

Response of Sugar Beet Yield and Water Use Efficiency to Deficit Irrigation and Weed Competition under Drip Irrigation System

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ABSTRACT

Under drip irrigation condition, two field experiments of sugar beet (*Beta vulgaris* L.) were conducted, in sandy soil, at El-Bostan area, Aly Mubarak Experimental Farm, Southern El-Tahrir Region, El-Buhira Governorate, Egypt, during 2013/14 and 2014/15 winter seasons, to evaluate the impact of water deficit irrigation and its relation with the critical period of weeds infestation on sugar beet yield, quality and water use efficiency. The experimental design was a split-plot design, where three water irrigation regimes treatments, i.e. 60, 80 and 100 % of evapotranspiration (ET_0), were allocated in the main plots, and the ten weed removal intervals were allocated in the sub-plots which included five weed free for 3, 6, 9, 12 weeks after planting (WAP) and weed free the whole season, and five weed infestation for 3, 6, 9, 12 (WAP) and weed infestation for the whole season. The main findings indicated that the highest significant reduction on the fresh weights of grassy, broad-leaved and total weeds was obtained by irrigation at 60 % ET_0 by 14.8, 16.0 and 15.6 %, respectively, in 2013/14 season and 25.0, 13.6 and 17.3 %, respectively, in 2014/15 season, as compared to 100 % ET_0 , which reflected in increases on root and gross sugar yield per faddan by 58.8 and 60.2 %, respectively, in 2013/14 season and 65.5 and 40.1 %, respectively, in 2014/15 season, as compared to irrigation at 100 % ET_0 . Furthermore, water use efficiency of irrigation at 60% ET_0 gave the highest values of root and sugar yield by 7.2 and 1.2 kg/m³, respectively, in the first season and 7.1 and 1.3 kg/m³, respectively, in second season. The dominant annual weeds were the broadleaf weeds with infestation rates 3.0 kg and 3.5 kg fresh weight /m² in the first and second seasons, respectively. Whilst, the infestation rate of the grassy weeds was 1.3 kg and 1.4 kg fresh weight/m² in the both seasons, respectively. In the both seasons, the highest reduction on the fresh weight of the two weeds categories and their total was obtained from all weed free and weed infestation treatments (> 90 %) as compared to weed infestation for the whole season, except with weed free for 3 weeks (< 70%). These results reflected on sugar beet yields (ton/fed). In the first season, the significant increasing on dry weight of tops, roots and the gross sugar yield (ton/fed) was between 118.6, 302.5 and 353.8 %, respectively, in weed free for the whole season to 58.5 % for tops by weed free for 3 weeks, 135.2 % for roots by weed free for 6 weeks and 50.0 % for gross sugar yield by weed infestation for 9 weeks, as compared to weed infestation for the whole season. In second season, the significant increasing on dry weight of the tops, roots and gross sugar yield (ton/fed) was between 98.8, 311.3 and 288.7 %, respectively, in weed free for the whole season to 37.5 % for the tops and 35.0 % for the roots in weed free for 3 weeks and 106.5 % in weed infestation for 6 weeks, as compared to weed infestation for the whole season. While, the rest weed free and weed infestation treatments in the both seasons didn't reach to significant increasing values. For sugar beet quality i.e. TSS, sucrose and purity %, all weed free and weed infestation treatments gave the same values approximately in deferent intervals. Also, different weed removal intervals can raise water efficiency by 240-320 % compared to leave the weeds to compete sugar beet plants for whole season. Concerning the interaction effects, the data indicated that the great reduction on the fresh weight of the two weed categories and their total was obtained from irrigation at 60 % ET_0 with weed free for whole season, weed competition for 3 WAP and weed free for 12 WAP, in both seasons. Also, the interactions between both 60 and 80% ET_0 irrigation regimes with both weed free for 12 weeks and the whole season gave the highest increasing on the roots and gross sugar yields (ton/fed) in the both seasons. The findings also revealed that the critical period of weed interference between 3 and 12 weeks after planting and the yield losses in this period. Thus, we can conclude that to save water irrigation and maximize root and sugar yields of sugar beet (ton/fed) must be irrigate at 60% ET_0 with controlling weeds until 12 week from planting.

Keywords: Sugar beet (*Beta vulgaris* L.) critical period, weed competition, deficit irrigation, water use efficiency.

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is one of an important sugar crop in the world and come in second riant crop after sugarcane for sugar production in Egypt. Vertical and horizontal expansion of sugar beet is one of the governmental plans in order to the gradually close the gap between sugar consumption and production. In Egypt, the area of sugar beet was 523188 faddans in 2016/17, 147631 faddans on reclaimed lands (Annual report, 2018). Cultivation sugar beet crop in the pilot farms at the newly reclaimed desert lands at west Nubaria and El-Bustan regions was successful, but the studies which conducted on the competition of weeds for sugar beet crop and linked it to the amount of irrigation water were very rare. Because the over population in Egypt, water become scare to the agricultural sector is becoming a major constraint for agricultural production. One way to maximize the use of this limited resource is through the use of a proper and efficient irrigation system. Area in a need to raise water use efficiency by new irrigation methods as drip irrigation water and it is considered as a highly efficient method of delivering water and fertilizer uniformly to most crops. Bucks and Davis (1986) demonstrated that drip irrigation increased the

beneficial use of water, enhanced plant growth and yield, limited weed growth, decreased energy required and improved cultural practices. Badr (1987) found that the total applied irrigation water for sugar beet in the sandy soils of Nubaria region was 3364 m³/fed under sprinkler irrigation and the water application efficiency value was 81.2%. Awad *et al.* (2003) found that average seasonal applied irrigation water by sprinkler system was 2982 m³/fed, while it was 3958 m³/fed for surface irrigation, and they reported that root yields were 25.81 and 20.94 t/fed for sprinkler and surface irrigation, respectively. On the other hand, weed competition is one of the major obstacles in preventing the achievement of maximum sugar beet yield especially under drip irrigation condition due to the increase in number of irrigation. Weeds and sugar beet plants were compete for the necessary elements of growth such as light, water and nutrients, in addition there are harbor insects and increase the incidence of diseases and harvest losses. The critical period of weed-sugar beet competition and amount of sugar beet yield losses due to weed competition differed by differing the time appeared of these weeds after sugar beet emergence (Kropff *et al.*, 1992). Deveikyte and Seibutis (2006) reported that the sugar beet plants are a poor competitor with weeds. Also,

uncontrolled weeds which emerge with the crop typically could cause yield losses by 50 to 100%. Salehi *et al.* (2006) showed that sugar beet root yield was decreased by 92.9% and 61.2% presence of weeds during 1999 and 2000 growing seasons, respectively. Alaoui *et al.* (2003) indicated that sugar beet sucrose yield was reduced by 99 to 100% by full-season weed interference and by 5 or 10% if weeds were allowed to interfere with sugar beet for 2 to 2.5 or 5 to 5.5 weeks after sugar beet emergence. The critical timing of weed removal to avoid 5 and 10% root yield loss was 30 and 43 days after sugar beet emergence, respectively (Odero *et al.*, 2009). It is possible to reduce the loss of irrigation water and increase the efficiency of water consumption by adopting a good irrigation system and reduce the loss of water resulting from the presence of weeds by removing weeds at the time of weed competition for sugar beet. These present investigation was carried out to determine the response of sugar beet yield and juice quality to deficit irrigation and estimation the critical period of weed competition and water use efficiency of sugar beet plants.

MATERIALS AND METHODS

Two field experiments were carried out in El-Bostan area - Aly Mubarak Experimental Farm, Southern El-Tahrir Region, (30.57° N latitude and 30.71° E longitude), El-Buhira Governorate, Egypt, during 2013/14 and 2014/15 successive winter seasons, to determinate the impact of deficit water irrigation and critical period of weeds infestation on sugar beet yield and its quality and water use efficiency under drip irrigation system and sandy soil conditions. The experimental design was split-plot with four replications.

Studied factors:

- Factor A: In main plots, three irrigation regime treatments into the whole plots as follows:

- 1) 60 % of Evapotranspiration (ET₀).
- 2) 80 % of ET₀.
- 3) 100 % of ET₀.

- Factor B: In sub-plots, ten duration of weed free and weed infestation periods into sub-division of the whole plots as follows:

- 1) Weed free for 3 weeks after planting (WAP).
- 2) Weed free for 6 WAP.
- 3) Weed free for 9 WAP.
- 4) Weed free for 12 WAP.
- 5) Weed free for the whole season.
- 6) Weed infestation for 3 WAP.
- 7) Weed infestation for 6 WAP.
- 8) Weed infestation for 9 WAP.
- 9) Weed infestation for 12 WAP.
- 10) Weed infestation for the whole season.

In 1 to 5 treatments, the crop is kept free the weeds until a certain time, after which weeds are allowed to grow and in 6 to 10 treatments, weeds are allowed to grow from the beginning to a certain time, after which they are removed until the end of the growth cycle.

Weed removal were done by hand pulling and hand hoeing at the estimated periods.

The sugar beet variety *viz.* Gloria (polygerm) was planted, at 3 kg/fed, on 16th and 9th of October, in the first and second seasons, and harvested in 25th and 18th of April, respectively. Plot area was 10.5 m², number of ridges was 5 with length of 3.5 m. and 0.6 m in width. The optimum agronomics practices recommended for the region were done.

Soil samples were collected before cultivation to determine the physical and chemical characteristics of the experimental site (Table 1).

The irrigation network consisted of a main delivery pipe (PE, 32 mm) and the secondary ones (PE, 25 mm). The drip laterals were of 16 mm diameter polyethylene with wide space 0.6 m and the space between emitters was 0.25 m. The discharge rate of the emitter was 4 liters/hour.

Table 1. Means of soil physical and chemical characteristics of the experimental site.

Soil depth (cm)	Particle size distribution %			Soil texture	Available nutrients (mg/kg soil)			Field capacity %	Wilt point %	Available water
	Sand	Silt	Clay		N	P	K			
0-15	90.5	5.5	4.0	Sandy	12.55	8.14	80.10	12.3	5.3	7.0
15-30	91.3	4.7	4.0		10.11	7.15	60.17	12.0	5.2	6.8
30-45	92.6	2.9	4.5		6.45	5.75	40.70	11.1	4.3	6.8
Soil depth (cm)	BD (g/cm ³)	EC ds/cm	pH	Soluble cations and anions (meq/l)						
				Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	HCO ₃ ⁻	SO ₄ ⁻²	Cl ⁻
0-15	1.43	0.87	8.6	2.80	0.85	3.53	1.30	1.57	2.62	4.29
15-30	1.60	0.89	8.8	2.91	0.90	3.62	1.41	1.69	2.75	4.40
30-45	1.71	0.91	8.8	3.01	0.93	3.70	1.46	1.75	2.64	4.71

Applied Irrigation Water:

Evapotranspiration (ET₀) was calculated according to Penman-Monteith equation as follows:

$$ET_0 = \frac{0.408 \Delta (Rn - G) + \gamma [900 / (T + 273)] U_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34 U_2)}$$

Where:

Δ= slope of vapor pressure and temperature curve (kPa °C-1). Rn= net radiation (MJ m-2d-1). G = soil heat flux (MJ m-2d-1). γ= psychrometric constant (kPa °C-1). T= mean daily air temperature at 2 m height (°C). U₂= wind speed at 2 m height (ms-1). e_s-e_a= vapor pressure deficit (kPa).

The input parameters which needed to calculate ET₀ using the CROPWAT model (Smith, 1992) are temperature, relative humidity, sunshine hours, and wind speed. The data from Wadi- El-Natrun Station were used in this study.

The amounts of applied irrigation water were calculated according to the equation given by Vermeiren and Jopling (1984) as follows:

$$AIW = \frac{ET_0 \times Kc \ I}{Ea (1 - LR)}$$

Where:

AIW= depth of applied irrigation water in mm. ET₀= evapotranspiration, mmd⁻¹. Kc = crop coefficient (for sugar beet crop as reported by Allen *et al.*, 1998). I= irrigation intervals (days). Ea= irrigation application efficiency of the drip irrigation system. L.R = leaching requirements.

Irrigation time for drip irrigation system was determined before an event by measuring the actual emitter discharges according to the equation given by Ismail (2002) as follows:

$$t = \frac{AIW \times A}{q}$$

Where:

t = irrigation time (h). A = wetted area (cm²).

q = emitter discharge (L/h).

AIW = applied irrigation water (cm).

Table 2. Sugar beet crop coefficient.

Growth stage	Days	Crop coefficient (Kc)
Initial stage	30	0.35
Development	60	1.2
Midi stage	60	0.7
End stage	40	0.5
Total	190	--

The total amount of applied irrigation water for 60, 80, and 100% of ET₀ irrigation treatments were 469.8, 626.4 and 783.0 mm, respectively, in the 2013/14 season, and were 459.3, 612.4, and 765.5 mm, respectively, in 2014/15 season.

Data recorded:-

1. Weed survey:

At harvest, in each plot, weeds were hand pulled from one square meter chosen at random then identified and classified to annual grassy, broad-leaved weeds and their total.

2. Sugar beet yield and juice quality:

At harvest, sugar beet plants in each the whole plot were harvested and weighted to determine the following traits:-

- 1- Top yield (ton/fed).
- 2- Root yield (ton/fed).
- 3- Gross sugar yield, GSY (ton/fed) = root yield (ton/fed) x sugar percentage.
- 4- Total soluble solids (TSS %).
- 5- Sucrose %: Juice sugar content of each treatment was estimated in fresh samples of sugar beet root by using Saccharometer according to the method described by A.O.A.C. (Ahadi and Sobhani, 2005).
- 6- Purity percentage: It was estimated according to the following formula:

$$Purity \text{ ,\%} = \frac{Sucrose \text{ ,\%}}{TSS \text{ \%}} \times 100$$

At harvest, sugar beet plants of each plot were up-rooted, topped, cleaned and weighed to determine root yield as ton/fed, sugar yield (ton/fed) was estimated after taking subsamples from each plot (10 roots) and fully cleaned roots and sent to Nile Sugar Company Lab and Sugar Crops Institute at Nubaria to determine physiological and chemical characters. Preparation of thick juice from sugar beet sub-samples (each sample was 10 kg of beet) on a laboratory scale, according to the method of Wieninger and Kubadinow (1971).

3. Irrigation Water Use Efficiency (IWUE):

Irrigation water use efficiency was calculated according to Jensen (1983) as the following equations:

$$IWUE_{\text{root yield}} \text{ (kg/m}^3\text{)} = \frac{\text{root yield (kg/fed)}}{\text{applied irrigation water (m}^3\text{/fed)}}$$

$$IWUE_{\text{sugar yield}} \text{ (kg/m}^3\text{)} = \frac{\text{sugar yield (kg/fed)}}{\text{applied irrigation water (m}^3\text{/fed)}}$$

Statistical Analysis

All data were statistically analyzed according to technique of analysis of variance (ANOVA) for the split-plot design as mentioned by Gomez and Gomez (1984) by means of "SAS" and SPSS computer software packages Duncan multiple range test was used for compare among treatments mean (Duncan, 1955).

RESULTS AND DISCUSSION

During the two growing seasons of sugar beet crop the major weed species at the experimental sites were *Avena* spp., *Polypogon monspeliensis* and *Phalaris* spp. as annual grassy weeds, and *Cichorium endivia* L., *Beta vulgaris* L., *Chenopodium album* L., *Sonchus oleraceus* L., *Medicago polymorpha* L., *Melilotus indica* L., *Anagallis arvensis*, *Ammi majus* L., *Emex spinosus* L., *Senecio glaucus* L. and *Rumex dentatus* L. as annual broad-leaved weeds.

A. Effect of deficit irrigation:

I- On weeds (g/m²):

Table 3 showed that the highest significant reduction in the fresh weight of grassy, broad-leaved and total weeds was obtained by irrigation at 60 % evapotranspiration (ET₀) treatment (14.8, 16.0 and 15.6 %, respectively, in 2013/14 season and 25.0, 13.6 and 17.3 % in 2014/15 season, respectively, as compared to 100 % ET₀ treatment. This may be due to that usually, the water restriction initially affects the most sensitive organs, such as the leaves, inflorescences and roots, regardless of the studied species. Patterson (1995) and Lima *et al.* (2016) who mentioned that the water deficit caused a reduction on the leaf dry matter and consequently total dry matter accumulation of some weed species.

Table 3. Effect of irrigation water treatments on the fresh weight of annual weeds (g/m²) in 2013/2014 and 2014/2015 winter seasons.

ET ₀ % treatments	2013 / 2014 season			2014 / 2015 season		
	Grassy weeds (g/m ²)	Broad-leaved weeds (g/m ²)	Total weeds (g/m ²)	Grassy weeds (g/m ²)	Broad-leaved weeds (g/m ²)	Total weeds (g/m ²)
60	200.8 b	461.1 c	661.9 c	226.6 c	543.4 c	770.0 c
80	233.3 a	493.1 b	726.4 b	252.2 b	583.7 b	835.9 b
100	235.6 a	548.8 a	784.4 a	302.3 a	628.7 a	931.0 a

II- On sugar beet yield and juice quality:

The effects of irrigation water deficit treatments on the yield and juice quality of sugar beet are presented in Table 4 showed that irrigation water at 60 % of ET₀ significantly reduced the sugar beet top yield (ton/fed) by 21.4 and 25.5 % in the first and second seasons, respectively, as compared to 100 % ET₀. Irrigation at 60 % ET₀ gave the highest value of root yield (20.18 and 20.02 ton/fed) in the first and second seasons, respectively. The percentage increase of root yield of sugar beet at 60 % of ET₀ was account as 58.8 and 60.2% than the treatment of 100% of ET₀ in the two seasons, respectively. These results are in agreement with those of Emara (1996) and Abdel-Nasser *et al.* (2014).

- Irrigation at 60 % and 80 % ET₀ gave the highest significant values of gross sugar yield (3.36, 3.06 and 3.11, 3.13 ton/fed) in the two seasons, respectively. The increase in sugar yield was due to both increase in sugar content and root yield in which sugar yield was adversely affected by water deficit. Increasing the impurities in the root of stressed plants decreased extraction of sugar. So, deficit irrigation improved sugar beet quality by reducing these impurities (Abdel-Nasser *et al.*, 2014). Irrigation at 60 % and 80 % ET₀ gave the highest values of TSS (20.62, 20.57 and 20.42, 20.52 %) in 2013/14 and 2014/15 seasons,

respectively. Irrigation at 60 % and 80 % ET₀ gave the highest significant values of sucrose % in 2013/14 and 2014/15 seasons. Similar results were obtained by

Kirda (2002), meanwhile purity % did not affect by any water irrigation treatments (Osman *et al.*, 2005 showed the similar results).

Table 4. Effect of irrigation treatments on the yield and juice quality of sugar beet in 2013/2014 and 2014/2015 winter seasons.

ET ₀ % treatments	Top yield (ton/fed)	Root yield (ton/fed)	Gross sugar yield (ton/fed)	TSS %	Sucrose%	Purity %
2013 / 2014 season						
60	5.33 b	20.18 a	3.36 a	20.62 a	16.75 a	81.73 a
80	6.00 b	17.70 b	3.06 a	20.57 a	17.27 a	81.36 a
100	6.78 a	12.71 c	2.03 b	19.60 b	15.99 b	80.94 a
2014 / 2015 season						
60	5.49 b	20.02 a	3.11 a	20.42 a	17.10 a	82.04 a
80	5.72 b	17.38 b	3.13 a	20.52 a	17.57 a	82.25 a
100	7.37 a	12.50 c	2.22 b	20.06 b	16.05 b	81.44 a

B. Effect of weeds removal intervals treatments:

I- On weeds (g/m²):

The effect of weeds removal intervals treatments on the fresh weight of grassy, broad-leaved and total weeds (g/m²) were presented in Table 5. The data illustrated that the dominant annual weeds in this study were the broadleaf weeds with infestation rates 3.0 kg and 3.5 kg fresh weight/m² in the first and second seasons, respectively. Whilst, the infestation rate of grassy weeds was 1.3 and 1.4 kg fresh weight/m² in the

both seasons, respectively. In the both seasons, the reduction percentage of the fresh weight broadleaf weeds, grasses and their total under all weed free and weed infestation intervals treatments were more 90 % as compared with weed infestation for the whole season with exception of weed free for 3 weeks only, which reached to 68.5, 69.6 and 69.3 %, respectively, in the first season and 65.4, 68.8 and 76.8 %, respectively, in second season. These results are in agreed with Kropff *et al.*, 1992 and Salehi *et al.*, 2006.

Table 5. Effect of weeds removal interval treatments on the fresh weight annual weeds (g/m²) in 2013/2014 and 2014/2015 winter seasons.

Weed removal or infestation intervals	2013 / 2014 season			2014 / 2015 season		
	Grassy weeds (g/m ²)	Broad-leaved weeds (g/m ²)	Total weeds (g/m ²)	Grassy weeds (g/m ²)	Broad-leaved weeds (g/m ²)	Total weeds (g/m ²)
Weed free for 3 WAP ⁽¹⁾	403.2 b	921.8 b	1324 b	477 b	1105 b	1582 b
Weed free for 6 WAP	124.0 c	200.4 c	324.4 c	243.9 c	278.6 c	522.5 c
Weed free for 9 WAP	43.7 c	149.6 c	193.3 c	49.7 d	169.5 c	219.2 c
Weed free for 12 WAP	26.9 c	101.8 c	128.7 c	31.3 d	117.7 c	149.0 c
Weed free for the whole season	34.4 c	68.7 c	103.1 c	40.6 d	80.5 c	121.1 c
Weed infestation for 3 WAP	44.5 c	81.0 c	125.4 c	50.9 d	94.0 c	144.9 c
Weed infestation for 6 WAP	73.5 c	151.0 c	224.4 c	84.6 d	182.5 c	267.2 c
Weed infestation for 9 WAP	97.5 c	112.0 c	269.5 c	123.1cd	131.3 c	254.4 c
Weed infestation for 12 WAP	106.3 c	192.8 c	299.1 c	133.3cd	155.1 c	288.4 c
Weed infestation for the whole season	1278 a	3030 a	4308 a	1378 a	3538 a	4916 a

⁽¹⁾WAP = weeks after planting.

II- On sugar beet yield and juice quality:

Data in Table 6 showed that increasing weed free or weed infestation intervals from planting caused consistent significant increases in top, root and sugar yields (ton/fed) than weed infestation for the whole season. These results were true in 2013/14 and 2014/15 winter seasons, meanwhile TSS %, sucrose % and purity % were not affected significantly by either early or late weed removal intervals in both season except with TSS % in second season where the highest TSS % were obtained by weed free for the whole season which increased by 7 % than weed infestation for the whole season. Concerning the top yield per faddan, both weed free for the whole season and weed free for 12 WAP increased top yield by 138.3 and 118.6% in 2013/14 season and by 98.7 and 95% in 2014/15 season, respectively, as compared to weed infestation for the whole season. Concerning the sugar beet yield (ton/fed), weed free for the whole season significantly increased the sugar beet yield by 302.5 % in 2013/14 season, whereas, in 2014/15 season weed free for the whole season, weed free 12 WAP and weed infestation for 3 WAP increased the root yield by 311.3, 305.4 and 292.7 %, respectively, as compared to weed infestation for the whole season (weedy check). Also, weed free for the whole season, weed free 12 WAP and

weed infestation for 3 WAP increased gross sugar yield by 353.8, 333.7 and 291.3 %, respectively, in 2013/14 season, and by 288.7, 258.9 and 228.2 %, respectively, in 2014/15 season, as compared to weed infestation for the whole season (weedy check). Similar findings were obtained by Jursik *et al.*, 2008; Salehi *et al.*, 2006; Mobarak *et al.*, 2012 and Fayed *et al.*, 1999.

C. The interaction between deficit water irrigation and weeds removal intervals treatments:

Table 7 showed that the effect of irrigation water x weeds removal interval treatments interaction was statistically significant, in both seasons, on grassy, broad-leaved and total weeds fresh weights, root and sugar yield (ton/fed). The highest significantly values of the fresh weights of grassy, broad-leaved and total weeds were recorded from weed infestation for the whole season treatment, in the two seasons, regardless of the Irrigation water amount. Wherever, the lowest values of these characters, in the two seasons, were obtained from the low irrigation water treatment (60 % ET₀) under all weed removal interval treatments. These results may be due to deficit irrigation from 100 to 60 % ET₀ reduce the number and growth of weeds. Concerning the root yield (ton/fed), the highest significantly values of sugar beet yield were

recorded from weed free for the whole season and weed free for 12 WAP treatments at 60 % ET₀ and weed free for whole season, weed free for 12 WAP and weed infestation for 3 WAP at 80 % ET₀ in the two seasons. Wherever, the lowest values of root yield were obtained from the high irrigation water treatment (100 % ET₀) under all weeds removal time treatments, in both seasons. These results may be due to deficit irrigation from 100 to 60 % ET₀ cause reduction on the growth of weeds and therefore reduction on

infestation of weeds with sugar beet plants which leads to increasing on sugar beet plants growth and yield. On the other hand, the highest significantly values of gross sugar yield (ton/fed) were recorded from weed free for the whole season and weed free for 12 WAP treatments at 60 and 80 % ET₀ in the two seasons. Wherever, the lowest values of gross sugar yield were obtained from the high irrigation water treatment (100 % ET₀) under all weeds removal time treatments, in both seasons.

Table 6. Effect of weeds removal interval treatments on the yield and juice quality of sugar beet in 2013/2014 and 2014/2015 winter seasons.

Weed removal or infestation intervals	Top yield (ton/fed)	Root yield (ton/fed)	Gross sugar yield (ton/fed)	TSS %	Sucrose %	Purity %
2013 / 2014 season						
Weed free for 3 WAP ⁽¹⁾	5.88 b	7.86 ef	1.18 ef	20.50 a	16.11 a	82.06 a
Weed free for 6 WAP	6.04 b	16.11 d	2.66 d	20.83 a	16.98 a	81.82 a
Weed free for 9 WAP	6.72 b	21.05 b	3.99 c	20.92 a	16.10 a	82.79 a
Weed free for 12 WAP	8.11 a	26.49 b	4.51 ab	20.83 a	17.23 a	81.85 a
Weed free for the whole season	8.84 a	27.57 a	4.72 a	20.58 a	17.10 a	82.67 a
Weed infestation for 3 WAP	6.79 b	25.67 b	4.07 ab	20.81 a	16.75 a	81.25 a
Weed infestation for 6 WAP	6.21 b	18.24 c	3.04 d	20.62 a	16.71 a	82.48 a
Weed infestation for 9 WAP	4.16 c	10.35 e	1.56 e	20.52 a	16.06 a	82.62 a
Weed infestation for 12 WAP	3.91 c	8.46 f	1.37 ef	20.46 a	17.15 a	81.83 a
Weed infestation for the whole season	3.71 c	6.85 f	1.04 f	20.39 a	16.42 a	82.05 a
2014 / 2015 season						
Weed free for 3 WAP	5.50 de	8.71 d	1.43 d	20.42 ab	16.48 a	80.90 a
Weed free for 6 WAP	6.78 bc	17.24 c	2.92 c	20.62 ab	16.99 a	82.00 a
Weed free for 9 WAP	7.61 bc	23.09 b	3.98 b	21.17 a	16.17 a	82.94 a
Weed free for 12 WAP	7.80ab	26.15 a	4.45ab	20.67 ab	16.97 a	81.43 a
Weed free for the whole season	7.95 a	26.53 a	4.82 a	21.42 a	16.73 a	83.74 a
Weed infestation for 3 WAP	6.52 cd	25.33 a	4.34 ab	20.40 ab	17.04 a	82.42 a
Weed infestation for 6 WAP	6.84bc	16.52 c	2.56 c	20.04 ab	16.15 a	81.74 a
Weed infestation for 9 WAP	4.71ef	8.77 d	1.45 d	20.67 ab	17.00 a	81.04 a
Weed infestation for 12 WAP	4.21 f	7.60 de	1.01 d	20.50 ab	17.14 a	80.55 a
Weed infestation for the whole season	4.00 f	6.45 e	1.24 d	19.92 b	16.75 a	82.34 a

⁽¹⁾WAP = weeks after planting.

D. Irrigation Water Use Efficiency (IWUE):

The effect of deficit irrigation on water use efficiency (IWUE) values for both root and gross sugar yields are presented in Table 8 showed that decreasing the amount of irrigation water from 100 % to 80 % and 60 % of ET₀ increased IWUE of root and sugar yield. The highest IWUE root yield values of 7.50 and 7.95 kg root/m³ of applied water were obtained from the lowest ET₀ irrigation (60 %) during 2013/14 and 2014/15 seasons, respectively. While, the highest IWUE sugar yield values of 1.23 and 1.34 kg sugar/m³ of applied water were obtained from the same irrigation treatment (60 % of ET₀) in the first and second growing seasons, respectively. These findings are in line with those reported by Awad *et al.* (2003), Osman *et al.* (2005), Esmaceli (2011). On the other hand, the highest IWUE for root yield values (kg root/m³) were obtained from weed free for whole seasons (11.19 and 10.83 kg/m³), during 2013/14 and 2014/15 seasons, respectively. Also, the highest IWUE for sugar yield values were obtained from weed free for whole seasons (1.83 and 1.84 kg sugar/m³) in 2013/14 and 2014/15 seasons, respectively. These results show what the weed removal from sugar beet fields can raise water efficiency by 240-320 % as compared to leave the weeds to compete sugar beet plants for whole season. From these results also, to obtain maximum water use efficiency must be irrigated at 60 % of ET₀ and save the sugar beet crop without weeds for the whole season, while 100 % of ET₀ and weed infestation for the whole season decreased water use efficiency to minimum values.

E. Estimation yield losses and the critical period of weed infestation to sugar beet yield:

Data presented in Table 6 and Figure 1 showed the biological response curve to weed removal intervals on root and sugar yield (ton/fed) and revealed that the losses in either root or gross sugar yield. In general, there is no significant differences in either root or sugar yield (ton/fed) for weed free period for the whole season or weed free for 12 weeks from planting in both seasons, meaning that sugar beet plants can tolerate weeds which germinate after this period until harvest. On the other hand, the yields of root or sugar per faddan from weed free treatments didn't affect significantly than their corresponding yields of weed infestation treatments for three weeks or weed infestation for the whole season meaning that sugar beet plants can tolerate weeds in this period, meaning that both root sugar beet and sugar yield can be sensitive to weed infestation through the period of from 3- 12 weeks and can be considered that weeds should be controlled through the critical period by hoeing or herbicides combinations through this prolonged period of weed competition to maintain sugar beet potential productivity. These results are agreed with those obtained by Odero *et al.* 2009 and Odero *et al.* 2010. Zindahl (1979) mentioned that because sugar beet leaf canopy forms slowly, entire crops can be decimated by competition from certain weed species and weeds must begin by the time sugar beet have four to six true leaves and yield can be depressed 120 to 150 kg/ha for each day weeds remain beyond this growth stage. He

mentioned that weeds need to be controlled until 10 to 12 early weed competition until 4 weeks from seedling and true leaves and he mentioned that sugar beets can tolerate need weed free period for 6 weeks after emergence.

Table 7. Effect of irrigation water * weeds removal interval treatments interaction on the fresh weights (g/m²) of grassy, broad-leaved and total weeds in 2013/2014 and 2014/2015 winter season.

ET ₀ % treatments	Weeds removal or infestation periods treatments	2013/2014 season					2014/2015 season				
		Grassy weeds (g/m ²)	Broad-leaved weeds (g/m ²)	Total weeds (g/m ²)	Root yield (ton/fed)	Gross sugar yield (ton/fed)	Grassy weeds (g/m ²)	Broad-leaved weeds (g/m ²)	Total weeds (g/m ²)	Root yield (ton/fed)	Gross sugar yield (ton/fed)
60	Weed free for 3 WAP ⁽¹⁾	250.5	510.2	760.7	10.20	1.58	349.4	676.4	1025.8	9.53	1.55
	Weed free for 6 WAP	123.1	136.9	260.0	16.44	2.95	48.8	154.0	202.8	17.53	3.15
	Weed free for 9 WAP	38.6	75.4	112.0	27.11	4.71	43.4	37.5	80.9	26.92	4.63
	Weed free for 12 WAP	21.7	89.8	111.5	31.76	5.51	17.4	99.2	116.7	30.60	5.35
	Weed free for the whole season	29.3	58.6	87.9	33.25	5.44	35.0	69.0	104.0	32.74	5.82
	Weed infestation for 3 WAP	37.2	73.3	110.5	28.46	4.60	42.2	86.2	128.5	24.99	4.05
	Weed infestation for 6 WAP	63.2	87.9	151.2	23.17	3.96	73.2	123.6	196.8	15.69	2.52
	Weed infestation for 9 WAP	136.7	84.8	221.5	12.92	1.98	154.0	107.9	261.9	9.95	1.87
	Weed infestation for 12 WAP	154.7	352.4	507.1	9.68	1.56	214.2	522.8	737.0	7.54	1.18
Weed infestation for the whole season	1126.1	2946.4	4092.5	6.42	1.31	1206.3	3123.5	4329.8	8.68	1.40	
80	Weed free for 3 WAP	337.3	637.4	974.7	6.68	1.05	380.4	704.6	1085.0	8.51	1.40
	Weed free for 6 WAP	175.8	325.4	501.2	15.91	2.64	209.4	379.2	588.6	18.51	2.62
	Weed free for 9 WAP	47.6	247.7	295.3	26.20	4.62	53.4	285.3	338.7	22.30	3.84
	Weed free for 12 WAP	24.5	122.6	147.2	30.32	5.59	35.1	124.6	159.7	31.80	5.51
	Weed free for the whole season	34.6	69.0	103.6	31.76	5.27	41.8	81.2	123.0	31.75	5.79
	Weed infestation for 3 WAP	48.2	79.6	127.8	28.61	4.57	54.2	91.4	145.6	29.40	4.54
	Weed infestation for 6 WAP	68.9	169.7	238.6	17.92	2.97	79.6	197.1	276.7	20.75	3.11
	Weed infestation for 9 WAP	164.8	113.8	278.6	9.82	1.60	206.8	124.1	330.9	8.25	1.51
	Weed infestation for 12 WAP	171.9	428.9	600.8	7.57	1.22	296.5	590.8	887.3	6.64	1.00
Weed infestation for the whole season	1306.2	2780.4	4086.6	6.91	1.22	1417.6	3473.1	4890.7	7.59	1.27	
100	Weed free for 3 WAP	381.4	657.7	1039.1	5.44	1.02	403.1	734.4	1137.6	8.09	1.03
	Weed free for 6 WAP	143.2	198.9	342.2	14.47	2.38	143.5	232.2	281.1	15.67	2.98
	Weed free for 9 WAP	45.1	125.6	170.7	15.73	2.64	52.5	185.8	238.3	20.04	2.91
	Weed free for 12 WAP	34.4	93.0	127.4	18.69	3.06	41.5	129.3	170.8	17.04	2.69
	Weed free for the whole season	39.3	78.5	117.8	16.95	2.82	44.9	91.3	136.3	16.01	2.64
	Weed infestation for 3 WAP	48.0	90.0	138.0	18.33	2.73	56.4	104.3	160.7	19.60	2.92
	Weed infestation for 6 WAP	88.3	195.2	283.5	13.64	2.18	101.1	226.9	328.0	13.10	2.03
	Weed infestation for 9 WAP	171.0	137.5	308.5	7.62	1.10	188.5	161.9	350.4	8.09	1.26
	Weed infestation for 12 WAP	182.2	397.3	579.5	7.95	1.12	309.2	622.3	931.4	5.16	0.88
Weed infestation for the whole season	1302.1	3645.0	4947.1	6.02	1.00	1511.5	4018.1	5529.6	6.51	1.05	
L S D at 0.05		183.1	544.9	669.9	4.25	0.78	216.46	638.5	785.7	3.71	0.80

⁽¹⁾WAP = weeks after planting.

Table 8. Effect of deficit water irrigation and weed removal interval treatments on irrigation water use efficiency (IWUE) of sugar beet crop during 2013/2014 and 2014/2015 winter seasons.

Weed removal or infestation intervals	IWUE _{root yield} (kg/m ³)				IWUE _{sugar yield} (kg/m ³)			
	60% ET ₀	80% ET ₀	100% ET ₀	Mean	60% ET ₀	80% ET ₀	100% ET ₀	Mean
2013 / 2014 season								
Weed free for 3 WAP ⁽¹⁾	3.33	2.23	3.15	2.90	0.51	0.45	0.39	0.45
Weed free for 6 WAP	7.09	6.24	5.37	6.23	1.16	1.03	0.96	1.05
Weed free for 9 WAP	10.27	8.86	7.71	8.95	1.84	1.51	1.29	1.55
Weed free for 12 WAP	11.05	10.89	8.31	10.08	2.06	1.78	1.38	1.74
Weed free for the whole season	13.38	11.04	9.16	11.19	2.19	1.80	1.50	1.83
Weed infestation for 3 WAP	11.30	9.61	8.98	9.96	1.70	1.59	1.34	1.54
Weed infestation for 6 WAP	7.57	7.03	6.69	7.10	1.29	1.16	1.07	1.17
Weed infestation for 9 WAP	4.22	3.85	3.73	3.93	0.65	0.63	0.54	0.61
Weed infestation for 12 WAP	3.89	3.16	2.97	3.34	0.51	0.48	0.65	0.55
Weed infestation for the whole season	2.95	2.71	2.10	2.59	0.33	0.44	0.49	0.42
Mean	7.50	6.56	5.82		1.23	1.09	0.95	
2014 / 2015 season								
Weed free for 3 WAP	4.12	3.22	3.11	3.48	0.69	0.52	0.51	0.57
Weed free for 6 WAP	9.73	6.08	5.15	6.99	1.54	1.02	0.97	1.18
Weed free for 9 WAP	9.80	8.74	7.82	8.79	1.71	1.50	1.42	1.54
Weed free for 12 WAP	12.67	10.47	8.35	10.50	2.16	1.68	1.32	1.72
Weed free for the whole season	12.67	10.47	9.35	10.83	2.27	1.96	1.30	1.84
Weed infestation for 3 WAP	12.17	10.31	8.61	10.36	2.17	1.68	1.32	1.72
Weed infestation for 6 WAP	8.13	7.14	6.42	7.23	1.22	1.00	0.82	1.01
Weed infestation for 9 WAP	3.96	3.23	3.12	3.44	0.66	0.55	0.51	0.57
Weed infestation for 12 WAP	3.19	2.97	2.84	3.00	0.46	0.50	0.52	0.49
Weed infestation for the whole season	3.02	2.41	2.27	2.57	0.49	0.38	0.34	0.40
Mean	7.95	6.44	5.67		1.34	1.08	0.90	

⁽¹⁾WAP = weeks after planting

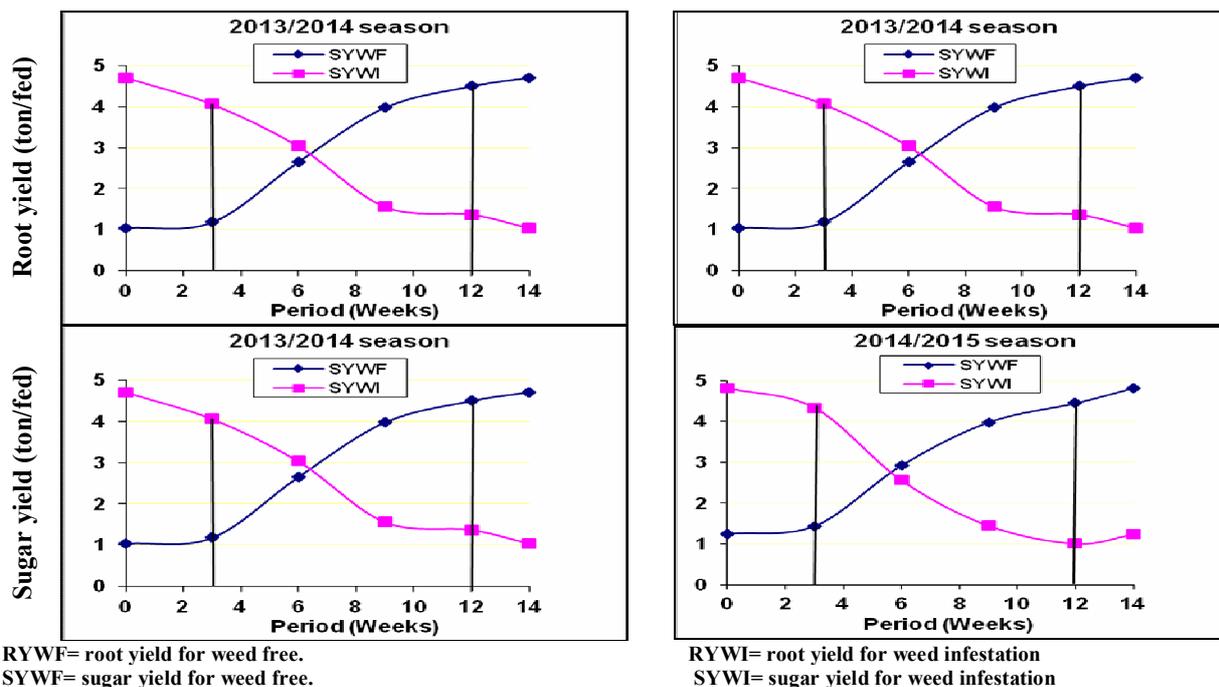


Fig. 1. Biological response curve of sugar beet yields (ton/fed) to weed infestation intervals during 2013/2014 and 2014/2015 winter seasons.

CONCLUSION

It could be concluded from this study that:

- Irrigation at 60 % of evapotranspiration could be used for sugar beet grown in sandy lands under drip irrigation conditions such as El-Bostan region without decrease of root and sugar yields.
- Water use efficiency values increased slightly with increase in water deficit.
- The sugar beet plants are weak in the early stage of plant growth and it can't compete with weeds such as weed species that appear with the emergence of sugar beet.
- The critical period of weed – sugar beet interference was 3-12 weeks after planting and must need to weed control during this period.
- The losses of sugar beet root and sugar yields in weed infestation for whole season treatment was 75 and 76 % as compared to the weed free for whole season treatment, and the loss in yield was started after 3 weeks and the maximum loss at 12 weeks after planting.

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استجابة محصول بنجر السكر وكفاءة الإستخدام المائي لنقص الري ومنافسة الحشائش تحت ظروف نظام الري بالتنقيط

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¹المعمل المركزي لبحوث الحشائش ، مركز البحوث الزراعية ، الجيزة ، مصر.

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أقيمت تجربتان حقليتان تحت نظام الري بالتنقيط لمحصول بنجر السكر بمنطقة البستان - مزرعة على مبارك البحثية - جنوب التحرير - محافظة البحيرة وذلك خلال الموسمين الزراعيين 2013/2014 و 2014/2015 لتقييم تأثير نقص مياه الري وعلاقته بالفترة الحرجة لمنافسة الحشائش لبنجر السكر وذلك على محصول وجوده وكفاءة الإستخدام المائي لمحصول بنجر السكر المنزرع تحت ظروف الأراضي الرملية. وقد استخدم تصميم القطع المنشقة مرة واحدة. وقد اشتملت كل تجربة على ثلاث معدلات للري ، في القطع الرئيسية، على أساس البخر- نتج وهي 60 و 80 و 100 % من معدل البخر- نتج وقد وضعت، وعشر معاملات منافسة الحشائش تحت ظروف قترات من الإزالة اليدوية للحشائش، حيث وزعت بالقطع المنشقة، وتشتمل على خمس قترات ازالة بعد 3 و 6 و 9 و 12 أسبوع من الزراعة وازالة طول موسم النمو ، وخمس قترات من ترك الحشائش لمنافسة لمدة 3 و 6 و 9 و 12 أسبوع من الزراعة وتركها طول موسم النمو. وقد أظهرت النتائج أن أقصى خفض في الوزن الغض للحشائش النجيلية وعريضة الأوراق والكلية نتيجة الري عند 60 % من البخر- نتج حيث بلغت نسبته 14.8 ، 16.0 و 15.6% في موسم 2013/2014 و 25.0 ، 13.6 و 17.3% في موسم 2014/2015 - على الترتيب - بالمقارنة بالري عند 100% من البخر- نتج ، والذي بدوره انعكس إلى زيادة في محصول الجذور والسكر للفدان بلغت 58.8 و 60.2% في موسم 2013/2014 وبمقدار 65.5 و 40.1% في موسم 2014/2015 عن الري بـ 100% من البخر- نتج، على الترتيب. كذلك أعطى الري عند 60% و 80% من البخر-نتج أعلى قيم المواد الصلبة الكلية ونسبة السكروز بينما لم تتأثر معنوياً نسبة النقاوة خلال الموسمين. علاوة على ذلك فإن أعلى قيم لكفاءة الإستخدام المائي لمحصول الجذور ومحصول السكر (7.2 و 1.2 كجم/م³ في الموسم الأول و 7.1 و 1.3 كجم/م³ في الموسم الثاني) تم الحصول عليه من الري عند 60% من البخر- نتج. وقد كانت الحشائش الحولية عريضة الأوراق في السائدة حيث بلغ وزنها الغض 3 و 3.5 كجم/م² في الموسمين الأول والثاني على الترتيب، بينما بلغ الوزن الغض للحشائش النجيلية 1.3 و 1.4 كجم/م² في كلا الموسمين على الترتيب. وفي كلا الموسمين فإن أعلى انخفاض لكلا قسمي الحشائش ومجموعهما تم الحصول عليه من كل معاملات ازالة وترك الحشائش (أكبر من 90%) وذلك بالمقارنة بترك الحشائش طول الموسم (أقل من 70%)، وقد انعكست هذه النتائج على محصول بنجر السكر (طن/فدان) ، حيث أنه في الموسم الأول بلغت الزيادة المعنوية في الوزن الجاف للعرش والجذور ومحصول السكر (طن/فدان) بين 118.6 و 302.5 و 353.8% على الترتيب من معاملة ازالة الحشائش طول الموسم إلى 58.5% للعرش من معاملة ازالة الحشائش لمدة 3 أسابيع ، و 135.2% للجذور من معاملة ازالة الحشائش لمدة 6 أسابيع ، و 50% لمحصول السكر من معاملة ترك الحشائش لمدة 9 أسابيع وذلك بالمقارنة بمعاملة ترك الحشائش طول الموسم. وفي الموسم الثاني بلغت الزيادة في الوزن الجاف للعرش والجذور ومحصول السكر (طن/فدان) بين 98.8 و 311.3 و 288.7% على الترتيب من معاملة ازالة الحشائش طول الموسم إلى 37.5% للعرش و 35% للجذور من معاملة ازالة الحشائش لمدة 3 أسابيع و 106.5% من معاملة ترك الحشائش لمدة 6 أسابيع وذلك بالمقارنة بمعاملة ترك الحشائش طول الموسم، بينما باقي معاملات ترك وازالة الحشائش في كلا الموسمين لم تصل إلى الزيادة المعنوية. أما بالنسبة لصفات الجودة (% للمواد الصلبة الكلية والسكروز والنقاوة) فقد أعطت كل معاملات ازالة وترك الحشائش تقريبا نفس القيم المتحصل عليها في كلا الموسمين. كذلك فإن معاملة ازالة الحشائش طول الموسم أدت إلى زيادة كفاءة الإستخدام المائي بنسبة من 240-320% لنباتات بنجر السكر بالمقارنة بترك الحشائش لمنافسة بنجر السكر طول الموسم. أما بالنسبة إلى تأثيرات التداخل فإن النتائج تشير إلى أن أعظم انخفاض في الوزن الغض لكلا قسمي الحشائش ومجموعهما تم الحصول عليه من الري عند 60 % من البخر- نتج مع معاملات ازالة الحشائش طول الموسم وترك الحشائش لمدة 3 أسابيع وازالة الحشائش لمدة 12 أسبوع ذلك في كلا الموسمين. كذلك أعطى التداخل بين معاملي الري عند 60 و 80% من البخر- نتج وكلا من معاملي ازالة الحشائش لمدة 12 أسبوع وطول الموسم أكبر زيادة في محصولي الجذور والسكر (طن/فدان) في كلا الموسمين. ومن دراسة معامل الإندثار فإن الفترة الحرجة هي من 3 حتى 12 إسبوع بعد الإنبات والفقذ في المحصول يحدث خلال تلك الفترة. لذلك فإن ما تم التوصل إليه من هذه الدراسة هو أنه يجب الري عند 60% من البخر-نتج مع مكافحة الحشائش حتى 12 أسبوع من الزراعة.