Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Impact of Plant Density and Leaves Defoliation of Sunflower Intercropped with Sugar Beet on The Productivity of Both Crops and Competitive Relationships

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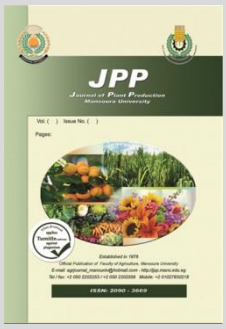

ABSTRACT

At Sakha Agricultural Research Station, two field experiments were conducted during 2018/2019 and 2019/2020 seasons to study the effect of sunflower densities (12.5, 25.0 and 37.5 % from the recommended) and defoliation (25.0, 37.5 and 50.0 % leaves) of sunflower intercropped with sugar beet on productivity and quality of both crops and economic evaluation. The productivity of sugar beet root yield t/fed. reached 83.69 and 83.07% compared to pure stand in both seasons, respectively. Simultaneously, increase defoliation of sunflower leaves increased all studied characters of sugar beet in both seasons. Sugar beet yields *i.e.* root, top and sugar yield t/fed were significantly affected by the interaction between plant density and leaves defoliation ratio in both seasons. Plant height, seed yield kg/fed. and oil yield kg/fed. of sunflower were increased by increasing sunflower plant densities from (12.5 to 37.5) in both seasons. All studied characters of sunflower were not significantly affected by increasing defoliation except, 100-seed weight and seed yield/plant in both seasons. Stem and head diameter, seed yield/plant and seed oil % were significantly affected by the interaction between plant density and defoliation ratio in both seasons. The treatment of intercropping sunflower with the highest density and 50% defoliation gave the highest values for land equivalent ratio (LER), total and return incomes in both seasons. It could be concluded that sunflower intercropped with sugar beet at (37.5%) and 50% sunflower leaves defoliation gave the highest LER, total income and economic return for sugar beet and sunflower were obtained when .

***Keywords*:** Sunflower, sugar beet, yield, economic evaluations.

INTRODUCTION

Sugar beet (*Beta Vulgaris* var. *saccharifera* L.) crop has an important position in Egyptian crop rotation as a winter crop for sugar production in the fertile soils and new reclaims oils. The total cultivated area of sugar beet in the 2018 season reached 521.427 feddan, and the total production exceeded 11.223 million ton roots with an average of 21.523 t/fed (FAO, 2020).

Sunflower is an essential crop because of its quality and quantity rank among the oil seed crops and high temperature and limited moisture conditions (Unger, 1990).However, the area devoted to sunflower in the crop structure in Egypt is very limited. Therefore, increasing oilseed crops is an important target to reduce the gap between local production and consumption of edible oils.

Sugar beet-sunflower intercropping obtained the highest values for LER, total and return incomes(El-Dessougi *et al*., 2003).

Plant density is the most critical agronomic practice affected on sunflower yield and seed oil percentage. Seed yield positively correlated with plant density, Plant height, head diameter, 100-seed weight, and seed yield plant-1 decreased with increasing plant density (Hafiz *et al.*, 2014).Mohammed and Abd El-Zaher (2013) pointed out that intercropping pattern of 100% sugar beet + 67% sunflower of plant density gave the highest yield of root and sugar. On the other hand, the lowest seed yield of sunflower, while intercropping 100% sugar beet + 100% sunflower of plant density, gave the lowest yield of root and sugar and the highest seed yield of sunflower with the yield of monoculture sugar beet. Sheha *et al*.(2017)showed that root length and diameter, top and root weights plant^{-1} and top, root and sugar yields fad^{-1}, purity, total soluble solids (TSS%) and sucrose% of sugar beet were significantly increased by reducing sunflower plant density when intercropped with sugar beet from 50 to 33.3 and up to 25% of its pure stand. While plant height and seed yield fad^{-1} of sunflower were significantly increased by increasing sunflower plant density with sugar beet from 25, 33.3 and up to 50%, yield components showed the opposite trend.

Sunflower seed yield loss increased with increasing level of leaves defoliation. The pre-flowering stage was the most sensitive; at this stage, a 100% defoliation of leaves surfaces resulted in 92% yield loss, reducing the number of seeds per head and 1000-seed

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DOI: 10.21608/jpp.2021.84134.1041

weight. A 100% defoliation at the end of stem timidly behind the head gave a 50% yield loss. At physiological maturity, defoliation did not affect seed yield (Muro *et al.*, 2001).Abbaspour *et al.*(2001) indicated that plant height, harvest index, and seed yield of sunflower were decreased due to partial or complete leaf excision compared to the undefoliated plants (control).Erbas and Baydar (2007) demonstrated a close relationship between sunflower seed yield reduction and defoliation levels. At the higher defoliation level, seed yield was highly reduced. Complete and partial leaf removal treatments reduced oil percentage when compared with the undefoliated pants(check).Mohammed and Abd El-Zaher (2013) indicated that the intercropping pattern of sugar beet and sunflower and 75% defoliated leaves gave the highest sugar beetroot and sugar percentage yield and the lowest seed yield sunflower. Intercropping sugar beet and sunflower without defoliated leaves gave the lowest yield of sugar beetroot, sugar percentage, and sunflower's highest seed yield. The highest value of Land Equivalent Ratio (LER) and Area Time Equivalent ratio (ATER) of 1.51 and 1.17 were recorded with 100% sugar beet + 80% sunflower of plant density and 50% defoliating of sunflower leaves over the two seasons. This treatment also gave the highest income (L.E 8729 fed^{-1}) as the average of both seasons. Sheha *et al.*(2017) showed that the highest value of land equivalent ratio LER (1.50), land equivalent coefficient LEC (0.53), area time equivalent ratio ATER (1.15) were obtained with intercropping planting pattern (100% sugar beet +50% sunflower). The best relative crowding coefficient (RCC)was obtained with (100% sugar beet + 25% sunflower). Also, the highest monetary advantage index MAI (4750 L.E) and gross profit (14252 L.E) were shown with a 100% sugar beet + 50% sunflower intercropping pattern.

This study aims to determine the effect of plant density and leaves defoliation of sunflower intercropped with sugar beet to reduce the gap between local production and consumption of edible oil, increase land usage ratio, and farmers' total income under the environmental conditions of Kafr El-Sheikh Governorate, Egypt.

MATERIALS AND METHODS

At Sakha Agricultural Research Station Farm, Agricultural Research Center, Egypt, two field experiments were conducted during the two winter growing seasons of 2018/2019 and 2019/2020to study the effect of plant density and defoliation of sunflower leaves (Sakha 53 *cv.*) intercropped with sugar beet (Platos *cv.*) on the productivity and quality of both crops as well as competitive relationships and economic evaluation.

A split-plot design with four replications was accomplished for the field experiment. The main- plots were allocated to three plant densities of sunflower on raised bed 120 cm width and 30, 40 and 80 cm between hills, leaving one plant/hill intercropped with sugar beet (12.5, 25 and 37.5%) of the recommended plant density of sunflower grown on top of the raised bed.

The sub-plots were deal out to three ratios of sunflower defoliation i.e : defoliation of 25.0, 37.5 and 50.0 % of the total number of sunflower leaves/plant at the age of 60 days sowing.

Each basic experimental unit (sub-plot) included three raised beds, each of 1.2 m width and 4.0 m length, resulting in14.4 m^2. The preceding summer crop was rice (*Oryza sativa* L.) in both seasons.

During soil preparation of both growing seasons, the soil samples from the experimental sites were randomly taken from(0 - 30 cm) of the soil surface. Then particle size distribution and chemical analyses were passed by the method described by Page *et al.* (1982), and the results are shown in Table 1.

Table 1. Theexperimental sites' particle size distribution and chemical soil properties during the 2018/2019 and 2019/2020 growing seasons.

Properties		2018/2019 season	2019/2020 season
A: particle size distribution :			
Sand %		9.85	9.76
Silt %		30.15	29.98
Clay %		60.00	60.26
Texture		Clayey	Clayey
B: Chemical analysis:			
PH		7.75	7.81
EC ds/m		2.95	2.65
Organic matter (g kg^{-1})		10.7	10.9
Total N %		0.14	0.13
Total carbonate %		61.40	61.38
CEC meq/100 g soil		61.44	61.42
SP %		78.45	78.38
SAR		4.51	4.68
Available mg/kg	N	28.00	25.40
	P	8.75	8.45
	K	255.70	365.00
Soluble cations meq/L	Ca^{++}	6.46	6.25
	Mg^{++}	6.36	5.41
	Na^{+}	10.03	9.95
	K^{+}	0.41	0.45
Soluble anions meq/L	CO_3^{--}	0.00	0.00
	HCO_3^{-}	4.50	4.16
	Cl^{-}	9.56	8.50
	SO_4^{--}	11.09	10.87

The experimental field was well prepared through three ploughings, compaction, division and then divided into the experimental units with dimensions as previously mentioned. Monocalcium superphosphate fertilizer (15.5 % P_2O_5) was applied in one dose for all plots during soil preparation at the rate of 200 kg/fed. Sugar beet was intercropped with sunflower by sowing 3-5 balls/hill (seed rate was 4 kg/fed) on both sides of the raised bed, 120cm width, and 20cmbetween hills on October 24th and 20thin the first and second seasons, respectively and thinned after 30 days from sowing to one plant/hill to give 31500 plants/fed. However, the sunflower was intercropped with sugar beet by sowing the sunflower described above plant densities on the top of the sugar beet raised bed at the same sowing date of sugar beet in both seasons. The soloed cultivation of both sugar beet and sunflower was done by the Ministry of Agriculture recommendations for each crop.

Nitrogen fertilizer in the form of ammonium nitrate (33.5%) at 80 kg N/fed was added in two equal doses, just before the first and second irrigations. Potassium sulphate (48 % K_2O) at the 50 kg/fed rate was applied for experimental plots just before the second irrigation. The other agricultural practices for sunflower and sugar beet were done as normal practices according to the recommendations.

Harvesting was completed for sugar beet on May6thand 2ndin the first and second seasons. While, harvesting dates ofsunflower were on March28thand 24thin the first and second seasons, respectively.

Data recorded:

1. Sugar beet traits:

At harvesting date, five guarded plants from the two outer raised beds were chosen at random, from the pure stand and intercropped sub-plots of sugar beet to determine yield components and quality characters,*i.e.* root length (cm), root diameter (cm), root and foliage fresh weights (kg/plant), total soluble solids (TSS%) in the juice of the fresh roots by using Hand Refractometer, sucrose % was determined polarimetrically on lead acetate extract of fresh macerated roots according to the method of Carruthers and Oldfield (1960), and purity % was determined as a ratio between sucrose% and TSS% of fresh roots. Plants that were produced from the inner bridges of each sub-plot were collected and cleaned. Roots and tops were separated and weighted in kilograms, then converted to estimate; root and top yields ton/fed. Sugar yield ton/fed. was calculated by multiplying root yield by sucrose percentage.

2. Sunflower traits:

The number of days from the sowing date to the beginning of 50 % and full flowering were counted. At the end of the complete flowering stage, each sub-plot two outer raised beds were bagged with paper bags to avoid bird's damage. At harvest time, five guarded plants were randomly taken from each sub-plot's two outer raised beds and were separately harvested, bagged, cleaned from straw and other residues. Then, the following traits were recorded; plant height (cm), stem diameter (cm),head diameter (cm), 100-seed weight (g), seed yield/ plant (g), seed yield/fed. (kg).Seed oil % was determined using the Soxhlet apparatus according to A.O.A.C (2007). Oil yield fed.(kg) was calculated by multiplying seed yield/fed by oil percentage.

3. Competitive relationships:

a- Land equivalent ratio (LER)was determined according to the following formula described by Willey and Rao (1980):

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Yaa and Ybb were a pure stand of the crop, a (sugar beet) and b(sunflower), respectively. Yab is the mixture yield of a crop, and Yba is the mixture yield b crop.

- Aggressivity (Ag)was calculated according to Mc-Gilchrist (1965) as the following formula:

- For crop (a),

$$A_{ab} = \frac{Y_{ab}}{Y_{aa}\ x\ Z_{ab}} - \frac{Y_{ba}}{Y_{bb}\ x\ Z_{ba}}$$

- and for the crop (b),

$$A_{ba} = \frac{Y_{ba}}{Y_{bb}\ x\ Z_{ba}} - \frac{Y_{ab}}{Y_{aa}\ x\ Z_{ab}}$$

Where:

Aab = aggressively value for the component a (sugar beet).
Aba = Aggressively value for the component b(sunflower).
Yab is the intercrop yield of sugar beet, Zab is the percentage of the area occupied by sunflowers.

b- Relative crowding coefficient (RCC) or K was calculated according to De-Wit (1960) as follows:

K = Kab × Kba

$$Kab = \frac{Yab\ x\ Zba}{(Yaa - Yab)Zab} \qquad Kba = \frac{Yba\ x\ Zab}{(Ybb - Yba)Zba}$$

Where: a is sugar beet, and b is the sunflower, respectively. Zab is the percentage of the area occupied by sugar beet, and Zba is the area occupied by sunflowers.

c- Area time equivalent ratio (ATER): the ratio between hectare – days required in monoculture to the number of hectare days used in the intercrop to produce identical quantities of each component, was calculated to Hiebsch and Mc-Collum (1987) as follows:-

ATER = (Rya x ta) + (Ryb x tb))/T

or **ATER =** $\frac{yab}{yaa}$ **x ta +** $\frac{yba}{ybb}$ **x tb /T.**

Where, Ry – relative yield of crop a (sugar beet) or crop b (sunflower),*i.e.*,the yield of intercrop/yield of the main crop, t = duration (days) for species a or b and T= duration (days) of the intercropping system.

d- Monetary advantages index (MAI) fed^{-1}: suggests that the economic assessment should be in terms of the soil saved value. The basis of the rentable value of soil MAI calculated according to the formula suggested by Willey (1979).

$$MAI = \frac{Valued\ combined\ intercropped\ X\ (LER-1)}{LER}$$

4. Economic evaluations:

Gross return from each treatment was calculated in Egyptian pounds (L.E.) according to the Ministry of Agriculture and Lands Reclamation, Economic Affairs Sector, Agricultural Statistics. Where market prices of sugar beet were594 and 640 L.E./ton, sunflower seed was 7,and 8L.E./kg and sunflower oil was 24 and 28 LE/kg oil in 2018/2019 and 2019/2020 seasons, respectively.

Net return = Total income – Total costs

Fed.(L.E.) = Gross return – Total costs

The obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) as published by Gomez and Gomez (1984) using the "MSTAT-C" software package. In addition, treatment means were compared by Duncan's Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSIONS

I. Sugar beet:

Data presented in Tables 2 and 3 revealed that all characters of sugar beet,*i.e.* root length, root diameter, root weight, fresh foliage weight, TSS%, sucrose%, purity%, root yield t/fed., top yield t/fed. and sugar yield t/fed. were significantly affected by intercropping sunflower plant density with sugar beet, except purity% in both seasons. Data revealed that increasing sunflower plant density (from 12.5, 37.5%) decreased growth traits of sugar beet,*i.e.* root length, root diameter, fresh root wt. and fresh foliage wt. in both seasons. The highest values of sugar beet growth characters were obtained when sunflower intercropped with sugar beet by 12.5% of its pure stand followed by 25%. Sunflower intercropped with 37.5% treatment gave the lowest values of these characters in both seasons. These results are mainly due to competition between sugar beet and sunflower plants to nutrients, water and light. These results are similar to those obtained by Mohammed and Abd El-Zaher (2013) and Sheha *et al.*(2017).

TSS% and sucrose% were significantly affected by intercropping with sugar beet and sunflower plant density, whereas purity% was not significantly affected in both seasons, as shown in Table 3.Increasing sunflower plant density from 12.5 to 25 up to 37.5 % of its pure stand decreased TSS% and sucrose% in both seasons. Root quality of sugar beet pure stand recorded the highest values compared with the intercropping treatments in both seasons. These results were the negative correlation between the concentration of these characters and sunflower plant density in intercropping treatments. These results may be due to interspecific competition between sugar beet and sunflower plants. Similar results were obtained by EL-Karamity *et al.*(2016), who found that the chemical character of sugar beet was decreased by increasing wheat plant density from 12.5 to 25.0 t0 37.5 up to 50% of its pure stand.

Table 2. Root length and diameter, root and foliage fresh weights/plant of sugar beet intercropped with sunflower as affected by plant density and defoliation of sunflower and their interaction during 2018/2019 and 2019/2020 seasons.

Character / Treatment		Root length (cm)		Root diameter (cm)		Root fresh weight plant (kg)		Foliage fresh weight plant (kg)	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
(Plant density):									
Sugar beet	Sunflower								
100% +	12.5 %	26.34a	26.41a	9.60a	9.78a	0.775a	0.780a	0.261a	0.266a
100% +	25.0 %	24.64b	24.66ab	8.94ab	9.25a	0.713b	0.719b	0.240b	0.245b
100% +	37.5 %	22.33c	22.10b	8.35b	8.74a	0.673c	0.678c	0.226b	0.231b
P-value		0.00**	0.00**	0.02*	0.03*	0.00**	0.00**	0.00**	0.00**
Ratios of sunflower defoliation:									
25.0 %		22.71c	22.83c	8.35c	8.72a	0.683c	0.688c	0.230c	0.235c
37.5 %		24.44b	24.32b	8.95b	9.26a	0.721b	0.726b	0.242b	0.247b
50.0 %		26.16a	26.02a	9.58a	9.80a	0.758a	0.763a	0.255a	0.260a
P-value		0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
Interaction:									
12.5 % from recommended plant density	25.0 % defoliation	25.26a	25.16a	9.03a	9.33a	0.739bc	0.745c	0.249bc	0.254cd
	37.5 % defoliation	26.43a	26.23a	9.53a	9.53a	0.776ab	0.781b	0.261ab	0.266b
	50.0 % defoliation	27.33a	27.83a	10.23a	10.50a	0.810a	0.815a	0.273a	0.276a
25.0 % from recommended plant density	25.0 % defoliation	22.60a	22.90a	8.40a	8.66a	0.675de	0.680e	0.228de	0.232f
	37.5 % defoliation	24.36a	24.73a	9.00a	9.40a	0.714cd	0.720d	0.241cd	0.246de
	50.0 % defoliation	26.96a	26.36a	9.43a	9.70a	0.751bc	0.756c	0.253dc	0.258bc
37.5 % from recommended plant density	25.0 % defoliation	20.26a	20.43a	7.63a	8.16a	0.635e	0.640f	0.214e	0.219g
	37.5 % defoliation	22.53a	22.00a	8.33a	8.86a	0.672de	0.677e	0.225de	0.230f
	50.0 % defoliation	24.20a	23.86a	9.10a	9.20a	0.713cd	0.718d	0.240cd	0.245e
P-value		0.31 NS	0.25 NS	0.69 NS	0.32 NS	0.00**	0.00**	0.00**	0.00**
Solo sugar beet		27.40	27.90	10.50	10.80	0.817	0.821	0.282	0.288

***, ** and NS indicate p< 0.05, p< 0.01 and not significant, respectively. Means of each column designated by the same letter are not significantly different at 5% level using Duncan's multiple range test.**

Table 3. Total soluble solids (TSS), sucrose and apparent purity percentages, root, top and sugar yields t/fed of sugar beet intercropped with sunflower as affected by plant density and defoliation of sunflower as well as their interaction during 2018/2019 and 2019/2020 seasons.

Character / Treatment			TSS (%)		Sucrose (%)		Purity (%)		Root yiel fed.(t)		Top yield fed.(t)		Sugar yield fed.(t)	
			2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020
(Plant density):														
Sugar beet		Sunflower												
100%	+	12.5 %	24.20a	23.80a	19.42a	18.80a	80.26a	79.93a	23.250a	23.380a	7.830a	7.967a	4.519a	4.457a
100%	+	25.0 %	23.06b	22.66b	18.46ab	18.06ab	80.05a	79.70a	21.403b	21.567b	7.253b	7.360b	3.957b	3.901b
100%	+	37.5 %	21.88c	21.51c	17.52b	17.12b	79.99a	79.62a	20.203c	20.353c	6.787b	6.933b	3.546c	3.491c
P-value			0.00**	0.00**	0.00**	0.00**	0.10 NS	0.13NS	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
Ratios of sunflower defoliation:														
25.0 %			22.40b	22.00b	17.91b	17.51b	79.98a	79.61a	20.493c	20.653c	6.903c	7.050c	3.681c	3.627c
37.5 %			23.08a	22.68a	18.46ab	17.84ab	79.99a	79.64a	21.623b	21.783b	7.313b	7.420b	4.005b	3.947b
50.0 %			23.66a	23.28a	19.03a	18.63a	80.34a	80.00a	22.740a	22.863a	7.653a	7.790a	4.336a	4.274a
P-value			0.00**	0.00**	0.00**	0.00**	0.22 NS	0.35 NS	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
Interaction:														
12.5 % from recommended plant density		25.0 % defoliation	23.46a	23.06a	18.76a	18.36a	79.94a	79.60a	22.180c	22.350c	7.470bc	7.620cd	4.162cd	4.104cd
		37.5 % defoliation	24.46a	24.06a	19.57a	18.50a	80.00a	79.67a	23.270b	23.430b	7.840ad	7.990b	4.555b	4.492b
		50.0 % defoliation	24.66a	24.26a	19.92a	19.52a	80.83a	80.52a	24.300a	24.360a	8.180a	8.290a	4.840a	4.774a
25.0 % from recommended plant density		25.0 % defoliation	22.46a	22.06a	17.96a	17.56a	79.98a	79.61a	20.250e	20.410e	6.830de	6.970f	3.639e	3.586ef
		37.5 % defoliation	23.13a	22.73a	18.50a	18.10a	79.97a	79.62a	21.430d	21.600d	7.350c	7.370de	3.964d	3.909d
		50.0 % defoliation	23.60a	23.20a	18.93a	18.53a	80.22a	79.87a	22.530c	22.690c	7.580dc	7.740bc	4.268c	4.207c
37.5 % from recommended plant density		25.0 % defoliation	21.26a	20.86a	17.02a	16.62a	80.01a	79.63a	19.050f	19.200f	6.410e	6.560g	3.243f	3.191g
		37.5 % defoliation	21.66a	21.26a	17.33a	16.93a	80.00a	79.63a	20.170e	20.320e	6.750de	6.900f	3.495ef	3.440fg
		50.0 % defoliation	22.73a	22.40a	18.23a	17.83a	79.96a	79.62a	21.390d	21.540d	7.200cd	7.340e	3.900d	3.842de
P-value			0.19 NS	0.25 NS	0.33 NS	0.45 NS	0.28 NS	0.36 NS	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
Solo sugar beet			25.10	24.64	20.14	19.73	80.51	80.60	24.410	24.500	8.190	8.300	4.850	4.785

***, ** and NS indicate p< 0.05, p< 0.01 and not significant, respectively. Means of each column designated by the same letter are not significantly different at 5% level using Duncan's multiple range test.**

Concerning sugar beet yield/fed. *i.e.*root, top and sugar, data revealed that root and top yields t/fed. were related to the previous growth characters of sugar beet in both seasons. Intercropping treatments of sunflower with sugar beet reduced these characters compared with sugar beet pure stand in both seasons. The decrease was more evident when the sunflower was intercropped at 25.0 and37.5% of its pure stand. Sugar beetroot and top yields t/fed. were 88.66 and 83.69% of its pure stand when sunflower was intercropped with sugar beet by 25 and 37.5% of its pure stand, in the first seasons, respectively and were 88.02 and 83.07% in the second season respectively in the second season. Similar results were obtained by Mohammed and Abd El-Zaher (2013) and Sheha *et al.*(2017).

Sugar yield t/fed. was decreased by increasing sunflower plant density from 12.5 up to 37.5% in both seasons. These decreases were 6.82, 18.41 and 26.88% when intercropping sunflower by12.5, 25.0 and 37.5% with sugar beet in the first season, respectively, and were 6.85, 18.49 and 27.04 in the second season, respectively. Also, sugar yield t/fed. under intercropping treatments was decreased compared with sugar yield in pure stand. This result has coincided with those obtained by Sheha *et al.*(2017).

II. Sunflower:

Data presented in Table 4 revealed that all studied sunflower characters were significantly affected by sunflower plant density in both seasons, except days to the beginning of flowering, days to 50% flowering and days to full flowering.

Days to the beginning, 50% and full flowering were not significantly affected by different plant densities of sunflower,*i.e.* 12.5, 25 and 37.5% of its pure stand in both seasons as shown in Table 4. This result may be attributed to thecompetition between sunflower with high density and sugar beet plants. These results agree with those obtained by Mohammed and Abd El-Zaher (2013), Hafiz *et al.*(2014). and Sheha *et al.*(2017).

Increasing the plant density of sunflower from 12.5 to 25 up to 37.5% of its pure stand increased the plant height of sunflower gradually in both seasons, as shown in Table 4. Plants tended to elongate with increasing plant density. These results may be due to increase competition between sunflower plants and sugar beet plants for light. Similar results were obtained

by Abbaspour *et al.*(2001), Muro *et al*.(2001) and Erbas and Baydar (2007).

Table 5 indicated that sunflower plants were sown by 12.5% plant density of its pure stand gave the highest value followed by 25%,simultaneously the lowest value was due to 37.5%. This was completely true for each stem diameter, head diameter. 100-seed wt. and seed yield/plant in both seasons. This result is mainly due to the effect of sunflower intercropping with sugar beetat high population densities on these traits, indicating the effect of intra-specific competition among sunflower plants. Similar results have coincided with those obtained by Hafiz *et al.*(2014).

Seed oil percentage of sunflower were significantly affected by different plant density in both seasons Table (5). Increasing sunflower plant density from 12.5 up to 37.5% of its pure stand reduced oil percentage in sunflower seeds. These reductions were very light and difficult to reach 5% level.

Seed yield kg/fed. of sunflower behaved opposite yield components,*i.e.*stem diameter, head diameter, seed yield/plant and oil yield kg/fed. in both seasons as shown in Tables(4 and 5). These results increased sunflower plant densities from 12.5 to 25.0 and 37.5% of its pure stand. These results are in accordance with those obtained by Abbaspour *et al.*(2001), Muro *et al.*(2001), Erbas and Baydar (2007) and Mohammed and Abd El-Zaher (2013).

III. Competitive relationships:

(a) Equivalent Land ratio:

Table 6 showed that all treatments of the interaction between plant density and defoliation of sunflower intercropped with sugar beet raised land productivity compared with planting sugar beet or sunflower in pure stand in both seasons shown in Table (6). In both seasons, the best treatment included (100% sugar beet + 37.5% sunflower) and 50% defoliation of sunflower leaves; this treatment increases land usage by 34%. Simultaneously, the lowest treatment was sunflower intercropped by 12.5% of its pure stand and 25% defoliated of its leaves. This treatment increased land productivity by 9% in the first and 12% in the second season. Thus, it is evident that sugar beet was the better contributor in LER in all treatments in both seasons. Similar results were obtainedby Mohammed and Abd El-Zaher (2013) and Sheha *et al.*(2017).

Table 4. Number of days to the beginning, 50 % and full flowering, plant height and stem diameter of sunflower intercropped with sugar beet as affected by plant density and defoliation of sunflower and their interaction during 2018/2019 and 2019/2020 seasons.

Character		Days to beginning flowering %		Days to 50 % flowering		Days to full flowering		Plant height (cm)		Stem diameter (cm)	
Treatment		2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020
(Plant density):											
Sugar beet	Sunflower										
100% +	12.5 %	61.5 a	61.3a	67.7a	68.3a	74.4a	75.2a	158.3c	156.6a	2.850a	2.91a
100% +	25.0 %	61.1 a	61.1a	67.5ab	68.1a	74.1a	74.8a	162.7b	161.1ab	2.644b	2.64b
100% +	37.5 %	59.8b	60.7a	67.1b	67.7a	73.7a	74.8a	167.2a	166.1b	2.533c	2.47c
P-value		0.15 NS	0.21 NS	0.55 NS	0.42 NS	0.12 NS	0.24 NS	0.03*	0.01*	0.04*	0.023*
Ratios of sunflower defoliation:											
25.0 %		61.1a	61.4a	68.2a	68.5a	74.6a	75.3a	163.8a	162.7a	2.71a	2.69a
37.5 %		60.8a	61.0a	67.2b	68.1ab	73.8a	75.1a	163.3a	161.6a	2.67ab	2.66a
50.0 %		60.5a	60.7a	67.0b	67.5b	73.7a	74.5a	161.1a	159.4a	2.63b	2.67a
P-value		0.32 NS	0.25 NS	0.18 NS	0.28 NS	0.32 NS	0.19 NS	0.36 NS	0.61 NS	0.12 NS	0.18NS
Interaction:											
12.5 % from recommended plant density	25.0 % defoliation	62.0a	62.0a	68.6a	69.0a	75.0a	75.6a	161.6a	158.3a	2.91a	3.01a
	37.5 % defoliation	61.3a	61.6a	67.6a	68.3a	74.3a	75.0a	158.3a	156.6a	2.88a	2.95a
	50.0 % defoliation	61.3a	60.3a	67.0a	67.0a	74.0a	74.0a	155.0a	155.0a	2.75b	2.76b
25.0 % from recommended plant density	25.0 % defoliation	61.6a	61.3a	68.6a	68.0a	75.0a	75.3a	163.3a	160.0a	2.70bc	2.73bc
	37.5 % defoliation	61.0a	60.6a	67.3a	68.0a	74.3a	74.6a	163.3a	158.3a	2.65bcd	2.66bcd
	50.0 % defoliation	60.6a	60.3a	66.6a	67.3a	73.0a	74.6a	161.6a	165.0a	2.58cde	2.53de
37.5 % from recommended plant density	25.0 % defoliation	60.3a	61.6a	67.3a	68.6a	74.3a	75.6a	171.6a	168.3a	2.56de	2.55cde
	37.5 % defoliation	59.6a	61.0a	67.3a	68.6a	74.0a	75.6a	165.0a	166.6a	2.51e	2.48de
	50.0 % defoliation	59.6a	60.6a	66.6a	67.6a	73.0a	74.3a	165.0a	163.3a	2.51e	2.40e
P-value		0.11 NS	0.42 NS	0.35 NS	0.23 NS	0.45 NS	0.22 NS	0. 71 NS	0.51 NS	0.00**	0.00**
Solo sunflower		60.0	60.0	67.0	67.0	73.0	74.0	175.0	175.0	2.40	2.45

***, ** and NS indicate p< 0.05, p< 0.01 and not significant, respectively. Means of each column designated by the same letter are not significantly different at 5% level using Duncan's multiple range test**

Table 5. Head diameter, 100-seed weight, seed yield per plant and feddan, seed oil percentage and oil yield kg/fed of sunflower intercropped with sugar beet as affected by plant density and defoliation sunflower as well as their interaction during 2018/2019 and 2019/2020 seasons.

Character	Head diameter (cm)		100-seed weight (g)		Seed yield plant (g)		Seed yield fed.(kg)		Oil (%)		Oil yield fed.(kg)	
Treatment	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020
(Plant density):												
Sugar beet Sunflower												
100% + 12.5 %	24.55a	25.11a	6.81a	6.94a	60.44a	62.00a	250.1c	279.2c	39.70a	39.50a	95.3c	109.4c
100% + 25.0 %	23.11b	23.44b	6.46b	6.57b	54.88b	57.55b	498.6b	504.9b	38.96b	39.36ab	194.3b	198.7b
100% + 37.5 %	21.44c	22.00c	6.32c	6.43c	51.77c	54.00c	671.6a	660.2a	38.13c	39.22b	288.7a	258.8a
P-value	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
Ratios of sunflower defoliation:												
25.0 %	23.11a	24.22a	6.60a	6.71a	56.33a	58.33a	477.5a	484.7a	39.02a	39.41a	204.30a	196.34a
37.5 %	23.00a	23.22a	6.53ab	6.66ab	55.77a	58.11a	473.1a	483.2a	38.91a	39.38a	195.90b	190.11b
50.0 %	23.00a	23.11a	6.46b	6.57b	55.00a	57.11b	469.8a	476.4a	38.86a	39.28a	178.25b	180.62c
P-value	0.32NS	0.45NS	0.00**	0.00**	0.00**	0.00**	0.11NS	0.16NS	0.35NS	0.46NS	0.00**	0.00**
Interaction:												
12.5 % from recommended plant density — 25.0 % defoliation	25.00a	26.00a	6.93a	7.08a	61.00a	63.66a	251.6a	288.5a	39.80a	39.36abc	100.8a	112.4a
12.5 % from recommended plant density — 37.5 % defoliation	24.66a	25.66ab	6.83a	6.95a	60.33a	62.00b	250.0a	277.3a	39.76a	39.23abc	95.8a	114.4a
12.5 % from recommended plant density — 50.0 % defoliation	24.00ab	23.66c	6.68a	6.80a	60.00a	60.33c	248.8a	271.8a	39.53a	39.06c	89.7a	101.6a
25.0 % from recommended plant density — 25.0 % defoliation	23.33abc	24.33bc	6.51a	6.65a	56.00b	59.00c	500.5a	512.1a	39.03b	39.66ab	201.4a	209.0a
25.0 % from recommended plant density — 37.5 % defoliation	23.00abcd	23.33c	6.45a	6.56a	55.33bc	57.00d	500.5a	507.5a	39.00b	39.30abc	195.2a	199.5a
25.0 % from recommended plant density — 50.0 % defoliation	23.00abcd	22.66c	6.41a	6.51a	53.33cd	56.66d	495.0a	495.1a	38.86b	39.13bc	186.4a	187.8a
37.5 % from recommended plant density — 25.0 % defoliation	22.00bcd	22.66c	6.36a	6.46a	52.00d	54.33e	682.0a	670.2a	38.43c	39.73a	310.8a	267.7a
37.5 % from recommended plant density — 37.5 % defoliation	21.33cd	22.66c	6.31a	6.41a	52.00d	54.00e	667.3a	656.7a	38.06cd	39.63abc	296.7a	256.5a
37.5 % from recommended plant density — 50.0 % defoliation	21.00d	20.66d	6.28a	6.41a	51.33d	53.66e	665.6a	653.7a	37.90d	39.13bc	258.7a	252.5a
P-value	0.00**	0.00**	0.71 NS	0.8 NS	0.00**	0.00**	0.62 NS	0.43 NS	0.00**	0.00**	0.23 NS	0.38 NS
Solo sunflower	19.00	20.00	6.50	6.52	47.00	48.00	1455.0	1440.0	39.00	39.30	630.6	598.7

***, ** and NS indicate p< 0.05, p< 0.01 and not significant, respectively. Means of each column designated by the same letter are not significantly different at 5% level using Duncan's multiple range test.**

(b) Aggressivity (A):

Data presented in Table 6 revealed that sugar beet dominated crop in 3 treatments due to the interaction between plant density and defoliation leaves of sunflower and sunflower was dominated crop in 6 treatments out of 9 in both seasons. It is evident that a sunflower crop had higher competitive abilities compared with sugar beet, However, sugar beet was planted by 100% of its pure stand and sunflower was intercropped with sugar beet from12.5 up to 37.5% of its pure stand and defoliated its leaves by 25.0, 37.5 and 50.0%. Similar results were obtained by Mohammed and Abd El-Zaher (2013) and Sheha *et al.*(2017).

(c): Relative crowding coefficient (RCC):

Table 6 showed that the interaction between factors under study achieved yield advantageous in all treatments in both seasons. The highest yield advantage was recorded by the interaction between intercropping system (100.0% sugar beet of its pure stand, 25% plant density and 50.0% defoliation leaves of sunflower (6.91 and 7.72) the first and second seasons, respectively. On the other hand, the lowest yield advantage was showed with treatment (100% + 12.5%) and defoliated 25.0% of sunflower leaves (2.28 and 2.95) in the first and second seasons, respectively. Similar results were obtained by Mohammed and Abd El-Zaher (2013) and Sheha *et al.*(2017).

IV: Economic evaluation:

Data presented in Table 7 revealed that all treatments of the interaction between intercropping pattern and defoliation ratio of sunflower leaves intercropped with sugar beet were exceeded total income and net return compared sugar be*et al*one in both seasons. The highest values of total income and net return were achieved at the intercropping,including (100% sugar beet +37.5% sunflower) and 50% defoliation of sunflower leaves in both seasons. On the other hand, the lowest values for these characters were obtained with (100% sugar beet + 12.5 % sunflower) and 25.0 % defoliation of sunflower leaves in both seasons. The total income and net return (2862.3 and 3335.3 L.E) for total income and (2295.3 and 2705.2 L.E) for net income compared with sugar be*et al*one in the first and second seasons, respectively. Table (7) revealed that index of monetary advantage was positive in all treatments concerning the monetary advantage

index. 100% sugar beet + 37.5% sunflower with 50% defoliation gave the highest values (4351, 4752 L.E) for monetary advantage index in both growing seasons. Similar trends were obtained by Stoyanov *et al.*(1997).

Table 6. Equivalent Land ratio (LER), aggressivity (Ag) and relative crowding coefficient (RCC) of intercropping sunflower with sugar beet as affected by the interaction between the intercropping system and defoliation leaves of sunflower during 2018/2019 and 2019/2020 seasons.

Character Treatment		Land equivalent ratio (LER)			ATER	Aggressivity (Ag)		Relative crowding Coefficient (RCC)			Land equivalent ratio (LER)			ATER	Aggressivity (Ag)		Relative crowding Coefficient (RCC)		
		L.s.b	Ls	LER		Ags.b	Ag.s	Ks.b	K.s	K	L.s.b	Ls	LER		Ags.b	Ag.s	Ks.b	K.s	K
Density of Sunflower	Defoliation %	2018/2019 season									2019/2020 season								
12.5%	25.0%	0.92	0.17	1.09	1.05	-0.47	+0.47	1.37	1.67	2.28	0.92	0.20	1.12	1.07	-0.68	+0.68	1.49	2.00	2.95
	37.5%	0.96	0.17	1.13	1.09	+0.27	-0.27	6.19	0.83	5.14	0.97	0.19	1.16	1.11	+0.20	-0.20	7.32	0.95	6.98
	50.0%	1.00	0.17	1.16	1.13	+0.55	-0.55	9.60	0.55	5.28	0.99	0.19	1.18	1.15	+0.50	-0.50	8.12	0.62	5.04
25.0%	25.0%	0.84	0.34	1.18	1.10	-1.92	+1.92	0.64	4.19	2.68	0.84	0.36	1.20	1.12	+0.13	-0.13	0.67	4.42	2.98
	37.5%	0.89	0.34	1.23	1.15	-0.49	+0.49	1.93	2.10	4.04	0.89	0.35	1.24	1.16	-1.93	+1.93	2.05	2.18	4.47
	50.0%	0.93	0.34	1.27	1.19	+0.02	-0.02	5.03	1.38	6.91	0.94	0.34	1.28	1.20	-0.44	+0.44	5.53	1.40	7.72
37.5%	25.0%	0.79	0.47	1.26	1.15	-0.34	+0.34	0.46	7.06	3.26	0.79	0.47	1.26	1.16	-0.45	+0.45	0.48	6.96	3.32
	37.5%	0.83	0.46	1.29	1.19	-1.00	+1.00	1.25	3.39	4.23	0.84	0.46	1.29	1.19	-0.07	+0.07	1.30	3.35	4.36
	50.0%	0.88	0.46	1.34	1.24	-2.96	+2.96	2.84	2.25	6.40	0.89	0.45	1.34	1.24	-2.74	+2.74	3.00	2.22	6.66

s.b = sugar beet, s = sunflower.

Table 7.Effect of the interaction between plant density and defoliation of sunflower on economic evaluation in 2018/2019 and 2019/2020 seasons.

Character		2018/2019						2019/2020					
Plant densities of sunflower	Ratios of sunflower defoliation	Actual sugar beet root yield/fed. (LE)	Actual sunflower seed yield/fed. (LE)	Total income (LE)	Total cost (LE)	Net return (LE)	MAI	Actual sugar beet root yield/fed. (LE)	Actual sunflower seed yield/fed. (LE)	Total income (LE)	Total cost (LE)	Net return (LE)	MAI
12.5 % from recommended plant density	25.0 %	13197.0	1761.2	14958.2	9189.0	5769.2	1128	14304.0	2308.0	16612.0	9510.0	7102.0	1681
	37.5 %	13845.7	1750.0	15595.7	9189.0	6406.7	1734	14995.2	2218.4	17213.6	9510.0	7703.0	2231
	50.0 %	14485.5	1741.6	16200.1	9189.0	7011.1	2312	15590.4	2174.4	17764.8	9510.0	8254.8	2749
25.0 % from recommended plant density	25.0 %	12048.8	3503.5	15552.3	9378.0	6174.3	2300	13062.4	4096.8	17159.2	9720.0	7439.2	2724
	37.5 %	12750.9	3503.5	16254.4	9378.0	6876.4	2952	13824.0	4060.0	17884.0	9720.0	8164.0	3392
	50.0 %	13405.4	3465.0	16870.4	9378.0	7492.4	3515	14521.6	3960.8	18482.4	9720.0	8762.4	3929
37.5 % from recommended plant density	25.0 %	11334.8	4774.0	16108.8	9567.0	6541.8	3213	12288.0	5361.6	17649.6	9930.0	7719.6	3520
	37.5 %	12001.2	4671.1	16672.3	9567.0	7105.3	3697	13004.8	5253.6	18258.4	9930.0	8328.4	4054
	50.0 %	12727.1	4659.2	17386.3	9567.0	7819.3	4351	13785.6	5229.6	19015.2	9930.0	9085.2	4752
Solo sugar beet		14524.0	—	14524.0	9000.0	5524.0		15680.0	—	15680.0	9300.0	6380.0	

CONCLUSION

it can be concluded that the maximum land equivalent ratio (LER), total income, and net return were obtained from intercropping sunflower with 37.5% plant density of its pure stand and defoliate 50.0 % of sunflower leaves after 60 days from sowing under the environmental conditions of Kafr El-Sheikh Governorate, Egypt.

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تأثير الكثافة النباتية وتوريق دوار الشمس المحمل على بنجر السكر على إنتاجية كلا المحصولين والعلاقات التنافسية

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في مزرعة محطة البحوث الزراعية بسخا ، مركز البحوث الزراعية ، مصر ، أجريت تجربتان حقليتان خلال موسمي 2019/2018 و 2020/2019 لدراسة تأثير الكثافة النباتية (12.5 ، 25.0 و 37.5٪ من كثافة النبات الموصى بها) ونسبة توريق دوار الشمس (25.0 ، 37.5 و 50.0٪ من العدد الإجمالي لأوراق نبات دوار الشمس)المحمل على بنجر السكر على إنتاجية كلا المحصولين والعلاقات التنافسيةوالتقييم الاقتصادي. تم تنفيذ التجربة في تصميم القطعة المنشقةمرة واحدة في أربع مكررات لكل تجربة حقلية. تم تخصيص القطع الرئيسية للكثافات النباتية لنبات دوار الشمس التى تم زراعتها على ظهر المصطبة . كما تم تخصيص القطع الشقية لنسب توريق دوار الشمس. تم زراعة نباتات بنجر السكر على مصاطب بعرض 120سم والزراعة فى جور على جانبى المصطبة. ولقد بينت النتائج المتحصل عليها أن النمو والمحصول ومكوناته وكذلك صفات الجودة لبنجر السكر قد تناقصت بزيادة الكثافة النباتية لدوار الشمس من 12.5 الى 25.0 وحتى 37.5% مقارنة بالبنجر المنفرد وذلك فى كلا الموسمين . كذلك إنتاجية محصول بنجر السكر المحمل من الجذور للفدان وصلت إلى 83.69 و 83.075% مقارنة بمحصول البنجر المنفرد من الجذور فى الموسم الأول والثانى على الترتيب . وفى نفس الوقت أدى توريق أوراق دوار الشمس من 25.0 إلى 37.5 وحتى 50.0% إلى زيادة صفات بنجر السكر المدروسة فى كلا الموسمين . ولقد وجد أن محصول بنجر السكر من الجذور والعرش و السكر للفدان قد تأثروا معنويا بالتفاعل بين عوامل الدراسة فى كلا الموسمين .ولقد وجد أن إرتفاع النبات ومحصول البذرة والزيت للفدان فى محصول دوار الشمس قد تزايدوا بزيادة الكثافة النباتية من 12.5 إلى 25.0 وحتى 37.5% فى كلا الموسمين , بينما أظهرت بقية الصفات عكس ذلك فى كلا الموسمين . ولم تتأثر كل الصفات المدروسة لمحصول دوار الشمس معنويا بزيادة التوريق من 25.0 وإلى 37.5 وحتى 50.0% من الأوراق , ما عدا صفات وزن الـ 100 بذرة ومحصول البذور للنبات فى كلا الموسمين، بينما تأثرت صفات قطر الساق وقطر القرص ومحصول البذور للفدان والنسبة المئوية للزيت معنويا بالتفاعل بين عوامل الدراسه فى كلا الموسمين . ومن النتائج المتحصل عليها فى هذه الدراسة يمكن استنتاج أنه عند تحميل بنجر السكر ودوار الشمس أن أقصى معامل لإستغلال الأرض (LER) وإجمالي الدخل وصافى العائد الاقتصادي لكل من بنجر السكر ودوار الشمس نتج من تحميلدوار الشمس على ظهر مصاطب بنجر السكر بعرض 120 سم و30 سم بين الجور (أى 37.5٪ من الكثافة النباتية الموصى بها) وتوريق 50.0٪ من العدد الإجمالي لأوراق دوار الشمس وذلك تحت الظروف البيئية لمحافظة كفر الشيخ ، مصر.