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EFFECT OF LATERALS DRAIN SPACING AND GROUNDWATER DEPTH ON SOIL WATER RELATIONS AND RICE PRODUCTIVITY IN THE NORTH NILE DELTA

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ABSTRACT: A field experiment was conducted in alluvial clay soil located at the north Nile Delta (Motobus District, Kafrelshiekh Governorate, Egypt). The soil was cultivated with rice crop (*Oryza sativa L*.) during two summer seasons 2018 and 2019. The impact of lateral drain spacing at 20m and 40m between laterals (main plots) with controlled drainage (CD) at 0.4, 0.8m depth and uncontrolled drainage at 1.2m below soil surface (sub plots) was studied to evaluate soil-water properties, Nitrate losses, water saving, rice productivity and economic return under rice crop cultivation.

Results showed that the relative groundwater depth values (RGWD) are inversely proportional to the drain spacing treatments. The highest values of drainable porosity (0.145 and 0.141%) were achieved in the plots subjected to 20 m drain spacing with uncontrolled treatment, while the lowest values (0.1 and 0.101%) were obtained at 40m drain spacing with 0.4m controlled drainage in both seasons, respectively.

It's clear that narrow drain spacing of 20m and water table depth at 0.4m was more efficient than the wider drain spacing at 40m in reducing values of soil salinity, SAR and bulk density compared with its values before installation of drainage system. On the other, hand it gave the highest values for water saving, nitrate saving, productivity of irrigation water, rice yields, net return, net income from water unit, economic efficiency compared to wider drain spacing (40 m) with 1.2 m ground water depth. The controlled drainage reduced drainage outflow compared to conventional drainage. It can be concluded that the treatment of controlled drainage gave more profit than the uncontrolled one.

Key words: Nitrate losses, drainable porosity, drain spacing, ground water depth, discharge rate, rice crop, economic return.

INTRODUCTION

Subsurface drainage is widely practiced in the Nile Delta region. Subsurface tile drainage has been effective in draining croplands. Detailed controlled studies were undertaken in order to understand the salt dynamics under rice and associated crops and their impact on soil and drainage water quality. This includes the influence of different crop rotations, farm practices, and subsurface drainage status on salt build-up, and the contribution of groundwater to evapotranspiration (Skaggs et al., 2012; El-Ghannam et al., 2016).

Excessive drainage might result in soil water deficit, nutrient leaching, and low irrigation system- and water use efficiencies (Campus, 2019). Therefore, the role of subsurface drainage might be changed from only controlling waterlogging and/or salinity to an essential element of integrated water and water-table (WT) management (Javani et al., 2018).

The ultimate objective of water table (WT) management is to maintain it at the desired depth to ensure adequate root-zone aeration (Lavaire et al., 2017). In controlled drainage (CD), the drains are shallower than in the free system, thus WT is maintained at lower depth, as a result, CD reduces deep percolation and increases upward flow by capillary as evapotranspiration reduces soil content in the surface soil layer (Lu et al., 2016). Therefore, the use of CD increase water availability for crops during dry periods thus reduced drought or water deficit (Skaggs et al., 2012). Controlled drainage was capable of reducing drainage volume and nitrate-nitrogen loss by 40% to 50% compared to conventional free drainage (Skaggs et al., 2010). Phosphorus losses were decreased by 25% to 35%. These general findings have been confirmed elsewhere (Feser et al.,2010), resulting in the generalization that a properly sited and managed controlled drainage system can lower discharges and pollutant loads by roughly 30% compared to free drainage systems. The benefit of controlled drainage on crop yields has generally been modest and highly dependent on management and soil conditions. Several studies suggest that crop yields from controlled drainage systems may surpass those from conventional or free drainage systems by 5% to 10% (Skaggs et al., 2012 and Sobeih et al., 2017).

The outflow from the 6 m spacing treatment was approximately 2 times that of the 12 m spacing treatment for all levels of outflow. Water table heights mid-way between adjacent drain lines averaged 100 mm lower on the 3 m spacing plots compared to the 6 and12m spacing plots for periods when the water table for all treatments was above the compacted subsoil. The sum of the excess water table levels above a 300 mm depth for the 3 m spacing treatment were significantly lower than those for the 6 and12 m spacing treatments (Madani and Brenton 1994). The subsurface drainage with spacing of 15 m and depth of 80 cm (due to the proper water table depth and higher yield) and subsurface drainage with distance of 10 m and depth of 80 cm (due to the highest resistance to penetrometer penetration and the lowest soil moisture content) are recommended as the best drainage treatment for midseason and end-season drainage, respectively (Alizadeh et al 2018).

The reductions in the drained water volumes corresponded an increase in evapotranspiration and plant water uptake (Craft et al., 2018) and reduce N transport (by 18% to 75%) and total P (by 35%-45%) depending on drainage system design, climate, soil, and site conditions (Ayars et al., 2006; Craft et al., 2018; Drury et al., 2009; Helmers et al., 2012; Javani et al., 2018; Lavaire et al., 2017; Liu et al., 2019; Lu et al., 2016; Skaggs et al., 2012).

Rice (*Oryza sativa L.*) is the staple food for more than half of the human population, and as such it plays a key role in ensuring food security all over the world. Rice crop plays a significant role in Egypt, for sustaining the food self-sufficiency and for export. Rice is considered the most popular and important field crop in Egypt for several reasons: as a staple food for more than 50% of Egyptians, as an important exporting crop, as a land reclamation crop for improving the productivity of the saline soils widely spread in Nile Delta and coastal area (IRRI,2020). Average rice yield obtained under subsurface drainage systems were however noticeably higher when compared with harvest from fields without such a drainage facility irrespective of the season (Elghannam et al., 2016).

The main objective of the current work was to study the effect of drainage dynamics on rice productivity, with respect to compute irrigation water Also, to find out the proper depth of water table

in computing irrigation water in North Nile Delta region where the study took place and to find out the most suitable lateral distance for maximizing crop-water productivity.

MATERIALS AND METHODS

A field experiment was conducted during the two summer seasons (2018 and 2019), to determine the impact of drain spacing at 20m and 40m between laterals (main plots) with controlled drainage at 40cm, 80cm and (120cm un managed treatment) below soil surface (sub plots) on soil salinity, water saving, nitrate losses, productivity and economic returns for water and yield of rice crop.

The experiment is located at 31˚ 21ˊ 33.77˝ Latitude and 31° 38′ 47.7″ Longitude in Motobus District, Kafr El-Sheikh Governorate, Egypt. The tile lines were spaced to simulate a 20m and 40m spacing, 100 m length and 1.2 m depth with a slope of 0.1%. Some soil properties before conducting the experiments are presented in Table (1). The different agricultural practices were performed as recommended through the two growing seasons. In the summer seasons (2018 and 2019) rice (*Oryza sativa*) Sakha Super 300 cultivar was transplanted in 15th June, 2018 and 25th May, 2019. All plots received 150 kg fed.$^{-1}$ Ca-superphosphate (15.5% P_2O_5) during tillage operation and nitrogen was applied at rate of 100 kg fed.$^{-1}$ (as urea 46.5%N) in one dose after 15 days from transplanting. Rice was harvested on the 25th of September, 2018 and 15th of September, 2019. Grains and straw yields of rice were determined and converting to kg fed^{-1} for different treatments.

Soil samples were taken to a depth of 1.2 m, before conducting the experiment and after harvesting the first and second seasons for analysis. Salinity was determined in saturated soil paste extract according to Page et al., (1982). Soil bulk density and total porosity of the soil were measured using the core sampling technique as described by Campbell (1994). Drain discharge rates were manually measured two times every day when drain flow occurred, by measuring the amount of water running from tile line during a short interval and converting to m^{3}fed^{-1}. The average daily discharge rates were used in this study as recommended by Dieleman and Trafford, 1976. Several water samples from tile effluent (as drainage water) were collected at different times along the day and composite daily samples were taken for analysis. The water samples taken from tiles were analyzed for NO^{-}_{3} using Kjeldahl method and available N content of soil were determined using Kjeldahl digestion (Cottenie et al., 1982).

Table (1): The initial of some soil properties for the experimental field

Soil depth (cm)	Particle size distribution%			Texture grade	EC (dSm^{-1})	SAR	CEC Meq/ 100g soil	pH	OM %	Available N (mgkg^{-1})
	Sand	Silt	Clay							
0-30	16.70	33.27	50.03	Clayey	2.57	3.4	44.6	7.95	1.94	16.4
30-60	15.55	34.5	49.95	Clayey	2.85	3.9	37.6	8.10	1.80	24.5
60-90	17.52	32.54	49.94	Clayey	3.25	4.5	36.0	8.15	1.62	19.5
90-120	20.45	30.54	49.01	Clayey	3.40	5.35	39.5	8.17	1.25	22.55
Mean	17.55	32.71	49.73	Clayey	3.02	4.29	39.42		1.65	20.73

Applied irrigation water

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

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

Where: Q = Discharge (m^3s^{-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}) was calculated according to Ali et al., (2007) as follows:

$$PIW = Gy/WA, \text{ where}$$

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

Drainable Porosity (f)

Soil drainable porosity (f) is defined as the volume of water that is drained (or taken up) by a unit volume of soil when the water table drops or rises over a unit distance. The value of (f) is not generally constant but besides other things, it is a function of water table depth i.e. soil depth, Z (Taylor, 1960). The time of drawdown and shape of the water table depends on the particular way in which drainable porosity is related to water table depth. Thus, it is convenient and often necessary in drawdown studies to express f as a function of Z. A functional relationship between f and Z was developed by regression which is described by the following equation:

$$f = aZ^b$$

Where 'a' and 'b' are the regression coefficients (a=0.138; b=0.550).

Salt balance

Salt residual ($kgfed^{-1}$) was calculated by deducting the salt removed from salt added, ($kgfed^{-1}$). Salt added ($kgfed^{-1}$) was calculated by multiplying irrigation water amount (m^3fed^{-1}) by its salinity (EC, dSm^{-1}) and 0.64. Salt removed ($kgfed^{-1}$) was calculated by multiplying drainage water amount (m^3fed^{-1}) by its salinity (EC,dSm^{-1}) and 0.64, whereas; EC x 0.64 =

$$\frac{gm}{liter} = \frac{10^{-3}kg}{10^3(10^{-6}m^3)} = \frac{kg}{m^3} = \frac{kgfed^{-1}}{m^3fed^{-1}}$$

Economic evaluation

Cash inflows and outflows for various treatments (at prices of the local market) were calculated, and some economic indicators were estimated such as:

- **Net return:** It can be calculated by deducting the total cost from the total return, ($LEfed.^{-1}$)
- **Economic efficiency:** It can be calculated by dividing the total seasonal net return on total seasonal cost
- **Net return from water unit (L.E m^3):** It can be calculated by dividing seasonal net return (LE $fed.^{-1}$) on seasonal water applied (m^3 $fed.^{-1}$).

Meteorological data *such as* monthly temperature (°C), relative humidity and rainfall of Sakha area, Kafr El-Sheikh Governorate during the two growing summer seasons 2018 and 2019 are shown in Table 2. The data were estimated from Sakha meteorological station in the studied area.

Statistical analysis:

Data obtained for rice grain and straw yields are subjected to statistical analysis according to Snedecor and Cochran (1980). The differences between the means compared by Dukun's multiple range test.

Table 2: Monthly maximum and minimum temperature (°C), relative humidity (%), wind speed and Pan Evaporation at the experimental site during the two growing seasons

Months	Air Temperature (°C)			Relative humidity (%)		Wind speed	Pan E
	Max	Min	Mean	Max	Min	Km day^{-1}	mm day^{-1}
1St season 2018							
May	31.2	23.8	27.5	75.6	43.9	95.8	6.33
June	32.6	25.3	29.0	75.5	48.0	98.6	7.71
July	34.2	25.4	29.8	82.6	51.0	89.5	7.37
August	33.9	25.2	29.6	82.4	51.8	76.0	6.42
September	32.8	23.5	28.2	83.1	48.3	68.7	4.98
2nd season 2019							
May	31.9	25.4	28.7	76.4	37.9	68.4	6.83
June	33.0	28.0	30.5	81.5	50.0	103.0	8.46
July	33.5	28.4	31.0	85.2	54.4	83.8	8.08
August	34.2	28.9	31.6	89.7	55.6	68.7	6.82
September	32.4	27.9	30.2	83.4	52.9	76.9	5.90

RESULTS AND DISCUSSION

Relative groundwater depth (RGWD)

The drainage systems are mainly constructed in the arid and semi-arid regions to remove both of excess groundwater and soluble salts. In Egypt, the intended groundwater depth was taken as 0.8 m indicating that the values more than one-meter reveal to a good drainage conditions and vis versa. Water table depth in the plots which not subjected to subsurface open drains is high and mostly close to the ground surface, so the RGWD values are smaller than that in drained plots. On the other hand, the relative groundwater depth values (RGWD) are inversely proportional to the drain spacing treatments indicating the high efficient of narrow drain spacing to evacuate excess groundwater (Table 3). The high groundwater under the highly evaporation conditions predominated in the studied area rises to ground surface by capillary fringes, evaporates and leaves a considerable amounts of soluble salts. The increase percentages in relative groundwater depth are 0.67, 0.91 and 1.10 m in the plots subjected to drain spacing of 20 m and 0.58, 0.79 and 1.01 m for 40 m spacing of drain under 40, 80 and 120 cm of water table, respectively during 2018 growing season. As the same trend in the second growing season, these findings are agreed with those of Gupta et al., (1998) and Abdalla (2000) who stated that the decrease in drain spacing was more efficient to lower groundwater depth resulting in a good aeration and improving soil structure. Such improvements in soil structure play an important role in root and water penetration and consequently enhance the rooting depth of most crops, (Armstrong et al, 1990).

Table (3): Effect of controlled drainage and drain spacing treatments on relative groundwater depth (RGWD), physical and chemical properties among two summer seasons of 2018 and2019

Treatments		RGWD	Bulk density Mg/m^3	Total porosity %	Drainable porosity %	EC of GW dSm^{-1}	SAR
Drain space (m)	Drain depth (m)						
1st season 2018							
20	0.4	0.67	1.27	52.07	0.11	2.35	5.40
	0.8	0.91	1.29	51.32	0.13	2.15	4.70
	1.20	1.10	1.30	50.94	0.145	1.75	3.55
40	0.4	0.58	1.29	51.31	0.10	2.85	6.70
	0.8	0.79	1.32	50.18	0.117	2.45	5.85
	1.20	1.01	1.35	49.05	0.138	2.1	4.50
2nd season 2019							
20	0.4	0.63	1.28	51.69	0.107	2.45	5.25
	0.8	0.89	1.28	51.69	0.129	2.29	4.65
	1.20	1.05	1.30	50.94	0.141	1.62	2.25
40	0.4	0.57	1.27	52.07	0.101	2.55	6.75
	0.8	0.75	1.31	50.56	0.118	2.19	4.90
	1.20	0.99	1.32	50.18	0.137	1.16	2.45

Drainable porosity (f)

Drainable porosity outlined the effectiveness of drainage to improve soil structure. Good structure means favorable conditions for simultaneous aeration and storage of soil moisture. The highest values (0.145 and 0.141 %) with 1.2 m of ground water table (unmanaged treatment) as well as 20 m drain spacing and lowest one of drainable porosity (0.1 and 0.101 %) are achieved in the plots subjected to 40 m drain spacing treatment and controlled drainage at 40 cm depth of water table in the both seasons respectively, (Table 3). On the other hand, the effect of drainage installation age is clearly pronounced on the drainable porosity, where the greatest values of (f) are achieved after two years of drain installation. This favorable effect may be due to the friable granules existing after drainage installation, which promotes wetting and drying cycles sufficient to bring about cracking and aeration of the soil.

Soil salinity

Implementation of strategies aimed to increase plant water use from a shallow groundwater source since it will need to carefully consider soil salinity increases and implement appropriate monitoring. While the increase in soil salinity is a drawback associated with controlled drainage, mitigation of its effects should be possible by leaching between periods of controlled drainage, e.g. allowing free drainage during the first irrigation of the next season.

Results concerning the soil salinity of the studied soil before and after the two growing seasons are given in Table (4). It is clear from the obtained data that, salinity (ECe) of the soil before the experimental setup was moderate and varied from 2.57 to 3.4 dSm^{-1} with an average of 3.02 dSm^{-1} for all depths during the 1st growing season and varied from 2.4 to 3.9 dSm^{-1} with an average 3.16 dSm^{-1} in the 2nd season.

Table (4): Effect of distance and depth of lateral treatments on salinity (EC), dSm^{-1} distribution in the studied soils

Soil depth (cm)	Initial dSm^{-1}	20-m spacing			40-m spacing		
		40cm depth	80cm depth	120cm depth	40cm depth	80cm depth	120cm depth
1st season 2018							
0-30	2.57	1.75	1.50	1.40	1.95	1.90	1.50
30-60	2.85	2.10	1.90	1.70	2.91	2.15	1.80
60-90	3.25	2.90	2.10	1.90	3.35	2.50	2.10
90-120	3.40	3.25	3.10	2.25	3.95	3.70	2.70
Average	3.02	2.50	2.15	1.81	3.04	2.56	2.03
2nd season 2019							
0-30	2.40	1.85	2.35	1.40	2.30	2.50	1.70
30-60	2.90	2.10	2.70	1.90	2.50	2.85	2.15
60-90	3.45	2.75	3.17	2.70	3.10	3.30	2.95
90-120	3.90	3.15	3.10	3.40	3.50	3.50	3.65
Average	3.16	2.46	2.83	2.35	2.85	3.04	2.61

Results in Table (4) show that, the salinity of the soil after rice harvesting were 2.5, 2.15 and 1.81 dSm^{-1} for 40, 80 and 120 cm of water table depth under 20 m spacing between laterals, while the corresponding values were 3.04, 2.56 and 2.03 dSm^{-1} for 40, 80 and 120 cm depth of water table under 40m spacing lateral after the first growing season. On the second season the soil salinity values 2.46, 2.83 and 2.35 dSm^{-1} for managed treatments 40 , 80 cm depth of water table as well as un managed 120 cm depth of ground water under 20 m spacing, while the salinity values were 2.85, 3.04 and 2.61 dSm^{-1} for 40 and 80 cm controlled drainage and uncontrolled treatment (120cm) respectively. These results indicate that the applied treatments caused decrease of soil salinity compared to free drainage treatment before installation of drainage system. The effect of drainage intensity and rice crop on reducing soil salinity is attributed to the increase of leaching salts with drainage water. Similar results were obtained by (Hornbuckle, 2003).

It is obvious that secondary salinization due to the capillary rise of groundwater table is the main source of soil salinity in the studied soils. In general salt concentration and its composition reflect the balance between the different sources of recharge and discharge and the interaction between water table and soil salinity.

Drain discharge

Data in Table (5) showed that the mean values of lateral drain discharge as affected by controlled drainage treatments under rice crop during the two successive seasons of 2018 and 2019. Concerning to the treatments of 40 and 80 cm the disposal of drains discharge started during irrigation and increased to the high value after few hours from irrigation then decreased with time for all irrigation cycles. Ibrahim et al., 2002. Antar, 2007 and Ramadan et al., 2009 pointed out that the majority of water discharge in clay soil is from preferential flow or from water movement through soil cracks and macro pores.

It's worth to mention that, the cumulative drain discharge (m^3 fed^{-1}) was higher under uncontrolled treatment of 120 cm than 40 cm. The values of total cumulative drain discharge were 927 and 1651.3 m^3 fed^{-1} under 20 m spacing of lateral and 855 and 1467.5 m^3 fed^{-1} for 40 m spacing for water table levels of 40 and 120 cm, respectively in the first season. While in the second season the data were 932.4 and 1676.5 m^3 fed^{-1} under 20 m spacing and 833 and 1551 m^3 fed^{-1} under 40 m spacing for ground water table depth of 40 and 120 cm, respectively.

It can be seen that, the controlled drainage reduced drainage outflow compared to conventional drainage without outlet control under different spacing of drainage lateral. The different outflow volumes had a large effect on the salt loads; the uncontrolled drainage removed more substantial loss of salts than the controlled drainage treatments. The obtained results are in the accordance with those reported by Evans et al., (1996). After harvesting for each season the control valves were removed from the controlled drainage laterals to allow the drains to flow freely and some salts were leached. This provided the opportunity to compare the performance of those laterals with and without control valves. It can be clearly seen that controlled drainage was effective in controlling drain discharge and this caused a reduction in drainage discharge which had the benefit of reducing disposal problems due to the decreased drainage volumes and subsequently lower salt loads to drains. However, two issues need to be considered regarding the suitability of controlled drainage. Firstly, if controlled drainage management is to be successful then it relies on the crop being able to successfully use water from the water table to meet part of its evapotranspiration requirements, secondly, it can be seen that salt accumulation occurred in the controlled drainage treatments. Therefore, the effects of controlled drainage on soil salinity levels need to be thoroughly investigated in order to assess the sustainability of the system (El-Ghannam et al., 2016).

Nitrate in drainage water

Drainage water management is a conservation practice that has the potential to reduce drainage outflow and nitrate loss from agricultural fields which maintaining or improving crop yields. Data in Table (5) show the nitrate losses as affected by controlled drainage during the two successive seasons of 2018 and 2019 under rice crop. Seasonal concentration of NO_3^- N-loss in drainage water varied from 34 to 48ppm with 20m spacing and varied from 31 to 44 ppm under 40 m spacing for free drainage treatment (120 cm depth of water table) and 40 cm of water table depth treatment in the 1st season. While in the 2nd growing season, the values of NO_3^- N-loss in the drainage water fluctuated from 34 to 50 ppm under 20 m lateral distance and varied from 39 to 53 ppm through 40 m lateral spacing for the free drainage compared to controlled drainage at 40 cm depth of water table.

The cumulative nitrate loss in the subsurface drainage water from the free drainage treatment (56.14 and 45.49 $kgfed^{-1}$ for 20 and 40m lateral spacing, respectively) were greater than the controlled drainage at 40 cm depth of water table (44.5 and 37.62 kg fed^{-1} for 20 and 40m lateral spacing, respectively) by 20.74 and 17.31 % in the first season.

Table (5): Effect of distance and depth of lateral treatments on drain outflow and Nitrate losses.

Treatments		Drains discharge ($m^3 fed^{-1}$)	NO_3^- Con, (ppm)	Losses NO_3^- ($kg fed^{-1}$)	Saving NO_3^- (%)
Drains distance (m)	Ground water depth (cm)				
1st season					
20	40	927.0	48	44.50	20.74
	80	1110.0	43	47.73	14.98
	120	1651.3	34	56.14	-
40	40	855.0	44	37.62	17.31
	80	1043.0	38	39.63	12.88
	120	1467.5	31	45.49	-
2nd season					
20	40	932.4	50	46.62	18.21
	80	1145.0	44	50.38	11.62
	120	1676.5	34	57.00	-
40	40	833.0	53	44.15	27.01
	80	1103.0	45	49.64	17.94
	120	1551.0	39	60.49	-

The seasonal nitrate loss was reduced from (57 and 60.49 kg fed^{-1}) for the free drainage to (46.62 and 44.15 kg fed^{-1}) for the 40 cm depth of water table treatment in the 2nd season for 20 and 40 m lateral spacing, respectively. It can be concluded that, the volume of water that flowed through the soil was a primary factor responsible for N loss. These findings are in accordance of that reported by Tan et al., (1993) and Drury et al., (1996).

The amount of nitrate had been saved to rice crop in 2018 season under different treatments were 20.74, and 14.98% , for the 40 and 80 cm water table depths under 20 m spacing and 17.31 and 12.88 % for managed treatments for 40 spacing as compared to the 120 cm depth. Concerning water table management under rice crop, the 40 cm depth of controlled drainage saved about 18.21 and 27.01% of nitrate for 20 and 40m lateral distance as compared to 120 cm depth in 2019 season. These results fall in line with findings of Wahba et al., (2001&2008) and Skagges et al., (2010).

Rice Yield

The crop growth and subsequently the yield primarily depend on the favorable environment in the root zone, rooting depth, sensitivity of crop for water. The poor root proliferation may be rendered to the high groundwater, causing an extreme defect on oxygen and the domination of reduction process reasonable to nutrients unavailability and root diseases.

Results in Table (6) showed that there were significant differences in the rice grain yield as compared to the control. Rice grain yield for 20-m spacing increased by about 996, and 261 $kgfed^{-1}$ for controlled drainage at 40 and 80cm depth, respectively as compared to conventional drainage in the first season, meanwhile with 40m spacing the yield increased by 901 and 330 kg fed^{-1} under controlled drainage at 40 and 80 cm depth of water table as compared to uncontrolled drainage in the same season.

Table (6): Effect of different applied treatments on rice yields (kg fed^{-1}.)

Treatments		Panicle length cm	1000 grain weight (g)	Plant height (cm)	Rice grain (kgfed^{-1})	Straw yield (kgfed^{-1})	Biological yield (Kg fed $^{-1}$)
Drains distance (m)	Ground water depth (cm)						
20	1st season						
	40	21.77 a	26.17 a	120.0 a	4832.6 a	3422.7 a	8255.3 a
	80	18.70 b	23.20 b	118.0 ab	4097.0 b	2991.0 b	7088 b
	120	16.73 c	20.70 c	117.0 b	3836.0 c	2815.0 c	6651 c
	Mean	19.07	23.36	118.3	4255.22	3076.2	7331.42
40	40	20.20 a	23.40 a	117.3 a	4321.3 a	3150.0 a	7471.3 a
	80	18.27 b	22.13 b	114.0 b	3747.3 b	2886.0 b	6633.3 b
	120	15.50 c	20.27 c	113.0 b	3420.0 c	2563.0 c	5983 c
	Mean	17.99	21.93	114.8	3829.56	2866.3	6695.86
	LSD at 5 %	0.86	0.85	1.6	15.33	7.9	4.8
	LSD at 1 %	1.24	1.24	2.4	22.30	11.5	7.0
20	2nd season						
	40	23.2 a	27.5 a	125.0 a	4897.0 a	3447.0 a	8344.0 a
	80	19.5 b	25.1 b	122.0 a	4139.3 b	3046.0 c	7185.0 b
	120	17.8 c	23.1 c	118.0 b	3878.0 b	3150.0 b	7028.0 c
	Mean	20.167	25.233	121.667	4304.7	3214.30	7519.0
40	40	21.5 a	26.3 a	121.0 a	4320.0 a	3312.0 a	7632.0 a
	80	18.7 b	24.4 b	117.6 b	3750.0 a	2943.0 b	6693.0 b
	120	16.9 c	22.6 c	114.3 c	3480.0 a	2933.0 c	6413.0 c
	Mean	19.033	24.456	117.667	3850.0	3062.7	6912.7
	LSD at 5%	0.255	0.441	2.27	13.33	2.2	4.8
	LSD at 1 %	0.371	0.642	3.30	19.35	3.2	7.0

In the second season, the highest values of grain yield were 4897 and 4320 kg fed-1 for controlled drainage at 40 cm depth under 20 and 40m spacing of lateral, while the lowest ones were 3878 and 3480kg fed^{-1} for free drainage under the same spaces of lateral respectively.

There was a marked variation between the treatments whereas the controlled drainage at 40 cm depth led to an increase in the grain yield by 25.96 and 26.35 % for 2018 and 26.28 and 24.14 % for 2019 under 20 and 40 m lateral spacing, respectively. From the abovementioned discussion, it can be concluded that the controlled drainage may give more profit than the uncontrolled one. The obtained results are agreed with those reported by Elghannam, (2015), Skagges et al., (2012) and Sobeih et al., (2017).

Applied water and productivity of irrigation water (PIW)

Results in Table (7) revealed that, narrow drain spacing (20 m) and/or deep ground water (120cm) had received the highest amount of irrigation water as compared to wider drain spacing (40 m) and/or shallowing ground water (40cm or 80cm). This is due to, under narrow spacing and/or deep groundwater, high amount of drainage water was recorded. On the other hand, wider drain spacing and/or rising groundwater was stored more water. Data showed that, controlled drainage at 40 and 80cm depth resulted in water saving amount by 21.07 and 14.94% under 20-m spacing and 19.59 and 11.16% under 40 m spacing, in the first season and 22.74 and 14.62 % under 20 m spacing and 25.35 and 11.06% under 40 m spacing, respectively in the second season as compared to 120cm depth.

Table (7): Water applied (m^3fed^{-1}) and productivity of irrigation water (PIW, kgm^{-3}) of rice yield as affected by different treatments.

Treatments		Water applied (m^3fed^{-1})	Water saving		PIW, kg m^{-3}	
Drains distance (m)	Ground water depth (cm)		(m^3fed^{-1})	%	Grain	Straw
1st season						
20	40	5150	1375	21.07	0.94	0.66
	80	5550	975	14.94	0.74	0.54
	120	6525	-	-	0.59	0.43
40	40	4720	1150	19.59	0.92	0.67
	80	5215	655	11.16	0.72	0.55
	120	5870	-	-	0.58	0.44
2nd season						
20	40	5180	1525	22.74	0.95	0.67
	80	5725	980	14.62	0.72	0.53
	120	6705	-	-	0.58	0.47
40	40	4632	1573	25.35	0.93	0.72
	80	5519	686	11.06	0.68	0.53
	120	6205	-	-	0.56	0.47

Data in Table (7) indicated that productivity of irrigation water (PIW) of rice yields were greatly affected by different treatments in both seasons. Data showed that the values of PIW for rice grain yield were ranged from 0.56 to 0.95 kgm^{-3} with all treatments. The high values of PIW were observed with 20m drain spacing and/or 120cm groundwater depth compared to 40m spacing with 40cm and/or 80cm groundwater depth. The mean values of PIW for rice grain yield were 0.94, 0.74 and 0.59 kg m^{-3} with 20m spacing and 0.92, 0.72 and 0.58 kg m^{-3} with 40m spacing for controlled water table at 40, 80 and 120cm, respectively in the first season. For the second season, the values were 0.95, 0.72 and 0.58 kg/m^{-3} with 20m spacing and 0.93, 0.68 and 0.56 kg m^{-3} with 40m spacing, respectively.

Salt balance

The main source of fresh irrigation water in the studied area is Brenbial branch canal where the salinity average of irrigation water was 0.7 and 0.8 dSm^{-1} for first and second seasons, respectively. The salts added to the soil from irrigation water (Table 8 and Fig. 1) were estimated as; 2307.2, 2486.4 and 2923.2 $kgfed^{-1}$ with 20m spacing and 2128.0, 2336.3 and 2629.8 $kgfed^{-1}$ with 40m spacing for ground water of 40, 80 and 120cm, respectively in the first season. The corresponding values for the second season (Table 8 and Fig. 2) were 2652.2, 2931.2 and 3433.0 $kgfed^{-1}$ with 20-m spacing and 2371.6, 2825.7 and 3177.0 $kgfed^{-1}$ with 40-m spacing, respectively. Salinity average of drainage water were 1.7, 1.6 and 1.45 dSm^{-1} with 20-m spacing and 1.95, 1.8 and 1.7dSm^{-1} with 40-m spacing for ground water of 40, 80 and 120cm, respectively in the first season and were 1.65, 1.4 and 1.25 dSm^{-1} with 20-m spacing and 1.55, 1.4 and 1.0 dSm^{-1} with 40-m spacing, respectively in the second season. Data in Table 8 and illustrated in the Figure 1 showed that the salts removed from the soil with drainage water were 1008.6, 1136.6 and 1532.4 kgfed^{-1} with 20-m spacing and 1067.0, 1201.5 and 1596.6 kgfed^{-1} with 40-m spacing for groundwater of 40, 80 and 120cm, respectively in the first season. The corresponding values were 984.6, 1025.9 and 1341.2kgfed^{-1} with 20-m spacing and 826.3, 988.3 and 992.6 kgfed^{-1} with 40-m spacing, respectively in the second season (Fig. 2).

Economic evaluation

Data in Table 9 indicated that the highest values of net return, economic efficiency and net return from water unit for rice yields were recorded with narrow drain spacing, while, the lowest values were recorded with wider drain spacing in both seasons. The maximum values of net return (10570 and 10833 L.E. fed^{-1}), economic efficiency (1.16 and 1.19) and net return from water unit (2.05 and 2.09 L.E.m^{-3}) of rice grain yield and (1.99 and 2.02 L.E.m^{-3}) for biological yield were recorded under 20-m spacing with 40cm groundwater depth in the first and second seasons, respectively. While, the minimum values were (5236 and 5513 L.E. fed^{-1}), (0.60 and 0.63) and (0.89 and 0.89 L.E.m^{-3}) were achieved with 40-m spacing under 120cm groundwater depth, respectively.

Table (8): Effect of distance and depth of lateral treatments on salt balance

Variables	20-m spacing			40-m spacing		
	40cm depth	80cm depth	120cm depth	40cm depth	80cm depth	120cm depth
First season						
Irrigation water(m^{3}fed^{-1})	5150	5550	6525	4750	5215	5870
EC IW (dSm^{-1})	0.7	0.7	0.7	0.7	0.7	0.7
Salt added (kgfed.$^{-1}$)	2307.20	2486.40	2923.20	2128.00	2336.32	2629.76
Drainage water (m3fed^{-1})	927	1110	1651.25	855	1043	1467.5
EC Dw (dSm^{-1})	1.7	1.6	1.45	1.95	1.8	1.7
Salt removed (kgfed.$^{-1}$)	1008.58	1136.64	1532.36	1067.04	1201.54	1596.64
Salt residual (kgfed.$^{-1}$)	1298.62	1349.76	1390.84	1060.96	1134.78	1033.12
Second season						
Irrigation water(m^{3}fed^{-1})	5180	5725	6705	4632	5519	6205
EC Iw (dSm^{-1})	0.8	0.8	0.8	0.8	0.8	0.8
Salt added (kgfed.$^{-1}$)	2652.16	2931.20	3432.96	2371.58	2825.73	3176.96
Drainage water (m3fed^{-1})	932.4	1145	1676.5	833	1103	1551
EC Dw (dSm^{-1})	1.65	1.4	1.25	1.55	1.4	1
Salt removed (kgfed.$^{-1}$)	984.61	1025.92	1341.20	826.34	988.29	992.64
Salt residual (kgfed.$^{-1}$)	1667.55	1905.28	2091.76	1545.25	1837.44	2184.32

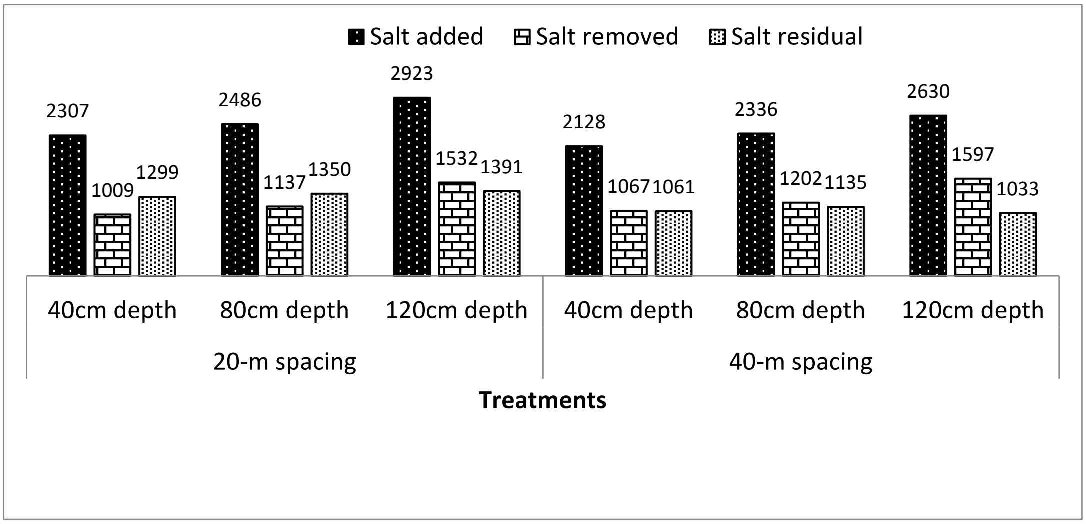

Fig. (1): Salt balance as affected by drain spacing and ground water depth in the 1st season

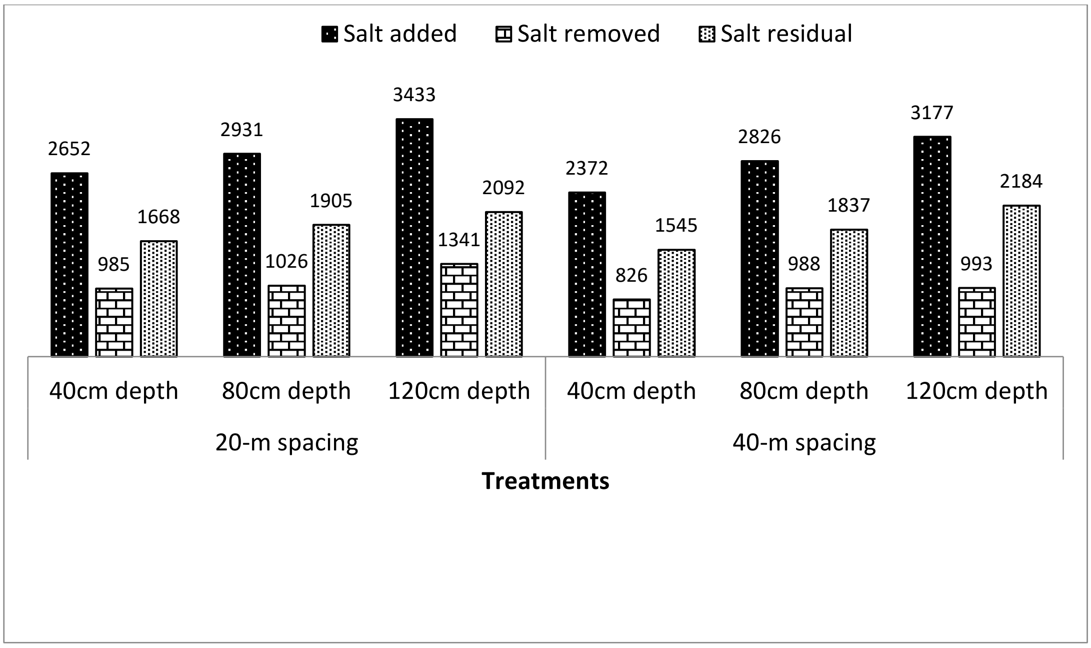

Fig. (2): Salt balance as affected by drain spacing and ground water depth in the 2nd season.

Table (9): Total revenue, total cost, net return, economic efficiency and net return from water unit for rice yields with different treatments.

Variables	20-m spacing			40-m spacing		
	40cm depth	80cm depth	120cm depth	40cm depth	80cm depth	120cm depth
First season						
Grain yield revenue (LE.fed^{-1})	19328	16386	15344	17284	15000	13680
Straw yield revenue (LE. fed^{-1})	342	299	282	315	289	256
Total revenue (LE. fed^{-1})	19670	16686	15626	17599	15289	13936
Treatments cost (LEFed^{-1})	600	500	400	300	250	200
Costs of VAP (LE fed^{-1})	4000	4000	4000	4000	4000	4000
Land rent for summer season	4500	4500	4500	4500	4500	4500
Total cost (LE. fed^{-1})	9100	9000	8900	8800	8750	8700
Net return (L.E. fed^{-1})	10570	7686	6726	8799	6539	5236
Water applied m^{-3}fed^{-1}	5150	5550	6525	4750	5215	5870
Net return from water unit (L.E.m^{-3}) for G.y	2.05	1.38	1.03	1.85	1.25	0.89
Net return from water unit (L.E.m^{-3}) for B.y	1.99	1.33	0.99	1.79	1.19	0.85
Economic efficiency for Gy	1.16	0.85	0.76	1.00	0.75	0.60
Economic efficiency for By	1.12	0.82	0.72	0.96	0.71	0.57
Second season						
Grain yield revenue (LE.fed-1)	19588	16554	15512	17280	15000	13920
Straw yield revenue (LE. fed-1)	345	305	315	331	294	293
Total revenue (LE. fed-1)	19933	16859	15827	17611	15294	14213
Treatments cost (LEFed-1)	600	500	400	300	250	200
Costs of VAP (LE fed^{-1})	4000	4000	4000	4000	4000	4000
Land rent for summer season	4500	4500	4500	4500	4500	4500
Total cost (LE. fed-1)	9100	9000	8900	8800	8750	8700
Net return (L.E. fed-1)	10833	7859	6927	8811	6544	5513
Water applied m-3fed-1	5180	5725	6705	4632	5519	6205
Net return from water unit (L.E.m-3) for Gy	2.09	1.37	1.03	1.90	1.19	0.89
Net return from water unit (L.E.m-3) for By	2.02	1.32	0.98	1.83	1.13	0.84
Economic efficiency for Gy	1.19	0.87	0.78	1.00	0.75	0.63
Economic efficiency for By	1.15	0.84	0.74	0.96	0.71	0.6

Price of grain yield = 4200 LE ton^{-1} and 100 LE ton^{-1} for straw in both seasons

All price according to the local market (LE)   Gy= Grain yield

VAP = variable costs of agricultural practices   By=Biological yield

This is due to improved soil properties under narrow drain spacing which caused water-air balance in the root zone, which in turn led to increase the rice yields. Also data indicated that, the controlled of groundwater near the root zone (40-cm and 80cm) under rice cultivation resulted in high values of net return, economic efficiency and net return from water unit. These increments in production of rice crop could be attributed to that under controlled of groundwater, which accompanied with less irrigation water, more energy is forced to extract more water with its content of fertilizers, which in turn resulted in decreasing the withdrawn of fertilizers. Similar results were obtained by (Antar, 2013).

Conclusion

The obtained results of the current study showed that narrow drain spacing of 20m and water table depth to 0.4 m was more efficient according to the concept of water saving, nitrate saving, productivity of irrigation water, rice yields, net return, net return from water and economic efficiency compared to wider drain spacing with 1.2 m ground water depth. Therefore, it can be concluded that the treatment of controlled drainage gave more profit than the uncontrolled one.

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تأثير مسافات حقليات الصرف وعمق الماء الأرضي علي بعض العلاقات المائية وخواص التربة و إنتاجية الأرز في الأراضي الطينية بشمال الدلتا

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الملخص

أجريت تجربة حقلية بشمال الدلتا (مركز مطوبس– محافظة كفر الشيخ) خلال المواسم الصيفية (٢٠١٨–٢٠١٩) لدراسة وتقييم تأثير مسافات المصارف علي ٢٠ متر و٤٠ متر بين الحقليات (معاملات رئيسية) مع التحكم في الصرف علي ٠.٤ و ٠.٨ متر عمق الماء الارضي وكذلك معامله المقارنة علي عمق ١.٢ متر أسفل منسوب سطح التربة (معاملات شقية) تحت ظروف زراعة الأرز علي خواص التربة ، فقد النترات، ترشيد المياه، إنتاجية الأرز والعائد الأقتصادي.

أظهرت النتائج أن قيم عمق الماء الأرضي النسبي يتناسب عكسيا مع معاملات مسافات الصرف وأن أعلي القيم للمسامية الصرفية (٠.١٠١،٠.١٤٥٪) تحققت في القطع التي كانت مسافات الصرف بها علي ٢٠ متر وغير متحكم في الماء الارضي (١.٢متر) بينما أقل القيم (٠.١ و ٠.١٠١٪) تحصل عليها مع مسافات الصرف علي ٤٠ متر ،٠.٤ متر مستوي عمق الماء الارضي في كلا الموسمين .

يتضح أن مسافات الصرف الضيقة عند ٢٠ متر وعمق الماء الأرضي علي ٠.٤ متر كانت أفضل من مسافات الصرف الواسعة علي مسافة ٤٠ متر في خفض ملوحة التربة ، نسبة الصوديوم المدمص، الكثافة الظاهرية بالمقارنة بالقيم المتحصل عليها قبل تنفيذ نظام الصرف.

وان التحكم في الصرف يقلل من كميات المياه المنصرفه الي المصارف مقارنة بالصرف التقليدي كما أعطيت مسافات الصرف الضيقة علي ٢٠ متر وعمق الماء الأرضي ٠.٤ متر أعلي القيم في ترشيد مياه الري، توفير النترات ، الأنتاجية المائية لمياه الري، محصول الأرز، صافي العائد، الكفاءة الأقتصادية، صافي العائد من وحده المياه بالمقارنة بمسافات الصرف الواسعة وعدم إدارة الماء الأرضي. يمكن أن نستنتج أن إدارة الماء الأرضي أعطي أعلي ربحية من عدم التحكم في الصرف.

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