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Intercropping of some Faba Bean Cultivars with Sugar Beet using Different Irrigation Intervals under Sprinkler System in Sandy Soils

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ABSTRACT

A two-year field experiment was carried out at Ismailia Agriculture Research Station, ARC, Egypt during 2018/19 and 2019/20 seasons to assess the effect of two deficit irrigation intervals (irrigation every 4 (I_2) and 5 days (I_3), compared to irrigation every 3 days (I_1)) and intercropping three faba bean cultivars (Giza 716, Giza 843 and Sakha 1) with sugar beet on yield of both crops, water equivalent ratio (WER),land equivalent ratio (LER) and profitability. Strip-plot design with three replicates was used. The results revealed that the highest values of sugar beet and faba bean characters were obtained by I_1. Intercropping sugar beet with Giza 843 resulted in the highest yield of sugar beet and its attributes. However, Sakha1 had the highest seed yield and its attributes compared with Giza 716 and G 843. Application of I_2 and I_3 saved 22 and 36% of the applied water, but resulted in sugar beet yield reduction by 7 and 32% and in faba bean by 11 and 32%, compared to its values under I_1. The highest values of LER (1.38 and1.38),total return(17339 and 17478 L.E fed^{-1})and monetary advantage index(4774 and 4813)were obtained from intercropping sugar beet with G 843 cultivar under I_1. Whereas, the highest value of WER(1.51)was recorded under I_2. In conclusion, intercropping sugar beet with faba bean G843 cultivar and irrigation every 3 days is recommended under availability of irrigation water to increase farmer total income. Furthermore, under water shortage, irrigation every 4 days could be applied to increase WER.

Keywords: Irrigation intervals, land equivalent ratio, water equivalent ratio, monetary advantage index.

INTRODUCTION

Intercropping is one of the techniques of land utilization for optimum production (Bhatnagar *et al.*, 2007). The most common reason for the adoption of intercropping systems technique is yield advantage, which is explained by the greater resource depletion by intercrops than monocultures (Hauggaard-Nielsen *et al.*, 2006). These advantages of intercropping system are more apparent when the co-crops have different requirements of the available resources, in quantity, quality, and time of demand (Alfa *et al.*, 2015). The efficiency of the intercropping is directly depends on proper management of the factors of production (Porto *et al.*, 2011). These factors, when properly managed, can bring ecological and economic benefits, as a result of increasing production when compared to monoculture (Batista *et al.*, 2016).

Sugar beet is one of the important cultivated crops in Egypt. The crop was introduced to Egypt 15 years ago to contribute in the reduction of sugar production-consumption gap. Compared to sugarcane, sugar beet has lower growth season, and consequently lower water requirements. Furthermore, sugar beet have high sugar content (15–17%), high sugar recovery (12–14%), high purity (85–90%), and ability to withstand drought and salinity, compared to sugarcane (Pathak and Kapur 2013). The cultivated area of sugar beet was steadily increased in the past 10 years. However, the spread of sugar beet cultivation was on behalf of legume crops, specifically faba bean.

To overcome this situation, faba bean intercropping system with sugar beet was recommended to increase its production without using additional area (Abdel Motagally and Metwally, 2014; Zohry and Ouda, 2019). Faba bean cultivar selection is important to attain higher yield of both crops. In this context, Hendawey and Younes (2013) mentioned that faba bean cultivars "Sakha 1" and "Sakha 4" were superior in plant height, fresh weight, seed yield/plant, 100-seed weight, seed yield and protein yield. On the other hand, the lowest values of such parameters were achieved by Giza 843 except protein yield under water stress conditions.

To reduce aggressively between faba bean and sugar beet and improve sugar yield and quality in the intercropping systems, several planting density for faba bean were studied. Intercropping faba bean with sugar beet with relatively high planting density, namely 33% significantly reduced sugar beet root yield by 15%, compare to sugar beet sole planting (Farghaly *et al.*, 2003). Whereas, Zohry and Ouda (2019) indicated that sugar beet root yield was reduced by 6% under faba been intercropped with 25% planting density with sugar beet, compared to its sole planting. Furthermore, Farghaly *et al.* (2003) stated that total soluble solids percentage in sugar beet yield was reduced by 3% and sucrose percentage was reduced by 4%, whereas purity percentage was increased by 1% under intercropping with faba bean using 33% planting density.

Deficit irrigation practice can play an important role in water conservation under the current situation of water

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scarcity. Chai *et al.* (2016) stated that deficit irrigation is considered as an irrigation practice characterized by application of irrigation water below the full required amounts for optimal growth and yield, aiming at improving the response of plants to a certain degree of water deficit in a positive manner, and improving crop's water use efficiency. Thus, deficit irrigation is looked upon as a key contributor in water saving technology. One of water saving strategy is deficit irrigation (Du *et al.,* 2014). In this strategy, vegetative and reproductive growth are controlled by water stress through water deficits imposed during crop growing phases that are not yield reducing (Girona *et al.*, 2005). El-Darder *et al.* (2017) indicated that application of deficit irrigation to sugar beet resulted in saving 23% of the applied water to sugar beet grown in sandy soil under sprinkler system and 8% yield losses. Whereas, sugar beet yield losses were 7% and water saving was 22%, when sugar beet was irrigated with drip system. In sandy loam soil of Behira governorate of Egypt, Mehanna *et al.* (2017) studied the effect of application of deficit irrigation on sugar beet yield and they found that 33% saving in the applied irrigation water reduced yield by 18%. Eid and Ibrahim (2010) tested the effect of saving 17% of the applied irrigation water to sugar beet grown under surface irrigation in salt affected soil, where irrigation was done using fresh water and they found that percentage of yield reduction was 14%. With respect to faba bean, Sallam *et al.* (2014) indicated that application of deficit irrigation to faba bean grown in salt affected soil under surface irrigation, where 17% of the applied water was saved resulted in 12% yield losses.

Thus, the objective of this study was to assess the effect of intercropping three faba bean cultivars with sugar beet under deficit irrigation intervals on productivity of both crops, sugar quality, competitive relationships and profitability under sprinkler system in sandy soil.

MATERIALS AND METHODS

This research was carried out at Ismailia Research Station (Lat. 30° 35' 30" N, Long. 32° 14' 50" E, 10 m elevation above sea level), Ismailia governorate, Egypt, during of 2018/19 and 2019/20 seasons. The objective was to assess the effect of intercropping three faba bean cultivars with sugar beet under deficit irrigation on productivity of both crops, sugar quality, competitive relationships and profitability under sprinkler irrigation system in sandy soil.

A Strip-plot design with three replicates was used. Irrigation water intervals were arranged in vertical strips as irrigation every 3 days (control) and two deficit irrigation intervals (irrigation every 4 and 5 days), whereas horizontal strips were devoted to faba bean cultivars (Giza 716 (foliar disease resistant), Giza 843 (Orobanche tolerant) and Sakha 1 (foliar disease resistant)). All the three cultivars were sown in Orobanche free of soil The sub-plot area was 14.40 m^2, consisting of eight ridges 3 m long and 0.60 m in apart.

Peanut was the previous summer crop in both seasons. Average monthly weather data at the experimental site during the two growing seasons were obtained from https://power.larc.nasa.gov/data-access-viewer/ and are presented in Table 1. These data were used to calculate monthly reference evapotranspiration (ETo) values using Penman-Monteith equation, as presented in the United Nations FAO Irrigation and Drainage Paper by Allen *et al.*, (1998). This equation is included in Basic Irrigation Scheduling model (BISm, Snyder *et al.* 2004).

Chemical and physical soil analyses of the experimental soil before sowing were conducted by the standard methods as described by Tan (1996) as shown in Tables 2 & 3.

Table 1. Monthly solar radiation (Srad), maximum temperature (Tmax), minimum temperature (Tmin), wind speed (Ws), dew point temperature (Td), and reference evapotranspiration (ETo) for the experimental site in 2018/19 and 2019/20 seasons.

Month	Srad ($MJ\ m^{-2}\ day^{-1}$)	Tmax (ºC)	Tmin (ºC)	Ws ($m\ s^{-1}$)	Td (ºC)	ETo ($mm\ day^{-1}$)
			2018/19			
November	14.6	24.3	14.2	2.4	11.1	3.3
December	11.2	21.5	12.3	2.5	9.1	2.7
January	12.8	17.4	6.2	2.3	4.8	2.3
February	16.0	19.4	6.8	2.3	5.1	2.9
March	20.5	23.8	10.4	2.6	6.4	4.4
April	24.1	27.9	12.7	2.9	7.5	6.0
May	27.7	33.1	17.1	2.9	9.6	7.7
			2019/20			
November	14.3	23.9	12.6	2.3	9.8	3.2
December	11.0	21.2	10.8	2.2	7.6	2.6
January	12.1	17.8	7.5	2.6	5.7	2.4
February	15.8	19.7	8.5	2.5	6.4	2.9
March	20.2	23.9	11.5	3.0	7.7	4.5
April	23.8	27.4	13.5	3.1	9.1	5.8
May	27.5	32.6	17.9	3.1	11.3	7.5

Table 2. Physical analysis of the experimental soil before sowing.

Soil depth (cm)	Particle size distribution			Texture Class	Bulk density ($mg\ m^{-3}$)	Field capacity(%)	Permanent wilting point(%)	Available water(%)
	Sand(%)	Silt(%)	Clay(%)					
0-20	94.30	3.70	2.00		1.65	12.75	3.60	9.15
20-40	95.80	3.00	1.20	Sandy	1.73	11.20	2.90	8.30
40-60	96.20	2.95	0.85		1.70	7.40	2.10	5.30

Table 3. Chemical analysis of the experimental soil before sowing.

Soil depth (cm)	pH (1:2.5)	EC ($dS\ m^{-1}$)	Soluble cations ($meq\ L^{-1}$)				Soluble anions ($meq\ L^{-1}$)			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
0-20	7.66	0.56	1.22	0.53	1.54	0.18	-	1.10	1.72	0.65
20-40	7.59	0.50	1.20	0.50	1.58	0.15	-	1.06	1.74	0.63
40-60	7.40	0.48	1.25	0.48	1.62	0.16	-	1.08	1.75	0.68

Sugar beet seeds (c.v Sauther) were sown on November 3rd and 5th in 2018/19 and 2019/20 seasons, respectively and harvested on May 6th and 9th in the first and second seasons, respectively, in both solid and intercropping cultures. However, faba bean seeds were sown on November 18th and 20th in 2018/19 and 2019/20 seasons, respectively and harvested on April 16th and 20th in first and second seasons, respectively. Faba bean seeds were inoculated with *Rhizobium leguminosarum* before sowing using Arabic gum as a sticking agent in solid and intercropping cultures.

In the intercropping culture, sugar beet seeds were sown on one side of the ridge in 20 cm hills and one seed $hill^{-1}$, while faba bean seeds were sown on the other side of the fourth ridge of sugar beet in 25 cm hills and one seed $hill^{-1}$. This cultivation pattern attained 100% plant density of sugar beet and 12.5% plant density of faba bean. The recommended solid culture of both crops was grown and used to estimate competitive relationships.

Calcium superphosphate (15.5 % P_2O_5) at a rate of 30 kg P_2O_5 fed^{-1} and potassium sulphate (48% K_2O) at a rate of 50 kg K_2O fed^{-1} were applied during seed bed preparation. Mineral N fertilizer in the form of Urea (46% N) at a rate of 100 kg N fed^{-1} was applied to sugar beet in three equal doses at 20, 40 and 60 days after planting, while faba bean plants were fertilized by mineral N at rate 20 kg per fed 20 days after sowing. All cultural practices were applied as recommended for both crops.

Sprinkler system was used to irrigate the experiment. A solid-set sprinkler irrigation system with rotary RC 160 sprinklers of 0.40 to 1.12 an average 0.58 m^3/hr discharge rate at 2.80 bars nozzle pressure was used to irrigate the crops. The sprinkler system consists of main PVC pipe line (160 mm diameter), sub main PVC pipe lines (110 mm diameter), and PVC lateral lines (50 mm diameter). The laterals were spaced at 10 X 10 meters apart. Application of the irrigation water intervals started 30 and 15 days after sowing sugar beet and faba bean, respectively.

1. Water relations

Applied irrigation water (AIW)

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

$$AIW = \frac{ETo \times I}{Ea\,(1 - LR)}$$

where:

AIW = depth of applied irrigation water (mm)
ETo = reference evapotranspiration (mm d^{-1}).
I = irrigation interval (days)
Ea = irrigation application efficiency
LR= leaching requirements (was not considered because soil Ec is low).

Water consumptive use (WCU)

Crop consumptive water use was estimated by the method of soil moisture depletion according to Majumdar (2002) as follows:

$$WCU = \sum_{i=1}^{i-4} \frac{\theta 2 - \theta 1}{100} \times Bdxd$$

where:

WCU= water consumptive use or actual evapotranspiration, ETa (mm).
I = number of soil layer.
θ2 = soil moisture content after irrigation, (%, by mass).
θ1 = soil moisture content just before irrigation, (%, by mass).
Bd = soil bulk density, (g/cm^3)
d = depth of soil layer, (mm).

Water equivalent ratio (WER)

Water equivalent ratio was used to quantify the efficiency of water use by an intercropping system (Mao *et al.,* 2012). The WER is defined as the total water needed in sole crops to produce the equivalent amount of the species yields on a unit area of intercrop as follows:

$$WER = \frac{\left(\frac{Y_{int,s}}{WU_{int}}\right)}{\left(\frac{Y_{mono,s}}{WU_{mono,s}}\right)} + \frac{\left(\frac{Y_{int,f}}{WU_{int}}\right)}{\left(\frac{Y_{mono,f}}{WU_{mono,f}}\right)}$$

Where:

$Y_{int,s}$ and $Y_{int,f}$ are the yield of intercropped sugar beet and faba bean. WU_{int} is water consumptive use by the intercropped crops. $Y_{mono,s}$ and $Y_{mono,f}$ are the yield of mono sugar beet and faba bean. $WU_{mono,s}$ and $WU_{mono,f}$ are water consumptive use by mono sugar beet and faba bean, respectively.

1.Sugar beet traits

At harvest of sugar beet (185 days after planting), root of ten plants were pulled from the middle sub-plot to measure root length (cm) and root diameter (cm). While, plants of whole sub-plot were harvested then separated into tops and roots and weighted, then converted to estimate root and top yield ton per feddan (fed = 4200 m^2).

2.Quality traits of sugar beet:

Samples of 26 g fresh root weight were taken for each treatment to determine:

1. Total soluble solids % (TSS %) measured by Refractometer according to A.O.A.C. (1990).
2. Sucrose (%) was estimated according to methods described by Le – Doct (1927).
3. Purity (%) was determined as ratio of sucrose (%) divided by TSS% of roots as method outlined by Carruthers and Oldfield (1960).
4. Sugar yield per fed., was calculated according to the following equation:

Sugar yield per fed (ton) = (root yield ton fed^{-1} × sucrose %).

3.Faba bean traits:

At harvest ten guarded plants were randomly taken from each sub-plot to measure plant height (cm), number of branches per plant, number of pods per plant, pod weight per plant (g), 100-seed weight (g), seed yield (ardab fed^{-1}) (one ardab =155 kg, fed = 4200 m^2).

4.Competitive relationships

Land Equivalent Ratio (LER)

Land equivalent ratio is the ratio of area needed under sole cropping to produce the same production under intercropping at the same management level to produce an equivalent yield was calculated according to Willey (1979) as follows:

LER = (Yab/Yaa) + (Yba/Ybb)

Where:

Yaa and Ybb are the sole crop yields of crops a (sugar beet) and b (faba bean), respectively; while Yab and Yba is the intercrop yield of crop a and b.

Land equivalent coefficient (LEC)

LEC is a measure of interaction concerned with the strength of relationship (Adetiloye *et al.,* 1983). LEC is used for a two- crop mixture the minimum expected productivity coefficient (PC) is 25 percent, that is, a yield advantage was obtained if LEC value was exceeded 0.25.

It is calculated as follows:

LEC = La x Lb

Where:

La = relative yield of crop a (sugar beet) and Lb = relative yield of crop b (faba bean).

Aggressivety (A)

It mean a comparison of how much relative yield increase for the intercropped crop (a) on crop (b) with the expected crop to find out which of the two crops dominated in yield according to Mc-Gilchrist, (1965).

Aab = Yab / (yaa X zab) - Yba/ (ybb X zba).

The result of this equation is equal value for the main and the intercropped crops with either negative or positive signs. If the aggressivity is high for the dominant crop, the sign will be positive. The opposite occur if the sign is negative, thus the crop is dominated. The greater numerical value of (Agg), gave greater difference in competitive abilities and hence the larger difference between actual and expected yield.

5. Farmer's benefit

Total return of intercropping cultures

Total return of intercropping culture = Price of sugar beet yield + price of faba bean yield. To calculate the total return, the average prices of sugar beet was 480 L.E. per ton and for faba bean was 823 L.E. per ardab. The average price of sugar beet and faba bean were obtained from Bulletin of Statistical Cost Production and Net Return (2018).

Monetary advantage index (MAI):

It suggests that the economic assessment should assess on the basis of the rentable value of this land. MAI was calculated according to the formula suggested by Willey (1979).

MAI= Value of combined intercrops x LER-1/LER

Statistical Analysis:

Data were statistically analyzed using the MSTAT-C Statistical Software Package (Freed, 1991). The treatment means were compared using the Least Significant Differences (LSD) test with a significance level of 5% according to Gomez and Gomez (1984).

RESULTS AND DISSECTIONS

1. Applied irrigation water and water saving:

The results in Table 4 indicated that the applied irrigation water was decreased as a result of increasing irrigation intervals from 3 days (control) to 4 and 5 days between irrigation. These two prolonged irrigation intervals resulted in 22 and 21% saving in the applied irrigation water in the first and second season, respectively under irrigation every 4 days. Additionally, under irrigation every 5 days, the saving in the applied irrigation water reached 36 and 35% in the first and second season, respectively. Furthermore, it could be noticed from the table that the applied irrigation water to sugar beet intercropping systems was slightly higher than its value of the sole cultivation of sugar beet by 2 and 1% in the first and second season, respectively. These results are similar to that was obtained by Zohry and Ouda (2019), where they stated that the applied irrigation water to intercropped faba bean with sugar beet was slightly higher than the applied water to sole sugar beet.

Table 4. Applied irrigation water to faba bean cultivars intercropped with sugar beet under deficit irrigation and water savings in both growing seasons.

Irrigation interval	Cultivar	2018/19		2019/20	
		Applied irrigation Water (m^3 fed^{-1})	Water saving (%)	Applied irrigation Water (m^3 fed^{-1})	Water saving (%)
I_1	Giza716	3310	-	3329	-
(every 3 days)	Giza 843	3310	-	3329	-
	Sakha1	3310	-	3329	-
I_2	Giza716	2596	22	2616	21
(every 4 days)	Giza 843	2596	22	2616	21
	Sakha1	2596	22	2616	21
I_3	Giza716	2113	36	2150	35
(every 5 days)	Giza 843	2113	36	2150	35
	Sakha1	2113	36	2150	35
Solid sugar beet		3255		3308	
Giza716		2525		2557	
Giza 843		2525		2557	
Sakha1		2525		2557	

2.Sugar beet traits

Effect of irrigation intervals

Irrigation treatments had significant effect on root length, root diameter, root and top yield/fad (Table 5). The highest values of these traits were produced under irrigation every 3 days (control), while increased the interval between irrigations to every 5 days significantly decreased these traits. Mahmoodi *et al.* (2008) found that the lowest top yield for sugar beet was obtained in the lowest soil water content conditions. Similarly, Nourjou (2008) stated that increasing the irrigation interval decreased sugar beet root yield. These results are in accordance with those obtained by Eid and Ibrahim (2010) and Yonts (2011), where they stated that sugar be*et al*locates more photo-assimilates to root growth under full irrigation conditions, which lead to greater root development and an increase in root diameter and length.

Concerning sugar yield/fed and chemical traits, data in Table 6 indicated that sugar yield/fed of sugar beet was slightly reduced when irrigation interval was increased from 3 to 4 days. However, increasing irrigation interval to 5 days significantly and highly reduced the yield in both seasons, compared to the control tratment. Furthermore, increasing irrigation interval significantly reduced percentage of total soluble solids under both deficit irrigation treatments, compared to the control. On the contarary, sucrose percenatge and purity percenatge were significantly increased as irrigation interval was increased from 3 to 5 days in both growing seasons, These results are agreed with those obtained by Topak *et al.* (2011) and Ghamarnia *et al.* (2012), where they found that sucrose percentage of sugar beet increased with increasing water deficit. Furthermore, they stated that these results could be attributed to the decrease in root weight and diameter at the highest deficit irrigation level, which leads to decrease water content in the tissues, as well as non-sucrose substance (proteins and alpha amino nitrogen), and that consequently increased sucrose content in sugar beet roots.

Table 5. Effect of irrigation interval, intercropping some faba bean cultivars on sugar beet and their interaction on sugar beet yield and its components in 2018/19 and 2019/20 seasons.

Trait		Root length (cm)		Root diameter (cm)		Top yield(t/fed)		Root yield(t/fed)	
Treatment		2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
	G 716	19.28	19.40	11.12	11.35	3.17	3.57	28.12	28.53
I_1	G 843	18.13	19.20	11.79	11.79	3.44	3.77	28.75	28.80
	Sakha1	17.60	18.93	11.15	11.33	2.89	2.87	27.67	27.66
Mean		18.34	19.18	11.35	11.49	3.17	3.40	28.18	28.33
	G 716	17.63	18.73	10.31	10.82	3.01	3.20	26.92	26.5
I_2	G 843	17.47	18.50	10.86	11.20	3.26	3.47	27.03	26.87
	Sakha1	16.00	17.33	10.22	10.66	2.58	2.73	25.57	25.20
Mean		17.03	18.19	10.46	10.89	2.95	3.13	26.51	26.19
	G 716	17.20	18.27	9.87	10.55	2.52	2.63	19.38	19.03
I_3	G 843	17.13	18.20	10.29	10.84	2.72	3.03	19.85	19.37
	Sakha1	15.77	16.83	9.39	10.19	2.04	2.13	18.92	18.47
Mean		16.70	17.77	9.85	10.53	2.43	2.60	19.38	18.96
G 716		18.04	18.80	10.43	10.91	2.90	3.13	24.81	24.69
G 843		17.58	18.63	10.98	11.28	3.14	3.42	25.21	25.01
Sakha 1		16.46	17.70	10.25	10.73	2.50	2.58	24.05	23.78
LSD 5% A		0.95	0.20	0.31	0.06	0.37	0.31	0.79	0.41
LSD 5% B		N.S	N.S	0.38	0.07	N.S	0.32	0.94	0.68
LSD 5% AxB		N.S	N.S	N.S	0.12	N.S	N.S	N.S	N.S

I_1, I_2 and I_3 were irrigation every 3, 4 and 5 days, respectively.

Table 6. Effect of irrigation water interval, intercropping some faba bean cultivars on sugar beet and their interaction on chemical traits of sugar beet in 2018/19 and 2019/20 seasons.

Trait		Sugar yield (ton/fed)		TSS%		Sucrose %		Purity %	
Treatment		2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
	G 716	4.55	4.56	20.13	20.17	16.17	15.98	80.33	79.23
I_1	G 843	4.69	4.58	20.30	20.40	16.31	15.90	80.34	77.94
	Sakha 1	4.29	4.38	19.97	20.10	15.50	15.81	77.62	78.66
Mean		4.51	4.50	20.13	20.22	16.00	15.91	79.43	78.61
	G 716	4.41	4.35	19.30	19.00	16.40	16.43	84.97	86.47
I_2	G 843	4.47	4.43	19.43	19.13	16.53	16.47	85.07	86.10
	Sakha 1	4.18	4.13	19.07	18.70	16.33	16.40	85.63	87.70
Mean		4.35	4.30	19.27	18.94	16.42	16.43	85.23	86.76
	G 716	3.26	3.26	18.80	18.60	16.83	17.13	89.52	92.10
I_3	G 843	3.36	3.34	18.80	18.63	16.93	17.23	90.05	92.49
	Sakha 1	3.17	3.10	18.73	18.60	16.75	17.10	89.43	91.94
Mean		3.26	3.23	18.78	18.61	16.84	17.16	89.67	92.17
G 716		4.07	4.06	19.41	19.26	16.47	16.51	84.94	85.93
G 843		4.17	4.12	19.51	19.39	16.60	16.54	85.16	85.51
Sakha 1		3.88	3.87	19.26	19.13	16.20	16.45	84.23	86.10
LSD 5% A		0.14	0.28	0.26	0.12	0.11	0.06	1.68	1.96
LSD 5% B		0.16	0.10	0.20	0.12	0.10	0.04	N.S	N.S
LSD 5% AxB		N.S	N.S	N.S	0.19	N.S	N.S	N.S	N.S

I_1, I_2 and I_3 were irrigation every 3, 4 and 5 days, respectively.

With respect to reduction in sugar beet traits and its chemical analysis due to deficit irrigation, The results in Table (7) indicated that application of deficit irrigation, namely irrigation every 4 and 5 days for intercropped sugar beet with faba bean cultivars resulted in reduction in sugar beet traits and chemical analysis, compared to full irrigation every 3 days (control). Under irrigation every 4 days, both sugar beet top and root yield reduction was 7%, whereas under irrigation every 5 days, the losses were 24 and 32%, respectively. These results were true for all other studied traits, where its reductions were higher under irrigation every 5 days, compared to irrigation every 4 days.

Table 7. Percent reduction in sugar beet yield and its chemical traits as a result of deficit irrigation intervals, averaged over the two seasons.

Deficit Irrigation	Cultivar	Root length	Root diameter	Top yield/fed	Root yield/fed	Sugar yield/fed	TSS %	Sucrose %	Purity %
	Giza 716	-6	-6	-8	-6	-4	-5	+2	+7
I_2	Giza 843	-4	-6	-7	-6	-4	-5	+2	+8
	Sakha 1	-9	-7	-8	-8	-4	-6	+5	+11
Average		-6	-7	-7	-7	-4	-5	+3	+9
	Giza 716	-8	-9	-24	-32	-28	-7	+6	+14
I_3	Giza 843	-5	-10	-20	-32	-28	-8	+6	+15
	Sakha 1	-11	-13	-28	-32	-28	-7	+8	+16
Average		-8	-11	-24	-32	-28	-7	+7	+15

I_1, I_2 and I_3 were irrigation every 3, 4 and 5 days, respectively. (-) sign means reduction and (+) sign means increase.

It is worth to mention that, irrigation every 4 days (saved 22% of the applied irrigation water) reduced sugar beet yield by 7% averaged over the two growing seasons. Furthermore, application of irrigation every 5 days (saved 36% of the applied irrigation water) resulted in high reduction in sugar beet yield by 32% as shown in Tables (4) and (7). Similar results were obtained by El-Darder *et al.* (2017) who indicated that saving 23% of the applied water to sugar beet grown in sandy soil under sprinkler system resulted in 8% yield losses. In sandy loam soil of Behira governorate of Egypt, Mehanna *et al.* (2017) found that 33% saving in the applied irrigation water reduced yield by 18%. Thus, irrigation every 4 days caused low reduction in suagr yield and TSS (%) and caused low increase in sucrose (%) and high increase in purity (%). Furthermore, irrigation every 5 days highly reduced suagr yield and TSS (%) and increased sucrose (%) and highly increased purity (%) averaged over the two growing seasons (Table 7).

Effect of faba bean cultivars

The results presented in Tables (5 and 6) showed that faba bean cultivars was significantly affected sugar beet yield and its components as well as chemical traits in both seasons, except top yield in the 1st season only, while root length and purity % were not significantly affected by faba bean cultivars in both seasons. The highest values for root diameter, top yield, root yield, sugar yield, TSS (%) and sucrose (%) were observed by intercropping sugar beet with faba bean cultivar Giza 843 in both growing seasons, whereas intercropping sugar beet with faba bean Sakha 1 gave the lowest values for all traits except for purity percentage in the second season which gave the highest values.

It is worth to mention that differences between Giza 843 and Giza 716 in most cases failed to reach the level of significance. Root and sugar yield decreased by intercropping sugar beet with cultivar Sakha 1 by 5% for root yield/fed in both growing seasons and by 7 and 6% for sugar yield, compared to cultivar Giza 843 in first and second seasons, respectively (Table 5 and 6).

The results in Table (7) showed that the reduction in root yield/fed of sugar beet intercropped with Giza 716 or Giza 843 cultivar was the lowest and equal, namely 6%, compared with Sakha1cultivar 8% under 4 days irrigation interval. Whereas, sugar beet yield losses of the three cultivars were high and equal 32% under 5 days irrigation interval. Similarly, the lowest percentages of reduction in TSS, sucrose and purity percenatges averaged over the two growing seasons were found by intercropping sugar beet with Giza 716 and Giza 843 under irrigation every 4 days, however high percentages of reduction for these traits were found withShaka 1 cultivar, as averaged over the two growing seasons under 5 dayes irrigation intrval. However, reduction in sugar yield/fed of sugar beet intercropping with any faba bean cultivars were equal and reach 4 and 28% averaged over the two growing seasons under irrigation every 4 and 5 days, respectively, compare to irrigation every 3 days.

Variation between different faba bean cultivars is due to the differences in the genetic structure. Faba bean Sakha 1 had tallest plants and higher number of branches per plant compared to Giza 716 and Giza 843 cultivars. That is increased shading effect around sugar beet plants and interspecific competition, which reduced sugar beet traits, compared other cultivars. In this regard, differences among faba bean cultivars in growth parameters were noticed by Hendawey and Younes (2013), El-Shamy and Shahein (2016), Hamdany and El-Aassar (2017).

Effect of the interaction:

Sugar beet traits were insignificantly affected by interaction between irrigation intervals and faba bean cultivars in both growing seasons, ecxept for root diameter and TSS (%) in 2nd season only as shown in Tables (5 and 6). The highest values of root diameter and TSS (%) were 11.79 cm and 20.40% were obtained from intercropping sugar beet with faba bean Giza 843 and irrgation every 3 days, meanwhile, the lowest values, 10.39 cm and 18.60% were obtained under the irrigation every 5 days and intercropping sugar beet with Sakha 1 faba bean cultivar.

3. Faba bean traits:

Effcet of irrigation intervals

Results illustrated in Tables (8 and 9) clearly indicated that the irrigation intervals significantly affected on faba bean traits in both growing seasons. The highest values of faba bean yield and yield components were obtained when plants were irrigated every 3 days, comapred to irrigation every 4 and 5 days. While, irrigation every 5 days highly reduced faba bean yield and its components. These results are in agreement with the previous research of El-Gindy *et al.* (2003) and Abdel-Mawgoud (2006) on the effect of irrigation amount on faba bean yield and its componenets, they revealed that its highest values were obtained under application of full irrigation.

Table (10) showed the percentage of reduction in faba bean yield and its components under implementing deficit irrigation treatments by increasing irrigation interval. The table showed that under irrigation every 4 days treatments seed yield/fed was decreased by 11% averaged over both growing seasons. In this case, 22% of the applied irrigation water was saved (Table 4). Whereas, irrigation application every 5 days resulted 36% saving in the applied irrigation water (Table 4) and reduction in faba bean seed yield was 32% (Table 10). These results are in agreements with those obtained by Hendawey and Younes (2013) they reported that the reduction in growth and yield components due to water stress during seed filling might have been due to the inhibition in photosynthesis efficiency under insufficient water conditins. Similar results have been reported by Alghamdi *et al.* (2015) and Guoju *et al.* (2016).

Effect of faba bean cultivars

Data in Tables (8 and 9) showed that pod weight per plant, 100-seed weight and seed yield per fed of faba bean were significantly affected by the variation between faba bean cultivars in both seasons, meanwhile, plant height, number of branches/plant and number of pods/plant were significantly affected in second season only. Faba bean cultivar Sakha 1 had the highest values for the previously mentioned traits, while the lowest values were produced by Giza 843 cultivar in both growing seasons.

Intercropping faba bean cultivar Sakha 1 with sugar beet increased its seed yield by 3 and 6% in the 1st season and 6 and 7% in the 2nd season compared to Giza 716 and Giza 843 cultivar, respectively. ICARDA (2008) indicates that replacing of traditional cultivars with the improved cultivars led to gains in yield by 18% in Egypt, 8% in Sudan and 42% in Ethiopia. The variations in growth, seed yield and its components among faba bean cultivars under this study were due to differences in their genetic makeup.

Hendawey and Younes (2013) mentioned that faba bean Sakha 1 exceeded Giza 843 in plant height, fresh weight, seed yield/plant, 100-seed weight, and seed yield/fed under water stress conditions. These results are in accordance with those obtained by Hendawey and Younes (2013), El-Shamy and Shahein (2016), Hamdany and El-Aassar (2017)

Table 8. Effect of irrigation water intervals, intercropping some faba bean cultivars on sugar beet and their interaction on faba bean traits in 2018/19 and 2019/20 seasons.

Irrigation interval		Plant height (cm)		No.of branches/plant		No.of pods/plant	
		2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
	G 716	88.00	87.67	4.33	5.73	20.13	21.17
I_1	G 843	86.67	84.33	3.90	5.47	18.60	20.47
	Sakha 1	89.33	89.33	4.73	5.97	21.20	23.77
Mean		88.00	87.11	4.32	5.72	19.98	21.80
	G 716	87.67	86.00	4.20	4.93	15.40	18.30
I_2	G 843	85.33	83.67	4.20	4.90	15.33	17.47
	Sakha 1	89.00	88.33	4.53	5.17	16.27	19.50
Mean		87.33	86.00	4.31	5.00	15.67	18.42
	G 3716	71.00	69.67	2.77	3.40	12.67	15.10
I_3	G 843	70.00	72.33	2.67	3.63	12.20	14.17
	Sakha 1	75.67	74.33	2.87	4.02	13.83	16.43
Mean		72.22	72.11	2.77	3.68	12.90	15.23
G 716		82.22	81.11	3.77	4.69	16.07	18.19
G 843		80.67	80.11	3.59	4.67	15.38	17.37
Sakha 1		84.67	84.00	4.04	5.05	17.10	19.90
LSD 5% A		4.37	5.26	0.25	0.28	0.61	0.18
LSD 5% B		N.S	3.36	N.S	0.36	N.S	0.29
LSD 5% AxB		N.S	N.S	N.S	N.S	N.S	0.18

Table 9. Effect of irrigation water intervals, intercropping some faba bean cultivars on sugar beet and their interaction on faba bean traits in 2018/19 and 2019/20 seasons.

		Pod weight/plant (g)		100 seed weight (g)		Seed yield (ardab/fed)	
		2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
	G 716	38.33	42.52	86.67	85.67	4.36	4.47
I_1	G 843	37.33	38.69	81.00	85.67	4.30	4.44
	Sakha1	41.00	45.59	88.00	88.67	4.66	4.70
Mean		38.89	42.26	85.22	86.67	4.44	4.53
	G 716	35.67	36.97	80.00	82.67	3.97	4.00
I_2	G 843	34.33	33.84	78.67	79.67	3.83	3.95
	Sakha 1	37.33	38.19	84.67	84.67	4.00	4.12
Mean		35.78	36.33	81.11	82.33	3.93	4.02
	G 716	27.73	27.82	65.67	69.33	2.96	3.02
I_3	G 843	26.53	27.00	62.67	66.33	2.92	3.00
	Sakha 1	29.67	30.79	67.33	72.33	3.00	3.33
Mean		27.98	28.54	65.22	69.33	2.96	3.12
Average of cultivars							
G 716		33.91	35.77	77.44	79.22	3.76	3.83
G 843		32.73	33.18	74.11	77.22	3.68	3.80
Sakha 1		36.00	38.19	80.00	81.89	3.89	4.05
LSD 5% A		1.43	1.86	4.55	6.60	0.07	0.07
LSD 5% B		2.09	2.68	4.46	5.65	N.S	0.12
LSD 5% AxB		5.67	3.33	N.S	N.S	N.S	N.S

Table 10. Percentage of reduction in faba bean yield and its components as a result of deficit irrigation treatments averaged over the two growing seasons.

Deficit Irrigation		Plant height	No. of branches/plant	No. of pods/plant	Pods weight/plant	100-seed weight	Seed yield
	G 716	1	8	19	10	6	10
I_2	G 843	1	1	16	10	5	11
	Sakha 1	1	9	21	13	4	13
Average		1	6	18	11	5	11
	G716	20	38	33	31	22	32
I_3	G 843	17	33	33	30	23	32
	Sakha 1	16	36	33	30	21	32
Average		18	36	33	30	22	32

Effect of the interaction

Number of pods/plant in the 2nd season and pods weight/plant in both seasons were significantly affected by the interaction between irrigation water intervals and faba bean cultivars (Table 8 and 9). The highest number of pods per plant (23.77) and heaviest pods weight per plant (41.00 and 45.59 g) was found for Sakha 1 cultivar intercropped with sugar beet and irrigated every 3 days. In contrary, intercropping faba bean Giza 843 under irrigation every 5 days produced the lowest number of pods per plant (14.17) and pods weight/plant (26.53 and 27.00 g) in 2nd season and both seasons, respectively. These results are accordance with those obtained by (Hendawey and Younes 2013) they mentioned that faba bean Sakha 1 and Sakha 4 exceeded the other cultivars in plant height, fresh weight, seed yield/plant, 100-seed weight, seed yield and protein yield. On the other hand, the lowest values of such parameters were achieved by Giza 843 except protein yield under water stress conditions.

4. Competitive relationships

Land equivalent ratio (LER) and Land equivalent coefficient (LEC):

The values of LER were estimated using data of recommended solid cultures of both crops. Intercropping different faba bean cultivars with sugar beet increased LER to be higher than 1.0 as compared to solid cultures of both crops under irrigation every 3 and 4 days in both seasons and LER was lower than 1.0 for deficit irrigation every 5 days as shown in Table (11). Furthermore, the lowest value of LER was obtained for Sakha 1. Generally, intercropping sugar beet with the three faba bean cultivars under control treatment and deficit irrigation every 4 days tended to increase land usage by about 34 and 25% in 1st season and by 36 and 24 % in 2nd season, respectively. The highest value of LER (1.38) was achieved under irrigation every 3 days (control) and intercropping sugar beet with Giza 843, while the lowest LER (0.89) value was obtained by intercropping faba bean Sakha 1 with sugar beet under deficit irrigation every 5 days in both seasons.

LEC value took the same trend as LER, where intercropping faba bean cultivars with sugar beet increased LEC to be higher than 0.25. This intercropping advantage was achieved under application of irrigation intervals every 3 and 4 days in both seasons. The opposite was found for application of deficit irrigation every 5 days in both seasons; where LEC value was lower than 0.25. The highest values of LEC (0.38 and 0.39) were detected by intercropping faba bean Giza 843 with sugar beet and irrigation every 3 days in the 1st and 2nd seasons, respectively. These results are expected since insufficient soil moisture decreased yield and its components consequently decreased relative yields of both crops. While, intercropping faba bean with sugar beet under full irrigation showed efficient utilization of land and water resources by growing both crops together. These results are in agreement with those obtained by Zohry and Ouda (2019), El-Dein (2015) and El-Shamy *et al.* (2019).

Aggressivity:

It was obvious from data in Table (11) that aggressivity values of faba bean were positive, whereas its values were negative for sugar beet, meaning that faba bean was dominant and sugar beet was dominated. The results herein were in accordance with those recorded by El-Dein (2015).

5. Total return and monetary advantage index (MAI):

The total returns and monetary advantage index (MAI) of intercropped faba bean with sugar beet as compared to solid sugar beet in both seasons are shown in Table (11). Intercropping faba bean with sugar beet and application of irrigation every 3 days in both seasons increased total returns and MAI compared to solid sugar beet. Intercropping faba bean Giza 843 with sugar beet and irrigation every 3 days gave the highest total return, namely 17339 and 17478 L.E. fed^{-1} compared to solid sugar beet 13934 and 14040 L.E. fed^{-1} in 2018/19 and 2019/20 seasons, respectively. On the contrary, application of deficit irrigation every 5 days in both seasons had negative effects on total return and MAI. These results supported by what was found by El-Darder *et al.* (2017) and El -Shamy *et al.* (2019).

Table 11. Effect of irrigation water intervals, intercropping some faba bean cultivars on sugar beet and their interaction on competitive relationships, total return and MAI 2018/19 and 2019/20 seasons.

Trait / Treatment		LER			LEC	Aggressivity		Return L.E.fed^{-1}		Total return L.E.fed^{-1}	MAI
		L sug.	L fab.	LER		Sugar	Faba	sugar	Faba		
2018/19 season											
I_1	G 716	0.97	0.39	1.36	0.38	-2.43	2.43	13498	3267	17086	4523
	G 843	0.99	0.39	1.38	0.38	-2.40	2.40	13800	3152	17339	4774
	Sakha 1	0.95	0.38	1.33	0.36	-2.34	2.34	13282	3292	17117	4247
I_2	G 716	0.93	0.35	1.28	0.32	-2.17	2.17	13402	3588	16189	3541
	G 843	0.93	0.34	1.28	0.32	-2.08	2.08	13454	3539	16126	3528
	Sakha 1	0.88	0.32	1.20	0.28	-1.94	1.94	12754	3835	15566	2594
I_3	G 716	0.67	0.26	0.93	0.18	-1.64	1.64	9302	2436	11738	-884
	G 843	0.68	0.26	0.95	0.18	-1.62	1.62	9528	2403	11931	-628
	Sakha 1	0.65	0.24	0.89	0.16	-1.46	1.46	9082	2469	11551	-1428
Root yield of solid sugar beet				29.03 ton fed^{-1}				13934	-	13934	-
Seed yield of solid faba bean cv. Giza 716				11.25 ardab fed^{-1}				-	9259	9259	-
Seed yield of solid faba bean cv. Giza 843				11.12 ardab fed^{-1}				-	9152	9152	-
Seed yield of solid faba bean cv. Sakha 1				12.42 ardab fed^{-1}				-	10222	10222	-
2019/20 season											
I_1	G 716	0.98	0.40	1.37	0.39	-2.50	2.50	13694	3292	17373	4692
	G 843	0.98	0.40	1.38	0.39	-2.49	2.49	13824	3251	17478	4813
	Sakha 1	0.95	0.37	1.32	0.35	-2.33	2.33	13277	3391	17145	4156
I_2	G 716	0.91	0.35	1.26	0.32	-2.20	2.20	13214	3679	16506	3406
	G 843	0.92	0.35	1.27	0.32	-2.17	2.17	13378	3654	16628	3535
	Sakha 1	0.86	0.33	1.19	0.28	-2.01	2.01	12576	3868	15967	2549
I_3	G 716	0.65	0.27	0.92	0.17	-1.70	1.70	9134	2485	11620	-1010
	G 843	0.66	0.27	0.93	0.18	-1.68	1.68	9298	2469	11767	-886
	Sakha 1	0.63	0.26	0.90	0.17	-1.70	1.70	8866	2741	11606	-1290
Root yield of solid sugar beet				29.25 ton fed^{-1}				14040	-	14040	-
Seed yield of solid faba bean cv. Giza 716				11.31 ardab fed^{-1}				-	9308	9308	-
Seed yield of solid faba bean cv. Giza 843				11.23 ardab fed^{-1}				-	9242	9242	-
Seed yield of solid faba bean cv. Sakha 1				12.59 ardab fed^{-1}				-	10362	10362	-

Water Equivalent Ratio (WER)

Figure 1 showed that water consumptive use of faba bean intercropped with sugar beet was higher in the first growing season, compared to the second growing season. Furthermore, water consumptive use of the intercropping system was slightly higher than its value under sole sugar beet cultivation due to cultivation of 100% of sugar beet planting density and 12.5% of faba bean planting density. It worth mentioning that sole faba bean cultivation was done using 100% of its planting density.

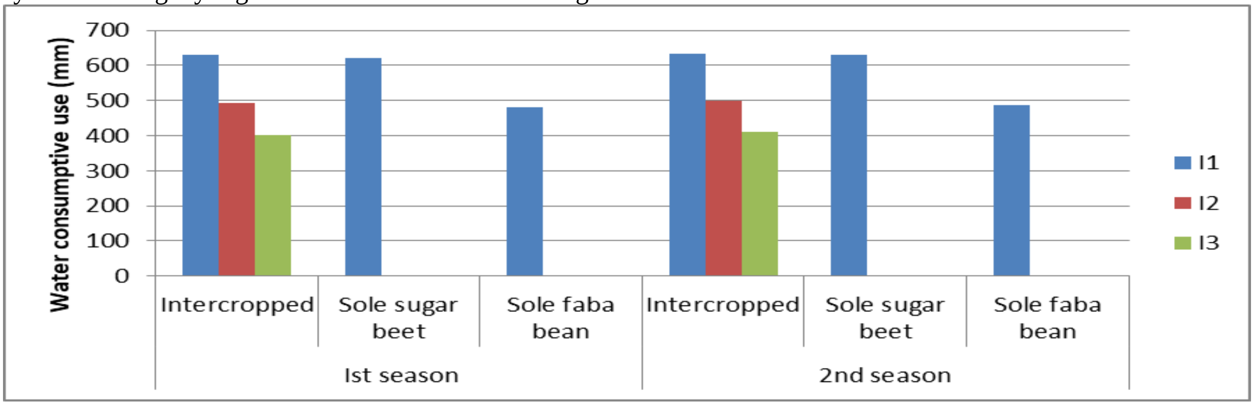

Figure 1. Water consumptive use faba bean intercropping system with sugar beet and sole cultivation of both crops in both growing seasons.

The results in Table (12) indicated that the highest value of WER for faba bean, WER for sugar beet and total WER was obtained under application of deficit irrigation every 4 days for all the three faba bean cultivars in both growing seasons. The results also showed that the highest total WER was obtained for Giza 843 cultivar under the three irrigation treatments in both growing seasons. The lowest value of total WER was obtained under irrigation every 3 days.

Table 12. Effect of irrigation water interval, intercropping of some faba bean cultivars with sugar beet and their interaction on water equivalent ratio 2018/19 and 2019/20 seasons.

Irrigation interval	Cultivar	WER faba bean		WER sugar beet		WER total	
		2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
I_1	G 716	0.30	0.30	0.95	0.97	1.25	1.27
	G 843	0.29	0.30	0.97	0.98	1.27	1.28
	Sakha 1	0.29	0.29	0.94	0.94	1.22	1.23
I_2	G 716	0.34	0.35	1.16	1.15	1.50	1.49
	G 843	0.33	0.34	1.17	1.16	1.51	1.51
	Sakha 1	0.31	0.32	1.10	1.09	1.42	1.41
I_3	G 716	0.31	0.32	1.03	1.00	1.34	1.32
	G 843	0.31	0.32	1.05	1.02	1.37	1.34
	Sakha 1	0.29	0.31	1.00	0.97	1.29	1.29

CONCLUSION

In this research, we determined the best faba bean cultivar to be intercropped with sugar beet, namely Giza 843, which resulted in the highest sugar beet yield, the highest value of LER, total income and MAI under the application irrigation every 3 days (control treatment). Thus, we recommend implementing this intercropping system under the availability of irrigation water. Furthermore, application of deficit irrigation every 4 days to the studied faba bean Giza 843 cultivar intercropped with sugar beet resulted in 22% saving in the applied irrigation water with 7 and 11% losses in the yield of sugar beet and faba been, respectively and also resulted in the highest WER value 1.51. Thus, application of deficit irrigation every 4 days in sandy soil under sprinkler systems can be recommended under water shortage to increase WER.

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تحميل بعض أصناف الفول البلدي مع بنجر السكر باستخدام فترات ري مختلفة تحت نظام الري بالرش في الأراضي الرملية

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أجريت تجربة حقلية بمحطة البحوث الزراعية بالإسماعيلية خلال موسمي النمو 2019/2018 و 2020/2019 لتقييم تأثير نقص مياه الري (الري كل 4 ايام (I_2) وكل 5 أيام (I_3) ، مقارنة بالري كل 3 ايام (I_1)) و تحميل ثلاثة اصناف من محصول الفول البلدي (جيزه 716، جيزه 843، سخا 1) مع محصول بنجر السكر على انتاجية كلا المحصولين و كفاءة استخدام مياه الري والارض والعائد النقدي . تم استخدام تصميم الشرائح في ثلاث مكررات والنتائج كالتالي: سجلت معاملة الري كل 3 ايام أعلى القيم لصفات بنجر السكر والفول البلدي. حقق تحميل بنجر السكر مع صنف الفول جيزة 843 اعلى القيم لمحصول بنجر السكر و مكوناته. بينما حقق تحميل بنجر السكر مع الفول البلدي صنف سخا 1 اعلى القيم لمحصول الفول البلدي و مكوناته مقارنة بصنفي الفول جيزه 716، جيزه 843. كما أدى الري كل 4 أيام (I_2) و5 ايام (I_3) الى توفير كمية من مياه الري المضافة مقارنة بالري كل 3 ايام (I_1) بنسبة 22، 36% و صاحب ذلك نقص محصول بنجر السكر بنسبة 7، 32% وكذا في محصول الفول البلدي بنسبة 11، 32% في الموسم الاول والثاني على التوالي، كما سجلت اعلى قيمة للمكافئ الأرضي 1.38 و إجمالي عائد نقدى 17339 و 17478 جنية للفدان و ميزة نقدية بلغت 4774 و 4813 جنية بتحميل الفول البلدي صنف جيزه 843 مع البنجر والري كل 3 أيام. بينما سجلت أعلى قيمة للمكافئ المائي WER 1.51 بتحميل البنجر مع نفس الصنف والري كل 4 أيام. الخلاصة: تحميل الفول البلدي صنف جيزة 843 مع بنجر السكر والري كل 3 ايام يؤدى الى زيادة دخل المزارع في ظروف وفرة مياة الري. لكن في ظل ندرة مياه الرى توصى الدراسة بالرى كل 4 أيام لزيادة كفاءة استخدام مياة الرى.