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Improvement of Salinity Soil Properties and Rice Productivity under Different Irrigation Intervals and Gypsum Rates

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ABSTRACT

The study was carried out in of 2015 and 2016 seasons at the Experimental Farm of El-Sirw Agriculture Research Station, Damietta Governorate, and Egypt. The main objective of an attempt was to determine the effect of short, medium and prolong irrigation intervals (irrigation every three, six and nine days) and gypsum rates (0, 0.5,1.0 and 1.5 t ha^{-1} $CaSO_4$) on some soil prosperities, some plant elements, plant growth and grain yield of Sakha 104 rice cultivar, under saline soil conditions. A strip plot design, with four replicates, was used. The horizontal plots were devoted to irrigation intervals, however, the gypsum rates were allocated in the vertical plots. The soil of the experimental site was clayey and salinity levels were 7.5 and 7.3 dSm^{-1} in 2015 and 2016 seasons, respectively. The results obtained could be summarized as follows: Irrigation every three days increased chlorophyll content, LAI, plant height, number of tillers, panicle length, number of panicles, filled grains/panicle, panicle weight, 1000-grain weight, grain and straw yields as a compared with irrigation every nine days, which recorded the highest values of unfilled grains. Irrigation every three days significantly increased soil bulk density as well as Ca^{++} and K^{+} (in the soil and plant). However, it decreased the soil EC, Na^{+} (in the soil and plant) and Na/K ratio in the plant. Irrigation every three days consumed the highest amount of irrigation water, while prolonged irrigation intervals up to six and nine days tended to decrease the amount of water used. Furthermore, nine days treatment recorded the highest water use efficiency. Gypsum (as a soil amendment) rated 1.5 t^{1} CaSo4 ha^{-} significantly raised all studied growth parameter (except plant height), grain yield and its components without any significant differences with 1.0 t ha^{-1} $CaSo_4$ in some traits in both seasons. Gypsum at the rate of 1.5 t ha^{-1} $CaSo_4$ mitigate the hazardous effect of salinity by decrease soil EC, Na^{+} (in the soil and plant) and Na/K ratio in the plant. Generally, under the same condition, irrigation every three days and gypsum at the rate of 1.5 t ha^{-1} $CaSo_4$ are favorable for improve soil properties and enhance rice productivity under saline soil conditions.

Keywords: rice, irrigation intervals, salinity, gypsum, grain yield

INTRODUCTION

Rice is a vital cereal crop cultivated in various types of Egyptian soils. Also, it is cultivated for several purposes such as consumption and export as well as a reclaimed crop. In spite of rice is salt sensitive crop, it is considered as reclamation crop for saline-sodic soils because of its submergence condition.

Saline sodic soils are commonly occurring in northern part of Egypt. Irrigation is the most nominated practice to stabilize crop production in arid and semi-arid regions. Soil salinization and alkalization owing to low precipitation and high evaporation reduces soil quality and threatening the sustainability of the agricultural system (Silveira *et al*., 2008). Under salt affected soil, total soluble salt is high and sodication had high exchangeable sodium percentage in the root zone. The distribution of salt affected soils is relatively more extensive in the arid and semi-arid regions (Mustafa, 2007).

Salts and water scarcity are the main obstacles to rice production in Egypt. Salt-affected soils are mainly lowering agricultural productivity in irrigated areas of Egypt. Furthermore, salty soil restricted plant nutrient status by reducing Ca/Na, inducing Ca deficiency and deficiencies of phosphorus, zinc, manganese and other minerals attributed to low solubility availability.. Different interventions, such as reclamation, drainage, water control and soil amendments could be used to talking salinity problems.

Intensive flooding in the saline soil is generally applied to leach salt by drainage from the root zone particularly with poor quality of water. It was found watering every 4 days interval gave the highest yield with high total applied water, with leached the salts and decreased the value of basic infiltration rate compared with 6 and 8 days intervals (Zayed, 1997). (El-Wehishy and Abd El-Hafez 1998) found that grain yield and yield components of rice significantly decreased by extending watering interval for 14 days. El-Sharkawy *et al*. (2006) demonstrated that prolonged irrigation interval of 12 days under saline soil in the northern part of delta in Egypt was unfavorable for rice growth and flooding every 3 or 6 days should be followed to prevent the soil chemical composition degenerating and unbalance nutrients. Zayed *et al*., (2013) found that watering every 4 days possessed favorable impact on reducing soil salinity and improving soil properties, rice growth and productivity comparing to prolonging irrigation intervals under saline soil and poor quality water.

Saline-sodic soil had poor soil structure resulted in bad drainage system (Suarez, 2001 and Qadir and Schubert, 2002). Saline-sodic soils are reclaimed by substituting the exchangeable sodium (ESP) with calcium. This could be commonly obtained by adding gypsum, since it is relatively soluble and cheapest chemical amendments. Gypsum is the most common amendment used to provide calcium for sodic soils reclamation because it is calcium-rich, dissolves at high pH, and dos not contain elements or compounds might interfere with reclamation and the sulfate in gypsum is not likely to be a problem for crops (Horneck *et al*., 2007).

As mentioned previously, gypsum supplied soil with more Ca^{+2} and S providing less soil sodium content and desired soil pH value resulted in reclaimed soil with high quality that hold true under saline sodic soil in Egypt (Qadir and Oster, 2002). Gypsum had several beneficial roles return on breaking up compacted soil and more progressed aggregates formation. In addition, gypsum booted up water productivity of crops through improving water hydraulic conductivity rate and yields (Shainberg *et al*., 1989). (Hafez *et al*., 2015) found that applying gypsum under salt affected soil significantly improved soil proprieties reflecting on optimizing rice growth and yield components as well as grain yield.

Therefore, the study aimed to find out the optimum gypsum rate with different water regime for soil quality and rice productivity under saline soil conditions in the northern part of Egypt.

MATERIALS AND METHODS

A field trails were assigned at El-Sirw Agricultural Research Station, Damietta Governorate, Egypt during 2015 and 2016 seasons. A rice variety Sakha 104 was used in this study. The experiment was laid out in strip plot design, with four replications. The horizontal plots were devoted to three irrigation intervals (continuous flooding with irrigating every 3 days, irrigation every 6 and 9 days). Meanwhile, gypsum rates (0, 0.5, 1.0 and 1.5 t ha^{-1} $CaSO_4$) were allocated in the vertical plots the gypsum was applied before ploughing and was tightly incorporated in to soil to 15cm depth. Soil texture was clayey and soil samples were taken before land preparation at the depth of 0-30 cm from the soil surface. The soil samples before cultivation were completely mixed, dried and grounded then both of physical and chemical characteristics were analyzed according to Piper, (1950) and presented in Table (1).

Table 1. Soil chemical properties of experimental soils in 2015 and 2016 seasons

Season	pH	ECe dS m^{-1}	ECw dS m^{-1}	ESP	Cation meql^{-1}				Anion meql^{-1}		
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	SO_4^{-2}	Cl^{-}	HCO^{-3}
2015	8.2	7.5	1.94	1.00	19.8	17.8	38.0	0.30	32.0	40	11
2016	8.1	7.3	1.91	0.97	20.9	17.0	37.0	0.31	30.0	43	12

The phosphorus and potassium fertilizers were basally applied in the forms of calcium super phosphate (15.5 % P_2O_5) and potassium sulphate (48% K_2O) in the rates of 37 kg P_2O_5 and 50 K_2O ha^{-1}, respectively. Recommended nitrogen (165 kg N ha^{-1}) in the form of urea (46.5 % N) added into three equal splits (at 25, 50 and 75 days after transplanting). The experiments were sown on 3rd and 5th of May in the two successive seasons. Seedlings, aged 30 days, were transplanted at spacing of 20 X 20 cm in plot size of 10 m^2 (2 x 5 m). Weeds were controlled chemically using Saturn 50% at 7.5 liters ha^{-1} into 350 liter water ha^{-1} and sprayed at four days after transplanting. Zinc (Zn So_4), as well as all other cultural practices, was applied as recommended. Each irrigation treatment was tightly surrounded by deep ditches with 2 m wide and 1 m depth to isolate each other then irrigation treatments were applied as aforementioned.

At heading stage; plant samples (five hills) from each plot were taken to estimate leaf area index (LAI) according to Yoshida *et al*. (1976). LAI is the ratio between the leaf area (cm^2) of the plant divided by ground area occupied by the plants (cm^2). Chlorophyll content (SPAD value) was estimated by chlorophyll meter (Model Li 3000L). Dried rice plant of each plots were analyzed to assessment of Na+, K+ and Na+/ K+ ratio of rice plants according to Yoshida *et al*., (1976).

Prior harvest, plant height was estimated and total number of tillers and panicles of five hills for each plot was counted to determine the numbers m^{-2}. Ten main panicles from each plot were packed to determine panicle length (cm), number of filled and unfilled grains $panicle^{-1}$, panicle weight and 1000-grain weight. The plants of the six inner rows of each plots were harvested, dried, threshed and then grain and straw yields were determined and adjusted to 14 % moisture content as well as converted into t $ha^{-1.}$

After harvest, soil was sampled in two parts, one part of it was stored in the refrigerator for chemical analysis and the other one used for physical analysis according to Piper, (1950), Cottein *et al*., (1982), Page *et al*. (1982) and Kemper and Rosenau (1986). Soil analysis and measurements includes soil EC dSm^{-1} in soil paste extract, soil pH in 1: 2.5 soil water suspension, bulk density kg m^{-3}, soluble cations and anions meq $liter^{-1}$.

The volume of irrigation water applied in each plot was measured by a calibrated water meter with water pump. Rice water use efficiency (WUE) was calculated as described in Equation of Jensen, (1983):

WUE (kg m^{-3}) = rice grain yield (kg ha^{-1}) / total consumptive water used (m^3h^{-1})

Data were statistically analyzed according to the proceeding described by Gomez and Gomez (1984) using the computer program (COSTAT). The means of studied treatment were compared using Duncan's multiple range test Duncan (1955). * and ** symbol used in all tables indicate the significant at 5% and 1% levels of probability, respectively, while, NS means not significant.

RESULTS AND DISCUSSION

A- Growth parameter:

As evident in Table (2) irrigation intervals and gypsum rates had a significant effect on some growth characters in 2015 and 2016 seasons. Data showed that the highest values of chlorophyll content, leaf area index, number of tillers and panicle length produced by the irrigation interval of three days followed by irrigation interval every six days. Also, the tallest plants obtained by irrigation interval every three days without significant difference with six days interval in both seasons. On the other hand, the lowest values were resulted by irrigation interval every nine days. The decrease of rice growth parameter with increasing water intervals was also observed by Wan *et al*., (2009), El-Sherkawy *et al*., (2006) and Zayed *et al*., (2013).

Table 2. Effect of irrigation intervals and gypsum rates on chlorophyll content, LAI, plant height number of tillers and panicle length of Sakha 104 rice cultivar in 2015 and 2016 seasons.

Irrigation interval (days)	Chlorophyll content (SPAD value)		LAI		Plant height (cm)		No. of tillers hill^{-1}		Panicle length (cm)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
3	41.0a	42.3a	5.97a	5.90a	92.24a	92.22a	18.05a	17.91a	17.17a	16.66a
6	40.0b	40.0b	5.06b	5.12b	92.24a	92.36a	17.10b	16.95b	16.82b	17.15b
9	34.4c	35.9c	3.60c	3.66c	88.19b	89.63b	15.49c	15.42c	16.23c	16.81b
F. test	**	**	**	**	*	**	**	**	**	*
Gypsum rates $CaSO_4$ (t ha^{-1})										
0	30.1c	32.1c	3.13c	3.20c	88.29	91.47	14.60d	14.56d	16.20b	16.30c
0.5	37.7 b	40.0 b	4.16b	4.30b	90.99	92.58	15.73c	15.55c	16.59b	16.94b
1.0	42.7 a	43.5 a	5.40a	5.00a	92.47	90.77	18.24b	18.09b	17.59a	17.36b
1.5	42.2 a	44.5 a	5.35a	5.10a	91.81	90.76	18.95a	18.84a	16.58b	18.23a
F. test	**	**	**	**	NS	Ns	**	**	**	**
Interaction	NS	NS	NS	NS	Ns	Ns	**	**	**	**

***, ** and Ns indicate P < 0.05, P < 0.01 and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.**

With respect to gypsum rates, increasing gypsum rate up to 1.0 or 1.5 t ha^{-1} $CaSo_4$ obviously increased chlorophyll content, leaf area index, number of tillers and panicle length, without significant difference between each other for chlorophyll content and leaf area index in both seasons (Table 2). On the other side, the control treatment (none of gypsum application) gave the lowest values of abovementioned traits. Meanwhile, gypsum rates did not exert any apparent significant effect on plant height in the two study seasons. The alleviation of salinity stress illness basically involves removing the sodium ions from soil particles with adding more favorable calcium ions. Application of gypsum could be deemed as an effective way to mitigate the salinity stress on rice to a marked extent consequently, removing the sodium ions by calcium, resulting in improvement of saline sodic soil. Gypsum is another source of sulfur that had high potentiality to reduce pH value of sodic soil. Similar findings had been proved by Vakeesan and Nishanthan, (2007), Singh *et al*., (2008) and Singh *et al*., (2009). It replaces the Na^+ ion of soil. Alleviate the harmful effect of salt on rice plants by gypsum application is reported in saline soil as well as in saline sodic soils.

The interaction between irrigation intervals and gypsum rates had no significantly effect on growth parameters except number of tillers and panicle length (Table 3). . By the way, combination between the irrigation intervals of three days and gypsum rates at 1.0 or 1.5 t ha-1 $CaSo_4$ gave the highest values of number of tillers, without significant different between the two gypsum rates in both seasons. While, the combination of irrigation intervals of three days and gypsum rates at 1.0 t ha-1 $CaSo_4$ gave the longest panicle in 2015 and 2016 seasons.

Table 3. Effect of interaction between irrigation intervals and gypsum rates on number of tillers and panicle length of Sakha 104 rice cultivar in 2015 and 2016 seasons.

Gypsum rates $CaSO_4$ (t ha^{-1})	Irrigation Interval (days)					
	3	6	9	3	6	9
	2015			2016		
Number of tillers/hill						
0	15.55e	14.69f	13.56g	15.06d	14.53e	13.56f
0.5	16.77d	15.76e	14.67f	16.4d	15.68d	14.57e
1.0	19.91a	19.00b	15.80e	19.80a	18.82b	15.65d
1.5	19.96a	18.95b	17.94c	19.84a	18.77b	17.90c
Panicle length (cm)						
0	16.45b	16.54b	15.62b	16.58bcd	16.42bcd	15.91d
0.5	16.70b	16.94b	16.12b	17.41bcd	17.16bcd	16.25cd
1.0	19.02a	16.88b	16.87b	19.45a	17.37bcd	17.88b
1.5	16.5b	16.92b	16.33b	17.20bcd	17.65bc	17.22bcd

Means of each season designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

B-Na^+, K^+ and Na^+/ K^+ ratio of rice plants:

Data in Table (4) showed that irrigation intervals and gypsum rates in terms of $CaSo_4$ exerted significant effect on Na^+, K^+ and Na^+/K^+ ratio in both seasons. Irrigation intervals and gypsum rates was versa since prolonging irrigation intervals significantly reduced K^+ and increased Na^+ leaf contents as well as Na^+/K^+ ratio but increasing gypsum rates recorded the opposite pattern in this concern. Increasing Na^+ and Na^+/K^+ ratio in rice plants with prolonging irrigation intervals are mainly owing to increasing Na^+ soil content and reducing both of Ca^{++} and K^+ as previously detected. Applying gypsum in increment rate might be substituted Na^+ by more Ca^{++} on soil absorption complexes. Also, adding $CaSO_4$ might be improved and reduced pH soil value resulted in nutrients availability such K^+ and improved plant uptake to those elements against Na^+ reducing low Na/K ration under gypsum application. It is became fact that gypsum application is crucial issue under reclaimed saline sodic soil cultivated by rice to prolong irrigation intervals up to 6 days. Similar data had been obtained by El-Sherkawy *et al*., (2006), Zayed *et al*., (2013) and Hafez *et al*., (2015).

Table 4. Effect of irrigation intervals and gypsum rates on content of Na^+, potassium and Na/K ratio in plant of Sakha 104 rice in 2015 and 2016 seasons.

Irrigation interval (days)	Na content		K		Na/K ratio	
	2015	2016	2015	2016	2015	2016
3	1.44b	1.59c	1.77a	1.84a	0.83c	0.88c
6	1.50b	1.65b	1.55b	1.64b	0.98b	1.03b
9	1.88a	1.93a	1.44c	1.35c	1.32a	1.49a
F. test	**	**	**	**	**	**
Gypsum rates $CaSO_4$ (t ha^{-1})						
0	1.74a	1.90a	1.34d	1.35d	1.31a	1.46a
0.5	1.66b	1.77b	1.45c	1.47c	1.15b	1.23b
1.0	1.57c	1.66c	1.63b	1.68b	0.96c	1.00c
1.5	1.44d	1.56d	1.92a	1.94a	0.76d	0.84d
F. test	**	**	**	**	**	**
Interaction	NS	NS	**	**	**	**

** and NS indicate $P < 0.05$ and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

The interaction between irrigation intervals had significant effect on Na^+ and Na/ K ratio in both seasons (Table 5). The data of interaction effect with current concern markedly came to confirm that applying gypsum in higher rate under prolonging irrigation intervals under newly reclaimed saline soil irrigated by poor quality water could ameliorate the hazardous effect resulted from high Na^+ accumulation by remove such Na by replacing more Ca^{++} and K^+ as well as reducing pH value and improving soil drainage systems.

Table 5. Effect of interaction between irrigation intervals and gypsum rates on potassium content and Na/K ratio in Sakha 104 rice plant in 2015 and 2016 seasons.

Gypsum rates $CaSO_4$ (t ha^{-1})	2015			2016		
	Irrigation interval (days)					
	3	6	9	3	6	9
K content						
0	1.50f	1.33g	1.20h	1.57de	1.41f	1.07h
0.5	1.60de	1.40g	1.36g	1.63cd	1.54de	1.23g
1.0	1.76c	1.60de	1.53f	1.85b	1.71c	1.48ef
1.5	2.23a	1.86b	1.66d	2.31a	1.90b	1.61cd
Na/K ratio						
0	1.03de	1.22c	1.69a	1.05d	1.27c	2.07a
0.5	0.96fg	1.07d	1.41b	1.01de	1.10de	1.58b
1.0	0.77h	0.92g	1.20c	0.83f	0.94e	1.23c
1.5	0.55i	0.73	1.00ef	0.63g	0.80f	1.08d

Means of each season designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

C- Grain yield components:

Data in Table (6) indicated that irrigation interval and gypsum rates markedly influence number of panicles, filled grains panicle^{-1}, unfilled grains panicle^{-1}, panicle weight and 1000-grain weight in both seasons. Prolonged irrigation interval up to nine days significantly decreased the mention grain yield component, except unfiled grain and 1000-grain weight which was increased under irrigation interval of nine days in both seasons. The prolonged irrigation interval decreased rice production has been reported by researches (El-Sherkawy *et al*., (2006) and Zayed *et al*., (2013)).

Table 6. Effect of irrigation intervals and gypsum rates on number of panicle, filled grains/panicle, panicle weight, unfilled grains/panicle, panicle weight and 1000-grain weight of Sakha 104 rice cultivar in 2015 and 2016 seasons.

Irrigation interval (days)	No. of panicle hill^{-1}		Filled grains/panicle		Unfilled grains/panicle		Panicle weight (g)		1000-grain weight (g)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
3	17.14a	16.36a	77.38a	72.68a	21.36c	21.74c	2.06 a	2.02ab	22.89b	22.16c
6	16.24b	15.48b	68.39b	68.68b	31.09b	31.97b	2.07 a	2.09a	22.43b	24.13a
9	14.72c	14.08c	63.6c	65.21c	44.27a	45.40a	1.73 b	1.89b	24.32a	23.46b
F. test	**	**	*	**	**	*	**	*	**	*
Gypsum rates $CaSO_4$ (t ha^{-1})										
0	13.87d	13.30d	57.32c	56.56d	42.91a	43.97a	1.49 d	1.58d	23.74a	23.03bc
0.5	14.95c	14.20c	64.44b	66.26c	32.16b	32.95b	1.94 c	1.92c	22.87b	23.8ab
1.0	17.32b	16.52b	76.95a	78.25a	21.95c	22.68c	2.30 a	2.38a	22.38ab	24.18a
1.5	18.00a	17.20a	75.81a	74.36b	11.94d	12.54d	2.06 b	2.12b	22.85b	22.8c
F. test	**	**	**	**	**	**	**	**	NS	*
Interaction	**	**	**	**	NS	NS	**	**	NS	NS

*, ** and Ns indicate $P < 0.05$, $P < 0.01$ and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

Gypsum rates of 1.0 and 1.5 t ha^{-1} $CaSo_4$ raised most of grain yield components and decreased unfilled grains compared with control treatment in 2015 and 2016 seasons (Table 6). Gypsum content of, calcium which is basic for many plant growth functions, as cell division and elongation, enzyme activity and metabolism. Gypsum helped to improve P uptake by counteracting the nutrient imbalances within the plants similar results were reported by (Izhar-ul-Haq *et al*., 2007).

The interaction between irrigation intervals and gypsum rates significantly affected number of panicles, panicle weight, panicle length, filled grains and unfilled grains in both seasons (Tables 6 and 7).The combination of irrigation interval every three days and gypsum rates up to 1.5 t ha^{-1} $CaSO_4$ markedly increased number of panicles, panicle weight, panicle length, filled grain and decreased unfilled grain in both seasons.

Table 7. Effect of the interaction between irrigation interval and gypsum rates on number of panicles, filled grains, panicle weight and 1000-grain weight of Sakha 104 rice cultivar in 2015 and 2016 seasons

Gypsum rates $CaSO_4$ (t ha^{-1})	2015			2016		
	Irrigation interval (days)					
	3	6	9	3	6	9
	No. of panicle $hill^{-1}$					
0	14.77e	13.96f	12.89g	14.25d	13.27e	12.39f
0.5	15.93d	14.97e	13.94f	14.98d	14.32d	13.31e
1.0	18.91a	18.05b	15.01e	18.09a	17.19b	14.29d
1.5	18.96a	18.00b	17.04c	18.12a	17.14b	16.35c
	Filled grains/panicle					
0	66.05fg	55.33fg	53.08g	59.47e	55.13e	55.08e
0.5	75.5bc	65.4de	62.43ef	67.16d	66.12d	65.51d
1.0	86.41a	77.4b	67.85cde	88.0a	77.91b	68.83d
1.5	92.16a	75.23bc	71.03bcde	76.08bc	75.58bc	71.41cd
	Panicle weight (g)					
0	1.62de	1.43e	1.44e	1.66d	1.58d	1.49d
0.5	1.83d	2.39b	1.61de	1.76d	2.19bc	1.83cd
1.0	2.92a	2.21bc	1.79d	2.81a	2.24b	2.10bc
1.5	1.86d	2.26bc	2.08 c	1.86cd	2.34b	2.16bc

Means of each season designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

D- Grain and straw yields

Data presented in Table (8) showed that grain and straw yields were significantly affected by irrigation interval and gypsum rates in both seasons. Irrigation intervals three days succeeded in increasing grain and straw yields without significant differences with six days. While, prolonged irrigation interval up to nine days decreased grain and straw yields. Increased grain yield by short irrigation interval may be due to increasing number of panicle $hill^{-1}$, panicle weight and number of filled grains $panicle^{-1}$. Similar conclusion was previously discussed by El-Sherkawy *et al*., (2006) and Zayed *et al*., (2013).

On other side, gypsum rates of 1.5 t ha^{-1} $CaSo_4$ without differ with 1.0 t ha^{-1} $CaSo_4$ overcome salinity effect and improved grain and straw yields of Sakha 104 rice cultivar over control treatment in the two seasons (Table 8). The increases in rice yield and its component by gypsum due to (1) substituting of sodium by calcium, (2) improving soil pH, blooming the nutrient availability and nutrient use efficiency of the crop as well as decreased the hazardous effect of salinity and sodicity. These results stand in well agreement with those of Bello (2012), Helmy (2013) and Hafez *et al*. (2015).

The interaction between irrigation interval and gypsum rates had a significant effect on grain yield in the two seasons (Table 9). The combination of irrigation interval of three days with gypsum rate 1.0 t ha^{-1} $CaSO_4$ significantly increased grain yield in the two seasons. On the other hand, control treatment and irrigation interval nine days gave the lowest values of grain yield in both seasons.

Table 8. Effect of irrigation interval and gypsum rates on grain and straw yields (ton ha^{-1}) of Sakha104 rice cultivar in 2015 and 2016 seasons.

Irrigation interval (day)	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	2015	2016	2015	2016
3	5.64a	5.89a	6.57a	6.19a
6	5.37b	5.45b	6.56a	6.12a
9	3.95c	4.29c	5.60b	5.66b
F. test	**	**	**	**
	Gypsum rates $CaSO_4$ (t ha^{-1})			
0	3.60c	3.78c	5.43c	5.40c
0.5	5.03b	5.33b	5.66b	5.80b
1.0	5.68a	5.79a	5.90a	6.36a
1.5	5.62a	5.92a	6.85a	6.40a
F. test	**	**	**	**
Interaction	**	**	NS	NS

**** and Ns indicate P < 0.01 and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.**

Table 9. Effect of the interaction between irrigation interval and gypsum rates on grain yield of Sakha 104 rice cultivar in 2015 and 2016 seasons.

Gypsum rates $CaSO_4$ (t ha^{-1})	2015			2016		
	Irrigation interval (days)					
	3	6	9	3	6	9
0	4.20de	3.68e	2.94f	4.38d	3.74e	3.25e
0.5	5.72b	5.54b	3.85de	6.06b	5.63bc	4.29d
1.0	6.67a	5.93ab	4.46cd	6.76a	5.98b	4.63d
1.5	5.98ab	5.93ab	4.94c	6.15b	6.24b	5.37c

Means of each season designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

E: Soil properties:

Data in Table (10) referred that Na^+ of soil, soil salinity (EC) and bulk density of soil showed great variation under the tested irrigation intervals. At the same time, varying gypsum rates markedly affected the abovementioned soil properties in both seasons. Prolonging irrigation interval increased the values of sodium soil content, salinity level and bulk density in both season. The longest irrigation interval (nine days) without gypsum application gave the highest values of measured soil properties. The shortest period of irrigation intervals of three days and high gypsum rate apart had well soil properties as well as higher Ca^+ and K soil content. Couple Ca^{+2} and K^+ reached significantly their highest values under three days irrigation interval and 1.5 t ha^{-1} $CaSo_4$ apart. Applying gypsum had several advantages under target domain studied soil that are Na^+ removal from soil adsorption complexes, reducing pH soil as result of H_2So_4 formation and substring both Ca^{+2} and K^+ the Na^+ place in soil complexes, reducing sodium in soil attributed to gypsum application bloomed soil aggregates leading to reduce bulk density, resulted in improving soil drainage system against soil depression. Short or medium irrigation intervals might be ensured sufficient water addition to the soil resulted in reasonable and high effective Na leaching from soil to drainage channels the prolonging irrigation intervals showed the opposite pattern. Removing Na^+ from soil owing to gypsum application resulted in improved soil properties such as aggregates and bulk density.

The interaction between studied factors significantly affected Na^+ and Ca^{+2} soil content in the two seasons Table (11). Whereas, the best combination was irrigation every three day with gypsum application at the rate of 0.5 or 1.0 t ha^{-1} $CaSO_4$. The obtained findings in are a good conformity with those reported by Muhammad (2001), Zayed *et al.,* (2013) and Hafez *et al*., (2015).

Table 10. Effect of irrigation interval and gypsum rates on Na^+ content of soil, electrical conductivity, bulk density, Ca^{++} and K^+ in 2015 and 2016 seasons.

Irrigation interval (days)	Na^+ content 2015	Na^+ content 2016	EC S m^{-1} 2015	EC S m^{-1} 2016	Bulk density (g) 2015	Bulk density (g) 2016	Ca^{++} 2015	Ca^{++} 2016	K^+ 2015	K^+ 2016
3	24.91c	26.08c	6.5c	6.4c	1.65a	1.64a	8.17a	8.98a	0.616a	0.641a
6	32.50b	34.16b	7.0b	6.7b	1.70b	1.67b	6.83b	7.55b	0.491b	0.50b
9	47.00a	48.5a	8.4a	8.5a	1.74c	1.75c	5.75c	6.77c	0.383c	0.308c
F. test	**	**	**	*	**	*	**	**	**	**
Gypsum rates $CaSO_4$ (t ha^{-1})										
0	47.00a	50.11a	8.6a	8.5a	1.76a	1.75a	4.65d	5.61d	0.40d	0.41d
0.5	37.22b	39.55b	7.3b	7.1b	1.73b	1.71b	5.87c	6.75c	0.45c	0.46c
1.0	31.44c	31.88c	6.7c	6.7c	1.67c	1.67c	7.573b	8.16b	0.51b	0.50 b
1.5	23.55d	23.44d	6.3d	6.2d	1.63d	1.62d	9.564a	10.54a	0.62a	0.55a
F. test	**	**	**	**	**	**	**	**	**	**
Interaction	**	**	NS	NS	NS	NS	**	**	NS	NS

***, ** and Ns indicate $P < 0.05$, $P < 0.01$ and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.**

Table 11. Effect of the interaction between irrigation intervals and gypsum rates on sodium and calcium content meq/l of soil in 2015 and 2016 seasons.

Gypsum rates $CaSO_4$ (t ha^{-1})	2015			2016		
	Irrigation interval (days)					
	3	6	9	3	6	9
Na^+ content						
0	34.00d	43.66c	63.33a	35.66e	49.00c	65.66a
0.5	26.66e	34.00d	51.00b	26.33i	38.33e	54.00b
1.0	22.33f	30.33d	41.66c	23.66j	29.00g	43.00d
1.5	16.66g	22.00f	32.00d	18.66k	20.33k	31.33f
Ca^{++} content						
0	5.36f	4.50gh	4.1h	6.20h	5.36i	5.26i
0.5	7.60d	5.43f	4.6g	7.73e	6.66g	5.86h
1.0	8.40c	7.60d	6.73e	9.33c	7.86e	7.30e
1.5	11.33a	9.8b	7.56d	12.66a	10.30b	8.66d

Means of each season designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

F- Water use efficiency:

Comparing the different treatments of irrigation interval (Table 12), it was observed that irrigation every three days received the highest amounts of water throughout the season, while, the lowest amounts were received by irrigation every nine days. Data in Table (13) provide that irrigation interval with gypsum rates significantly increased water use efficiency (WUE) compared with control treatment (without applying gypsum) in both seasons. Irrigation interval every nine days and gypsum rates 1.5 t ha^{-1} $CaSo_4$ raised WUE compared with other treatments in both seasons. Similar data was obtained by Hafez *et al.*, (2015).

Table 12. Effect of irrigation intervals on total applied water of Sakha 104 rice cultivar in 2015 and 2016 seasons.

Irrigation interval (days)	Total applied water(m^3 ha^{-1}) 2015	2016
3	14155	14765
6	12545	12500
9	8940	8950

Table 13. Effect of irrigation interval and gypsum rates on water use efficiency of rice variety Sakha104 in 2015 and 2016 seasons.

Gypsum rates $CaSO_4$ (t ha^{-1})	2015				2015			
	Irrigation interval (days)							
	3	6	9	Means	3	6	9	Means
0	0.297	0.293	0.329	0.306	0.297	0.300	0.363	0.320
0.5	0.404	0.441	0.430	0.425	0.410	0.450	0.479	0.447
1.0	0.471	0.473	0.499	0.481	0.458	0.478	0.517	0.484
1.5	0.422	0.473	0.553	0.483	0.416	0.499	0.600	0.505
Means	0.399	0.420	0.453	0.424	0.395	0.432	0.490	0.439

Generally, under the same experiment condition, it can be concluded that the shortest irrigation interval every three days and application gypsum ($CaSo_4$) at the rate of 1.0 or 1.5 t ha^{-1} could be decreased the hazardous effect of salinity and increased grain yield and its component of Sakha104 rice cultivar.

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تحسين خواص الأراضى الملحيه وزيادة إنتاجيه الأرز تحت فترات رى و معدلات جبس مختلفه

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أقيمت تجربتان حقليتان بمزرعة محطة بحوث السرو- دمياط – مصر خلال موسمي 2015 و 2016 م لدراسة تأثير فترات ري مختلفة (3 و 6 و 9 أيام) ومعدلات مختلفة من الجبس الزراعى (صفر و 0.5 و1.0 و 1.5 طن/ هكتار) وذلك على خواص التربة و محتوى النبات لبعض العناصر و صفات النمو ومكونات المحصول ومحصول الحبوب لصنف الأرز سخا 104 تحت ظروف الأراضى الملحية الصوديه. استخدم تصميم الشرائح المتعامده، فى اربع مكررات، حيث وضعت فترات الرى فى القطع الأفقيه فى حين وضعت معدلات الجبس فى القطع العمودية. وكانت التربة طينية ومستوى ملوحة التربة 7.5 و 7.3 ديسيسمنز$^{-1}$ في موسمي الزراعة، على التوالي. و يمكن تلخيص أهم النتائج المتحصل عليها في الآتى: سجلت معاملة الرى كل 3 أيام زيادة فى محتوى الكلوروفيل و دليل مساحة الورقة و إرتفاع النباتات و عدد الأشطاء و طول الدالية وعدد الداليات و عدد السنيبلات الممتلئة و وزن الدالية و وزن الألف حبة و محصول الحبوب و القش و ذلك بالمقارنة مع معاملة الرى كل 9 أيام و التى سجلت أعلى القيم لعدد السنيبلات الفارغة. أثرت فترات الري على خواص التربة و الصفات الكيماويه للنبات فأدت فتره الري كل ثلاثة أيام الى زيادة نسبه البوتاسيوم والكالسيوم في النبات والتربة وأيضا الكثافة الظاهرية في التربة وخفضت نسبه الصوديوم ونسبه الصوديوم إلى البوتاسيوم في كل من التربة و النبات وخفضت من معدل التوصيل الكهربي للتربة. إستهلكت معاملة الرى كل 3 أيام طوال الموسم أكبر كمية مياه رى فى حين قلت كميات مياه الرى المستهلكة بزيادة فترات الرى إلى 6 و 9 أيام. فى حين سجلت معاملة الرى كل 9 أيام أعلى القيم لكفاءة استخدام مياة الرى. أدى استخدام الجبس الزراعى (كمحسن للتربة) بمعدل 1.5 طن/هكتار الى الزيادة المعنوية فى جميع صفات النمو المدروسة (ما عدا ارتفاع النباتات) و محصول الحبوب و مكوناتة مع عدم وجود اختلافات معنوية مع إضافة الجبس بمعدل 1.0 طن/هكتار فى بعض الصفات فى كلا الموسمين. و كان لإضافه الجبس بمعدل 1.5 طن/هكتار تأثير معنوي أيضا علي تحسين خواص التربة و النبات عن طريق خفض معدل التوصيل الكهربى و محتوى الصوديوم و نسبة الصوديوم الى البوتاسيوم فى التربة و النبات و خصوصا مع زيادة فترات الري إلي 9 أيام . أثرت فترات الري و معدلات الجبس علي محصول الحبوب في كلا موسمي النمو معنويا. حيث وجد أن زيادة فترات الري حتي 9 أيام ادت الى نقص فى محصول الحبوب، بينما زيادة معدلات الجبس تدريجيا ادت الى زيادة محصول الحبوب و مكوناته نتيجة زيادة النمو. وقد وجد أن اضافه الجبس قد حسنت من كفاءة استخدام المياه. بصفة عامة، تحت نفس ظروف الدراسة، وجد أن معامله الري كل ثلاثة أيام مع إضافة الجبس الزراعى بمعدل 1.5 طن/هكتار قد أدت الى تحسين خواص التربة و زيادة انتاجية صنف الأرز سخا 104 تحت ظروف الأراضي الصوديه الملحية.