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EFFECT OF SOWING DATE AND INTERCROPPING SYSTEM OF SUNFLOWER WITH SUGAR BEET ON THE PRODUCTIVITY OF BOTH CROPS

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ABSTRACT: A field study was conducted during 2018/2019 and 2019/2020 seasons in Itay EL-Baroud Agric. Res. Station, Beheira Governorate, Egypt, to study the effect of three sowing dates of sunflower (simultaneously with sugar beet (T1), twenty one days after sowing sugar beet (T2) and thirty five days after sowing sugar beet (T3)) and three intercropping systems (25% (S1), 33.3% (S2) and 50% (S3) of sunflower plant density + 100% sugar beet) on yield and yield components of both crops. A split plot design with four replications was used. Results showed that all studied characters of sugar beet were significantly affected by sowing dates and intercropping systems of sunflower. Intercropping system (S1) significantly increased all characters of sugar beet at T3 over the other treatments. Early sowing date (T1) significantly accelerated days to 50% of flowering and maturity date and recorded the highest values for each of growing degree days (GDD) and seed yield and its components of sunflower. Significant differences were recorded for sunflower studied traits as affected by the intercropping systems. The highest seed and oil yields/fad., were achieved with sole sunflower followed by S3 system at T1 compared with the other treatments. The highest land equivalent ratio (LER) value 1.46 was recorded at T2 with S3, followed by 1.44 with T2 x S1, as average of both seasons. While T2 x S1 had the highest relative crowding coefficient (RCC) and net return. It can be concluded that T2 x S1 had the highest sugar yield valued 4.74 ton/fad., increased net return by 28.30% and produced 26.10 ton sugar beet plus 444.63kg seed of sunflower compared to sole sugar beet which had 26.91 ton sugar beet.

Key words: *Helianthus annuus* L., *Beta vulgaris* L., yield component, land equivalent ratio LER, relative crowding coefficient RCC, gross return.

INTRODUCTION

The edible oil production in Egypt is still very low for population demand, only 5% of total oil demand covered by domestic **(Bulletin of Statistical, Cost Production and Net Return, 2019)**. Therefore, increasing domestic oil yield per unit area of oil crops is in demand and could be achieved by adopting suitable cultural practices and applying intercropping. Intercropping is defined as the practice of growing two or more crops with one another on the same field (**Brooker *et al.*, 2015**).

Sunflower is one of the most important oil crops in the world, it's oil gaining more importance because of its light color, low saturated fatty acid content, ability to withstand high cooking temperatures (**Myers and Minor, 2002**) and affordable for the Egyptian consumer. However, the cultivated area of this crop in Egypt is very small due to the low economic yield compared with the other cash crops. Sunflower intercropping with sugar beet to share environment resources and production inputs was suggested to increased oil production and financial gain. Sugar beet is the most economical crop in Egypt, the second largest source of

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sucrose after sugarcane and the cash crop for farmers **(SCC, 2017)**. Management of intercrops to reach maximum complementarity and minimum competition includes agriculture different decisions as planting distribution and population density also relative sowing dates.

The optimal sowing time of sunflower can vary in different locations with different climatic variables; sowing date exerted a highly significant effect on all vegetative growth traits along with yield and its components of sunflower **(Kaleem *et al.*, 2010).** Differences of yield attributes in varying seasons might be due to the different climatic conditions that are based on the temperature prevailing during the crop life cycle **(Kll and Altunbay, 2005**). The earlier planting date was shown to give better seed yields than later planting (**Ahmed *et al.*, 2015**). Also, the number of infertile seeds/head was lower at the early planting time (**Baghdadi *et al.*, 2014; Demir, 2019).** The relative sowing time of component crop is an important management variable manipulated in the intercropping system but has not been extensively studied. Yield and its components of sugar beet significantly affected by sowing date of faba bean (**Hassan, 2007**), wheat (**Abou-Elela, 2012; Badr, 2017**) intercropped with sugar beet. **Enan *et al*. (2013)** found that sowing date of sunflower intercropping with cane significantly affected sunflower seed yield/fad.

The ideal planting density of the intercropping crops reduced competition for site resources is the principal reason for the high productivity (**Hauggaard-Nielsen *et al.*, 2006)**. Adjusting planting density of sunflower plants is an important tool to optimize the yield of both crops combination, under the intercropping system (**Enan *et al.*, 2013; Badr, 2017; Sheha *et al.*, 2017**). Root yield /fad and its components of sugar beet as well as quality traits were significantly increased by reducing sunflower plant density. While plant height and seed yield/ fad., of sunflower were significantly increased by increasing sunflower plant density with sugar beet, whereas yield components showed the opposite trend **(Mohammed and Abd El Zaher, 2013; Sheha *et al.*, 2017)**.

Numerous studied indicated that yield of sugar beet significantly influenced by the intercropping system but increased land equivalent ratio (**Hassan, 2007; Usmanikhail *et al.*, 2012; Badr, 2017; Sheha *et al.*, 2017**), relative crowding coefficient achieved advantageously by intercropping (**Mohammed and Abd El-Zaher 2013; Sheha *et al.*, 2017**) and monetary advantage (**Enan *et al.*, 2013; Sheha *et al.*, 2017; Manasa *et al.*, 2018**). This investigation aimed to increase the edible oil production in Egypt and land usage as well as economic return for the farmer by using the optimum sowing date and plant density of sunflower with sugar beet.

MATERIALS AND METHODS

A two-year field study was conducted at Itay El-Baroud Agricultural Research Station, Agricultural Research Center, El-Beheira Governorate, Egypt in 2018/2019and 2019/ 2020 seasons. This study was implemented to determine the effect of three sowing dates and three intercropping systems of sunflower with sugar beet on yields of sugar beet and sunflower, land equivalent ratio and gross return. Physical and chemical soil properties of the experimental site are (Table 1) was done by Water and Soil Res. Inst., A.C.R., using methods described by **Chapman and Pratt (1961)**. The average monthly temperature degree of the study region in two growing seasons is presented in Table 2.

The cumulative heat units (CHU) or the cumulative growing degree day (GDD) from emergence till crop maturity were calculated from meteorological data presented in Table 2 throughout the crop life cycle as given in the equation of **Dwyer and Stewart (1986).**

$$\mathrm{CHU} = \sum_{t2}^{t1} \frac{(T\max - T\min)}{2} - \mathrm{Tb}$$

Where: T max and T min are maximum and minimum daily air temperatures, respectively. Tb is the base temperature below which development ceases and t1 and t2 were the time intervals. Base temperature for sunflower development is 8°C (**Sadras and Hall, 1988**).

Treatments and Experimental Design

The treatments comprised three sowing dates of sunflower and three intercropping systems of

Table 1. Physical and chemical properties of the experimental soil in 2018/2019 and 2019/2020 seasons

Soil analysis	Physical properties				Chemical properties					
Season	Clay (%)	Silt (%)	Sand (%)	Texture	OM (%)	pH	EC , dsm^{-1}	Available NPK (ppm)		
								N	P	K
2018/2019	54.8	27.2	18.0	Clay	0.56	7.8	1.95	50.0	47.0	241
2019/2020	52.74	28.95	18.31		0.88	8.00	1.54	47.0	40.0	229

Table 2. Average temperature degree (°C) of the studied region (Behira, Governorate) during the two growing seasons 2018/ 2019 and 2019/2020

	Maximum	Minimum	Maximum	Minimum
	2018/2019 season		2019/2020 season	
September	29.78	22.42	30.78	23.57
October	27.51	19.96	28.77	20.64
November	23.56	13.86	24.96	15.33
December	21.25	12.90	19.70	12.45
January	18.77	10.74	17.74	7.12
February	21.14	11.60	18.92	8.78
March	24.38	12.80	19.83	11.35
April	26.26	16.17	23.0	13.26

sunflower with sugar beet. A split plot design with four replicates was used, where sunflower sowing dates occupied the main plots and the intercropping systems were allocated in the sub-plots. Area of each sub-plot was 21.6 m^2, which includes 12 ridges each 3 m long and 0.6m wide.

The Studied Fctors

Sunflower sowing dates

T1: Simultaneously with sugar beet date.

T2: Twenty one days after sowing sugar beet date.

T3: Thirty five days after sowing sugar beet date.

Sunflower intercropping systems

In the intercropping systems, sunflower seeds were sowing in hills at 20 cm and one seed $hill^{-1}$ on the other sides of:

S1**:** The fourth sugar beet ridge, to give 25% of its pure stand.

S2: The third sugar beet ridge, to give 33.3% of its pure stand.

S3: The second sugar beet ridge, to give 50% of its pure stand.

In addition to the sole culture of each crop as recommended.

Cultural Practices

Sowing dates of sugar beet (cv. Athospoly) were 17 and 19 September in first and second seasons, respectively, while harvest date was done after 180 days from sowing. Sunflower (cv. Sakha 53) sowing at T1, T2 and T3, while the harvested dates are presented in Table 6. Sugar beet and sunflower were sown on one side of the ridge spaced at 60 cm in hills at 20 cm apart (one plant per hill) in both intercropping and sole cropping. The soil was prepared as recommended for sugar beet crop. Six leaves of sunflower plants were defoliated at twice after

55 and 65 days from sowing, for all treatments. Calcium superphosphate (15% P_2O_5) was added during seedbed preparation at a rate of 150 kg/fad. Nitrogen fertilizer was added at the rate of 80 kg N/fad., for sugar beet and 30 kg N/fad., for sunflower (applied according to plant density of sunflower) in two equal doses in form of ammonium nitrate (33% N). Potassium fertilizer was added in form of potassium sulphate (48% K_2O) at a rate of 50 kg/fad. All the other agricultural practices were carried out as recommended for sugar beet and sunflower growing under the conditions of Behira, Governorate.

Studied Characters

Sugar beet characters

At 180 days, root of 10 plants were pulled from the inner ridges of sub-plot to determined root length (cm) and root diameter (cm). Plants of whole sub-plot were harvested then separated into tops and roots and weighted, then converted to estimate root yield (ton/fad). Sucrose (%) was determined polarimetrically on a lead acetate extract of 26 g fresh macerated roots according to **Carruthers and Oldfield (1960)** and sugar yield (ton/fad.) calculated by this equation. Sugar yield (ton/fad.)= root yield (ton/fad.)× sucrose (%).

Sunflower characters

Days to 50% of flowering, maturity date, growing degree days (GDD) of whole sub-plot. Ten sunflower plants were taken randomly at harvest from each sub-plot to estimate plant height (cm), stem diameter (cm), head diameter (cm), seed yield/plant (g), 100 seed weight. Seed yield kg/fad., and oil yield/fad., were estimated on basic whole sup-plot and converted to fad. Seed oil content (%) was determined according to **AOAC (2000)** using Soxthelt apparatus to calculated oil yield. Oil yield was estimated by using the following formula. Oil yield (kg/fad.) = oil (%) x seed yield (kg/fad.)/ 100.

Competitive relationships and yield advantages

Land equivalent ratio (LER)

This was determined according to **Willey (1979)**.

$$LER = Yab/Yaa + Yba/Ybb$$

Where: Yaa and Ybb are yields as sole crops of sugar beet (a) and sunflower (b) and Yab and Yba are yields as intercrops of sugar beet (a) and sunflower (b).

Area time equivalent ratio (ATER)

Area time equivalent ratio provides a comparison of the yield advantage of intercropping over monocropping in terms of time taken by component crops in the intercropping systems according to **Hiebsch (1980)**.

ATER = (LERsugar beet x Dc + LERsunflower x Dc) /Dt

Where LER is land equivalent ratio of crop, Dc is the duration (days) taken by crop, Dt is days taken by whole intercropping system from planting to harvest.

Relative crowding coefficient (RCC)

It was estimated by multiplying the coefficient (K) for the first crop (Kab) by the coefficient of the second crop (Kba), described by **Dewit (1960)** as follows:

$$K = kab \times kba$$

Kab = Yab x Zba / (Yaa-Yab) x Zab
Kba = Yba x Zab / (Ybb-Yba) x Zba

Where Zab and Zba are the sown proportions of sugar beet (a) and sunflower (b) when intercropping, respectively.

Aggressivity (A)

This was proposed by **Mc-Gilchrist (1965)** and was determined according to the following formula:

$$Aab = (Yab/Yaa \times Zab) - (Yba/Ybb \times Zba).$$

If Aab= 0, both crops are equally competitive, if Aab is positive, a is dominant, if Aab is negative a is dominated crop.

Economic evaluation (LE/fad)

Gross and net return from each treatment was calculated in Egyptian pounds per ton. The average of sugar beet and sunflower prices are presented by **Bulletin of Statistical Cost Production and Net Return (2019)**. The local prices were LE 620 of one ton of sugar beet root and LE 6000 of one ton of sunflower seed.

Statistical Analysis

Analysis of data was done according to **Freed (1991)** using MSTAT-C software for statistical analysis. The differences among means for all traits were tested for significance at 5% level of probability as developed by **Gomez and Gomez (1984)**.

RESULTS AND DISCUSSION

Sugar Beet

Effect of sunflower sowing dates

Results presented in Table 3 show that root length, root diameter, root yield (ton/fad.), sucrose (%) and sugar yield (ton/fad.) of sugar beet were significantly affected by different sunflower sowing dates in both seasons.

The highest value of root length (28.95 and 28.18 cm), root diameter (10.00 and 11.08 cm) and root yield (24.56 and 25.54 ton/fad.) were obtained with T3 in the first and second season, respectively. While the lowest values of the previously mentioned characters were achieved by T1. Sunflower simultaneously with sugar beet significantly reduced root yield/fad., by 3.84 and 5.13% in the first season and 3.30 and 4.82% in the second season, compared with T2 and T3, respectively. These results may be attributed to sunflower sowing at the same time of sugar beet had the highest competition between sunflower and sugar beet compared with late planting date. Results herein are in agreement with those obtained by **Hassan (2007)**. **Abou-Elela (2012) and Badr (2017)** where they found that sugar beet characters significantly affected by sowing date of wheat, under the different intercropping system.

In contrary, sowing sunflower at the same time of sugar beet (T1) significantly increased sucrose (%) compared with T2 by 0.59 and 0.65% and T3 by 4.88 and 3.24% in the first and second season, respectively. Decreased sucrose (%) by delaying sowing date may be attributed to delaying root growth and storage of sucrose. Results are in agreement with those obtained by **Hassan (2007)**. **Badr (2017)** who mentioned that sucrose (%) significantly decreased by delaying wheat sowing dates. On the other hand, **Abou-Elela (2012)** found that the late sowing date of wheat had the highest value of sucrose (%) of sugar beet.

However, the highest sugar yield/fad. (4.55 and 4.61 ton/fad.) produced by T2, followed by T3 (4.43 and 4.57 ton/fad.) in first and second seasons, respectively. These results may be attributed to that T2 had higher root yield and sucrose (%) compared to T1 and T3, respectively, where sugar yield/fad., positively correlated with root yield/fad., and sucrose (%). **Hassan (2007)** found that the maximum root yield of sugar beet could explain the superiority of sugar yield with the late sowing date of faba bean.

Effect of intercropping systems

As shown in Table 4, sunflower intercropping system revealed significant effect on all studied traits of sugar beet. The pure stand of sugar beet had the highest values for all traits compared to different intercropping systems.

Increasing plant density of sunflower intercropped with sugar beet from S1 (25% sunflower) up to 33.3 and 50% significantly decreased root length, root diameter, root and sugar yields/fad., of sugar beet followed by S2 (33%). While S3 (50%) produced the lowest values of these characters in both seasons and *vice versa* for sucrose (%).

The increases in root and sugar yields/fad., by S1 compared with S2 and S3 were 4.61 and 9.50% for root yield and by 2.81 and 7.14% for sugar yield, respectively, as the average of both seasons. Intercropping sunflower at S1 exhibited sufficient space under the sunflower canopy for sugar beet growth and development. These indicated that increasing plant density of sunflower from 25 to 50% increased specific competition between sunflower and sugar beet on water, nutrients and light. Furthermore, intercropping sunflower at different intercropping patterns decreased all sugar beet traits owing to the shading effect of sunflower plants especially at high S3 (50% of its pure stand), compared to pure stand. Similar results were found by **Mohammed and Abd El-Zaher (2013)** intercropping 67% sunflower of its pure stand with sugar beet recorded the highest yield of root and sugar/fad., while increasing plant density of sunflower up to100% gave the lowest yield of root and sugar/fad., as compared with the yield of pure stand sugar beet. These results are in agree with those obtained by **Abou-Elela (2012) and Sheha *et al.* (2017)**.

Table 3. Root length, root diameter, root yield, sucrose (%) and sugar yield of sugar beet as affected by sowing dates during 2018/2019 and 2019/2020 seasons

Trait / Sowing date	Root length (cm)		Root diameter (cm)		Root yield (ton/fad.)		Sucrose (%)		Sugar yield (ton/fad.)	
	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
T1	26.97	27.26	9.14	9.69	23.30	24.31	18.90	18.49	4.40	4.49
T2	28.49	27.70	9.56	10.26	24.23	25.14	18.79	18.37	4.55	4.61
T3	28.95	28.18	10.00	11.08	24.56	25.54	18.02	17.89	4.43	4.57
LSD 5%	**0.94**	**0.38**	**0.09**	**0.26**	**0.05**	**0.22**	**0.19**	**0.27**	**0.05**	**0.07**
Pure stand	30.88	30.29	10.2	10.31	26.57	27.24	17.75	17.33	4.71	4.72

T1: sowing sunflower at the same time of sugar beet, T2: showing 21 days after sugar beet, T3: showing 35 days after sugar beet

Table 4. Root length, root diameter, root yield, sucrose (%) and sugar yield of sugar beet as affected by sunflower intercropping system during 2018/2019 and 2019/2020 seasons

Trait / Interaction system	Root length (cm)		Root diameter (cm)		Root yield (ton/fad.)		Sucrose (%)		Sugar yield (ton/fad.)	
	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
S1	29.27	28.86	10.03	11.98	25.22	26.04	18.38	17.97	4.63	4.68
S2	28.28	27.82	9.48	10.40	24.08	24.92	18.64	18.33	4.49	4.57
S3	26.86	26.45	9.19	9.18	22.79	24.03	18.70	18.44	4.26	4.43
LSD 5%	**0.76**	**0.33**	**0.22**	**0.24**	**0.06**	**0.19**	**0.23**	**0.24**	**0.06**	**0.09**
Pure stand	30.88	30.29	10.2	10.31	26.57	27.24	17.75	17.33	4.71	4.72

S1: 25% sunflower of its pure stand, S2: 33.3% sunflower of its pure stand, S3: 50% sunflower of its pure stand

Meanwhile, intercropping 50% of sunflower plus 100% of sugar beet (S3) significantly increased sucrose (%) by 1.74 and 2.62% over S1 and by 0.30 and 0.60% compared to S2 in the first and second season, respectively. This trait seemed to be exclusively associated with root weight and governed by the dilution theory. Similar results were reported by **Hassan (2007), Abou-Elela (2012), Badr (2017) and Sheha *et al.* (2017)**.

Interaction effect

Results in Table 5 indicate that the interaction between sowing date and the intercropping system had a significant effect on root length and root diameter in the second season, while root yield/fad., sucrose (%) and sugar yield/fad., of sugar beet were significantly affected in both seasons.

Results cleared that sowing sunflower 35 days later sowing sugar beet (T3) under intercropping system S1 (25%S sunflower of its pure stand) gave the highest values of all the previously mentioned traits in both seasons. While the lowest values of these traits were obtained by intercropping sunflower at 50% of plant density simultaneously with sugar beet (T1). This means that increasing sunflower plants density with sugar beet from S1 (25% sunflower + 100% sugar beet) up to S3 (50% sunflower + 100% sugar beet) decreased root length, root diameter and yield/fad., of sugar beet. These results may be due to the increased of interspecific competition for light, water and nutrients as sunflower plant densities increase, especially when sunflower sowing at the same time of sugar beet. The successful intercropping combination is those that capitalize on both

Table 5. Root length, root diameter, root yield, sucrose (%) and sugar yield of sugar beet as affected by the interaction of sowing dates and sunflower intercropping systems during 2018/2019 and 2019/2020 seasons

Interaction	Trait	Root length (cm)		Root diameter (cm)		Root yield (ton/fad.)		Sucrose (%)		Sugar yield (ton/fad.)	
		2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
T1	S1	28.30	28.60	9.52	10.80	24.33	25.20	18.73	18.10	4.55	4.56
	S2	27.32	27.63	9.20	10.26	23.43	24.28	18.97	18.62	4.44	4.52
	S3	25.32	25.56	8.72	8.01	22.13	23.45	19.01	18.75	4.21	4.40
T2	S1	29.59	28.66	10.07	12.39	25.55	26.44	18.50	17.98	4.73	4.75
	S2	28.56	27.85	9.44	10.33	24.13	24.93	18.91	18.48	4.56	4.61
	S3	27.33	26.59	9.17	9.65	23.00	24.05	18.96	18.64	4.36	4.48
T3	S1	29.93	29.32	10.52	12.75	25.77	26.48	17.90	17.82	4.61	4.72
	S2	28.97	28.00	9.81	10.61	24.67	25.55	18.05	17.90	4.45	4.57
	S3	27.95	27.21	9.69	9.89	23.25	24.59	18.12	17.94	4.22	4.41
LSD 5%		**N.S**	**0.58**	**N.S**	**0.41**	**0.10**	**0.33**	**0.40**	**0.54**	**0.10**	**0.26**
Pure stand		30.88	30.29	10.2	10.31	26.57	27.24	17.75	17.33	4.71	4.72

T1: sowing sunflower at the same time of sugar beet, T2: sowing 21 days after sugar beet, T3: sowing 35 days after sugar beet

S1: 25% sunflower of its pure stand, S2: 33.3% sunflower of its pure stand, S3: 50% sunflower of its pure stand.

spatial and temporal complementarity, thus resulting in an overall increase in light intercepted by the system during a season (**Keating and Carberry, 1993**). Similar results were obtained by **Hassan (2007)** who found that delaying sowing date of the intercropping faba bean 45 days after sowing sugar beet increased all studied characters of sugar beet owing to reduced interspecific competition between the two species. Similarly, vertical diameter, horizontal diameter and single root yield of sugar beet were higher under lower plant population of the companion crop **(Abou-Elela, 2012; Usmanikhail *et al.*, 2012; Sheha *et al.*, 2017)**.

On the other hand, the highest values of sucrose (%) were gained by simultaneous sunflower with sugar beet (T1) under the highest plant density of sunflower (S3). While intercropping 25% of sunflower (S1) at 35 days later to sugar beet sowing (T3) produced the lowest sucrose (%). Interpretation of this criterion could be the weight and size of root rather than the effect of the sowing dates and intercropping systems of sunflower, where the higher root weight was the less sucrose (%). These results are in harmony with those obtained by **Hassan (2007) and Badr (2017).** The interaction effect of sowing dates and intercropping systems of sunflower on sugar yield/fad., had the same trend of individual factor. Where the highest sugar yield/fad., (4.73 and 4.75 ton/fad.) was produced by the T2 x S1 treatment, which had a moderate root weight/ fad., and sucrose (%). While the lowest sugar yield/ fad., (4.21 and 4.40 ton) was achieved with T1x S3, which had the lowest root yield/ fad. Similar results were obtained by **Hassan (2007) and Badr (2017)**.

Sunflower

Effect of sowing dates

Sunflower sowing dates had a significant effect on phenology traits *i.e.* days to 50% of flowering, days to maturity and growing degree days (GDD) as shown in Table 6.

Results presented in Table 6 show that late sowing date at T3 recorded the highest days to 50% flowering and maturity compared to T1 and T2 over the two growing seasons. Delaying of flowering may be due to the change of climate condition during this stage, the longtime taken to maturity was due to delay in flowering. These results are in accordance with those obtained by **Keshta and El-Baz (2004)** and are in complete agreement with findings of **Kaleem *et al.*, (2009)** who reported that crop growth duration was longer in autumn sowing than a spring sowing. This was obvious as high temperatures increase the rate of plant development and enhance flowering **(Ahmed *et al.*, 2015).** In contrary, the early sowing date (T1) exhibited the highest values of GDD (1298.59 and 1342.26) compared to T2 (1286.04 and 1284.95) and T3 (1258 and 1172.91) in first and second seasons, respectively. Total GDD decreased with delay in planting, as the late sown crop experienced lower temperatures during the growth period. These results are in agreement with those obtained by **Kaleem *et al.* (2011)** who detected that lower GDD is accumulated for autumn planting.

Results in Table 7 indicate that the early sowing date (T1) exhibited the highest values of plant height, head diameter and seed weight per plant compared to T2 and T3 during the two seasons. While the lowest values of the previously mentioned characters produced with delaying sowing date (T3). These results are in harmony with those obtained by **Kaleem *et al.* (2010)** who reported that plant height and other quantitative parameters decreased when it planted in late dates. These results are in agreement with the findings of **Ahmed *et al.* (2015) and Demir (2019).** However, early sowing date (T1) significantly decreased stem diameter compared to T2 and T3. This result may be attributed to early sowing date furnished favourable conditions for growth and hence produce the highest sunflower plants, which has the thinnest stem compared to plants sown at the late sowing date T3. An inversely proportional relationship was detected between plant height and stem diameter of sunflower, which is known to have a genetic origin **(Miller and Hammond, 1991)**.

Results in Table 8 show that sowing date of sunflower significantly affected 100 seed weight, seed yield/fad., oil (%) and oil yield /fad in both seasons.

The highest values of these traits were recorded at the first sowing date (T1) compared to delaying sowing date at T2 and T3. The reduction in seed and oil yields/fad., due to delaying sowing date of sunflower up to T3 compared to T1were 51.71 and 51.36% for seed and being 54.33 and 53.82% for oil yield in 2018/2019 and 2019/2020, respectively. The deficit of seed yield/fad., at delaying planting may be due to higher rainfall during peak flowering period that affecting pollen movement by obstructs bees movement resulted in presence large number of infertile seeds/head. The same conclusion was found by (**Sumangala and Giriraj 2003; Ahmed *et al.*, 2015 and Demir, 2019).** Delay of planting date significantly decreased seed yield of sunflower due to a decrease in number of seeds per head, seed weight plant^{-1} and 100 seed weight **(Baghdadi *et al.*, 2014).**

Significant differences in oil (%) were observed by sowing dates as shown in Table 8. Intercropping sunflower with sugar beet at T3 significantly decreased oil percentage compared to T1 and T2. This reduction related to climate conditions effect. Different sowing dates maybe give rise to flowering and seed development during periods of widely variable temperatures, radiation and day length that may lead to changes in seed oil content. **Ahmed *et al.* (2015)** noted that during the autumn season, the sunshine hours were shortened and the GDD accumulation decreased, leading to a decrease in the oil content. Similar results were obtained by **Demurin *et al.* (2000)**. **Demir (2019)** clarified that lower oil content accumulated when crops maturing at a lower temperature.

Effect of intercropping system

Results in Table 9 indicate that the intercropping systems had an insignificant effect on phenology traits *i.e.* days to 50% of flowering, days to maturity and growing degree days in both seasons. Which indicated that these traits were affected by climate condition and sowing date during the growth stage. Results herein are in agreed with those obtained by **Khan and Akmal (2014)** they found that 1:1 and 1:2 row intercropping of sunflower and mung bean did not show any statistical ($p<0.05$) differences in days to emergence, flowering and maturity of mung bean.

Table 6. Days to 50% of flowering, maturity date and growing degree days (GDD) of sunflower as affected by sowing dates during 2018/2019 and 2019/2020 seasons

Trait / Sowing date	Days to 50% of flowering		Maturity date		Growing degree days (GDD)	
	2018/19	**2019/20**	**2018/19**	**2018/19**	**2019/20**	**2018/19**
T1	56.00	58.33	97.33	96.75	1298.59	1342.26
T2	75.75	79.00	122.25	124.91	1286.04	1284.95
T3	124.41	127.66	140.66	141.66	1258.0 0	1172.91
LSD at 5%	**3.26**	**2.98**	**4.82**	**6.02**	**9.20**	**11.34**

T1: sowing sunflower at the same time of sugar beet, T2: sowing 21 days after sugar beet, T3: sowing 35 days after sugar beet

Table 7. Plant height, stem diameter, head diameter and seed weight/plant of sunflower as affected by sowing dates during 2018/2019 and 2019/2020 seasons

Trait / Sowing date	Plant height (cm)		Stem diameter (cm)		Head diameter (cm)		Seed weight/plant (g)	
	2018/19	**2019/20**	**2018/19**	**2019/20**	**2018/19**	**2019/20**	**2018/19**	**2019/20**
T1	162.66	171.33	1.94	1.85	23.50	23.15	65.07 a	65.12 a
T2	160.22	164.39	2.17	2.16	22.00	22.17	60.21 b	62.50 b
T3	152.55	149.66	2.66	2.60	20.68	21.07	28.95c	31.99 c
LSD at 5%	**4.86**	**3.45**	**0.18**	**0.12**	**0.07**	**1.05**	**4.78**	**0.37**

T1: sowing sunflower at the same time of sugar beet, T2: sowing 21 days after sugar beet, T3: sowing 35 days after sugar beet

Table 8. Hundred seed weight, seed yield/fad., oil (%) and oil yield/fad., of sunflower as affected by sowing dates during 2018/2019 and 2019/2020 seasons

Trait / Sowing date	100 seed weight (g)		Seed yield (kg/fad.)		Oil (%)		Oil yield (kg/fad.)	
	2018/19	**2019/20**	**2018/19**	**2019/20**	**2018/19**	**2019/20**	**2018/19**	**2019/20**
T1	7.41	7.28	565.91	551.55	38.60	39.08	219.04	216.00
T2	6.92	6.88	537.62	547.14	38.28	38.76	206.19	212.61
T3	3.32	3.23	273.27	268.30	36.62	37.16	100.03	99.74
LSD at 5%	**0.41**	**0.23**	**30.84**	**31.94**	**0.42**	**0.40**	**12.65**	**12.46**

T1: sowing sunflower at the same time of sugar beet, T2: sowing 21 days after sugar beet, T3: sowing 35 days after sugar beet

Table 9. Days to 50% of flowering, maturity date and growing degree days (GDD) of sunflower as affected by sunflower intercropping systems during 2018/2019 and 2019/2020 seasons

Intercropping system	Days to 50% of flowering		Maturity date		Growing degree days (GDD)	
	2018/19	2019/20	2018/19	2018/19	2019/20	2018/19
S1	85.00	88.16	119.91	120.91	1282.32	1264.49
S2	85.25	88.83	119.75	121.08	1279.75	1265.49
S3	85.91	88.00	120.58	121.33	1280.55	1269.86
LSD at 5%	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**
Pure stand of sunflower at different sowing dates						
T1	55.25	57.00	96.50	96.25	1298.59	1342.26
T2	76.75	78.50	121.50	121.25	1286.04	1284.95
T3	123.75	127.50	140.00	141.25	1258.00	1172.91

S1: 25% sunflower of its pure stand, S2: 33.3% sunflower of its pure stand, S3: 50% sunflower of its pure stand.

Intercropping sunflower with sugar beet at different intercropping system, significantly affected plant height, stem diameter, head diameter and seed weight plant-^{1}in both seasons (Table 10).

Results revealed significant increases in plant height of sunflower by increasing plant density up to S3 (100% sugar beet + 50% sunflower) compared with S1 (100%sugar beet + 25% sunflower) and S2 (100% sugar beet + 33.3% sunflower) over the two seasons. However, a pure stand of sunflower had the highest plant height over than other intercropping systems. This increase may be due to an increase in intraspecific competition on solar radiation. Same results were found by **Osman and Awad (2010), Mohammed and Abd-El-Zaher (2013)** and **Sheha *et al.* (2017)**. Meanwhile, stem diameter behaved the opposite trend of plant height. This could be attributed to the fact that plants strive for more solar radiation under high plant densities. Stem elongation is one of the mechanisms used by plants to increase the possibility of capturing more solar radiation (**Chang, 1974**).

Also results presented in Table 10 indicate that the highest value for each of head diameter and seed yield per plant were achieved by S1 (25% sunflower of its pure stand), while the lowest values obtained with S3 (50% sunflower) in both seasons. Even if, all intercropping system superior to pure stand of sunflower for stem diameter, head diameter and seed weight per plant This may be attributed to better environmental conditions under S1, which had less competition between plants as well as increase light penetration within plant canopy which increased assimilation rate of sunflower. These results are in agreement with finding by **Mohammed and Abd-El-Zaher (2013), Baghdadi *et al.* (2014) and Sheha *et al.* (2017)**.

Results in Table 11 indicate that the intercropping system significantly affected 100 seed weight, seed and oil yield/fad., and oil% of sunflower in both seasons.

The heaviest 100 seed weight (6.35 and 6.11g) were produced under intercropping system S1 (25% sunflower of its pure stand), while, the lowest values (5.46 and 5.37 g) were produced with the intercropping systems 50% of sunflower (S3), *vice versa* for oil (%) in both seasons. This reduction in 100 seed weight under S3 could be attributed to sever intraspecific competition between sunflower plants on environmental resources. However, intercropping sunflower at S3 (50% sunflower) significantly increased seed yield by 67.69 and 43.57% in the first season and 69.62 and 43.92% in the second season over than S1 and S2, respectively. However, the pure stand of sunflower outyielded seed yield/fad.,

Table 10. Plant height, stem diameter, head diameter and seed weight/plant of sunflower as affected by sunflower intercropping systems during 2018/2019 and 2019/2020 seasons

Trait / Sowing date	Plant heigh (cm)		Stem diameter (cm)		Head diameter (cm)		Seed weight/plant (g)	
	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
S1	154.22	156.28	2.46	2.33	23.07	23.00	56.00	55.08
S2	157.10	157.11	2.22	2.16	22.58	22.31	53.28	53.59
S3	164.11	171.99	2.09	2.12	20.54	21.08	44.95	50.95
LSD at 5%	**4.54**	**6.90**	**0.15**	**0.19**	**0.19**	**0.98**	**3.01**	**0.62**
Pure stand of sunflower at different sowing dates								
T1	173.33	169.83	1.93	2.07	20.98	22.40	53.10	52.30
T2	157.00	164.42	1.92	2.11	19.67	21.00	38.07	37.51
T3	154.93	156.67	2.06	2.17	19.00	20.13	22.93	22.83

S1: 25% sunflower of its pure stand, S2: 33.3% sunflower of its pure stand, S3: 50% sunflower of its pure stand.

Table 11. Hundred seed weight, seed yield/fad., oil (%) and oil yield/fad of sunflower as affected by sunflower intercropping systems during 2018/2019 and 2019/2020 seasons

Trait / Sowing date	100 seed weight (g)		Seed yield (kg/fad.)		Oil (%)		Oil yield (kg/fad.)	
	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
S1	6.35	6.11	358.09	350.21	37.45	37.90	135.21	136.12
S2	5.85	5.92	418.24	412.74	37.93	38.37	159.14	160.42
S3	5.46	5.37	600.47	594.04	38.12	38.73	230.92	231.57
LSD at 5%	**0.56**	**0.34**	**22.29**	**19.82**	**0.39**	**0.36**	**10.52**	**8.00**
Pure stand of sunflower at different sowing dates								
T1	7.60	7.13	1255.08	1207.91	39.46	39.51	495.25	477.25
T2	5.71	5.38	1190.91	1179.76	38.21	38.32	455.05	452.08
T3	2.99	3.08	937.13	845.32	37.37	37.73	350.21	318.94

S1: 25% sunflower of its pure stand, S2: 33.3% sunflower of its pure stand, S3: 50% sunflower of its pure stand.

compared to three intercropping systems irrespective sowing date, during the first and second seasons. These results may be due to the increase of sunflower plants per unit area. Similar findings were sole sunflower gave higher seed yield than intercropped one which was mostly resulted from the higher number of plant population in the sole stand than intercropping (**Enan *et al.*, 2013; Mohammed and Abd-El-Zaher, 2013; Sheha *et al.*, 2017**). The same trend was found for oil yield/fad., which gradually increased by increasing plant density from S1 to S3 as a result of increased seed yield due to a positive linkage between seed yield and oil yield. A similar result was obtained by **Enan *et al.* (2013) and Sheha *et al.* (2017)**.

Interaction effects

Results in Table 12 reveale that the two previous factors understudied had a significant effect on plant height, seed weight plant^{-1}, seed yield/fad., oil (%) and oil yield/fad., of sunflower in both seasons. Increasing plant density of sunflower in the intercrop system S3 at first sowing date (T1) resulted in increased sunflower plant height (166 and 184 cm) during both seasons. For seed weight plant^{-1} the highest values were obtained with T1 at 25% of plant density of sunflower (S1) in both seasons. Seed yield/fad., oil (%) and oil yield/fad., showed the highest values when 50% of sunflower plants were intercropped simultaneously with sugar beet (T1) in both seasons. While the lowest values of these characters were obtained when delaying sunflower sowing date up to T3 under intercropping system S1 during the two seasons, except seed weight plant^{-1}. Which recorded the lowest values when planted sunflower by 50% of its pure stand at T3. These reductions could be attributed to unfavourable condition to growth and development sunflower plants belong with a low plant density of sunflower, where seed and oil yields/fad., positively correlated with increasing plant density per unit area. Similar results were obtained by **Mohammed and Abd-El-Zaher (2013) and Sheha *et al.* (2017)**.

Competitive Relationships

Land equivalent ratio (LER)

Results in Table 13 show that all intercropping systems of sunflower with sugar beet irrespective sowing date clear increased LER than the 1.0 in both seasons. That indicated intercropping sunflower into sugar beet achieved yield advantage and increase land use by about 17 to 44 % in the first season and by 17 to 47% in the second season. Also, results pointed out that relative yield of sugar beet crop (RY_{sug}) was higher than the relative yield of sunflower crop (RY_{sun}). This result could be attributed to plant density of sugar beet was 100% of its pure stand, while the plant density of sunflower ranged from 25, 33.3 up to 50% of its pure stand. The highest LER values (1.44 and 1.47) were obtained by sowing 50% of sunflower plants at 21 days later of sugar beet, followed by 25% of sunflower at T2 were 1.42 and 1.45 during 2018/2019 and 2019/2020 season, respectively. This means that land usage ratio increased by 44% and 47% compared to growing sugar beet in pure stand. While the lowest values of LER 1.17 was shown with S1 (100% sugar beet +25% sunflower) at the third date (T3) in both season. Many researchers found similar results such as **Usmanikhail *et al.* (2012), Mohammed and Abd-EL-Zaher (2013) and Sheha *et al*. (2017)**.

Area time equivalent ratio

In all the treatments, the ATER values were less than LER values indicating the overestimation of resource utilization (Table 13). The reduction in ATER values to less than the unit in most cases indicating loss rather than yield advantage. In general, the highest ATER values were 1.26 and 1.29, in the first and second season, respectively, which achieved by intercropping system S3 (100% sugar beet +50% sunflower) at the second sowing date (T2). Whereas, the lowest ATER values (1.10 and 1.11) were produced by intercropping 33.3% of sunflower with sugar beet in the first date (T1) in first and second season, respectively. Similar results were reported by **Mohammed and Abd-El-Zaher (2013) and Sheha *et al.* (2017)**.

Relative crowding coefficient (RCC)

Results in Table 13 indicate that relative crowding coefficient (RCC) were more than one and this means that all treatments achieved yield advantages than solid planting of sugar beet. The best RCC values were obtained by sowing sunflower 21 days later of sugar beet (T2) at 25% of it pure stand (S1), which were 14.84 and 20.11 in the first and the second season, respectively.

Table 12. Plant height, seed weight/plant, seed yield/fad., oil (%) and oil yield/fad of sunflower as affected by the interaction effect of sowing dates and sunflower intercropping systems during 2018/2019 and 2019/2020 seasons

Interaction	Trait	Plant height (cm)		Seed weight/ plant (g)		Seed yield/fad. (kg)		Oil (%)		Oil yield/fad. (kg)	
		2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
	S1	161.33	163.00	70.00	66.66	446.55	453.10	38.08	38.36	170.05	173.81
T1	S2	162.66	166.33	68.94	65.10	515.31	491.01	38.50	39.33	198.39	193.11
	S3	166.00	184.66	56.27	63.62	735.87	710.53	39.23	39.56	288.68	281.09
	S1	156.33	163.86	66.49	64.97	443.03	446.23	38.09	38.38	168.75	171.26
T2	S2	162.00	162.33	60.78	61.82	486.12	499.55	37.92	38.39	184.34	191.78
	S3	162.33	167.00	53.36	60.72	683.72	695.64	38.83	39.50	265.49	274.78
	S1	145.00	142.00	31.52	33.61	184.70	171.29	36.18	36.95	66.82	63.29
T3	S2	146.65	142.66	30.13	33.85	253.29	257.67	37.38	37.40	94.68	96.37
	S3	164.00	164.33	25.21	28.51	381.81	375.95	36.30	37.12	138.60	139.55
LSD at 5%		**7.86**	**11.95**	**5.21**	**1.07**	**36.61**	**34.33**	**0.67**	**0.62**	**18.22**	**13.85**

T1: sowing sunflower at the same time of sugar beet, T2: sowing 21 days after sugar beet, T3: sowing 35 days after sugar beet

S1: 25% sunflower of its pure stand, S2: 33.3% sunflower of its pure stand, S3: 50% sunflower of its pure stand

Table 13. Competitive relationship affected by the interaction effect between sowing dates and intercropping systems of sunflower during 2018/2019 and 2019/2020 seasons.

Sowing Date	Inter. System	RY_{sug}	RY_{sun}	LER	ATER	K_{sug}	K_{sun}	K	A_{sug}	A_{sun}
						2018/2019				
	S1	0.92	0.36	1.27	1.11	2.72	2.21	6.00	-0.63	0.63
T1	S2	0.88	0.41	1.29	1.10	1.49	3.49	5.20	-1.56	+1.56
	S3	0.83	0.59	1.42	1.15	2.47	2.86	7.06	-0.53	+0.53
	S1	0.96	0.37	1.33	1.21	6.26	2.37	14.84	-0.66	+0.66
T2	S2	0.91	0.41	1.32	1.19	1.97	3.46	6.82	-1.51	+1.51
	S3	0.87	0.57	1.44	1.26	3.19	2.72	8.68	-0.44	+0.44
	S1	0.97	0.20	1.17	1.12	8.05	0.98	7.91	0.08	-0.08
T3	S2	0.93	0.27	1.20	1.14	2.59	1.86	4.81	-0.57	+0.57
	S3	0.88	0.41	1.28	1.19	3.47	1.39	4.81	0.23	-0.23
						2019/2020				
	S1	0.92	0.38	1.30	1.13	3.09	2.24	6.90	-0.64	+0.64
T1	S2	0.89	0.41	1.30	1.11	1.64	3.32	5.43	-1.47	+1.47
	S3	0.86	0.59	1.45	1.18	3.06	2.89	8.84	-0.49	+0.49
	S1	0.97	0.38	1.35	1.23	8.26	2.43	20.11	-0.68	+0.68
T2	S2	0.92	0.42	1.34	1.21	2.15	3.68	7.93	-1.61	+1.61
	S3	0.88	0.59	1.47	1.29	3.73	2.90	10.38	-0.46	+0.46
	S1	0.97	0.20	1.17	1.13	8.71	1.02	8.85	0.20	-0.20
T3	S2	0.94	0.30	1.24	1.18	3.02	2.20	6.63	-0.78	+0.78
	S3	0.90	0.44	1.34	1.25	4.59	1.62	7.43	0.01	-0.01

T1: sowing sunflower at the same time of sugar beet, T2: sowing 21 days after sugar beet, T3: sowing 35 days after sugar beet

S1: 25% sunflower of its pure stand, S2: 33.3% sunflower of its pure stand, S3: 50% sunflower of its pure stand

This indicated the high yield advantage due to intercropping sunflower at 25% with sugar beet after 21 days from sugar beet sowing. These results are in harmony with those obtained by **Sheha *et al.* (2017)**.

Aggressivity (A)

Results in Table 13 show that the component crops did not compete equally and the highest numerical value, the larger differences in competitive abilities. Also, results cleared that sugar beet had a negative sign while sunflower had a positive sign in all intercropping systems at T1and T2. This indicated that sunflower was the dominant crop while sugar beet was the dominated. The opposite trend was observed at T3 with intercropping systems S1 and S3. Interpretation of this criterion could be sunflower plants can acquire more resources than that sugar beet under T1 and T2 compared T3 with S1 and S3. These results are in a harmony with those obtained by **Sheha *et al.* (2017) and Bader (2017).**

Economic Evaluation

Economic evaluations of intercropping sunflower with sugar beet as compare with sole sugar beet are illustrated in Table 14. Concerning total gross return, the highest value (17547 LE) was recorded with sowing sunflower 21 days after sugar beet (T2) under the intercropping system S3 (50% sunflower), followed by 17485 LE with S1 (25% sunflower) with sowing date T2. These two intercropping systems increased total gross return by 14.42 and 14.01% compared with sole sugar beet, respectively. Increase plant density of sunflower from 25 up to 33.3 and 50% increased total cost by 4.15, 5.52 and 8.32% over sole sugar beet, respectively. Meanwhile, the highest net return was produced by intercropping 25% of sunflower (S1) with sugar beet at sowing date T2, which was 8033 LE/fad., and increased net return by 28.30% over sole sugar beet. In general, intercropping sunflower with sugar beet increased net return compared with sole planting of sugar beet, except the last sowing date (T3) with S3 reduced net return by 2.92% as the average of both seasons. These results may be due to the third sowing date (T3) had the lowest sunflower yield/fad., compersion to T1 and T2. This result indicated that unfavourable climate condition at T3 resulting in reduced flowering, seed fertility and seed yield/fad., for sunflower. The intercropping system like sugar beet with oilseeds could provide the farmer with high gross returns **(Usmanikhail *et al.*, 2012; Enan *et al.*, 2013; Badr, 2017).** Similar results were obtained by **Sheha *et al.* (2017)** who stated that sugar beet/sunflower combination considerably increases monetary returns.

Table 14. Gross and net return affected by the interaction effect between sowing dates x intercropping systems of sunflower as the average of both seasons

		Gross return (LE/fad.) of		Total gross return	Total cost	Net return
		Sugar beet	**Sunflower**			
T1	**S1**	14116	2639	16755	9452	7303
	S2	13597	2989	16586	9576	7010
	S3	12990	4339	17330	9830	7500
T2	**S1**	14817	2668	17485	9452	8033
	S2	13982	2957	16939	9576	7363
	S3	13409	4138	17547	9830	7718
T3	**S1**	14891	1068	15959	9452	6507
	S2	14313	1533	15846	9576	6269
	S3	13634	2273	15908	9830	6078
Sole sugar beet		**15336**	**-**	**15336**	**9075**	**6261**

T1: sowing sunflower at the same time of sugar beet, T2: sowing 21 days after sugar beet, T3: sowing 35 days after sugar beet

S1: 25% sunflower of its pure stand, S2: 33.3% sunflower of its pure stand, S3: 50% sunflower of its pure stand

Conclusion

Based on the wide range of sunflower to withstand different climatic conditions and its ability to grow with other crops, so we can summarize that sunflower can be intercropping with sugar beet and share inputs to maximizing oil production, farmer's net return and land productivity, without significant reduction in sugar beet yield/fad. Under the northern delta conditions, the intercropping system of 100% sugar beet + 50% (S3) sunflower by sowing sunflower at 21 days later of sugar beet (T2) produced the highest land equivalent ratio 1.44 and 1.47. Even if, S1 (100% sugar beet + 25% sunflower) at sowing date T2 had the highest sugar yield 4.74 ton/fad., relative crowding coefficient 17.47 and net return 8033 LE/fad., as well as produced 26.10 ton sugar beet plus 444.63kg seed of sunflower per fad compared to sole sugar beet 26.91 ton root and net return 6261 LE per fad. From this study, it can be recommended implemented 25% of sunflower intercropping with sugar beet after 21 days from sowing sugar beet to increased net return by 28.30% over sole sugar beet and increase oil production without significant effect on sugar beet.

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تأثير ميعاد الزراعة ونظام التحميل لدوار الشمس مع بنجر السكر على إنتاجية كلا المحصولين

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أجريت تجربة حقلية بمحطة بحوث إيتاى البارود- مركز البحوث الزراعية خلال موسمى النمو 2019/2018 و2020/2019، وذلك لدراسة تأثير ميعاد زراعة دوار الشمس المحمل على بنجر السكر (فى نفس ميعاد زراعة البنجر (T1)، بعد21 يومًا من زراعة البنجر (T2)، بعد 35 يومًا من زراعة البنجر (T3) وثلاثة نظم لتحميل دوار الشمس على (الخط الرابع والثالث والثانى لبنجر السكر، بنسبة 25، 33.3 و 50% من الكثافة النباتية لدوار الشمس، على التوالى) لزيادة إنتاج الزيت والمكافئ الأرضى ودخل المزارع تحت ظروف شمال الدلتا، محافظة البحيرة، مصر، استخدم تصميم القطع الشقية split-plot حيث وزعت مواعيد الزراعة على القطع الرئيسية ونظم التحميل على القطع الشقية مع إستخدام أربع مكررات وكانت أهم النتائج المتحصل عليها: تأثرت جميع صفات بنجر السكر المدروسة معنويا بمواعيد ونظم زراعة دوار الشمس، سجلت أعلى القيم لمحصول بنجر السكر ومكوناتة بزراعة 25% من دوار الشمس بعد 35 يومًا من زراعة بنجر السكر، بينما أدى زراعة دوار الشمس فى نفس ميعاد بنجر السكر وبأعلى كثافة نباتية (50%) إلى إنخفاض محصولى الجذور والسكر/فدان، أدت الزراعة المبكرة لدوار الشمس إلى التبكير فى فترة التزهير والنضج، كماسجلت أعلى القيم من درجات أيام النمو (GDD) ومحصول دوار الشمس ومكوناتة، أثرت نظم التحميل معنوياً على الصفات المدروسة لدوار الشمس فيما عدا فترة التزهير والنضج وGDD، سجلت الزراعة المنفردة أعلى محصول للفدان من البذرة والزيت، يليها نظام التحميل الثالث (100% بنجر سكر + 50% دوار شمس) مع زراعة دوار الشمس فى نفس ميعاد زراعة البنجر، سُجلت أعلى القيم للمكافئ الأرضى (1.46) بزراعة دوار الشمس بعد 21 يوم من زراعة بنجر السكر(T2) وبكثافة نباتية 50%، يعقبها زراعة الدواربنسبة 25% فى الميعاد الثانى T2 (1.44)،متوسط الموسمين، بينما سُجل أعلى معامل حشد نسبى وصافى دخل للفدان مع T2 وكثافة نباتية 25% من الزراعة المنفردة لدوار الشمس، كان محصول دوار الشمس هوالسائد عند الزراعة المبكرة T1 وT2، الخلاصة: تحميل دوار الشمس بنسبة 25% على الخط الرابع لبنجر السكر بعد 21 يومًا من زراعة بنجر السكر (T2) أدى إلى زيادة الإنتاج من دوار الشمس لتقليل الفجوة الغذائية من محاصيل الزيت مع زيادة صافى الدخل للمزارع بنسبة 28.30%، حيث حقق الفدان 26.10 طن بنجر سكر و444.63 كجم بذور مقارنة بالزراعة المنفردة لبنجر السكر 26.91 طن بنجر، كمتوسط الموسمين.

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