity of cell membranes (Willert *et al.*, 1972). Moreover, the proportions of Ca in the external solution that is adequate under non-saline conditions but becomes inadequate under saline-sodic conditions and may result in reduced yield due to ion imbalance. Different

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strategies, such as reclamation, drainage, water control and soil amendments could be used to overcome salinity problems. Furthermore, preventing the influx of salt water into root cells, leaching salts out of the root zone and correcting soil toxicities and nutrient deficiencies can help to convert saline lands to croplands. Rice is the possible crop for saline lands because the standing water that is necessary for leaching the salts causes chemical changes in the soil (Ponnamperuma, 1981).

Continuous irrigation in the saline soil is generally recommended to help leach salt by drainage from the root zone particularly with poor quality of water. It was found that irrigation by fresh water at 4 days interval gave the highest yield and received high amount of water, which leached the salts and decreased the value of basic infiltration rate compared with 6 and 8 days intervals (El-Mowelhi *et al.*, 1995; Zayed, 1997). Zayed (2002) stated that any water stress happened during the rice cycle under saline soil conditions reduced the yield and its components. The common reclamation and improvement processes, which applied for the salt affected soils are continuous irrigation in addition to adequate water quality in the presence of a good drainage system (Abo-Soliman *et al.*, 1992; El-Sabry, 1992; El-Serafy *et al.*, 1993). El-Wehishy and Hafez (1998). found that grain yield and yield components of rice significantly decreased by increasing the loading intervals up to 14 days. An interval of poor quality of irrigation water under saline soil has not been taking more attention for studying especially in the Northern Nile Delta in Egypt. The current study aims to investigate the effect of intervals of irrigation system using mixed water on some soil chemical compositions, soil salinity development and rice grain yield. Using irrigation intervals may play an important role in reducing the soil salinity hazards and in increasing rice yield potential in the paddy soil that have been affected by salinity.

MATERIALS AND METHODS

Soil salinity and water shortage in the Northern part of the Nile Delta in Egypt are the main challenges for rice production. The irrigation water used in this study is mixed water (50% fresh+ 50% drainage water). The current study was conducted to explore rice growing under mentioned previously conditions. Two field experiments were conducted at the farm of El-Sirw Agriculture Research Station during the 2000 and 2001 rice seasons. The average of the two seasons was performed and statistically analyzed. The experiments were laid in randomized complete-block design with four replications. Giza 178 rice cultivar was used in this study. Rice seeds were sown on May 15 in both seasons and seedlings of 25 days age were transferred to the permanent field. Other recommendations for rice growing were followed according to the Ministry of Agriculture, Egypt. Four irrigation intervals viz; 3, 6, 9 and 12 days were used in this study. Each treatment was receiving equal amount of irrigation water every irrigation time by adjust the water head in each plot at 5 cm depth. The irrigation treatments were started 15 Days After Sowing (DAS). The irrigation intervals were spaced tightly from each other by deep channels.

During the rice season, an irrigation water samples were taken at each time of irrigation to determine its salinity and chemical composition. The soil samples were taken from the experimental site from 0-30 cm depth of 30 cm and were chemically analyzed according to Black (1965). The average of what both soil and water samples were calculated (Table 1). To study salinity development during the season, weekly water samples were taken from root zones. Ceramic cup soil solution extractors were placed at a depth of 40 cm and they were distributed in three sample areas of the experimental plots. The soil solution was collected after both of the transplanting and heading stages using a vacuum pump. The soil solution was analyzed for ECs during June, July and August. The average temperatures for each month were recorded (27, 33 and 30°C, respectively). At the end of the season soil samples were gathered from each irrigation treatment. Soil samples were carefully transferred to the Laboratory, dried and ground to very fine particles (2 mm sieved). The data collected on soil were as follows; EC, pH and sodium (Na^+), chloride (Cl^-) potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}) and sulfate (SO_4^-) contents. Also, Na^+/K^+ and Na^+/Ca^{++}

Table 1: Chemical analysis of the experimental site before treatment application

Parameters	Irrigation water	Soil
Sand	-	11.59%
Silt	-	32.93%
Clay	-	55.48%
Texture class	-	Clay
Total N(m mol L^{-1})	0.89	3.2
EC dS m^{-1}	0.95	8.5
PH	8.02	7.22
SAR	3.70	-
ESP	-	18
Soluble anion(m mol L^{-1})		
Cl^-	2.80	33
SO_4^{--}	1.90	38
HCO_3	1.60	-
Soluble Cation (m mol L^{-1})		
Na^+	6.50	55
K^+	5.20	23
Ca^{++}	8.40	32
Mg^{++}	3.60	34

ratios and soil SAR were calculated. The soil EC and pH were measured in a 1:5 soil-water solution using pH and EC meters. Contents of soluble Ca, Mg, Na and K were determined using an Atomic Absorption Spectrophotometer (AAS) and soluble anions were determined according to Salinity laboratory staff US Salinity Laboratory Staff (1954). Concerning to the data related to grain yield and its components; ten main panicles were randomly chosen to determine the number of field grains panicle^{-1}, panicle weight (g), 1000 grain weight (g) and number of panicle hill^{-1}. The central six rows were harvested and threshed to estimate the grain yield. The obtained yield was converted into ton per hectare based on 14% moisture content of grain. The data were statistically analyzed according to Gomez and Gomez (1984). Irrigation intervals were compared for salinity, anions and cations changes in soil as well as grain yield and its components using LSD at 0.05 level of significance.

RESULTS AND DISCUSSION

Soil chemical compositions: Data in Table 2 and 3 showed that irrigation intervals significantly affected the electrical conductivity, sodium, potassium, calcium, magnesium, sulfate and Na/K ratio (Fig. 1). In contrast, the irrigation intervals didn't have any significant effect on pH and Na/Ca ratio (Fig. 1). Prolonging irrigation intervals up to 12 days significantly increased the salinity level of the soil and other studied chemical contents. The soil salinity and salts gradually increased as irrigation intervals increased. The highest values of all studied soil chemical properties were recorded by irrigation interval of 12 days. It seems that by decreasing the period of irrigation under saline soil is needed to avoid the soil salinity stress. The irrigation every 3 days significantly reduced the salinity level and other salts. Irrigation every three days gave the optimum values of the above-mentioned parameters (Table 2 and 3). Thereby, continuous flooding has to be followed under the saline soil to remove the soluble salts from the root growth zone to make up balance of nutrients between the plant's essential elements. Furthermore, when the irrigation was done every 3 days, sodium and chloride had more accumulated than sulfate, which was more leached than others. Both 9 days and 12 days treatments accumulated more Cl than Na (Table 2). Prolonging irrigation intervals up to 9 days significantly increased K content without any significant differences with those produced by a 12 days interval (Table 3). Meanwhile, delaying the irrigation interval of more than 9 days potassium content

Table 2: Changes in soil EC and pH, and Na and Cl contents as affected by irrigation intervals

Treatments (days)	Traits: EC (dS m^{-1})	pH	Na^{+} (meq L^{-1})	Cl^{-} (meq L^{-1})
3	3.78	8.00	21.08	16.00
6	5.56	8.07	37.38	29.13
9	12.25	8.15	59.70	80.25
12	14.50	8.03	80.25	101.75
F-test	**	ns	**	**
LSD5%	1.34	-	8.80	5.30

Table 3: Changes in K^{+}, Ca^{++}, Mg^{++} and So_4^{--} soil contents and soil SAR as affected by irrigation intervals

Treatments (days)	K^{+}	Ca^{++}	Mg^{++}	SO_4^{--}	
	meq l^{-1}				SAR
3	2.55	7.90	10.63	17.50	6.44
6	2.73	11.80	15.88	29.38	9.64
9	4.08	21.08	35.00	35.00	11.05
12	3.98	24.63	41.08	37.38	14.33
F-test	**	**	**	**	**
LSD5%	0.62	2.35	5.48	3.60	2.61

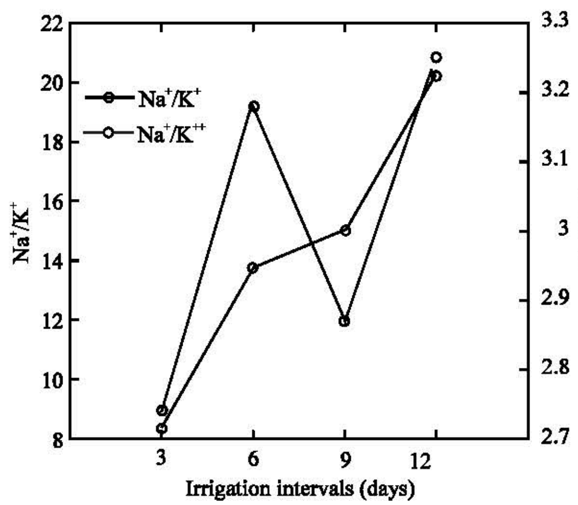

Fig. 1: Changes in Na/K and Na/Ca rations of soil as affected by irrigation intervals

decreased. Both 3 and 6 days irrigation intervals were check regarding potassium and magnesium contents (Table 3). The irrigation intervals of 9 and 12 days didn't differ significantly on SO^4. An increase in Na content severely reduced K+ content and significantly increased the Na/K as a result of prolonging irrigation intervals up to 12 days (Fig. 1). Subsequently, delaying the irrigation intervals markedly increase Na/K ratio in the soil. Abo-Soliman *et al.* (1996) and Zayed (1997). stated that Na/K in soil has to decrease, to eliminate the salts hazard and convert the salinity land to cropland.

It was recognized that the first two irrigation intervals of 3 and 6 days succeeded in reducing the soil salinity

Table 4: Change in salinity of water collected from root zone as affected by Irrigation intervals during three months

Treatments (days)	June	July	August	Mean
3	5.18	5.33	4.05	4.85
6	8.63	9.45	8.28	8.78
9	10.85	12.18	11.70	11.58
12	11.78	12.95	12.23	12.31
Mean	9.11	9.97	9.06	9.38
LSD 5%		0.23*		0.42**

*-LSD 0.05 value for means compression of months, **-LSD0.05 value for means compression of irrigation intervals

Table 5: Yield and its components of Giza 178 rice cultivar as affected by irrigation intervals

Treatments (days)	Panicles (number $hill^{-1}$)	Filled grains ($panicle^{-1}$)	Panicle weight (g)	1000-grain weight (g)	Grainyield (t ha^{-1})
3	13.80	120.00	3.09	20.78	5.68
6	13.10	111.25	2.98	20.50	4.85
9	10.35	95.75	2.08	18.18	3.43
12	7.75	75.50	1.55	16.83	2.50
F-test	**	**	**	**	**
LSD 5%	1.23	5.00	0.12	0.66	0.98

level and Na, Cl, Ca and Mg contents below of the original values before irrigation treatment application (Table 2 and 3). Furthermore, watering every 3 days could reduce the EC value of the soil below the critical value of soil salinity. Increasing the irrigation interval above 3 days increased the soil salinity level and soluble salts as compared to their values before the irrigation intervals application. Sodium absorption ratio of soil increased significantly with delaying the irrigation intervals. It demonstrates that irrigation water might have leached the sodium toward deeper depths. With higher salinity irrigation water, even lower SAR water could be used. The sodium hazard of irrigation water is also dependent upon the total salt concentration Gary (1977).

Developing salinity during the season: ECs of water collected from a lysimeter was significantly affected by the month in which it was collected (Table 4). Both June and August were on a par regarding the ECs level. Electrical conductivity reached the maximum value during July. During August, the ECs level started to decrease, because the temperature was raised during July and the first half of August while it started to decrease during the second half of August. Consequently the evapotranspiration will be increased when Zayed (2002). was studding some physical and chemical characteristics in the north part of Nile delta. Also, the ECs of water collected from lysimeters were significantly affected by irrigation intervals. Prolonging irrigation intervals gradually increased the ECs up to 12 days. The previous result may be as a result of the prolonging irrigation intervals help to concentrate the salts in the soil and accumulate more salts in the root growth zone. Thereby, it can be recommended that continuous irrigation may follow under such circumstances. The interaction between irrigation intervals and the months of collection had a significant effect on the ECs. The highest value of ECs was produced when a 12 days interval was followed during July, while the lowest value of ECs was obtained when a 3 day interval was pursued during August. During August, both 9 and 12 day intervals didn't significantly differ in their effect on ECs (Table 4). Also the interaction came to prove that high evapotranspiration in this area and shortages of water supply contribute to accumulating more salts in the soil (Zayed, 2002).

Yield and its components of rice: Irrigation intervals significantly affected the yield and yield components (Table 5). Likewise, prolonging irrigation interval gradually up to 12 days significantly decreased the number of panicles $hill^{-1}$, field grains $panicle^{-1}$, panicle weight, 1000-grain weight and the grain yield of Giza 178 rice cultivar. The irrigation at interval of every 3 days gave the highest value of the above-mentioned characters while the irrigation at intervals of 12 days gave the lowest values. Both of the irrigation intervals of 3 and 6 days didn't significantly differ in their effect on 1000-grain weight. Furthermore, the effect of water stress under saline soil conditions was more restricted on the panicle weight than the other yield components (Table 5). Likewise, water stress might affect the grain yield because of its unfavorable effect on yield components. The plant subjected to water stress under such circumstances will be suffering from double stresses, salinity stress and drought stress (Zayed, 2002). El-Wehishy and Hafez (1998) reported that the increasing of soil salinity the availability of most important macro nutrients to rice plant reduced. Due to prolonging irrigation interval under 9 and 12 days, the yield components decreased which in turn caused the yield decreased by 39.6 and 55.98%, respectively compared to the 3 days treatment. But no significant different found between 3 and 6 days intervals either in grain yield or in yield components (number of panicles, panicle weight and 1000 grain weight) at 5% level.

Continuous irrigation for 3 days followed by 6 days interval succeeded in reducing the Na/K ratio in the soil and can impair contentment growth under such conditions. Prolonging irrigation intervals raised the salinity level and encouraged secondary salinization. Therefore, prolonging irrigation interval more than 6 days under saline soil is unfavorable for rice growth. Finally, for considerable grain yield of rice, the continuous irrigation has been followed up with an improved fertilization management program. The amounts of irrigation water for each interval and the economical study are currently being evaluated.

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