Effect of Fixed Furrow Irrigation on Water Productivity of Cotton Irrigated with Saline Water

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Abstract: ***Partial Root Zone Irrigation (PRI) has been demonstrated as a promising irrigation method for crops in arid and semi-arid areas. This study verified that fixed furrow irrigation technique could affect the cotton yield irrigated with saline water. A field experiment was conducted for two successive years in summer seasons of 2017 and 2018. Water was applied to furrows either evenly to all the furrows (CFI, conventional furrow irrigation), or to one fixed furrow in every one (FFI1/1F, fixed one furrow irrigation) or to one fixed furrow in every two (FFI1/2F, fixed two furrows irrigation). The results illustrated that, the final seed cotton yield, which was accumulated from two hand-pickings (a traditional local harvesting practice) for the two seasons, produced on average, 76.11% for FFI 1/1F and 66.19% for FFI 1/2F of CFI yield. FFI(1/1F) and FFI (1/2F) can save irrigation water by 38.16% and 45.23% than CFI. FFI (1/1F) and FFI (1/2F) decreased water consumptive use by about 7.88 % and 20.3 %, respectively, as compared to CFI. It is obvious that, as increasing irrigation water applied the irrigation water productivity decreasing and vise versa with water productivity. The soil moisture content at the beginning of the season was the same in Alternate furrow irrigation treatments FFI (1/1F) & FFI (1/2F) as in conventional furrow irrigation, and when the season went on, they had lower moisture content than CFI. Soil salinity levels decreased with increasing depths of soil, and the change in salinity at deeper soil layers were not as great as in the top 30 cm soil. Furthermore, with growth of cotton plant, soil salinity increased. It can be recommended that under limited supplies of irrigation water and irrigation with low water quality, farmers could use FFI(1/1F) in irrigating cotton but with better fertilizers application in order to improve yield. Generally it can be concluded that, any increase in soil salinity, resulting from these practices, was at levels which could be leached in next winter season with rains.***

Keywords: fixed furrow irrigation, Saline Irrigation, Cotton Yield, Soil Water Distribution, Salt Accumulation

1. Introduction

Water deficit will result in reducing water losses, and this would be an advantage if it could be achieved without detriment to the crop performance.

The scarcity of water resources, environmental pollution and increased soil and water salinization are the feature of the 21st-century beginning (Shahbaz and Ashraf, 2013).

One of the most important environmental factors limiting the productivity of crop plants is salinity, and the land area affected by it is increasing day by day. For all important crops, average yields are only a fraction – somewhere between 20% and 50% of record yields; these losses are mostly due to drought and high soil salinity, environmental conditions which will worsen in many regions because of global climate change. Efficient resource management can help to overcome salinity stress.(Pooja and Rajesh, 2015)

Guirguis, et al. (2015) reported that, furrow irrigation treatments can be used as alternative and surge alternative for cotton production in conditions of being deficient in irrigation water and in arid and semi-arid areas where production depends powerfully on irrigation.

Nelson and Al-Kaisi (2011) mentioned that using the Alternate Furrow Irrigation (AFI) method helps in saving water than other irrigation methods, consequently its environmental benefits and economical return is higher.
In terms of water savings, the Partial root zone drying technique has been modified to a wide variety of crops to improve water productivity (Wang et al., 2010; Jovanovic et al., 2010 and Yang et al., 2012 and 2013).

Richards (1954), Holland et al. (2007) Brady and Well (2008) and Bakker et al., (2010), reported that, salts are leached down from the furrow as soon as irrigation water is applied to the furrows on every flank of the bed. But salts accumulate on the tops and side slopes of the beds due to the evaporation of water during the drying periods. With the permanent skip furrow irrigation (PSFI) method, salts are pushed across the bed from the irrigated side of the furrow to the dry side, this management of root zone salinity improves emergence, stand establishment and finally crop yields in saline fields.

Permanent skipping furrow irrigation (PSFI) technology has the potential to reduce salt concentrations on the top and the side of the raised beds by 2-3 times compared to EFI (Every Furrow Irrigation) and ASFI (Alternate Skipping Furrow Irrigation). (Devkota et al, 2015)

The fixed furrow irrigation (FFI) method is essentially the same as conventional furrow irrigation (CFI), except that instead of irrigating every furrow, irrigation is applied to Fixed furrows, while the in-between furrows remain dry. This means each ridge receives water from only one side. Irrigating just one side of the ridge means there is significant potential to save irrigation water compared to CFI. There is however, also potential in some cases for a reduction in crop yield (Samadi and Sepaskah, 1984; Crabtree et al., 1985; Mashori, 2013)

Cotton (*Gossypium hirsutum*) is the most important cash crop and plays a significant role in the economic development of the country, it has always been the objects of expansive research to improve the yield potential of the crop under the local environmental conditions.(Anonymous, 2001). Therefore, the main objective of the present study is to find the best management of low water quality in order to minimize its deteriorating effects on soil and cotton yield.

2. Materials and Methods

2.1 Site and soil of the experiment and irrigation water quality

Field experiment was conducted at a farm (31°11'25.5" N, 30°49' 35.7" E.) 12 km west of Kafr ElShiekh Governorate, Egypt fig (1), during the summer seasons of 2017 and 2018. The soil of the study area is classified as clayey with 58.33% of clay, 1.8% and 19.17 coarse and fine sand, respectively and17.67 % of silt as average within 90 cm depth Table (1)

Figure 1: Experiment location

Soil pH ranged between 8.06–8.28.the soil EC ranged between 1.44–3.03 dSm^{-1} (extract 1:5) as shown in table (1) and (2). The drainage system in the study area is subsurface and it operates efficiently so there are no drainage problems at the experimental soil, the water table was deeper than 2 m before planting in the first season. Irrigation water was obtained from Om Dokhan canal (feeds from drainage water obtained from Nashart Drain), with average salinity (EC1.87 dSm^{-1}) and average SAR's 5.7, thus it needs to be carefully managed, Table (3).

Table 1 (a): Chemical Analysis of Experiment Soil

depth (cm)	*Cations (Meq L^{-1})*			
	Ca^{++}	*Mg^{++}*	*Na^{+}*	*K^{+}*
0-30	2.28	2.71	6.06	0.09
30-60	1.56	1.84	5.92	0.08
60-90	2.28	1.87	5.6	0.1
depth (cm)	Anions (Meq L^{-1})			
	Cl^{-}	HCO_3^{-}	CO_3^{--}	SO_4^{--}
0-30	3.5	0.57	0	7.08
30-60	5.25	0.64	0	3.51
60-90	4.7	0.45	0	5.56

Table 1 (b): Chemical analysis of experiment soil

depth (cm)	*Ec ($dScm^{-1}$)*	*pH (1:2.5)*	*O.M*
0-30	2.23	8.2	0.56
30-60	1.88	8.1	3.4
60-90	2.26	8.3	5.1

Table 2: mechanical analysis of experiment soil

depth (cm)	*clay %*	*coarse sand %*	*Fine sand%*	*silt %*	*texture class*
0-30	57	1.9	17.59	20	clayey
30-60	60	2.4	20.1	15	clayey
60-90	58	1.1	19.81	18	clayey

Table 3: Average chemical analysis of irrigation water

Ec ($dScm^{-1}$)	1.78
pH	7.8
SAR	5.70
RSC	-2.38
cations (meq L^{-1})	
Ca^{++}	3.10
Mg^{++}	2.81
Na^{+}	9.80
K^{+}	1.07
anions (meq L^{-1})	
Cl^{-}	5.97
HCO_3^{-}	3.52
CO_3^{--}	0.00
SO_4^{--}	6.68

2.2 Selected Crop and Agricultural Practices

Cotton (*Gossypium hirsutum L*) variety Giza 94, the popular cultivar was selected for the field experiment with a seeding drill and 80cm row spacing, at a seeding rate of 25 kg $fed.^{-1}$. Thinning was done to one plant when plants had three to four leaves, Fertilizers rates used were the same as generally practiced by the farmers, with rates of N, P and K were 120, 60 and 100$kgfed^{-1}$, respectively. One dose of N was applied at planting. The remaining N was applied at the late vegetative stage, 55–69 days after sowing (DAS), following the recommendations of Ministry of Agriculture, Egypt.

2.3 Experimental Design and Treatments

A randomized complete block design (RCBD) with three replicates was used to assess three treatments.

1) Conventional irrigation method (CFI), every furrow was irrigated.
2) Fixed furrow irrigation one by one FFI (1/1F) that is, one furrow was irrigated and kept the in-between furrow dried.
3) Fixed furrow irrigation one by two FFI (1/2F) that is, one furrow was irrigated and kept the in-between two furrows dried.

The experimental plot size was occupying an area of110 m^2 (10 m wide × 11 m long). Each treatment included 9 furrows and 18 planting ridges (rows). Furrow spacing was 0.80 m. The experimental plots were separated by ditches. Irrigation timing and amount followed the same tradition as local farmers irrigating their fields.

2.4 Water Relations

Applied water ($m^3 fed^{-1}$)

Irrigation water was controlled and measured by a flow meter installed in the water delivery unit of the irrigation pump. Each treatment received eight irrigations events during the first season and nine during second season.

Table 4: Sowing and Irrigations dates during the two successive years of the experiment

No. of Irrigation	*2017*	*2018*
1st irrigation.	28/04/2017	01/05/2018
2nd irrigation.	11/05/2017	01/06/2018
3rd irrigation.	07/06/2017	16/06/2018

4th irrigation.	28/06/2017	01/07/2018
5th irrigation.	20/07/2017	13/07/2018
6th irrigation.	04/08/2017	28/07/2018
7th irrigation.	25/08/2017	15/08/2018
8th irrigation.	10/9/2017	30/08/2018
9th irrigation.		15/09/2018

Cotton water consumptive use

Soil water storage was measured periodically in each plot by oven-drying the samples to constant weight (105 °C)., before and after each irrigation for the depths of 30, 60 and 90 cm, using the following formula, Doorenbos. andKassam, (1979).

$$CWU = \frac{(\theta 2 - \theta 1)}{100} \times B.d. \times D \times A \ldots\ldots\ldots\ldots.(1)$$

Where: CWU = water consumptive use. θ_1 = initial moisture content. θ_2 = final moisture content (after irrigation). B.d = bulk density. D = soil depth (cm) A = area.

Irrigation Water productivity

Crop water productivity (WP) and irrigation water productivity (IWP) were determined according to Ali et al., 2007 as follows:

$$WP = SCy/CWU \ldots\ldots\ldots\ldots.(2)$$

$$IWP = SCy/Wa \ldots\ldots\ldots\ldots.(3)$$

Where: WP, crop water productivity (kg m^{-3}), SCy, seed cotton yield (lint seeds weight, kg. fed^{-1}),IWP, productivity of irrigation water (kg m^{-3}), and Wa, irrigation water applied (m^3. fed^{-1}).

2.5 Soil salinity assessment and soil moisture distribution sampling

Set of soil samples was collected from 30, 60 and 90 cm soil depths at begin and end of the season and before every irrigation to assess soil salinity status and soil moisture distribution.

2.6 Statistical analysis

Data were analyzed by a complete randomized model using the (CO-Stat), as described by Snedecor and Cochran (1982**)**. Treatment means were compared by LSD test.

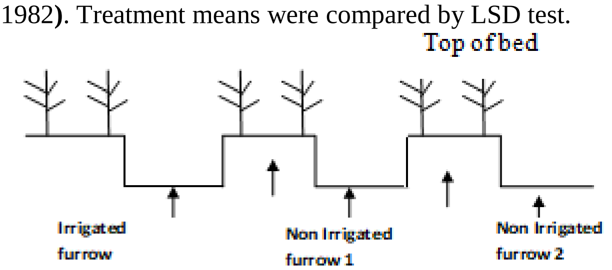

Figure 2: locations of soil salinity and soil moisture samples at the different treatments

3. Results and Discussion

3.1 Soil salinity before experiment

The soil salinity level before experiment (ECe dSm^{-1}) in each season was measured at the depths of 30, 60 and 90 cm. the results showed that salinity levels at different depths in 2018 were slightly higher in values than in 2017.the values of Ec were 2.26, 2.23 and 1.88 dSm^{-1} in 2017 and 3.03, 2.89 and 1.441 dSm^{-1} in 2018 for above mentioned depths, respectively.

3.2 Irrigation water applied and water saved

Irrigation water applied for conventional furrow irrigation (CFI) was about 3752.92 m^3 fed^{-1} which is higher than other treatments. It is followed by fixed furrow irrigation one by one (1/1F), which was about 2320.75 m^3 fed^{-1}, with about 1432.17 m^3 fed^{-1} (38.16%) water savings and finally, fixed furrow irrigation one by two (1/2F) which was about 2055.43 m^3 fed^{-1} with about 1697.49 m^3 fed^{-1} (45.23%) water saving. Thus, FFI (1/1F) and FFI (1/2F) can also reduce the harmful effect of over irrigation which is also common in the study region, Figure (3).

These results are in agreement with those obtained by (Thind et al, 2010) who showed that, same seed cotton yield can be obtained with 28 % less irrigation water applied than was applied in EF (every furrow), and also with Tang et al. (2005) who observed that, AF (alternate furrow) required up to 30 % less irrigation water when compared with EF irrigation without significant reduction in seed cotton yield. This also agrees with other conclusion by different research work mentioned that alternate furrow irrigation does not require the application of more than 50 –70 % of the water used in a fully irrigated furrow (every furrow irrigation method) Webber, et al. (2006) and with Eba, (2018).

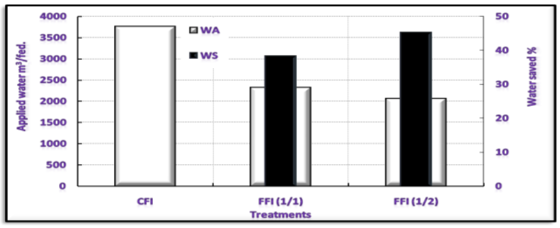

Figure 3: Average applied and saved water for all treatments

3.3 Water Consumptive Use

Results showed that, water consumptive use was decreased under alternate furrow irrigation treatments FFI (1/1F) & (1/2F) in both seasons. The highest mean value of water consumptive use value was recorded from CFI (221.51 mm fed^{-1}) followed by (204.04 mm.fed^{-1}) which obtained from FFI (1/1F), while the lowest average value was obtained with FFI (1/2F) (176.54 mm.fed^{-1}), Figure (4).

It can be stated that FFI (1/1F) and FFI (1/2F) decreased water consumptive use by about 7.88 and 20.3 %, respectively, as compared to conventional CFI treatment. This could be explained by the fact that cotton plants grow under FFI (1/1F) and FFI (1/2F) treatments conditions were subjected to water stress consequential from less recurring irrigation and minor amount of water applied and also due to less evaporation from the dry furrow that was a sign of decreasing total Evapotranspiration. These results are in close agreement with Eduardo et al (2010) and Eba (2018).

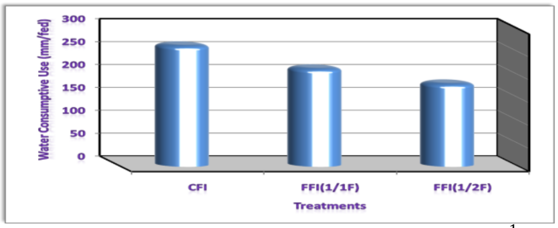

Figure 4: Average water consumptive use (mm fed^{-1}) for all treatments

3.4 Irrigation water productivity (IWP) and Crop water productivity (WP)

The average irrigation water productivity for CFI, FFI (1/1F) and FFI (1/2F) are 0.45, 0.55 and 0.54 kg m^{-3} respectively, indicating that FFI (1/1F) and FFI (1/2F), remarkably increases irrigation water productivity (Table 5). The IWP values are affected by irrigation methods. It is obvious that as increasing in irrigation water applied leads to decreasing irrigation water productivity and vice versa.

The highest irrigation water productivity value was 0.55 kg m^{-3} gained from the fixed furrow irrigation one by one treatment followed by 0.54 kgm^{-3} obtained from fixed furrow one by two. While, the lowest value is 0.45 kgm^{-3} which was attained from conventional furrow irrigation. The decrease of irrigation water productivity in conventional furrow irrigation practice was associated with extra volume of water added. This finding have the same opinion with result states that The highest water productivity (IWP) value was obtained with alternate furrow irrigation (AFI), whereas the lowest value was obtained under famer practice. Eba (2018)

On the other side, average WP values of cotton over two years were affected due to irrigation treatments. As shown in Table (5), the highest WP value (0.76 kgm^{-3})was recorded with CFI, whereas, the lowest WP values (0.63 and 0.62 kgm^{-3}) were recorded with FFI (1/1F) and FFI (1/2F), respectively.

This result agrees with the suggestions given by Kaman (2006), Shayannejad and Moharreri (2009), Holzapfel et al. (2010) and Eba (2018) who reported that fixed furrow irrigation lowers water productivity as a result of less evaporation from the dry furrow which in turn leads to decreasing total evapotranspiration and consequently decreases yield.

Table 5: Irrigation Water Productivity and Water Productivity (kg. m^{-3}) average of two seasons

Treatments	*IWP (kg. m^{-3})*	*WP (kg. m^{-3})*
CFI	0.45	0.76
FFI (1/1F)	0.55	0.62
FFI (1/2F)	0.54	0.63

3.5 Soil Moisture Distribution

Figures (5 to 7) illustrate soil moisture change and the distribution throughout one irrigation cycle (before and after irrigation, July 13-15). Results show an increase in moisture content under conventional furrow irrigation (CFI) all over the profile. The average increase in soil moisture content was about 5 to 10 % in the upper two layers for both the top and the bottom furrows as a result of irrigation. The change in the moisture content was small in the third depth. The water applied in this irrigation was about 482.8 m^3, Figure (5).

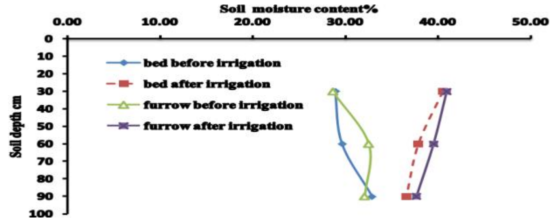

Figure 5: Soil moisture content with depth before and after irrigation cycle (July 13-15).with conventional furrow irrigation

It can be noticed from figure (6) that there was no appreciable increase in soil moisture content throughout the entire depths of 60 and 90 cm in the dry bottom furrow under alternate fixed furrow irrigation treatment FFI (1/1F) due to this irrigation.

This indicates that, these two depths (60 cm and 90 cm) stay wet from the previous irrigation cycle, and vice versa throughout the surface, where considerable drying at the surface occurred. It is also found that, the soil moisture content increased by about 13 percent. This is attributed to the horizontal distribution of roots, or the 241.04 m^3 of water applied to this treatment in this irrigation which is enough for acceptable wetting.

Figure (7) illustrates that, the soil moisture content in FFI (1/2F) treatment increased as the same in CFI (1/1F) treatment by about 11 percent in the surface layer (30 cm), and so on as in CFI(1/1F) treatment in the depths from 60 cm. It can be observed that no considerable increase in soil moisture content had obtained.

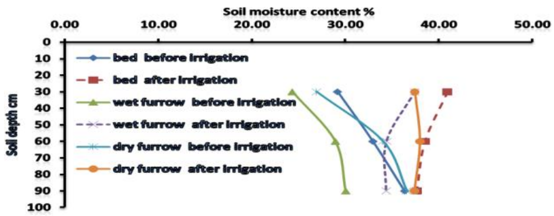

Figure 6: Soil moisture content with depth before and after irrigation cycle (July 13-15).with fixed furrow irrigation one by one

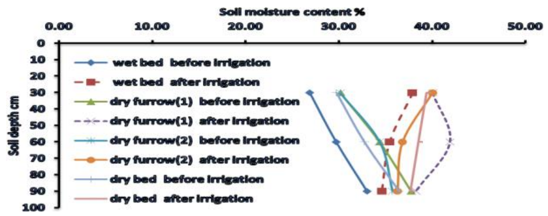

Figure 7: Soil moisture content with depth before and after irrigation cycle (July 13-15).with fixed furrow irrigation one by two.

Figure (8) shows the overall average soil moisture content with the progress of plant age. It is observed that, alternate furrow irrigation treatments [FFI(1/1F) & FFI (1/2F)] were as same as with the soil moisture content in conventional furrow irrigation at the beginning of season, and with the season progressing lower values of moisture content were obtained comparing with the CFI treatment. It is expected in viewpoint of the fact that CFI treatment received greater amount of irrigation water, but by virtue of the dry furrows moisture is not replenished by sufficient lateral movement from the wet furrow. Supporting the results is obtained by Eba, (2018) and Ebrahimian, et al. (2011). It is observed that, in fixed furrow irrigation the drier furrow remains dry throughout the growing season, due to low lateral water movement and more downward water flow is expected in fixed furrow method.

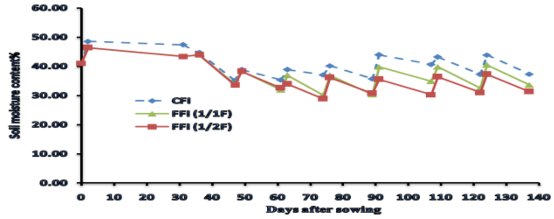

Figure 8: Overall average soil moisture content with time (average of all depths under different treatments

3.6 Salinity Distribution

Salt accumulation in Different Treatments

It is observed that, generally the results of using irrigation water with average salinity 1.78 dSm^{-1} (to irrigate cotton crop) soil salinity levels decreased with increasing depths of soil, and the change in salinity at deeper soil layers was not as great as in the top 30 cm soil**.** Furthermore, with the growth of cotton plants, soil salinity increased. This is attributed to irrigation with saline water throughout the season.

Salt accumulation in Conventional Furrow Irrigation:

The amount of irrigation water applied in this treatment (CFI) was the highest comparable by the other treatments FFI (1/1F) and FFI (1/2F). After three irrigations cycles, salinity level on **top beds** (5.055 dSm^{-1}) was higher than the values obtained for the other two depths (4.85 and 4.68 dSm^{-1}). Although the upper two layers (30 and 60 cm) were converged in their salinity levels after six irrigations cycles which were 9.955 and 9.97 dSm^{-1}, respectively. So, due to the progress in cotton growth, the increases in soil Ec were 5.065, 6.375and 2.585 dSm^{-1}comparing with the pre-experiment level, Figure (9).

On the other hand, results illustrated that the salinity levels of bed bottom in the CFI treatment almost unaffected till after 7 irrigations cycles, where its increment were 2.545, 2.782 and 0 dSm^{-1} in the depths of 30, 60 and 90 cm, respectively, in comparison with the pre-experiment salinity level. These results are in close agreement with those obtained by Devoketa et al (2015) who concluded that Soil salinity on top of raised beds increased when irrigation water was applied to both furrows flanking the beds.

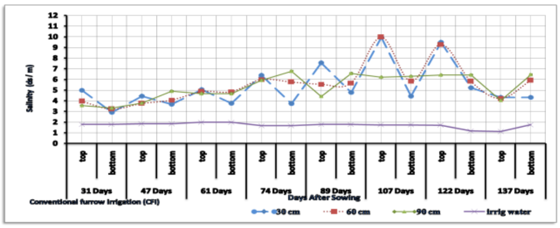

Figure 9: Salt distribution under conventional furrow irrigation treatment

Salt accumulation in fixed furrow irrigation one by one:

With FFI (1/1F), It is realized that there were clear fluctuation in EC values in both dry and wet bottom with the advance in cotton growth and throughout the different depths as shown in Figure (10). The EC values were fluctuated within the range (2.9 - 5.5 dSm^{-1}) in wet bottom and (3.23 - 7.25 dSm^{-1}) in dry bottom throughout the 30 cm depth. But for 60 cm depth in wet bottom the EC values ranged between 3.32 - 9.6 dSm^{-1} and 2.9 - 6.29 dSm^{-1}in dry bottom, respectively. It also ranged between (3.26 - 6.96 dSm^{-1}) and between (3.32 - 7.87 dSm^{-1}) in wet and dry bottoms, respectively, throughout the 90 cm depth.

It is noticed that there was an increment in EC values with depth in both wet and dry bottoms, but the dry bottom had the highest values, this could be explained by the fact that the salts had moved towards to the top and to the dry bottoms. This is in harmony with the results obtained by (Devkota et al, 2015) who stated that in permanent skip furrow irrigation, salts accumulated towards the dry furrows and the dry soil continuously wicked away the salts from the wet furrow causing in more salt accumulations at the dry furrow side.

It is noticed in the same figure that the salinity levels were higher in the top soil than the deeper layers and also with the progress cotton growth, these values were ranged between 4.9-7.46 dSm^{-1}.

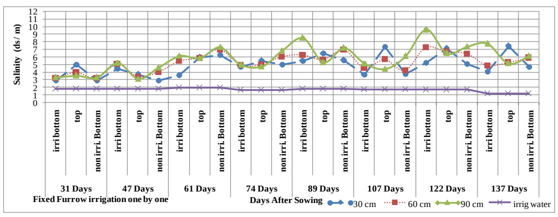

Figure 10: Salt distribution under Fixed Furrow irrigation one by one

Salt accumulation in Fixed furrow irrigation one by two:

In case of FFI (1/2F), it can be noticed that in both **wet and dry bed**s the salinity levels were higher in the top soil than the deeper layers and also with the cotton growth, these values were ranged between (4.89 - 7.32 dSm^{-1}) and (4.9-9.7 dSm^{-1}) in **wet and dry top**, respectively, Figure (11). EC values in both dry furrows increase with depth and also with the advance in plant age, but it was higher in second dry furrow which ranged between (3.16 - 7.99 dSm^{-1}) than in first dry furrow which ranged between (3.16 – 7.59 dSm^{-1}). These results are closest to that reported by (Cardon et al., 2010) who reported that, salts moved from the wet furrow towards to the dry furrow and this led to a salt distribution in a larger soil volume and hence some salt **accumulation** as compared with the pre-experiment salinity level in both years as a result of prior applications of saline water.

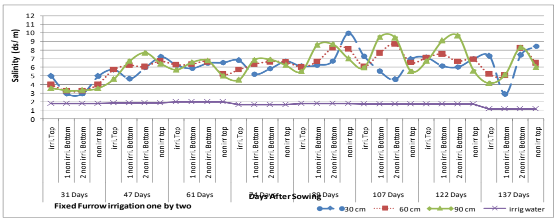

Figure 11: Salt distribution under Fixed Furrow irrigation one by two

3.7 Seed Cotton yield

Analysis of variance showed that, irrigation treatments had a significant effect on seed cotton yield in the first and second seasons, Table (6).

In both years, yield decreased linearly with decreasing amount of water applied, which the highest values were obtained from CFI (9.42 & 11.83 kentar fed.$^{-1}$), and the lowest values (6.7 & 7.73kentar fed.$^{-1}$) were from FFI (1/2 F) in first and second seasons, respectively. The final seed cotton yield, accumulated from two hand-pickings (a traditional local harvesting practice) for the two seasons, was on average, 76.11 % for FFI (1/1F) and 66.19 % for FFI (1/2F) of CFI yield. This may be due to the fact that Irrigating with saline water will produce some degree of soil salinization, and this, sequentially, will cause a decrease in crop yield corresponding to yield under non-saline conditions. Reduce of the yield should be coupled with a decrease in plant size and in Evapotranspiration. Salinity reduces the plants ability to consume water, and this rapidly causes drop in growth rate.

Similar findings were obtained by, Ling and Cang (2011) and Wang et al. (2009) who showed that, cotton yield of conventional furrow irrigation was higher on average than the fixed every other furrow irrigation, because it enhanced root growth and improved nutrient uptake of crop.

Table 6: Analysis of variance for seed cotton yield (SCY) for both seasons

Treatments	*Seed Cotton Yield (kentar)*	
	2017	*2018*
CFI	9.42	11.83
FFI (1/1F)	7.00	8.44
FFI (1/2F)	6.7	7.73
F test	**	**
L.S.D 0.01	1.73	3.349
L.S.D 0.05	1.045	2.019

** indicate significant differences at P 0.01 and, according to F test. (kentar=157.5 kg)

4. Conclusion

It is concluded from the results that:

1) Soil salts compete on water with cotton plants which reduce available water to plants, and this rapidly causes reductions in seed cotton yield. In general, when irrigation was reduced by 38.16%, the average final yield loss of FFI (1/1F) was 23.89%, and when it reduced by 45.23%, the FFI (1/2F) had a statistically significant reduction in yield of 33.81% in comparison to CFI.
2) Soil moisture distribution analysis showed that conventional furrow irrigation treatment had the highest overall average soil moisture content during the season. This was directly related to the amount of water (3752.92 m^3. fed^{-1}) received. The fixed furrow irrigation one by two had about 1697.49 m^3. fed^{-1} which express the less water applied and the lowest soil moisture content during the growing season. There was inadequate soil water movement from the wet furrow to the next dry furrow.
3) Using irrigation water with average salinity 1.78 dSm^{-1}, leads to decrease in soil salinity levels with increasing depths of soil. The change in salinity at deeper soil layers was not as great as in the top 30 cm soil**.** Furthermore, with the progress in growth of cotton plant, soil salinity increased. Salt accumulation in CFI was higher in the top than in the bottom. While it was concentrated in bed tops of dry furrows in both FFI (1/1F) and FFI (1/2F).

5. Recommendation

From the obtained results it can be concluded that, any increase in soil salinity, resulting from these practices, was at levels which could be leached in next winter season with rains.

It cab be recommended that, under limited supplies of irrigation water and irrigation with low water quality, farmers could use FFI (1/1F) in irrigating cotton but with better fertilizers application in order to improve yield. Furthermore for a precise evaluation of these techniques, an economic study is necessary.

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