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Effect of Intercropping Faba Bean with Sugar Beet on Yield and Yield Components under Salt Affected Soils Conditions

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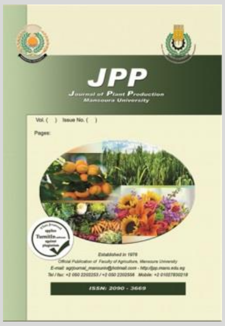

ABSTRACT

Field trial was conducted at El-Serw Research Station, A.R.C., Damietta Governorate, during 2017/2018 and 2018/2019 seasons to study the intercropping faba bean plant densities (33.3, 25.0 and 16.7%) with three sugar beet variety or genotype namely; Glorius (Z), Lilly (N) and Cleopatra (E). Split plot design with three replications was used. Results showed that the interaction between sugar beet varieties and faba bean plant densities significantly affected leaf area index (LAI), root diameter, root and sugar yields fed^{-1} and sucrose % in both seasons and other traits significantly affected in one season. Intercropping faba bean with Glorius variety had the highest yield and its attributes of faba bean comparison to those intercropping with other varieties in both seasons. Yield attributes of faba bean significantly increased by decreasing faba bean plant density from 33.33 to 16.7%, while the converse was hold true for plant height and seed yield fed^{-1} in both seasons. All studied traits of faba bean were not affected significantly by the interaction between sugar beet varieties and plant densities of faba bean in both seasons, except plant height in second season. The total land equivalent ratio (LER) and relative crowding coefficient (RCC) values were greater than one in all the studied treatments providing advantages of intercropping faba bean with sugar beet has advantages. Faba bean was dominant crop. Intercropping faba bean plants at 25% plant density with Glorius variety had the highest LER (1.29 and 1.33) and MAI (3449 and 4267) in both seasons.

Keywords: *Beta vulgaris* L., *Vicia faba* L., sugar beet varieties, faba bean plant densities, land equivalent ratio (LER), monetary advantage index (MAI).

INTRODUCTION

The efficiency and the advantage of an intercropping system are fundamentally dependent on the complementarities between the component crops. Since, variations in plant architecture of the component crops help a better utilization of the available resources (Liebman, 2002). Also, modification of planting density along with suitable genotype can be a viable tool for maximizing land usage and net return in intercropping systems (Dhima *et al.*, 2007).

Several studies indicated that sugar beet varieties significantly differed for root length, diameter, TSS%, sucrose%, sugar, top and root yields fed^{-1} (Afez 2016;Aly and Khalil, 2017; Gadallah, and Tawfik, 2017 and Behera and Arvadia, 2018). Differences among sugar beet varieties for leaf area index (LAI), root fresh weight plant^{-1}, foliage fresh weight plant^{-1}, root diameter and total dry weight plant^{-1} were also detected by Aly *et al.* (2017). Usmanikhail *et al.* (2013) reported significant differences among the three sugar beet varieties in leaf area, mean root weight and beet root yield, while they had nearly the same percentage of sucrose either in the sole crop or under intercropping systems. Masri and Safina (2015) found that sole planting of Carola had maximum beet root weight, beet root yield and sugar yield fed^{-1}in both seasons, followed by Farida when planted as a sole crop. Meanwhile, the highest gross revenue and net returns resulted from intercropping sugar beet varieties Carola and Glorius with onion, respectively.

Sugar beet (*Beta vulgaris* L.) is considered the first sugar crop in Egypt and the second in the world. Recently Egypt faces a great gab between consumption and production of both faba bean and sugar. So increasing faba bean and sugar production is necessary to meet demands of Egyptian population. One of the approaches to increase faba bean and sugar production is using intercropping system to raising unit area productivity. Sugar beet (C_3 crop) has a slow growth rate, especially at early growth stages. It needs long duration till the crop canopy developing and be able to receive not less than 75% of incident sun irradiance which encourage to intercropping some winter crops with sugar beet and diminish losses in solar energy, increased food production per unit area and farmers benefit. Intercropping faba bean (*Vicia faba* L.) with sugar beet has particular importance to replenish faba bean gap (Zohry and Ouda, 2015), enriching soil fertility by fixing biological N (Manna *et al.*, 2003), increased LER and net income with insignificant reduction in sugar beet yield (Salama *et al.*, 2016, Abd El Lateef*et al.*, 2019 and Zohry, and Ouda. 2019).

Inappropriate planting density of the intercropping crops developing site resources competition is the principal reason for the low productivity (Hauggaard-Nielsen *et al.*, 2006). Abd El-All (2002) found that the highest values of LER were obtained when 16 plants m^{-2} of faba bean were intercropped with sugar beet, but the highest yield of sugar beet was obtained from intercropping 5 plantsm^{-2} of faba bean. The intercropping pattern includes 100% sugar beet plus 12.5% faba bean recorded the highest sugar beet root yield, while the highest LER and net income recorded with 100% sugar beet + 33% faba bean (Mohammed *et al.* 2005). El-Shamy *et al* (2016) found that the faba bean plant density (17,500 plant fed^{-1}) gave the greatest values of number of branches plant^{-1}, number of pods plant^{-1}, number of seedsplant^{-1}, weight of 100 seeds, straw yield fed^{-1}, seeds yield fed^{-1}, protein percent, root diameter (cm), fresh leaves weight plant^{-1}, fresh root weight plant^{-1}, dry leaves weight plant^{-1}, dry root weight plant^{-1} and root yield fed^{-1} in both seasons and

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number of leaves plant^{-1} in the first seasons only, while the dense population of faba bean plants (70,000 plant fed^{-1}) recorded the lowest values in all previous characters for both crops. Hamdany and El-Aassar (2017) reported that root diameter, root fresh weight, top fresh weight, root yield fed^{-1}, top yield fed^{-1}, TSS and sucrose% were significantly increased by reduced faba bean plant densities from 37.5% to 12.5%, except root length and purity % were decreased. On the other hand, plant height, straw and seed yield fed^{-1} of faba bean, LER, total return, net profit fed^{-1} and monetary advantage index (MAI) were increased with increasing faba bean plant population from 12.5 to 25 and 37.5% of its pure stand. The density reducing of faba bean plants intercropping with sugar beet, which leads to low density for both crops per unit area resulted in minimizing the intra and inter competition of both crops leads to high efficiency of solar radiation utilized by sugar beet, and in turn high conversion of light energy to chemical energy and consequently high accumulation of dry matter (Ibrahim, 2018).

The goal of this research to obtain the best faba bean plant density intercropping with suitable sugar beet variety or type (E, N, Z) to optimize yield and quality of sugar beet and seed yield of faba bean, maximizing land usage and net return under salt affected soils conditions at Damietta Governorate.

MATERIALS AND METHODS

Two field experiments were carried out at El-Serw Agricultural Experiments and Research Station, ARC, Damietta Governorate, Egypt, during 2017/2018 and 2018/2019 winter seasons. The preceding summer crop was rice during the two growing seasons. Soil samples at 0–30 cm depth were taken before planting and soil properties were determined according to Jackson (1973).

Table 1. Mechanical and chemical analyses at the experimental sites during both seasons.

Physical properties	First season	Second season	Chemical properties	First season	Second season
			pH	8.10	8.31
Sand (%)	22	20	EC (mmhos cm^{-1})	4.60	4.85
Silt (%)	33	35	OM (%)	0.98	0.92
Clay (%)	45	45	Available N (mg kg^{-1})	32.00	30.00
Texture class	Clay	Clay	Available P (mg kg^{-1})	8.23	8.45
			Exchangeable K (mg kg^{-1})	450.00	465.00
Soluble cations meq L^{-1}:			Soluble anions meq L^{-1}:		
Na^+	35.30	38.40	CO_3^-	-	-
K^+	0.53	0.55	HCO_3^-	2.34	3.22
Ca^{+++}	3.65	3.78	Cl^-	34.56	37.55
Mg^{++}	3.76	3.88	SO_4	6.34	5.84

The treatments were the combination between three sugar beet varieties and three plant densities of faba bean. Each variety represents type of sugar beet genotypes (Z, N and E). Split-plot design with three replications was used. Sugar beet varieties were randomly assigned to the main-plots and faba bean plant densities were allocated in sub-plots. The area of plot was 14.4 m^2, it consisted of 4 beds, and each bed was 3.0 m in length and 1.2 m width.

The experiment treatments were as follows:

I- Sugar beet genotypes

1. Glorius variety (Z) was developed by Strube Company, Germany.
2. Lilly variety (N) was developed by Maribo Seed Company, Denmark.
3. Cleopatra variety (E) was developed by Deprez Company, France.

II-Faba bean plant densities were:

D1: Faba bean intercropped with sugar beet bed at 15 cm apart between hills (33.3% of its pure stand).

D2: Faba bean intercropped with sugar beet bed at 20 cm apart between hills (25.0% of its pure stand).

D3: Faba bean intercropped with sugar beet bed at 30 cm apart between hills (16.7% of its pure stand).

Sowing date of sugar beet varieties was done on October 15th and 20th in first and second seasons, respectively. Meanwhile, faba bean Giza 716 cultivar was sown on November 13rd and 17th in first and second seasons, respectively. Sugar beet varieties were sown on hills spaced 20 cm on both sides of the bed 120 cm apart both of intercropping and sole culture to achieve full stand (35,000 plants fed^{-1}). Three weeks after sowing sugar beet weeds were controlled and sugar beet was thinned with leaving one plant hill^{-1}. Meanwhile, faba bean seeds were sown on the top of the bed in two lines at a spaced 15, 20 and 30 cm between hills and then thinned to one plant/hill, which achieved 33.3, 25.0 and 16.7% of its pure stand (in intercropping culture). In sole culture, faba bean was sowing in 2 lines on both sides (2 linesside^{-1}) of the bed had 20 cm between hills.

The soil of the experiments was prepared as recommended for sugar beet crop. The phosphorus fertilizer was basally applied in the form of calcium super phosphate (15.5 % P_2O_5) at the rate of 200 kg fed^{-1} during soil preparation. Nitrogen fertilizer was applied for sugar beet as ammonium nitrate at rate of 90 kg N fed^{-1}. Potassium fertilizer was added in the form of potassium sulphate (48% K_2O) at the rate of 48 kg fed^{-1} in two equal doses at the second and third irrigations. All the other recommended cultural practices for sugar beet and faba bean production were done.

Data recorded:

1: Sugar beet

A- Growth attributes:

Ten plants were taken at random and uprooted carefully from the middle ridge of each plot after 180 days from sowing date to estimate the following traits:

1- Number of leaves plant^{-1}

2- Leaf area index (LAI): It was estimated by the following formula

$$Leaf\ \ area\ index = \frac{leaves\ area\ \ per\ \ plant\ (cm^2)}{plant\ \ ground\ \ area\ (cm^2)}$$

B- Yield and Yield attributes:

At harvest time five plants were randomly taken from each sub-plot to estimate the following traits:

1- Root length (c 2- Root diameter (cm).
3- Root fresh weight plant^{-1} (g). 4- Top fresh weight plant^{-1} (g).
5- Root top ratio.
6- Sucrose %: It was estimated polarimetrically on a lead acetate extract of fresh macerated roots.
7- Top yield feddan^{-1} (ton). 8- Root yield feddan^{-1} (ton).
9- Sugar yield feddan^{-1} (ton). It was calculated by multiplying root yield by root sucrose %.

2- Faba bean:

- Growth characters

1- Plant height (cm). 2- Number of branches plant^{-1}

-Yield and yield components:

1- Number of pods plant^{-1}. 2- Weight of 100-seeds (g).
3- Seed weight plant^{-1} (g). 4- Seed yield feddan^{-1} (ardab).

Competitive relationships:

1- Land equivalent ratio (LER). Land equivalent ratio defines as the ratio of area needed under sole cropping to one of intercropping at the same management level to produce an equivalent yield (Mead and Willey 1980). It is calculated as follows:

$$LER = (Y_{sf}/Y_{ss}) + (Y_{fs}/Y_{ff})$$

Where Y_{ss} **= Pure stand yield of crop s (sugar beet),** Y_{ff} **= Pure stand yield of crop f (faba bean),** Y_{sf}**= Intercrop yield of crop s (sugar beet) and** Y_{fs} **= Intercrop yield of crop f (faba bean).)**

The values of LER were estimated by using data of recommended sole cultures of both crops. When LER of more than unity indicates yield advantage, equal to unity indicates no gain or no loss and less than unity indicates yield loss (Vandermeer, 1989).

2- Aggressivity (A): It mean a comparison of how much relative yield increase for the intercropped crop s (sugar beet) on crop f (faba bean) with the expected crop to find out which of the two crops dominated in yield according to Mc-Gilchrist, (1965).

For crop (s),

$$A_{sf} = \frac{Y_{sf}}{Y_{ss} \times Z_{sf}} - \frac{Y_{fs}}{Y_{ff} \times Z_{fs}}$$

and for crop (f),

$$A_{fs} = \frac{Y_{fs}}{Y_{ff} \times Z_{fs}} - \frac{Y_{sf}}{Y_{ss} \times Z_{sf}}$$

3- Relative crowding coefficient (RCC): It was estimated by multiplying the coefficient (K) for the first crop (K_{sf}) by the coefficient of the second crop (K_{fs}), described by De Wit (1960) as follows:

$$K = K_{sf} \times K_{fs}$$

$$K_{sf} = \frac{Y_{sf} \times Z_{fs}}{(Y_{ss} - Y_{sf}) \times Z_{sf}} \quad K_{fs} = \frac{Y_{fs} \times Z_{sf}}{(Y_{ff} - Y_{fs}) \times Z_{fs}}$$

Where; Z_{sf} **= the area ratio of the crop s (sugar beet) under intercropping** Z_{fs} **= the area ratio of the crop f (faba bean) under intercropping**

Economic evaluation:

Farmer's income was calculated by determining the total costs and net return of intercropping culture as compared to recommended solid culture of sugar beet.

- Total return of intercropping cultures = Price of sugar beet yield + price of faba bean yield (LE). The average of sugar beet and faba bean price were presented by Bulletin of Statistical Cost Production and Net Return (2018). The local prices were 480 and 843 LE of one ton of sugar beet and one ardab of faba bean seeds, respectively.

- **Monetary advantage index (MAI):** Suggests that the economic assessment should be assessed 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 × (LER-1/LER)

The Statistical Analysis:

The measured variables were analyzed by ANOVA using MSTATC statistical pack-age (Freed, 1991) and treatment means were compared by LSD test at the 5 % level of probability according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

A. Sugar beet

I. 1. Effect of sugar beet varieties:

Results presented in Table 2 shows clearly that sugar beet varieties were significantly differed in number of leaves plant^{-1}, leaf area index (LAI), root diameter, root and top weight plant^{-1} in both seasons, but root length was insignificantly differed in the first season. Sugar beet variety Cleopatra gave the highest values for the previously traits compared with the other varieties in both seasons. The variance between tested sugar beet varieties in measured traits might be due to the superiority of Cleopatra variety in number of leaves plant^{-1}and leaf area index (LAI) traits, which it essentially was related to their gene makeup action that plays vital roles in plant morphology and structure (Aly *et al.*, 2017).

It is indicated that Cleopatra variety was more effective in translocating photosynthesis substances from leaves to the developing root and top weight plant^{-1} than Glorius and Lilly varieties under intercropping conditions. The differences among sugar beet varieties were found by Afez (2016) for root length and root diameter, Aly and Khalil (2017) for root fresh weigh plant^{-1}, Aly *et al.*(2017) for leaf area index (LAI), root fresh weight plant^{-1}, foliage fresh weight plant^{-1}, root diameter and total dry weight plant^{-1}.

Table 2. Effect of sugar beet varieties on growth, yields and its attributes during 2017/2018 and 2018/2019 seasons.

Character Sugar beet variety	No. of leaves plant^{-1}	LAI	Root length (cm)	Root diameter (cm)	Top weight plant^{-1} (g)	Root weight plant^{-1} (g)	(Root top^{-1}) ratio	Top yield fed^{-1} (t)	Root yield fed^{-1} (t)	Sugar yield fed^{-1} (t)	Sucrose (%)
						2017/2018 season					
Glorius	20.00	6.97	18.85	14.36	473.52	686.54	1.42	16.12	24.42	4.57	18.72
Lilly	22.64	7.54	19.05	16.00	575.89	813.90	1.46	19.43	27.98	4.37	15.64
Cleopatra	29.93	7.95	21.20	18.84	650.73	868.33	1.33	21.04	29.82	4.27	14.35
LSD at 0.05	1.73	0.48	N.S	1.77	9.96	9.28	0.43	1.41	2.15	N.S	0.55
						2018/2019 season					
Glorius	22.03	7.30	20.67	14.93	509.35	734.17	1.44	16.59	26.84	4.82	17.96
Lilly	24.93	7.97	21.20	16.52	622.97	876.92	1.41	20.77	30.72	4.51	14.70
Cleopatra	31.99	8.46	23.34	19.31	709.89	997.68	1.40	23.20	32.86	4.61	14.03
LSD at 0.05	1.33	1.18	1.84	1.48	11.28	12.12	0.30	1.43	2.14	NS	0.70

The variation due to varieties was significant for (root top^{-1}) ratio, top yield fed^{-1} and root yield fed^{-1} as well as sucrose % in both seasons, while variations in sugar yield fed^{-1} not reach to the level of significance in both seasons (Table 2). The highest top yield (21.04 and 23.20 ton fed^{-1}) and root yield (29.82 and 32.86 ton fed^{-1}) were recorded with Cleopatra followed by Lilly variety, while the lowest ones (16.12 and 16.59 ton fed^{-1}) and (24.42 and 26.84 ton fed^{-1}) were found with Glorius for the previous mentioned traits in the first and second seasons, respectively, vice versa for root/top ratio. The superiority of Cleopatra in root yield may be due to the reflecting of increasing root length, root diameter and top and root weight plant^{-1} especially there was a positive and highly correlated relationship with root yield fed^{-1} . A positive linear relationship between root yield with individual beet weight and root length was observed, with those of Paul *et al.* (2019). With regard to sugar yield fed^{-1} and sucrose %, results indicated that the sugar yield fed^{-1} slightly differed among sugar beet varieties. The highest sugar yield (4.57 and 4.82 ton fed^{-1}) was produced by Glorius, followed by Lilly (4.37 and 4.51 ton fed^{-1}), which at par with Cleopatra (4.27 and 4.61ton fed^{-1}). Meanwhile, sugar beet varieties significantly differ in sucrose %, where the maximum sucrose % (18.72 and 17.96 %) was recorded with

Glorius variety followed by Lilly (15.64 and 14.70%) and the lowest one was observed by Cleopatra (14.35 and 14.03)

2. Effect of faba bean plant densities:

The faba bean plant density significantly affected yield and yield attributes of sugar beet in both seasons (Table 3). Decreasing plant density of faba bean plants from 33.3 to 25 and 16.7%significantly increased number of leaves plant^{-1}, LAI, root length, root diameter and fresh top and root weight plant^{-1} of sugar beet in both seasons, except root length in the second season. The increases of these traits could be attributed to better light distribution throughout their canopy as a result of their lower density, such distribution improves light utilization. It is important to mention that, plant density of faba bean could be related to the proportion of solar radiation that reaches to sugar beet plants during growth and development of sugar beet (Ijoyah *et al*., 2015). These results are in agreement with those reported by Ibrahim (2018) who found that reducing faba bean plants density when it was intercropped with sugar beet, resulted in minimizing the intra and inter competition of both crops leads to high efficiency of solar radiation utilized by sugar beet, and consequently high accumulation of dry matter.

Results in Table 3 indicated clearly that (root top^{-1}) ratio, top, root and sugar yields fed^{-1} as well as sucrose % were significantly increased by decreasing plant density of faba bean plants from 33.3, 25.0 up to 16.7% in both seasons. Faba bean intercropping with sugar beet at 16.7% plant density increased root and sugar yields fed^{-1} by 18.52 and 17.69 % in first season and 17.09 and 13.66 % in second seasons, respectively, as compared to 33.3%. The increase in root yields fed^{-1} being strongly related to root performance, i.e. root length, diameter and fresh weight plant^{-1}. The increase in sugar yield might due to 16.7% was superior in root yield fed^{-1}. The increase of root yield fed^{-1} might have attributed to the less intra and inter-specific competition for light and nutrients as well as mutual shading in case of 16.7%. These results are in agreement with those obtained by Mohammed *et al*. (2005) and Ibrahim (2018). El-Shamy *et al* (2016) found that intercropping faba bean at low plant density (17,500 plant fed^{-1}) with sugar beet gave the greatest values of root yield fed^{-1} in both seasons and number of leaves plant^{-1} in the first seasons only, while the high faba bean plant density (70,000 plant fed^{-1}) achieved the lowest values of sugar beet traits.

Table 3. Effect of faba bean plant densities on sugar beet growth, yields and its attributes during 2017/2018 and 2018/2019 seasons.

Character Faba bean plant density	No. of leaves plant^{-1}	LAI	Root length (cm)	Root diameter (cm)	Top weight plant^{-1} (g)	Root weight plant^{-1} (g)	(Root top^{-1}) ratio	Top yield fed^{-1} (t)	Root yield fed^{-1} (t)	Sugar yield fed^{-1} (t)	Sucrose (%)
2017/2018 season											
33.3%	20.88	5.76	18.95	14.97	521.49	695.05	1.35	17.53	24.95	4.09	16.50
25.0%	24.38	7.53	19.93	16.48	568.67	797.51	1.42	18.31	27.70	4.46	16.26
16.7%	27.31	9.17	20.23	17.75	609.98	876.21	1.45	20.74	29.57	4.66	15.95
LSD at 0.05	1.01	0.54	N.S	1.10	6.21	6.61	0.15	1.24	1.04	0.41	0.52
2018/2019 season											
33.3%	22.99	6.09	21.11	15.51	557.30	766.98	1.38	18.53	27.42	4.32	15.89
25.0%	26.50	8.06	21.70	17.19	611.63	864.42	1.41	20.55	30.73	4.72	15.48
16.7%	29.46	9.58	22.39	18.06	673.28	977.36	1.46	21.48	32.27	4.91	15.33
LSD at 0.05	0.97	0.85	1.81	1.37	8.49	6.36	0.26	1.27	1.19	0.46	0.47

3. Interaction effects:

Leaf area index, root diameter, root weight plant^{-1}, top yield fed^{-1} root and sugar yield fed^{-1} as well as sucrose% were significantly affected by the interaction between sugar beet varieties and plant densities of faba bean plants in both seasons, but number of leaves plant^{-1} and top weight plant^{-1} were significantly affected in the second and first seasons, respectively, meanwhile (root top^{-1}) ratio and root length were insignificantly affected in both seasons (Table 4). The highest values of the previous mentioned traits were obtained by intercropping faba bean with sugar beet Cleopatra at 16.7% of pure plant density compared with the others, except sugar yield and sucrose %. This effect may be due to genetic effect of Cleopatra variety as well as lower density of faba bean allow more solar radiation intercepted by sugar beet plants, which reflected positively on more translocation and stored of photosynthetic metabolites to the root. Abd El-All (2002) found that the highest yield of sugar beet was obtained from intercropping 5 plants m^{-2} of faba bean compared to 16 plants m^{-2} of faba bean.

Meanwhile, the highest sugar yield fed^{-1} (4.87 and 5.15 ton fed^{-1}) was obtained by grown Glorius variety with faba bean at 16.7% in both seasons, while intercropping faba bean with sugar beet at high density produced the highest sucrose %, which were 18.91% at 25% of faba bean plant density in first season and 18.24% at 33.3% of faba bean density in second season. These results attributed to high density of faba bean plants decrease root weight and diameter resulting in decreasing tissue, water content and non-sucrose substance consequently increased sucrose percentage in sugar beet roots. Similar results were obtained by Ibrahim (2018) reported that significant reduction in TSS, sucrose and purity percentages as the plant density of faba bean intercropped with sugar beet decreased.

B. Faba bean

II. 1. Effect of sugar beet varieties:

Plant height, number of branches plant^{-1}, number of pods plant^{-1}, 100-seed weight, seed yield plant^{-1}and seed yield fed^{-1} were significantly affected by sugar beet varietal variation in both seasons (Table 5).

With respect to plant height, intercropping faba bean with Cleopatra variety produced the tallest plants than those of intercropped with other varieties Glorius or Lilly in both seasons. On the contrary, the shortest faba bean plants were produced with Glorius variety in both seasons. These results probably due to differences in canopy architecture of sugar beet varieties, which induce a shading percentage around faba bean plants with varying light proportions. Differences in growth habit and vegetative traits among sugar beet genotypes may be led to differential performance of faba bean under intercropping systems.

With regard to yield and its attributes of faba bean, intercropping faba bean with Glorius variety had the highest number of branches plant^{-1}, number of pods plant^{-1}, 100-seed weight, seed yield plant^{-1} and seed yield fed^{-1} compared with those of intercropped with Cleopatra and Lilly in both seasons (Table 5). Intercropping faba bean with Glorius variety increased seed yield fed^{-1} by 11.62 and 33.3% in the first season and by 7.34 and 29.64% in the second season, compared to intercropping faba bean with sugar beet varieties Lilly and Cleopatra, respectively. The obtained results indicated that LAI and root size of variety Glorius played a major role to furnish better above and underground conditions for faba bean growth and development. The current findings imply that canopy architecture of variety Glorius contributed largely in climatic resources availability particularly solar energy, which reflected positively on more translocation of photosynthesis metabolites to the pod.

Table 4. Interaction effect between sugar beet varieties and faba bean plant densities on sugar beet growth, yield and its attributes during 2017/2018 and 2018/2019 seasons.

Sugar beet variety	Faba bean plant density	No. of leaves plant^{-1}	LAI	Root diameter (cm)	Top weight plant^{-1} (g)	Root weight plant^{-1} (g)	Top yield fed^{-1} (t)	Root yield fed^{-1} (t)	Sugar yield fed^{-1} (t)	Sucrose (%)
					2017/2018 season					
Glorius	33.3%	17.01	5.21	13.20	424.21	604.47	14.19	22.61	4.20	18.57
	25.0%	19.97	6.82	14.18	481.93	699.40	16.52	24.58	4.65	18.91
	16.7%	23.02	8.88	15.69	514.42	755.76	17.64	26.08	4.87	18.67
Lilly	33.3%	19.07	5.84	14.05	534.64	723.35	17.97	25.30	4.07	16.09
	25.0%	22.87	7.66	16.25	571.51	820.68	19.22	28.35	4.46	15.74
	16.7%	25.98	9.10	17.70	621.51	897.68	21.09	30.28	4.57	15.09
Cleopatra	33.3%	26.55	6.13	17.66	605.63	757.34	20.44	26.93	4.00	14.84
	25.0%	30.29	8.11	19.00	652.57	872.46	19.19	30.18	4.26	14.13
	16.7%	32.94	9.53	19.87	694.00	975.19	23.49	32.35	4.55	14.08
LSD at 0.05		NS	0.71	2.03	8.18	8.70	1.26	1.37	0.54	0.68
					2018/2019 season					
Glorius	33.3%	19.03	5.54	13.90	451.53	632.25	15.15	23.95	4.37	18.24
	25.0%	21.99	7.15	15.00	514.00	729.80	16.97	27.50	4.94	17.96
	16.7%	25.07	9.20	15.88	562.53	840.46	17.65	29.08	5.14	17.69
Lilly	33.3%	21.30	6.18	14.61	587.70	801.47	19.76	28.35	4.28	15.08
	25.0%	25.16	8.02	16.75	622.60	881.01	20.94	31.43	4.66	14.82
	16.7%	28.33	9.72	18.20	658.60	948.27	21.62	32.38	4.60	14.21
Cleopatra	33.3%	28.65	6.55	18.01	632.68	867.23	20.69	29.97	4.30	14.34
	25.0%	32.33	9.00	19.82	698.30	982.44	23.74	33.25	4.55	13.67
	16.7%	34.98	9.83	20.11	798.70	1143.36	25.16	35.35	4.98	14.08
LSD at 0.05		1.27	1.12	1.94	NS	10.23	1.32	1.57	0.61	0.62

Table 5. Effect of sugar beet varieties on yield of faba bean and its attributes during 2017/2018 and 2018/ 2019 seasons.

Character Sugar beet variety	Plant height (cm)	No of branches	No. of pods plant^{-1}	100-seed weight (g)	Seed yield plant^{-1}(g)	Seed yield fed^{-1} (ardab)
			2017/2018 season			
Glorius	73.13	5.33	20.11	84.89	17.83	4.12
Lilly	74.93	4.37	13.78	80.78	16.17	3.57
Cleopatra	82.18	3.65	11.67	78.22	14.98	3.09
LSD at 0.05	1.49	1.07	2.35	2.29	1.52	0.95
			2018/2019 season			
Glorius	75.50	3.53	23.11	89.89	21.83	4.68
Lilly	77.31	3.44	16.78	85.78	20.19	4.36
Cleopatra	84.59	2.83	14.67	83.22	18.93	3.61
LSD at 0.05	1.53	1.13	2.59	3.76	1.54	1.02

Differences in the performance of crops intercropping with sugar beet varieties were reported by Masri and Safina (2015) who reported that the highest dry onion yield 6.22 and 6.14 tons fed^{-1} was obtained when intercropped with sugar beet varieties Carolaand Glorius, respectively, while the lowest yield fed^{-1}was obtained with variety Farida. Sheha (2016) reported that all growth and yield characters of faba bean were significantly affected by wheat varieties.

II. 2. Effect of faba bean plant densities:

Data presented in Table 6 indicated clearly that plant density of faba bean plants significantly affected plant height, number of pods plant^{-1}, 100-seed weight, yield plant^{-1} and yield fed^{-1}in both seasons, while number of branches plant^{-1} was significantly affected only in the first season. Plant height of faba bean was significantly increased by increasing faba bean plant density from16.7, 25.0 to 33.3%. The lower plant density of faba bean 16.7% produced the shortest plants in both seasons. These results could be due to increasing plant density per unit area, increased intra-specific competition between faba bean plants for basic growth resources especially solar radiation, among different resources of competition, light is one of them. Mohammed *et al.* (2005) and Hamdany and El-Aassar(2017) found similar result.

With regards to yield attributes, numbers of branches and pods plant^{-1}, 100-seed weight and seed yield plant^{-1} were gradually increased by decreasing faba bean plant density from 33.3 to 25.0 and16.7 %. Meanwhile, the lowest values of those traits were produced by intercropping faba bean at plant density of 33.30% with sugar beet in both seasons. The lower plant density of 16.7% for faba bean could have enhanced a greater utilization of sunlight, thus produced more number of branches plant^{-1}, while shading by taller intercropped faba bean plants could have reduced the photosynthetic absorption rate for faba bean, thereby reducing number of branches at maturity. Obviously, decreasing faba bean density up to 16.7% progressively increased number of pods plant^{-1}, 100-seed weight and seed yield plant^{-1} (Table 6). This could be attributed to reduced intra and inter-specific competition for growth resources at a lower density. In addition, the highest number of branches plant^{-1} produced from intercropped faba bean at lowest plant density could have also been responsible for the highest number of pods per plant and seed yield plant^{-1}.

Table 6. Effect of faba bean plant densities on yield of faba bean and its attributes during 2017/2018 and 2018/2019 seasons.

Character Plant density	Plant height (cm)	No of branches plant^{-1}	No. of pods plant^{-1}	100-seed weight (g)	Seed yield plant^{-1} (g)	Seed yield fed^{-1} (ardab)
			2017/2018 season			
33.3%	82.38	2.94	11.67	74.00	14.34	4.13
25.0%	75.66	3.31	15.22	80.78	16.07	3.70
16.7%	72.20	3.38	18.67	89.11	18.56	2.95
LSD at 0.05	3.43	NS	2.23	2.63	1.26	0.84
			2018/2019 season			
33.3%	87.44	3.39	14.67	79.00	18.36	4.88
25.0%	75.70	4.69	18.11	85.78	20.09	4.29
16.7%	67.26	5.28	21.78	94.11	22.49	3.48
LSD at 0.05	3.41	0.83	2.48	2.26	1.3	1.13

On the contrary, the lowest plant density of faba bean was achieved the lowest seed yieldfed^{-1}. Intercropping faba bean with plant density of 16.7% significantly reduced seed yield fed^{-1} by 20.27 and 28.57% in first season and 18.88 and 28.69% in second season, respectively, compared to 25 and 33.3%. This reduction in seed yield fed^{-1}was expected as result of decreased faba bean plant density per unit area. Results herein are in harmony with those obtained by Mohammed *et al.*, (2005), Hamdany and El-Aassar (2017) and Ibrahim (2018).

II. 3. Interaction effects:

At the second season, plant height was a significantly affected by the interaction between sugar beet varieties and faba bean plant density. Meanwhile, other characteristics of faba bean were not affected in both seasons (Table 7). The tallest plants in the second season were obtained when faba bean was intercropped by 33.3% of its sole culture density with Cleopatra variety whereas, the shortest plants were showed at 16.7%of faba bean plant density with Glorius variety.

III. **Competitive Relationships:**

III. 1. Land Equivalent ratio (LER):

Results in Table (8) showed that the intercropped yields of sugar beet and faba bean were greater than their respective sole culture yields. The total LER values were greater than one in all the studied treatments. The LER ranged from 1.08 to 1.29 in the first season and from 1.15 to 1.33 in the second one. The highest LER values 1.29 and 1.33 were obtained by intercropping faba bean with Glorius variety at 25% of faba bean plant density in the first season and second seasons, respectively.

This advantage of the highest LER may be due to the canopy architecture of Glorius variety was more suitable with sown faba bean at 25% to continue in their growth and development compared with the others treatments. Intercropping culture increased LER as compared to sole cultures of both crops (Usmanikhail *et al.*, 2012). Similar results are reported by Mohammed *et al.* (2005), Masri and Safina (2013), Salama *et al.*, (2016) and Abd El Lateef *et al.*, (2019).

Table 7. Interaction effect between sugar beet varieties and faba bean plant densities on faba bean yield and its attributes during 2017/2018 and 2018/2019 seasons.

Sugar beet variety	Faba bean plant density	Plant height (cm)	Seed yield fed^{-1} (ardab)	Plant height (cm)	Seed yield fed^{-1} (ardab)
		2017/2018 season		2017/2018 season	
Glorius	33.3%	79.32	4.70	84.38	5.34
	25.0%	71.73	4.22	73.80	4.76
	16.7%	68.33	3.45	68.33	3.93
Lilly	33.3%	81.35	4.13	86.44	5.12
	25.0%	73.77	3.53	75.82	4.32
	16.7%	69.67	3.05	69.67	3.64
Cleopatra	33.3%	86.46	3.57	91.50	4.17
	25.0%	81.48	3.36	83.48	3.79
	16.7%	78.60	2.34	78.78	2.88
LSD at 0.05		N.S	N.S	4.49	N.S

Table 8. Interaction effect of sugar beet genotype and faba bean plant density on competitive relationships during 2017/2018 and 2018/2019 seasons.

Sugar beet variety	Faba bean plant density	Root yield fed^{-1} (ton)	Seed yield fed^{-1} (ardab)	Land equivalent ratio (LER) L_s	L_f	LER	Aggressivity (A) A_s	A_f	Relative crowding coefficient (RCC) K_s	K_f	K
Intercropping cultures:							2017/2018 season				
Glorius	33.3%	22.61	4.70	0.83	0.43	1.26	-0.59	0.59	1.69	2.22	3.75
	25.0%	24.58	4.22	0.91	0.38	1.29	-0.78	0.78	2.46	2.48	6.08
	16.7%	26.08	3.45	0.96	0.31	1.27	-1.10	1.10	4.29	2.77	11.87
Lilly	33.3%	25.30	4.13	0.81	0.37	1.18	-0.41	0.41	1.46	1.79	2.61
	25.0%	28.35	3.53	0.91	0.32	1.23	-0.46	0.46	2.59	1.88	4.87
	16.7%	30.28	3.05	0.97	0.28	1.25	-0.83	0.83	4.14	2.32	10.28
Cleopatra	33.3%	26.93	3.57	0.76	0.32	1.08	-0.28	0.28	1.06	1.43	1.53
	25.0%	30.18	3.36	0.85	0.30	1.15	-0.45	0.45	1.46	1.75	2.54
	16.7%	32.35	2.34	0.91	0.21	1.12	-0.44	0.44	1.77	1.64	2.89
					Sole cultures:						
Sugar beet (Glorius)		27.08	-	-	-	-	-	-	-	-	-
Sugar beet (Lilly)		31.09	-	-	-	-	-	-	-	-	-
Sugar beet (Cleopatra)		35.36	-	-	-	-	-	-	-	-	-
Faba bean (Giza 716)		-	11.04	-	-	-	-	-	-	-	-
Intercropping cultures:							2018/2019 season				
Glorius	33.3%	23.95	5.34	0.81	0.45	1.26	-0.73	0.73	1.42	2.48	3.52
	25.0%	27.50	4.76	0.93	0.40	1.33	-0.85	0.85	3.32	2.70	8.98
	16.7%	29.08	3.93	0.98	0.33	1.31	-1.22	1.10	9.75	3.04	29.69
Lilly	33.3%	28.35	5.12	0.83	0.43	1.26	-0.63	0.63	1.62	2.30	3.71
	25.0%	31.43	4.32	0.92	0.37	1.29	-0.68	0.68	2.84	2.31	6.55
	16.7%	32.38	3.64	0.95	0.31	1.26	-1.09	1.09	2.92	2.72	7.95
Cleopatra	33.3%	29.97	4.17	0.78	0.35	1.13	-0.38	0.38	1.15	1.64	1.89
	25.0%	33.25	3.79	0.86	0.32	1.18	-0.53	0.53	1.54	1.89	2.91
	16.7%	35.35	2.88	0.91	0.24	1.15	-0.66	0.66	1.76	1.96	3.46
					Sole cultures:						
Sugar beet (Glorius)		29.57	-	-	-	-	-	-	-	-	-
Sugar beet (Lilly)		34.20	-	-	-	-	-	-	-	-	-
Sugar beet (Cleopatra)		38.65	-	-	-	-	-	-	-	-	-
Faba bean (Giza 716)		-	11.80	-	-	-	-	-	-	-	-

III. 2. Aggressivity (A):

Aggressivity determines the difference in competitive ability of the component crops in intercropping association. The positive sign indicates the dominant component and the negative sign indicates the dominated component. Higher numerical values of aggressiveness denote greater difference in competitive ability, as well as, bigger difference between actual and expected yield in both crops. Results in Table 8 indicated that faba bean was the dominant crop component in all studied treatments. The highest positive values were obtained by intercropping faba bean with Glorius variety at the lowest density of faba bean plants, meanwhile intercropping faba bean at 33.3% plant density with Cleopatra variety had the lowest positive values. That indicated intercropping faba bean with Glorius variety is more competitive than intercropped faba bean with Lilly and Cleopatra varieties. Similar results were obtained by Mohammed *et al.* (2005) who showed that faba bean plants are dominant component and sugar beet plants are dominated component.

III. 3. Relative Crowding Coefficient (K):

Relative crowding coefficient (RCC) plays an important role in determining the competition effects and advantages of intercropping. Willey (1979) described that each crop in intercropping system has its own RCC (K). The crop with high value of "K" is dominant over the crop having lower value of "K". If the product of two values of K of two different crops is greater than unity, it means that intercropping system has advantages, disadvantages in case of value less than unity and it is equal to unity, it means that intercropping has no advantages. Table 8 showed that values of $K_{faba\ bean}$ was highest than those of $K_{sugar\ beet}$ under high density of faba bean, while values of $K_{sugar\ beet}$ was the highest under low faba bean plant density 16.7%, irrespective sugar beet variety, in both seasons. Results on RCC indicated that all intercropping treatments had yield advantages. The highest values of K were obtained by intercropping faba bean at 16.7% with Glorius variety, whereas the lowest value produced by intercropping faba bean with Cleopatra variety at 33.3% of faba bean plant density. Similar results were obtained by Mohammed *et al.* (2005).

IIII. Economic evaluation:

Total income and monetary advantage index (MAI) influenced clearly by intercropping faba bean plants at different plant densities and sugar beet varieties comparison to sole sugar beet culture as shown in Table (9). Intercropping faba bean with any sugar beet varieties were increased total income over than sole sugar beet culture in both seasons. The increases in total income were 16.85, 10.28 and 0.09% in first season and 16.49, 12.13 and 1.37 % in second season by intercropping faba bean with Glorius, Lilly and Cleopatra varieties compared with their sole culture, respectively. Similarly, Glorius variety had the highest MAI 3260 and 3895 in first and second seasons, respectively.

Table 9. Effect of sugar beet genotypes, faba bean plant density and their interaction on total income and monetary advantage index (MAI) during both seasons.

Sugar beet variety	Faba bean plant density	Income fed^{-1} (LE) Sugar Beet	Income fed^{-1} (LE) Faba bean	Total income fed^{-1} (LE)	MAI	Income fed^{-1} (LE) Sugar beet	Income fed^{-1} (LE) Faba bean	Total income fed^{-1} (LE)	MAI
Intercropping cultures:			2017/2018 season				2018/2019 season		
Glorius	33.3%	10853	3948	14801	3054	11496	4486	15982	3297
	25.0%	11798	3545	15343	3449	13200	3997	17197	4267
	16.7%	12518	2901	15419	3278	13958	3305	17263	4120
Mean		11723	3465	15188	3260	12885	3929	16814	3895
Lilly	33.3%	12144	3470	15614	2382	13608	4297	17905	3683
	25.0%	13608	2968	16576	3100	15086	3626	18713	4196
	16.7%	14534	2647	17182	3420	15542	3060	18603	3801
Mean		13429	3028	16457	2967	14745	3661	18407	3893
Cleopatra	33.3%	12926	2999	15925	1180	14386	3503	17888	1994
	25.0%	14486	2819	17385	2257	15960	3184	19144	2924
	16.7%	15528	1966	17494	1874	16968	2419	19387	2596
Mean		14313	2595	16988	1770	15771	3035	18806	2505
Average of plant densities	33.3%	11974	3472	15447	2205	13163	4095	17258	2991
	25.0%	13297	3111	16408	2935	14749	3602	18351	3795
	16.7%	14193	2505	16698	2857	15489	2928	18418	3506
Sole cultures:									
Sugar beet (Glorius)		12998	-	12998	-	14194	-	14434	-
Sugar beet (Lilly)		14923	-	14923	-	16416	-	16416	-
Sugar beet (Cleopatra)		16973	-	16973	-	18552	-	18552	-
Faba bean (Giza 716)		-	10538	10538	-	-	10040	10040	-

At the same time, decreasing faba bean plant density from 33.3 up to 25.0 and 16.7% when it was intercropped with sugar beet increased sugar beet income and total income (LE fed^{-1}) as well as MAI, vice versa for income of intercropping faba bean in both seasons. This expected since yield and income of faba bean positively correlated with its plant density.

Obviously, the highest total income 17494 and 19387 LE $fed^{-1}$was achieved by intercropping faba bean with Cleopatra variety at 16.7% of plant density, and at par with total income of the same variety at 25% faba bean plant density 17385 and 19144 LE fed^{-1}in first and second seasons, respectively. However, the highest MAI 3449 and 4267 was detected when intercropping faba beat at 25 % with Glorius variety. It is worth mentioning that, price evaluation of sugar beet depended on sucrose % rather than root yield fed^{-1}.

So, intercropping faba bean at 25% with Glorius variety was more profitability and produced the highest MAI over than the other sugar beet varieties. Intercropping sugar beet with faba bean crop was more profitability compared to sole sugar beet culture. Mohammed *et al.* (2005), Usmanikhail *et al.*, (2013), Masri and Safina (2015) Salama *et al.*, 2016, Ibrahim (2018) and Abd El Lateef *et al.* (2019) reported similar results.

CONCLUSION

In current study, yield and profitability of intercropping faba bean and sugar beet rely on select the best sugar beet variety, in terms of suitability to intercropping and their superiority in yield and quality traits. Therefore, plant density (25%) for intercropping faba bean reduced negative effect on yield and its quality of sugar beet, increased land use efficiency as well as MAI. Results revealed that, Glorius was the compatible sugar beet variety to intercropping with faba bean at 25% of its plant density, which recorded the highest LER (1.31) and monetary advantage index (MAI) 3858 as well as produced 4.80 ton $fed^{-1}$of sugar yield plus 4.49 ardab $fed^{-1}$of faba bean seed as average of both seasons, compared with other intercropping treatments under salt affected soils.

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أثر التحميل للفول البلدي مع بنجر السكر على المحصول ومكوناته تحت ظروف الأراضي المتأثرة بالأملاح

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أجريت تجربة بحثية بمحطة بحوث السرو - مركز البحوث الزراعية، خلال الموسم الشتوي لموسمين 2018/2017 و2019/2018 بمحافظة دمياط، لدراسة تأثير أنماط تحميل الفول البلدي المنزرع بكثافات نباتية مختلفة (33.3- 25- 16.7%) على بعض أصـــناف بنجر الســـكر والتي تتبع 3 طرز (جلوريا (يتبع طراز Z)، ليلي (يتبع طراز N)، كليوباترا (طراز E). استخدام تصـميم القطع المنشـقة في ثلاث مكررات. أظهرت النتائج ان التفاعل بين أصـناف البنجر والكثافة النباتية للفول البلدي كان معنويا بالنسـبة لدليل مسـاحة الأوراق، قطر الجذر، محصـول الجذر والسكر (طن/ف) في كلا الموسمين. تحميل الفول البلدي مع الصنف جلوريا حقق أعلى محصول فول بلدى ومكوناته مقارنة بتحميل الفول مع صــنفي كليوباترا وليلي. زادت مكونات الفول البلدي (عدد الفروع والقرون/للنبات، وزن 100 بذرة، محصــول البذور/نبات) معنويا بانخفاض كثافة الفول البلدي النباتية إلى 16.7%، بينما ارتفاع النبات ومحصـول بذور/الفدان سـلك العكس في كلا الموسـمين. لم تتأثر معنويا جميع صـفات الفول البلدي بالتفاعل بين أصـناف بنجر السـكر والكثافة النباتية للفول البلدي، ماعدا ارتفاع النبات في الموسـم الثاني. أظهرت النتائج ان قيم المكافئ الأرضــي ومعامل الحشـد النسـبي كانت أكبر من الواحد الصـحيح مما يؤكد تحقيق ميزة محصـوليه بتحميل الفول البلدي مع بنجر السـكر مقارنة بالزراعة المنفردة. الفول البلدي هو المحصــول السـائد في جميع معاملات التحميل. تحميل الفول البلدي مع الصــنف جلوريا بكثافة نباتية 25.0% حقق أعلى مكافئ أرضى 1.29 و1.33 وكذلك الميزة النقدية 3449 و4267 في كلا الموسمين.

الخلاصة: أدى تحميل الفول البلدي بنسبة 25 % + 100% بنجر السكر صنف جلوريا لتحقيق أعلى مكافئ أرضى 1.31 وميزة نقدية 3858 كما حقق الفدان 4.49 طن السكر+ 4.80 أردب من بذور الفول البلدي كمتوسط الموسمين مع زيادة العائد الاقتصادي مقارنة بالزراعة المنفردة تحت ظروف الأراضي الملحية.