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Improvement of Wheat Root Zone and Productivity in Heavy Clay Salt Affected Soil

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ABSTRACT

A field experiment was conducted at North Nile Delta (Kafer El-Shiek Governorate, Egypt), during the two winter seasons (2015/2016 and 2016/2017). In order to evaluate, the effect of open drains spacing (10-m, 15-m, 20-m) and irrigation intervals (15 and 20-days intervals irrigation) under gypsum application (3tonfed.$^{-1}$) on some soil properties, wheat productivity and affected of irrigated water (PIW). The results showed that: Soil salinity was reduced from10.03 to 7.32 dSm^{-1} and soil sodicity from 17.31 to 14.31, after two seasons from treatments application. Narrow drain spacing is superior at wider spacing in reducing soil salinity and sodicity. The average values were 6.59, 7.20 and 8.18 dSm^{-1} of salinity and 13.99, 14.25 and 14.68 of sodicity for 10-m, 15-m and 20-m spacing, respectively. Narrow irrigation intervals (15-days) decreased about 1.38dSm^{-1} of soil salinity and 0.76 of soil sodicity than wider irrigation intervals (20-days). Treatments application especially narrow spacing and narrow irrigation intervals with gypsum tend to increase Ca^{++}/TSS and decreased Na^{+}/TSS ratios. Treatments application especially narrow spacing and lower irrigation intervals seemed to be more effective in enhancing soil bulk density, total soil porosity, basic infiltration rate and cumulative infiltration. Application of treatments caused significant increases in wheat yields. The increases of wheat grains yield were 20.14 and 9.59% in the first season and 17.50 and 9.74% in the second season for 10-m and 15-m open drain spacing, respectively than 20-m drain spacing. The corresponding values of wheat straw yields were 11.44 and 6.16% in the first season and 10.70 and 6.16% in the second season, respectively. 15-days irrigation intervals caused higher wheat grain yields than 20-days irrigation intervals by 9.67 and 10.23 % in the first and second season, respectively. The corresponding values of wheat straw yield were 9.07 and 9.60 %, respectively. The interaction between narrow drainge spacing combined with low irrigation intervals tend to increasing wheat yields. PIW was superior to with narrow spacing and narrow irrigation interval, and the highest values were achieved under10-m drainge spacing with 15-days irrigation interval, while the lowest values were under 20-m drainge spacing with 20-days irrigation interval. Finally, narrow drainge spacing with reduce of irrigation intervals under gypsum application tend to improve physio-chemical characteristics of heavy clay salt affected soils, increase production and PIW for wheat crop.

Keywords: Clay soil, Drainge, Irrigation, Productivity, Wheat crop.

INTRODUCTION

In Egypt, north of the Nile Delta are huge areas which representing heavy clay salt affected soils of poor productivity. These soils suffered from shallow and highly saline ground water. Whereas, groundwater constitutes source and permanent threat for soil salinization and salt removal from this soil is difficult. Groundwater depth plays an important role in soil properties and crop productivity. Soils management in such conditions needs much attention, especially in countries with limited land resources and continuous increasing population. Unfortunately, in many semi arid and arid areas under irrigation, poor internal drainage in similar soils has led to salt accumulation that resulting insignificantly reduced yields and/or abandonment of the land. Local experience is very important to deal with the problem. The most important feature is the highly saline shallow ground water, which creates procedures for soil desalinization through leaching and drainage showed successful in some areas but were disappointing in other areas. The difficulty of desalinization in clay soils might arise from the preferential type of water flow. Since leaching water may pass only through macropores and not within clay peds. Consequently ,improving leaching efficiency through artificial reconstruction would be a possible solution (Tanton et al, 1990). One way of increasing production is proper soil management such as drainage and irrigation. Drainage is an important factor to overcome these interference problems. Many investigators such as Ritzema (1994), Moukhtar et al, (1995 and 1998) mentioned that heavy soils of low hydraulic conductivity often require very closely spaced drainage systems for satisfactory water control. The limited flow of water in salty clay soils restricts salt removal. This situation is aggravated if the shallow groundwater is highly saline; only shallow rooted crop can be grown. Gypsum applications followed by leaching, was successful in reclamation of a number of sodic and saline-sodic soils having good drainage conditions (Oster *et al*., 1996 and Reda 2006).

The management of such soils depends essentially on providing efficient drainage conditions beside regular irrigation to preserve the root zone from salinity in the cropping season and to restrict capillary rise from the saline groundwater between cropping seasons. Solutions for soil salinity problems are as follows; salt leaching which is the key of land improvement should not have special difficulty. The reclamation of salt-affected soils should be done by simple leaching practices to bring them to non-saline, non-sodic soils for economical crop production. Sufficient water should be available for reclamation, irrigation and leaching practices (Pazira, 1999 and Pazira and Homaee, 2010). Sarraf, et al., (2010) concluded that, the solved salts leaching from the alluvial, heavy textured, saline and sodic soils of the region using the intermittent water application (intermittent salt leaching method) has been effective in reducing the soluble salts, especially in the soil profile shallow layers. The salinity and sodicity classes of the lands before implementation of leaching operations was ranging from *S3A3* to *S4A3* while after implementation of the test it changed to *S2A2* .This indicates the possibility of soil profile leaching soluble salts using the leaching water application and without any need for chemical soil improving amendments. Furthermore, it is worthy to use a unit depth of leaching water per unit depth of soil segment as the reclamation requirement and to continue the salt leaching gradually by irrigation through the principle of leaching requirement (Pazira et al., 2010 and Pazira, 2006).

Wheat is a very important crop in Egypt. However, its production is not sufficient the local consumption. The production of wheat is mainly depending on soil quality, the irrigation amount and the time of applied irrigation water.

The objectives of this work were to evaluate the effect of open drainage (narrow and wider spacing) and irrigation interval on, reducing waterlogging problems, improving properties of heavy clay salt affected soils and improve wheat crop production.

MATERIALS AND METHODS

Two field experiments were conducted at North Nile Delta (Al-Hamul District, Kafer El-Shiek Governorate, Egypt), during the two winter seasons (2015/2016 and 2016/2017). In order to evaluate, the effect of open drains spacing (10, 15, 20 m) and irrigation intervals (15 and 20 days intervals irrigation) under gypsum application (3tonfed.$^{-1}$) on some soil properties, wheat productivity and productivity of irrigation water. The experiment is located at 31° 24′ 41.50″ Latitude and 31° 04′ 31.47″Longitude. The initial of some soil properties for the experimental field were presented in Table (1). The experiment conducted in split plot design, with three replications, where the main plots assigned to open drains spacing and the sub plot were irrigation intervals as follows:

The main plots: Open drainage spacing**.**

1- 20-m drainage spacing

2- 15-m drainage spacing.

3- 10-m drainage spacing .

Sub plots: Irrigation intervals**.**

1. 20-days irrigation intervals.
2. 15-days irrigation intervals.

Open drains spacing were set up at 90 cm depth. Like most of the northern lands, the field lies on the tail of the main canal, irrigation water is frequently insufficient. The salinity of irrigation water ranges between 1.11 - 1.39 dSm^{-1} with an average of 1.25 dSm^{-1} (mixed water).

In the winter seasons (2015/2016 and 2016/2017) wheat (*Triticum aestivum L.*) was planted at 13th November 2015 and 16-November 2016. All plots received 50 kg/fed Ca-superphosphate (15.5% P_2O_5) during tillage operation, and 75kg N/fed. (as urea 46%) was applied in two doses before the first and second irrigation. All plots received three tonfed.$^{-1}$ of gypsum before cultivation. The different agricultural practices were done as recommended. Gypsum requirements were determined according to the methods described by U.S., salinity laboratory staff (FAO and IIASA, 2000), so 3.0 Mgfed.$^{-1}$, (Mg = metric tons) are sufficient to reduce the initial ESP from 17.31 to 13% for 30-cm soil matrix as follows:

$$\mathbf{GR= (ESP_i - ESP_F)/100 \times CEC \times 1.72}$$

Where: **GR: gypsum requirement (Mgfed^{-1}), ESP$_i$: initial soil ESP, ESP$_f$: the required soil ESP and CEC: cation exchange capacity (cmol$_c$ kg^{-1}).**

Soil samples (0-20, 20-40 and 40-70 cm depth) were collected before conducting the experiment and after harvesting the first and second seasons from treatments instillation and monitored for some physical and chemical analysis. Salinity was determined in saturated soil paste extract according to Page et al. (1982). Exchangeable sodium was determined using ammonium chloride and measured by using flame photometer according to Page et al. (1982). Infiltration rate was determined using double cylinder infiltrometer as described by Garcia (1978). Soil bulk density and total porosity of the different layers of soil profile measured after first and second seasons using the core sampling technique as described by Campbell (1994) for all treatments. Wheat was harvested on the 2nd of April, 2016 and 4th of April, 2017. Wheat productivity (grains and straw) was determined for different treatments

Applied irrigation water:

Amount of irrigation water measured by using a rectangular sharp crested weir. The discharge calculated using the following equation as described by (Masoud, 1969).

$$\mathbf{Q = CL(H)^{1.5}}$$

Where: Q = Discharge (m^{3}s^{-1})
L = Length of the crest (m).
H = Head above the weir (m).
C= Empirical coefficient determined from discharge measurement.

Productivity of irrigation water:

(PIW, kgm^{-3}) calculated according to Ali et al., (2007) as follows:

$$\mathbf{PIW = Gy/WA,}$$

Where: Gy= Grain and straw yields, kg fed.$^{-1}$,
WA= Water applied, m^3 fed.$^{-1}$

Statistical analysis:

Data for grains and straw yields of wheat were recorded and were subjected to statistical analysis by ANOVA technique according to Snedecor and Cochran (1980).Treatments were compared by Duncan's multiple range test (Duncan, 1955).

Table 1. The initial of some soil properties for the experimental field.

Soil depth (cm)	Particle size distribution%			Texture grade	EC (dSm^{-1})	ESP	Bulk density Mgm^{-3}	E%	CEC	PH	IR (cmhr^{-1})	K (m/day)
	Sand	Silt	Clay									
0-15	12.89	32.75	54.36	Clayey	9.18	16.67	1.27	52.08	42.59	8.21	0.57	0.096
15-30	13.08	32.68	54.24	Clayey	9.62	17.23	1.34	49.43	40.93	8.17		
30-60	13.17	32.94	53.89	Clayey	11.28	18.04	1.40	47.17	38.67	8.11		
Mean	13.05	32.79	54.16	Clayey	10.03	17.31	1.34	49.56	40.73	8.16		

EC = Electrical conductivity (Soil salinity), ESP = Exchangeable sodium percentage (Soil sodicity), IR = Infiltration rate

RESULTS AND DISCUSSION

Salinity (ECe) and sodicity (ESP):

Salinity (ECe) and sodicity (ESP) of the soil were high before treatments application (Table 1). The average values of ECe and ESP were 10.03 dSm^{-1} and 17.31, respectively for all depths. Results (Table 2) show that, treatments application with gypsum caused a decrease in salinity and sodicity of the soil. Whereas, soil salinity varied from 5.11 to 10.02 dS/m with an average of 7.32 dSm^{-1} and ESP from 13.13 to 15.35 with an average of 14.31 after two years from treatments application. The beneficial effects of treatments were to avoid the harmful stagnation of irrigation water, dissolved, and removed salts around the root zone.

Data presented in Table 2 and illustrated in Figs 1and 2 show that, narrow drain spacing (10-m open) are superior compare with wider spacing (20-m open) in reducing soil salinity and sodicity especially in surface layers. The average values of soil salinity were 7.1, 7.9 and 8.6 dSm^{-1} also, soil sodicity were 14.24, 14.69 and 15.10 for drainage spacing of 10, 15 and 20-m, respectively after one year. The corresponding values after two years were 6.59, 7.20 and 8.18 dSm^{-1} and 13.99, 14.25and 14.68, respectively. The result may explained on the assumption that the narrow drain spacing gave good drainage efficiency, improving soil physical and chemical properties, which affected water down movement and into drains carrying soluble salts. Antar et al., (2016) obtained similar results.

Results (Table 2 and Figs 1and 2) indicated that, narrow of irrigation intervals with open drainage spacing seems to be favorable effective in reducing salinity and sodicity of the soil particularly with narrow drain spacing. This result was agreement with Pazira and Homaee, (2010) and Sarraf et al., (2010). Generally, 15 days irrigation intervals caused decrease about 0.56, 0.99 and 1.60 dSm-1 of soil salinity and were 0.45, 0.51and 0.72 of soil sodicity under drain spacing of 20, 15 and 10m, respectively after the first season. The corresponding values were 0.73, 1.57 and 1.84 dSm^{-1} and 0.42, 0.91 and 0.95, respectively after the second season.

Narrow of drain spacing enhance downward movement of irrigation water carrying off excess salts from surface layers. After wards, regular subsequent irrigations will gradually reduce the salt content in groundwater at least when it is close to soil surface. The decrease of ESP as affected by narrow of drain spacing and irrigation intervals can be attributed to increase the leaching of Na^+ ions compared with calcium and magnesium salts and consequently decreasing of SAR (Abdel-Mawgoud et al., 2003). Soil salinity and sodicity increased with the increasing of soil depth. Such increase resulted from the high solubility of salts especially sodium salts and its downward movement with leaching and irrigation water compared with calcium and magnesium salts.

Table 2. Effect of the different treatments on salinity and sodicity of the soil in2015/2016 and 2016/2017 seasons.

Treatments		Soil depth (cm)	After first season		After second season	
			EC	ESP	EC	ESP
20-m drainage spacing	20 days intervals irrigation	0-15	8.05	14.87	7.56	14.31
		15-30	8.42	15.46	8.04	15.02
		30-60	10.17	15.63	10.02	15.35
	15 days intervals irrigation	0-15	7.35	14.55	7.02	14.42
		15-30	8.12	14.74	8.04	14.11
		30-60	9.48	15.33	8.36	14.89
Average (20-m)			8.6	15.095	8.175	14.68
15-m drainage spacing	20 days intervals irrigation	0-15	7.23	14.27	6.67	14.03
		15-30	8.01	15.21	7.85	15.05
		30-60	9.87	15.34	9.41	15.02
	15 days intervals irrigation	0-15	6.22	14.01	5.78	13.53
		15-30	7.17	14.12	6.12	13.68
		30-60	8.74	15.17	7.32	14.16
Average (15-m)			7.875	14.685	7.195	14.245
10-m drainage spacing	20 days intervals irrigation	0-15	7.03	14.12	6.18	14.01
		15-30	7.62	14.68	7.22	14.52
		30-60	9.05	15.01	9.14	14.87
	15 days intervals irrigation	0-15	5.62	13.28	5.11	13.13
		15-30	6.13	13.98	5.49	13.32
		30-60	7.14	14.38	6.42	14.12
Average (10-m)			7.1	14.24	6.59	13.995

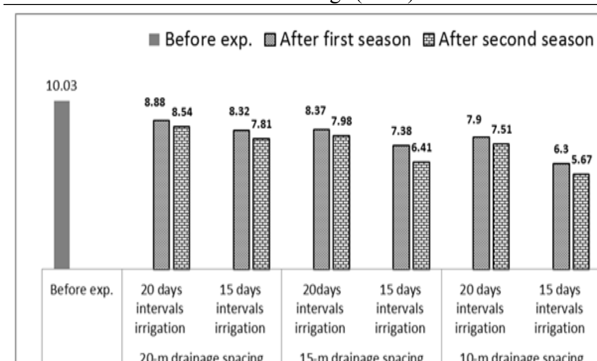

Fig (1): Avarage of soil salinity as affected by the different studied treatments.

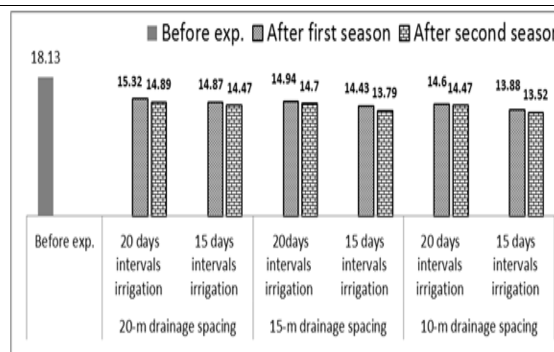

Fig (2): Avarage of soil sodicity as affected by the different studied treatments.

Ratios of Ca^{++}/TSS and Na+/TSS:

Results in Figs (3and 4) show that, treatments application with gypsum seemed to be more effective on increasing Ca^{++}/TSS and decreasing Na^{+}/TSS ratios than before application. The mean values of Ca^{++}/TSS ratio before treatments application was 17.54 while, after application the ratio was increased and varied from 19.90 to 26.70. On the opposite, the Na+/TSS ratio before application was higher (71.08) and decreased after application (varied from 65.60 to 58.90). The increases of Ca^{++}/TSS and decreases Na^{+}/TSS ratios after the second season from treatments application are more pronounced compared to after the first season. This may be due to the leachability of Na^{+} is higher than that of Ca^{++} and Mg^{++} with subsoiling. Also, Na^{+} and Cl^{-} are leached more readily than SO_4^{+}, Ca^{++} and Mg^{++}. In this concern, Ali and Kahlown (2001) mentioned that reclamation of saline – sodic and sodic soils, however, can not be achieved by simple leaching. Reclamation of these soils is difficult, time consuming and more expensive than that of saline soils due to replacement of exchangeable sodium with calcium. Hence, it requires the addition of chemical amendments such as gypsum along with leaching. They also added that, the effectiveness of gypsum depends upon: i. Degree of fineness, ii. Way in which it is incorporated on the soil and iii. Efficiency of drainage system.

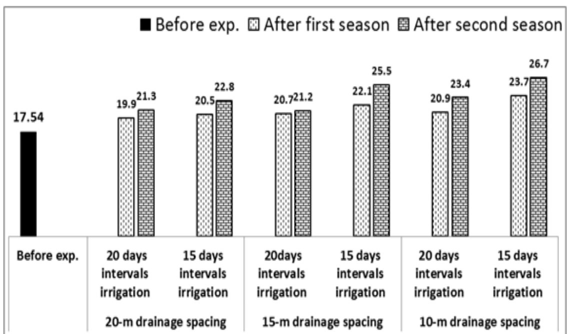

Fig (3): Avarage of Ca+/TSS as affected by the different studied treatments.

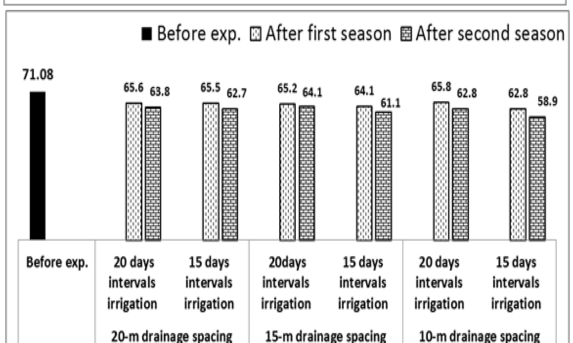

Fig (4): Avarage of Ca+/TSS as affected by the different studied treatments

The high ratio of Ca^{++}/TSS and the low ratio of Na^{+}/TSS were recorded with narrow drain spacing (Figs 3 and 4) compared to wider drain spacing especially after the second season . The average ratio of Ca^{++}/TSS were 22.00, 23.40 and 25.10 also, the average ratio of Na^{+}/TSS were 63.27, 62.58 and 60.81 for drainage spacing of 20, 15 and 10-m, respectively after the second season.

Narrow irrigation intervals seems to be favorable effective in increasing Ca^{++}/TSS ratio and decreasing Na^{+}/TSS ratio (Figs 3 and 4). 15 days irrigation intervals caused increase Ca^{++}/TSS ratio about 3.05 and decrease Na^{+}/TSS ratio about 2.69 than 20 days irrigation intervals after the first season.

Soil bulk density and Soil porosity

Data in Table (3) show that, treatments installation seemed to be more effective on decreasing soil bulk density and increasing total soil porosity. The average values of soil bulk density in the initial experimental was 1.34 Mgm^{-3} while, treatments application tend to decrease of soil bulk density and ranged from 1.36 to 1.11 Mgm^{-1} with an average of 1.20 Mgm^{-1}. On the opposite, total soil porosity before application was low (average, 49.56%) and increased with treatments application (varied from 48.68 to 58.11% with an average of 53.37%).

Results show that, narrow drain spacing (Table 3) are more pronounced on reduction of soil bulk density compared to wider drain spacing. The average values of soil bulk density were 1.20, 1.25 and 1.29 Mgm^{-3} after the first season and 1.19, 1.23 and 1.27 Mgm^{-3} after the second season for drainage spacing of 10, 15 and 20-m, respectively. In generally, total soil porosity values showed almost an opposite trend to that happened with bulk density with all treatments of study. This may be attributed to the assumption that, narrow drainage spacing (10-m open) gave a good drainage efficiency, improve soil properties and subsequently gave a better soil structure and improved soil permeability (Antar, 2000 and Antar et al., 2016).

On the other hand, bulk density and total porosity of the soil (Table 3) did not affect by irrigation intervals.

Infiltration rate (IR) and cumulative infiltration:

Results in Table (4) show that, basic infiltration rate before the experimental installation was lower (0.57 $cmhr^{-1}$) while, after one and two seasons from experimental installation were higher (varied from 0.75 to 0.88 $cmhr^{-1}$. This may be due to the drainage application gave the top soil layer a chance to dry and permitted for shrinkage and formation of water passage ways which allowed a rather easier movement of water into the drains. the result was agreement with Abdel-Mawgoud et al., (2006) .

Basic infiltration rate and cumulative infiltration under narrow drain spacing is superior to wider drain spacing. The average values of basic infiltration rate were 0.85, 0.80 and 0.75 cm hr^{-1} after the first season and 0.875, 0.845 and 0.75 $cmhr^{-1}$ after the second season for drainage spacing of 10, 15 and 20-m, respectively. The corresponding values of cumulative infiltration were 8.18, 8.02 and 7.40 cm after the first season and 8.35, 8.25 and 7.73 after the second season, respectively. The effect of narrow drain spacing in increasing the basic infiltration rate and cumulative Infiltration may be due to the lowering water table level, swelling, shrinkage and cycles which improved soil structure (El-Hamchary et al., 1989 and Antar, 2000). On the other hand, increasing basic infiltration rate ($cmhr^{-1}$) and cumulative infiltration (cm) of the soil (Table 4) do not affect by irrigation intervals.

Table 3. Soil bulk density and total porosity as affected by treatments application after the first and second seasons from wheat cultivation.

Treatments		Soil depth (cm)	After first season		After second season	
			Soil bulk density Mgm^{-3}	Porosity	Soil bulk density Mgm^{-3}	Porosity
20-m drainage spacing	20 days intervals irrigation	0-15	1.21	54.34	1.19	55.09
		15-30	1.29	51.32	1.28	51.70
		30-60	1.36	48.68	1.33	49.81
		Average	1.29	51.45	1.27	52.20
	15 days intervals irrigation	0-15	1.21	54.34	1.21	54.34
		15-30	1.31	50.57	1.26	52.45
		30-60	1.35	49.06	1.34	49.43
		Average	1.29	51.32	1.27	52.08
Average (20-m)			1.29	51.39	1.27	52.14
15-m drainage spacing	20 days intervals irrigation	0-15	1.20	54.72	1.18	55.47
		15-30	1.23	53.58	1.19	55.09
		30-60	1.31	50.57	1.31	50.57
		Average	1.25	52.96	1.23	53.71
	15 days intervals irrigation	0-15	1.15	56.60	1.14	56.98
		15-30	1.24	53.21	1.25	52.83
		30-60	1.32	50.19	1.30	50.94
		Average	1.24	53.33	1.23	53.58
Average (15-m)			1.25	53.15	1.23	53.65
10-m drainage spacing	20 days intervals irrigation	0-15	1.12	57.74	1.11	58.11
		15-30	1.20	54.72	1.19	55.09
		30-60	1.29	51.32	1.26	52.45
		Average	1.20	54.59	1.19	55.22
	15 days intervals irrigation	0-15	1.13	57.36	1.11	58.11
		15-30	1.20	54.72	1.16	56.23
		30-60	1.27	52.08	1.29	51.32
		Average	1.20	54.72	1.19	55.22
Average (10-m)			1.20	54.66	1.19	55.22

Table 4. Basic infiltration rate ($cmhr^{-1}$) and cumulative infiltration (cm) after the first and second seasons as affected by treatments application.

Treatments		After first season		After second season	
		Basic IR ($cmhr^{-1}$)	Cumulative infiltration (cm)	Basic IR ($cmhr^{-1}$)	Cumulative infiltration (cm)
20-m drainage spacing	20 days intervals irrigation	0.75	7.35	0.75	7.65
	15 days intervals irrigation	0.75	7.45	0.75	7.8
15-m drainage spacing	20 days intervals irrigation	0.8	8.05	0.84	8.24
	15 days intervals irrigation	0.8	8	0.85	8.25
10-m drainage spacing	20 days intervals irrigation	0.85	8.15	0.88	8.33
	15 days intervals irrigation	0.85	8.2	0.87	8.37

Yields:

Data in Table (5) indicated that, treatments application caused significant increases of wheat yields, especially in the second season. The yields were increase when improving soil properties as affected by treatments application. It can be conclude that heavy clay salt affected soils could have good productivity with the execution of open drainage especially narrow spacing and reduce of irrigation interval.

The increase of wheat yields were more pronounce with narrow drain spacing compared to wider drain spacing. The increases of wheat grains yield were 20.14 and 9.59% in the first season and 17.50 and 9.74% in the second season for 10-m and 15-m open drain spacing, respectively comparing with 20-m drain spacing. The corresponding values of wheat straw yield were 11.44 and 6.16% in the first season and 10.70 and 6.16% in the second season, respectively. Such findings attributed to the effect of narrow drain spacing on improving soil properties. It can be concluded that under such conditions the application of open drainage with narrow spacing are the most effective treatments that ameliorate saline sodic clay soil.

Results (Table 5) show that, the reduction of irrigation interval resulted in increasing of wheat yields. 15 days irrigation intervals caused higher in wheat grains yield than 20 days irrigation intervals by 9.67 and 10.23 % in the first season and second season, respectively. The corresponding values of wheat straw yield were 9.07 and 9.60 %, respectively. It can be conclude that under such conditions the reduction of irrigation interval is the most effective treatments that ameliorate saline sodic clay soil.

The interaction between open drain spacing and irrigation intervals, data showed that narrow drain spacing (10-m drain spacing) combined with low irrigation intervals (15 days irrigation intervals) resulted in high wheat yields. While, wider drain spacing (20-m drain spacing) combined with wider irrigation intervals (20 days irrigation intervals) resulted in low wheat yields.

Table 5. Wheat yields with different studied treatments.

Treatments		Wheat yields (kg fed-1)			
		After first season		After second season	
		Grains	Straw	Grains	Straw
Drain spacing					
20-m drainage spacing		1810 c	1705 b	1870 c	1705 b
15-m drainage spacing		2000 b	1810 a	2085 b	1810 a
10-m drainage spacing		2193 a	1900 a	2233 a	1888 a
F test		**	*	**	*
LSD 0.05 %		151	101	134	97
Irrigation interval					
20 days intervals irrigation		1903	1727	1952	1718
15 days intervals irrigation		2098	1883	2173	1883
F test		**	**	**	**
LSD 0.05 %		146	129	168	131
Drainage x Irrigation					
20-m drainage spacing	20 days intervals irrigation	1710 d	1630 d	1760 d	1630 c
	15 days intervals irrigation	1910 c	1780 bc	1980 c	1780 b
15-m drainage spacing	20 days intervals irrigation	1900 c	1730 c	1980 c	1730 bc
	15 days intervals irrigation	2100 b	1890 b	2190 b	1890 a
10-m drainage spacing	20 days intervals irrigation	2100 b	1820 b	2115 b	1795 b
	15 days intervals irrigation	2285 a	1980 a	2350 a	1980 a

Applied water and productivity of irrigation water (PIW, kgm^{-3}): -

Data are presented in Table (6) indicated that, the application of open drainage with narrow spacing had received the highest amount of irrigation water compared to wider drain spacing. This is due to, under narrow drain spacing noticed, high amount of drainage water was discharged also application of narrow drain spacing gave the top soil layer a chance to dry and permitted for shrinkage and formation of water passage ways which allowed a rather easier movement of water into drains. On the other hand, open drainage with wider spacing stored more water. The amount of water applied through the first season was higher than second season. This due to, in the second season the increase in setting of trench backfill after one year from digging and backfilling in such low permeability heavy textured soil (El-Hamchary et al., 1989). Total amount of water applied (m^3/fed) including rainfall (8cm) of wheat crop shown in Table (6). The average values of applied water were 2090, 2215 and 2330m^{3}fed^{-1} in the first season and 2065, 2195 and 2300m^{3}fed^1 in the second season for open drainage spacing of 20-m, 15-m and 10-m, respectively. In addition, irrigation intervals of 15 days had received the highest amount of irrigation water compared to irrigation intervals of 20 days. The average values of applied water were 2123 and 2300m^{3}fed.$^{-1}$ in the first season and 2107 and 2267 m^{3}fed.$^{-1}$ in the second season for 20 and 15 days irrigation intervals, respectively.

Productivity of irrigation water is (PIW) generally defined as crop yield per cubic meter of water applied (Ali et al., 2007). Data are presented in Table (6) illustrated that the values of PIW for wheat grain and straw yields were greatly influenced by different treatments in both seasons. Results indicate that, productivity of irrigation water (kg m^{-3}) are more pronounced with narrow drain spacing and 15 days irrigation interval compared to wider spacing and 20 days irrigation interval. The highest values of PIW for grain yield (0.95 and 1.00 kg m^{-3} for first and second season, respectively) were found under narrow drain spacing (10-m) with 15 days irrigation interval, while the lowest values (0.86 and 0.90 kg m^{-3} for first and second season, respectively) were found under wider spacing (20-m) with 20 days irrigation interval. The improvement of PIW may be due to improving the yields (Table 5). With respect to PIW for wheat straw yield, data showed that values of PIW were ranged from 0.81 to 0.83 kg m^{-3} in the first season, while the corresponding values of PIW ranged from 0.82 to 0.84 kg m^{-3} in the second season

Table 6. Water applied (m^{3}fed.$^{-1}$) and productivity of irrigation water (PIW, Kgm^{-3}) for both grain and straw yields of wheat crop as affected by different treatments.

Treatments		Water applied m^{3}fed^{-1}		Productivity of irrigation water (Kgm^{-3})			
				Grain yield		Straw yield	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
20-m drainage spacing	20 days intervals irrigation	1980	1960	0.86	0.90	0.82	0.83
	15 days intervals irrigation	2200	2170	0.87	0.91	0.81	0.82
15-m drainage spacing	20 days intervals irrigation	2130	2120	0.89	0.93	0.81	0.82
	15 days intervals irrigation	2300	2270	0.91	0.96	0.82	0.83
10-m drainage spacing	20 days intervals irrigation	2260	2240	0.93	0.94	0.81	0.80
	15 days intervals irrigation	2400	2360	0.95	1.00	0.83	0.84

CONCLUSION

Based on obtained results of the current study it can be concluded that, narrow open drain spacing with reduce of irrigation intervals under gypsum application had favorable effective to improve physio-chemical characteristics of heavy clay salt effect on soils as well as increase production and productivity of irrigation for wheat crop.

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تحسين منطقة الجذور وانتاجية القمح في الأراضي الطينية الثقيلة المتأثرة بالأملاح

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أجريت تجربة حقلية في شمال الدلتا بمحافظة كفر الشيخ - مصر خلال موسمي الشتاء 2016/2015 و2017/2016 ذلك لمعرفة تأثير مسافات الصرف المكشوف (10متر، 15 متر، 20متر بين المصارف) والفترة بين الريات (15يوم، 20 يوم) تحت إضافة الجبس الزراعي (3 طن للفدان) على بعض صفات التربة الطينية الثقيلة المتأثرة بألاملاح والإنتاج وايضا انتاجية وحدة المياه لمحصول القمح. وتوضح النتائج: إنخفاض في ملوحة وصودية التربة بعد موسمي من تطبيق المعاملات، حيث إنخفضت الملوحة من 10.03 الي 7.32 ديسيسيمنز للمتر والصودية من 17.31 ال 14.31. ومسافات الصرف الضيقة افضل من المسافات الواسعة في تقليل ملوحة وصودية التربة. حيث ان متوسط قيم الملوحة 6.59، 7.20، 8.18 ديسيسيمنز للمتر و متوسط قيم الصودية 13.99، 14.25، 14.68 للمسافات 10، 15، 20 متربين المصارف على التوالي. الفترة الضيقة بين الريات (15 يوم) أدت الى نقص الملوحة حوالي 1.38 ديسيسيمنز للمتر والصودية 0.76 مقارنة بالفترة الواسعة بين الريات (20 يوم). تطبيق المعاملات خصوصاً مسافات الصرف الضيقة والفترة الضيقة بين الريات مع إضافة الجبس الزراعي أدت الى زيادة نسبة الكالسيوم على الاملاح الكلية الزائبة ونقص نسبة الصوديوم على الاملاح الكلية الزائبة. تطبيق المعاملات خصوصاً مسافات الصرف الضيقة والفترة الضيقة بين الريات مع إضافة الجبس الزراعي تبدو اكثر فاعلية في تحسين الكثافة الظاهرية والمسامية الكلية للتربة وايضاً تحسين معدل التشرب الأساسي والرشح التجميعي للمياه في التربة. تطبيق المعاملات حققت زيادة معنوية في إنتاج القمح. حيث زاد انتاج القمح من الحبوب مقدار 20.14، 9.59% في الموسم الاول و17.50، 9.74% في الموسم الثاني للمسافات 10، 15 متربين المصارف الحقلية على التوالي مقارنة بالمسافة 20 متر بين المصارف. وكانت القيم المماثلة لانتاج القمح من التبن حوالي 11.44، 6.16% في الموسم الاول و10.70، 6.16% في الموسم الثاني على التوالي. وفترات الري 15 يوم حققت زيادة في انتاج القمح من الحبوب مقارنة بفترات الري 20يوم حوالي 10.23،9.67% في الموسم الاول والثاني على التوالي. وكانت القيم المماثلة لانتاج القمح من التبن 9.07، 9.60% في الموسم الاول والثاني على التوالي. وايضاً زاد انتاج القمح نتيجة التفاعل بين مسافات الصرف الضيقة ونقص الفترة بين الريات. وأن انتاجية وحدة المياه للقمح افضل مع مسافات الصرف الضيقة والفترة الضيقة بين الريات. حيث تحققت أعلى القيم مع المسافة 10 متر بين المصارف مع فترات ري 15 يوم بين الريات بينما اقل القيم مع المسافة 20 متر بين المصارف مع فترات ري 20 يوم بين الريات. عموماً مسافات الصرف الضيقة مع نقص الفترة بين الريات واضافة الجبس الزراعي تؤدي إلى تحسين الصفات الطبيعية والكيميائية للتربة الطينية الثقيلة المتأثرة بالأملاح وايضاً إلي زيادة الإنتاج وانتاجية وحدة المياه لمحصول القمح.