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Performance of Sunflower cv. Sakha-53 as Influenced by Accumulated Heat Units under Different Sowing Dates and Plant Spacing at Aswan Conditions

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ABSTRACT

The present study was carried out during the two seasons of 2019 and 2020 at the Experimental Farm of Faculty of Agriculture and Natural Resources , Aswan University, to estimate the crop phenology and vegetative growth, yield and thermal indices of sunflower *cv*. Sakha-53 under four sowing dates *i.e.* (SD_1: 1st July, SD_2: 15th July, SD_3: 1st August and SD_4: 15th August) and four plant spacing (P_1: 15 cm, P_2: 20 cm, P_3: 25 cm and P_4: 30 cm with constant width, 60 cm). The results refer to significant influences of sowing date, plant spacing and their interaction for all studied traits across both seasons.

Early sowing date on 1st July significantly increased thermal indices and the seed yield associated with as increase of other studied traits. With regard to plant spacing, increasing plant spacing from 15, 20, 25, and up to 30 cm recorded increase gradually of crop phenology, number of leaves plant^{-1}, leaf area plant^{-1}, stem diameter, head diameter, 1000-seed weight, seed weight plant^{-1}, daily seed weight plant^{-1}, growing degree days (GDD) and heliothermal units (HTU) while narrow spacing at 15 cm produced the tallest plants , heaviest seed, oil yield, highest heliothermal use efficiency (HTUE), heat use efficiency (HUE) and photothermal index(PTI). The interaction among sowing dates and plant spacing had a significant effect on all studied traits, revealing that the heaviest seed yield (1300 and 1327 kg fed^{-1}) was produced from the interaction of $SD_1 \times P_1$ in both seasons.

KEYWORDS: Aswan, Sunflower, Thermal indices, Sowing date, Plant spacing, Growth, Yield, Quality.

1. INTRODUCTION

Oilseed crops constitute a major part of nutrition in globally, the sunflower is one of the four important annual crops in the world for edible oil which belongs to the family Compositae. It is mostly native to North America, but it extensively planted in India, Russia and Egypt as a food source. Sunflower seed contains good quality oil from 34 to 52% and a high amount of protein about 14% (Rosa *et al*., 2009). Furthermore, the oil-containing about 55-65% of linoleic acid, 20-30 % oleic, variable amounts of vitamins K, E, D, and A and other fatty acids (Joksimovic *et al*., 2006). In Egypt, sunflower is a crop of choice for farmers due to its adaptability to various types of soils and climate conditions, high yield potential, it can be sown in two successive crop rotations because of its short growing seasons. Sunflower area gained cultivation in Egypt in 2019 was about 16.660 fed produced 21.000 tons with the average productivity of 1.26 ton fed^{-1} (FAOSTAT, 2019). The growing degree days (GDD) is a simple tool to estimate the relationship among plant growth and development which is depends on the accumulation of heat. Accumulated maximum GDD and higher seed yield, larger head diameter, and more number of seed head^{-1} due to sunflower sowed on 11th July (Qadir *et al.,* 2007). Sowing dates are a standout amongst the most fundamental agronomic variables that can play a major role in determining the seed yield especially in regions with a short growing season. In other words, sowing date is a very important advantage of growth and productivity of sunflower to cope changing climatic scenario (Shafiullah *et al*., 2018). Different sowing dates depend on different environmental conditions from emergence to maturity are based on the temperature prevailing through the crop life cycle (Kaleem *et al*., 2011). Several research studies for different climates have shown that sowing date affects the growth, yield, and quality of sunflowers (Abu Anga *et al*., 2019, Ahmed *et al*., 2020 and Hemeid & Zeid, 2020). The earlier sowing date on (17th September) significantly accelerated days to 50% of flowering and maturity date and recorded the highest values of GDD and seed yield and its components than later sowing on 22nd October (Mourad and El-Mehy, 2021).

Using optimum plant density is an important tool to take advantage of essential growth elements such as light, water, air, nutrients, etc. Earlier maturity, reduced cost of weed control and ensure maximum utilization of solar energy by the crop and reduces evaporation of soil moisture, thus increase of crop. Widely sown crop required slightly more accumulated growing degree days compared to closely sown for attaining physiological maturity (Dhillon *et al*., 2017).

Li *et al*. (2019) exhibited that the maximum diameter of stem and head both decreased with an increase in plant density, due to the interplant competition for resources such as nutrients, water, sunshine, while plant height and seed yield increased with increasing sunflower density. Ali *et al.* (2014) and Abd EL-Satar *et al*. (2017) discovered that the wider spacing of sunflower plants produces higher values in 1000-seed weight and seed yield plant^{-1} as compared with the narrow one. The highest growth, yield and seeds oil% of sunflower were recorded under the highest plant density (11.11 plants m^{-2}) used in this experiment (Fakirah *et al*., 2017). Demir (2020) attainted that the increase in plant density (narrow spaces) caused taller plant height and highest yield (2759.9 kg ha^{-1}), but decreased stem thickness, head diameter, 1000-seed weight, number of seeds head^{-1}, seed weight of plant^{-1}, crude oil ratio and number of days to maturity. Otherwise, the lowest yield (1341.9 kg ha^{-1}) was obtained at decrease plant density (wider spaces). Singh and Parajuli, (2020) demonstrated that the effect of three different seed rates i.e. 8, 10, and 12 kg ha^{-1} on yield and yield components, the results showed that the plants receiving 8 kg fed^{-1} gained the highest values of stem diameter, head diameter, and 1000-grain weight, but, the highest seed yield (2.13 ton ha^{-1}) was obtained from 10 kg ha^{-1} seed rate. This investigation was carried out to study the effect of thermal indices through sowing dates and plant spacing on the growth, yield, and quality of sunflower productivity under Aswan conditions.

2. MATERIALS AND METHODS

2.1. Description of experimental site

The present study was conducted during the 2019 and 2020 seasons at the Experimental Farm of Agriculture and Natural Resources Faculty, Aswan University, Aswan Governorate (23°59' 49" N Lat. and 32°51' 41" E Long.) to study the effect of sowing dates and plant spacing on growth, yield and quality of sunflower *cv*. Sakha-53 under environmental disparity to Aswan Governorate. This cultivar was provided by the Oil Crops Research Section, Field Crops Research Institute, ARC-Giza. The experiments were laid out under a drip irrigation system. The soil physical and chemical properties of the experimental area during the two growing seasons the 2019 and 2020 are presented in Table 1.

Table 1. Soil physical and chemical analysis of the experimental site during 2019 and 2020 seasons.

Soil properties	Physical properties				Chemical properties					
	Clay (%)	Silt (%)	Sand (%)	Soil texture	OM (%)	pH	EC (ds m^{-1})	Available NPK: Total N%	P (ppm)	K (ppm)
2019	3.02	2.28	94.70	Sandy	0.09	8.25	0.25	0.08	8.00	175
2020	3.07	2.26	94.67	Sandy	0.09	8.24	0.26	0.08	7.89	176

2.2. Weather data

Meteorological data of the experimental site was obtained from the Center Laboratory for Agricultural Climate (CLAC), Agricultural Research Center, Egypt , then calculated GDD or heat unites as described in Table 2.

2.2.1. Various measurements of accumulated heat units or thermal indices were calculated as follows:

1- Cumulative growing Degree Days (GDD) = ∑ [(Tmix + Tmin) / 2 – Tbase] (°C day). (Singh and Gupta, 2002)

2- Heliothermal unit (HTU) = GDD × duration of sunshine hours (ºC day hour). (Rajput, 1980)

3- Heliothermal use efficiency (HTUE) = Seed yield ÷ HTU (kg fed-1 ºC^{-1}). (Rajput, 1980)

4- Heat use efficiency (HUE) = Seed yield ÷ GDD (kg fed-1 ºC^{-1} day^{-1}). (Rajput, 1980).

5- Phenothermal index (PTI) = GDD ÷ Growth days (ºC day duration). (Haider et al., 2003)

Where:

- T mix. & T min. were daily maximum and minimum air temperature.
- Tbase = is 8 ºC base temperature for sunflower development (Sadras and Hall, 1988) the temperature below which no growth takes place (=zero points of growth).

2.3. Layout and Experimental design

The treatment combinations were arranged in a (RCBD) across split-plot experiment in with three replications as follows:

1- The main-plots were sowing dates (SD): four sowing dates were grown in every season on 1st July (SD$_1$), 15th July (SD$_2$), 1st August (SD$_3$) and 15th August (SD4).

2- The sub-plots were plant spacing cm (P): four plant spacing ***viz***, P$_1$= 15 cm (46.667 plant

Table 2. Weather data through the sunflower growing period in 2019 and 2020 seasons.

Months	Air temperature °C			GDD	RH	Sunshine	Air temperature °C			GDD	RH	Sunshine
	Max.	Min.	Mean		(%)	(hour)	Max.	Min.	Mean		(%)	(hour)
	2019						2020					
July	41.96	26.61	34.29	814.99	17.42	13.45	41.56	26.36	33.96	804.76	18.51	13.44
August	41.78	26.91	34.35	816.85	20.16	12.95	41.37	26.42	33.90	802.90	20.83	12.94
September	40.00	24.06	32.03	720.90	21.58	12.29	42.70	26.11	34.41	792.30	18.24	12.27
October	36.51	21.17	28.84	646.04	25.97	11.60	38.61	22.78	30.70	703.70	22.06	11.58
November	28.77	14.74	21.76	412.80	36.67	11.00	27.75	13.73	20.74	382.20	38.08	10.98
December	24.33	9.48	16.91	276.21	40.13	10.68	26.88	11.95	19.42	354.02	36.90	10.68

Mam.=Maximum, Min.=Minimum, RH=Relative humidity and GDD= Cumulative growing degree days

fed^{-1}), P_2= 20 cm (35.000 plant fed^{-1}), P_3= 25 cm (28.000 plant fed^{-1}) and P_4= 30 cm (23.333 plant fed^{-1}) on one side of the ridge (60-cm width), with one plant hill^{-1}.

3- The experimental plot area was 15 m^2 included 5 rows each of 5m length and 60-cm width between rows.

2.4. Agricultural practices

Sunflower seeds *cv*. Sakha-53 was sown manually and plants thinned to one plant hill^{-1} after 15th days from sowing. During soil preparation cultivation was added organic manure at a rate of 20 m^3 fed^{-1}. An applied dose was 45:150:50 kg N, P_2O_5, and K_2O fed^{-1} in the form of ammonium nitrate (33.5 % N), calcium superphosphate (15.5 % P_2O_5) and potassium sulphate (48 % K_2O), respectively. At soil preparation, P and K were applied in one dose directly, whereas N was applied at three equal doses *i.e.* the first after thinning and the other doses every 15 days as a solution with irrigation. All the agriculture practices were carried out as recommended for sunflower growing in sand soil under conditions of Aswan Governorate. After the pollination process, the heads were covered to prevent bird attacks. The harvesting date and season duration (days) for each sowing date are shown in Table 3.

Table 3. Sowing, harvesting dates and season duration during the two growing seasons 2019 and 2020.

Sowing dates	Harvesting date		Season duration (day)	
	2019	2020	2019	2020
1st July	27 September	28 September	89	90
15th July	8 October	8 October	84	84
1st August	19 October	20 October	80	81
15th August	1 November	1 November	77	77

2.5. Studied characters

The following traits were measured:

2.5.1. Crop phenology and vegetative growth traits:

1. Number of days from sowing to 50% flowering: It was determined by taking daily visual observations when 50% of the plants had opened flowers from each experimental unit.
2. Date of physiological maturity: It was recorded by taking daily visual observations when 75% of the heads from each experiment unit had changed to yellow color.
3. Vegetative growth traits: Ten plants of each experimental unit were taken randomly to measure some vegetative growth traits at 55 days after planting i.e. plant height (cm), number of leaves plant^{-1} and leaf area plant^{-1} (cm^2).

LA: area of green leaves plant^{-1} was determined using the following formula according to Schneiter (1978): LA= [(L×W) × 0.6684] – 2.45
Where: L and W = Maximum length and width of the leaf, respectively.

2.5.2. Yield attributes:

At harvest, ten guarded plants from each sub-plot were taken randomly to determine stem diameter (cm), head diameter (cm), 1000-seed weight, seed weight plant^{-1} and daily seed weight plant^{-1}.

Daily seed weight plant^{-1} was calculated by the following equation:
Daily seed weight plant^{-1}= seed weight plant^{-1} ÷ days to maturity.

2.5.3. Seed and oil yield traits:

1. Seed yield (kg fed^{-1}): plants in the sub-plot were harvested dried threshed and seeds were weighed and converted to yield kg fed^{-1}.

2. Oil yield (kg fed^{-1}): Oil yield fed^{-1} = seed yield (kg fed^{-1}) × Oil %

2.5.4. Quality traits:

1. Seed oil percentage: was estimated by using the Soxhlet apparatus according to A.O.A.C. (2000).
2. Protein percentage: was determined by according to A.O.A.C. (2000).

2.6. Statistical analysis:

Data were statistically analyzed according to procedures outlined by Gomez and Gomez (1984) by the MSTAT-C Computer program. Comparison among treatments means was done by least significant difference (LSD) procedures at 5% level of probability.

3. RESULTS AND DISCUSSION

The results of the study were presented under the following classes:

3.1. Effect of sowing dates:

3.1.1. Crop phenology and vegetative growth traits:

Temperature is one of the most important environmental factors which affects the growth and development of the sunflower plant. Data presented in Table (4) revealed that all crop phenology and vegetative growth traits were influenced significantly by different studied sowing dates in the two seasons. Delaying sowing date to 15th August (SD_4) resulted in a decrease in the number of days to 50% flowering, number of days to maturity, plant height, number of leaves plant^{-1}, and leaf area plant^{-1} in 2019 season by about 23.81, 13.48, 6.25, 33.92 and 26.77%, respectively, whereas, the corresponding percentages in 2020 season were 22.22, 14.14, 6.79, 37.78 and 26.74%, respectively compared with the sowing date on 1st July. Early 50% flowering (48 and 49 days) and days to physiological maturity (77 and 77 days) were observed from late planting on 15th August in the 1st and 2nd seasons, respectively. The number of days taken to attain days to 50% flowering and days to physiological maturity was in order $SD_1>SD_2>SD_3>SD_4$. These differences in crop phenology traits under different studied sowing dates occur due to the variation between climatic factors prevailing at each sowing date. Similar findings were reported by Dhillon *et al*. (2017) and Ahmed *et al*. (2020).

Physiological maturity duration recorded maximum values of GDD (2289 and 2334 ºC day) and HTU (29483 and 29975 ºC day hour) when sown on 1st July (89 and 90 days) in 1st and 2nd seasons, respectively (Table 8). This result is probably due to extended growing period. A longer growing season provided more time for light interception opportunity by a canopy for great utilize heat energy which could be increased dry matter accumulation to sustain vegetative growth, and ability to make efficient photosynthesis that reflects on increasing growth traits.

Furthermore, plants can get the full benefit of soil moisture and nutrients during a prolonged growth period, allowing more accumulated metabolites to be stored in seeds. Ulla *et al*. (2016) showed that delay sowing limits crop vegetative period. Delaying sunflower sowing leads to shorting growth period and exposure to unsuitable growing conditions (Table 3) along with reducing its ability for elongation and for generating new leaf. Many studies indicated that delayed sowing resulted in reduced vegetative growth traits such as plant height, leaf area plant^{-1} and number of leaves plant^{-1} (Ali *et al*., 2014; Ahmed *et al*., 2015; Hamza and Safina, 2015; Shahin *et al*., 2018; Abu Anga *et al*., 2019 and Hemeid and Zeid, 2020).

3.1.2. Yield attributes:

The data in Table (4) indicated that sowing date resulted in a significant impact on yield attributes in both seasons. The earlier sowing date SD_1 resulted in the greatest mean values (2.4 and 2.2 cm), (22.4 and 20.4 cm), (76.1 and 77.1 g), (82.4 and 81.7 g), and (0.923 and 0.913 g day^{-1}) for stem diameter, head diameter, 1000-seed weight, seed weight plant^{-1}, and daily seed weight plant^{-1} in the 1st and 2nd seasons, respectively. The lowest mean values of yield components were obtained by sunflower plants sown on 15th August SD_4. The increase of yield attributes in early sowing dates can be attributed to favorable climatic conditions during flowering and seed filling stages which increase the vegetative and reproductive growth periods consequently increase dry matter accumulation in plant organs.

Ahmed *et al*. (2020) indicated that the early sown had the largest vegetative growth duration which allowed plants to receive the highest heat unit accumulated or GDD (2303.51 ºC) and ability to effectively absorption of water and nutrients, hence increasing photo-assimilates in the leaves which might be had a positive influence on head diameter and 100-seed weight.

Sown sunflower plants on 1st June produced the highest averages of yield components than other sowing dates (Abdou *et al*., 2011). Hamza and Safina (2015) reported that the higher daily seed weight plant^{-1} was gained from planting in May than other sowing dates. Sunflower sown in May and July showed significant increase in head diameter and 100-seed weight compared to other sowing dates (Abu Anga *et al*. 2019).

Table 4. Effect of sowing dates on crop phenology, vegetative growth traits and yield components of sunflower during 2019 and 2020 seasons

Traits	Crop phenology				Vegetative growth traits						Yield attributes	
	Number of days to 50% flowering		Number of days to maturity (day)		Plant height (cm)		Number of leaves plant^{-1}		Leaf area plant^{-1} (cm)		Stem diameter (cm)	
Seasons	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Sowing dates (SD)												
1st July	63	63	89	90	161.5	163.4	28.3	27.0	176.7	179.5	2.4	2.2
15th July	56	57	84	84	158.3	159.2	25.5	23.7	156.0	158.2	2.3	2.0
1st August	52	53	80	81	154.6	156.4	23.2	21.0	139.6	142.5	1.9	1.8
15th August	48	49	77	77	151.4	152.3	18.7	16.8	129.4	131.5	1.5	1.4
LSD at 0.05	0.44	0.20	0.14	0.11	0.64	0.61	0.32	0.50	0.73	0.56	0.05	0.04

Traits	Yield attributes								Quality traits			
	Head diameter (cm)		1000-seed weight (g)		Seed weight plant^{-1} (g)		Daily seed weight plant^{-1} (g day^{-1})		Seed oil content %		Seed protein content %	
Seasons	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
1st July	22.4	20.4	76.1	77.1	82.4	81.7	0.923	0.913	38.5	38.8	19.84	20.03
15th July	20.7	18.4	73.1	73.9	75.2	75.1	0.895	0.890	37.4	37.7	19.91	20.06
1st August	18.9	17.7	67.9	68.7	69.5	69.0	0.867	0.857	35.7	36.0	20.22	20.33
15th August	16.7	15.5	58.4	59.8	59.3	59.3	0.771	0.767	34.4	34.7	22.15	22.38
LSD at 0.05	0.20	0.22	0.28	0.20	0.40	0.48	0.004	0.004	0.17	0.14	0.05	0.10

The present results are in full agreement with those found obtained by (Mahmood, 2013; Ahmed *et al*., 2015; Ulla *et al*., 2016; Demir, 2019 and Mourad and El-Mehy, 2021).

3.1.3. Seed and oil yields traits:

The final seed yield is an important trait in evaluating the ability of a crop to adapt to environmental changes. Data in Table 8 and fig.1 show that seed and oil yields were significantly affected by sowing dates. The maximum seed yield (1160 and 1188 kg fed^{-1}) and oil yield (447.4 and 461.1 kg fed^{-1}) were related to the earliest sowing on 1st July SD_1, and the minimum seed yield (556 and 590 kg fed^{-1}) and oil yield (191.3 and 204.8 kg fed^{-1}) were achieved in the latest sowing date on 15th August in the first and second seasons, respectively. The percentage of increases on 1st July for seed yield were 108.63 and 101.36% and for oil yield were 133.87 and 125.15% compared with 15th August in 1st and 2nd seasons, respectively. Early sown crops consume a greater number of days to physiological maturity to get sufficient time for their growth and development for producing more dry matter and consequently leading to yield increase during the extended growing season under appropriate climatic conditions. The differences in final seed yield of sunflower were closely associated with the variation observed in the vegetative growth leading to a reduction in components of yield, besides unfavorable temperatures during vegetative and early generative development. Early sowing of sunflower recorded higher seed yield due to accumulation of higher GDD, HTU, HTUE, HUE and PTI as shown in Table 8. At different sowing dates, the significantly highest HUE was attained by the earlier planting SD_1 (0.51 kg fed^{-1} day^{-1}) followed by late planting SD_4 (0.31 kg fed^{-1} day^{-1}). Saleem *et al*. (2008) found that the latest sowing in September suffered the reduced yields reason might be the impact of low temperature during its flowering and grain-filling period. Early sowing date recorded the highest values for each of GDD and seed yield of sunflower (Mourad and El-Mehy, 2021).

The highest seed yield may be attributed to the considerable increase in 1000-seed weight and seed weight plant^{-1}, higher dry matter accumulation due to higher crop growth rate under 1st July that improved its HUE (Dhilion *et al*., 2017).

Generally, oil yield depends on seed yield and it's calculated by multiplying the oil content by seed yield. In both seasons, oil yield decreased with delayed sowing dates. Shahin *et al*. (2018) clarified that the reductions in seed yield were 10.5 and 12.8% and oil yield 13.7 and 18.3%, with April and June sowings, respectively, compared to May sowing. These results are in conformity to those noted by Hamza and Safina (2015); Ulla *et al*. (2016); Shafiullah *et al*. (2018); Hemeid and Zeid (2020) and Mourad and El-Mehy (2021);

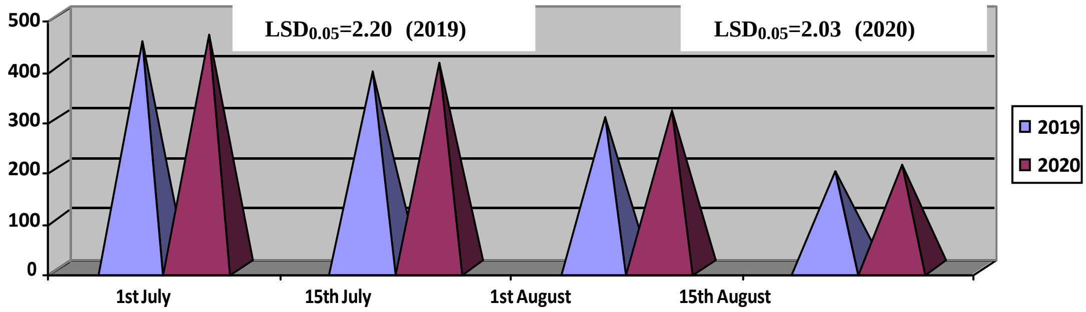

Fig 1. Effect of sowing dates on oil yield of sunflower during 2019 and 2020 seasons.

3.1.4. Quality traits:

Oil and protein contents in the two seasons were significantly affected by sowing dates (Table 4). The SD_1 sown crop resulted in the highest seed oil content (38.5 and 38.8%) while the lowest seed oil content (34.4 and 34.7%) was obtained from the last sowing date SD_4, in the first and second seasons, respectively. The differences in seed oil concentration among sowing dates were largely due to variations in seed oil ratio, rather than in seed weight (Saleem *et al*. 2008), and it's related to the effects of the climatic condition as widely variable temperature (Demir, 2019; Ahmed *et al*., 2020 and Mourad and El-Mehy, 2021). Decreased oil content attributed to relatively low mean daily temperatures due to delayed sowing date (Ulla *et al*., 2016). Sown sunflower during July month produced maximum yield and oil production (Shafiullah *et al*., 2018).

Otherwise, the highest seed protein content (22.15 and 22.38%) was obtained from sunflower plants sown on 15-August (SD_4), while the lowest seed protein content (19.84 and 20.03%) was produced by early sowing date on 1^{st} July (SD_1), in 2019 and 2020 seasons, respectively.

3.2. Effect of plant spacing:

3.2.1. Crop phenology and vegetative growth traits:

It is clear from the data in Table 5 that the plant spacing had a significant effect on crop phenology and vegetative growth traits in both seasons.

Increasing plant spacing produced the highest values in most traits in both seasons. Wider spacing at 30 cm gave the highest values for crop phenology and vegetative growth traits, exceeding the narrow spacing at 15 cm by (11.60 and 11.81%), (3.96 and 3.69%), (20.74 and 23.12%) and (22.38 and 21.67%) with regard to number of days to 50% flowering, number of days to maturity, number of leaves $plant^{-1}$ and leaf area $plant^{-1}$ in the first and second seasons, respectively.

This was due to wider spaces received more available resources *viz*., sunlight, space, nutrients, and soil moisture have helped the crop to utilize the resources to a greater extent, which enhanced values of previously mentioned traits as compared to plants in narrow spaces. Awais *et al*., (2013) reported that days taken for a flowering and physiological maturity increased with wider spacing.

Dense sowing has caused stress, resulting in early flowering and physiological maturity (Demir, 2020), and less number accumulated GDD (Dhilion *et al*., 2017). These results are in parallel with those obtained by Abd EL-Satar *et al*. (2017) and Kandil *et al*. (2017);

Conversely, plant height took the reverse trend with increasing plant spacing (decreasing plant density) in both seasons. Plant height was increased by decreasing plant spacing up to 15 cm between plants. Plant height scored at 15 cm spacing 160.2 and 162.0 cm in 1^{st} and 2^{nd} seasons, respectively, while heights obtained at 30 cm plant spacing were 149.8 and 152.0 cm in 2019 and 2020 seasons, respectively. This could be due to greater competition among plants for light by dense plants, resulting in acceleration of plant development and the elongation of the main stem. Increasing the dense plant (closer spacing) considerably increased sunflower plant height (Emam and Awad, 2017 and Li *et al*. 2019). These results are in harmony with those reported by Abido and Abo-El-Kheer (2020) and Farweez *et al*. (2020).

3.2.2. Yield attributes:

Regarding plant spacing the results showed a significant influence on yield attributes in both seasons as presented in Table 5. Using a 30 cm (P_4) distance between sunflower plants produced the maximum values for yield attributes, exceeding the 15 cm (P_1) distances between plants by (41.18 and 37.50%), (19.55 and 22.36%), (11.67 and 10.54%),

Table 5. Effect of plant spacing on crop phenology, vegetative growth traits and yield components of sunflower during 2019 and 2020 seasons

Traits	Crop phenology				Vegetative growth traits						Yield attributes	
	Number of days to 50% flowering		Number of days to maturity (day)		Plant height (cm)		Number of leaves plant^{-1}		Leaf area plant^{-1} (cm)		Stem diameter (cm)	
Seasons	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
						Plant spacing (P)						
15 cm	51.7	52.5	80.9	81.4	160.2	162.0	21.7	19.9	137.2	139.8	1.7	1.6
20 cm	53.6	54.3	82.0	82.2	159.2	159.6	23.1	21.3	144.1	146.4	1.9	1.7
25 cm	55.6	56.4	83.4	83.7	156.5	157.6	24.8	22.8	152.4	155.4	2.1	1.9
30 cm	57.7	58.7	84.1	84.4	149.8	152.0	26.2	24.5	167.9	170.1	2.4	2.2
LSD at 0.05	0.43	0.24	0.27	0.14	0.84	0.41	0.37	0.25	0.80	0.47	0.05	0.07
	Yield attributes								Quality traits			
Traits	Head diameter (cm)		1000-seed weight (g)		Seed weight plant^{-1} (g)		Daily seed weight plant^{-1} (g day^{-1})		Seed oil content %		Seed protein content %	
Seasons	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
15 cm	17.9	16.1	65.1	66.4	69.3	68.9	0.853	0.844	37.2	37.5	20.03	20.14
20 cm	19.3	17.6	67.4	68.5	70.7	70.5	0.858	0.855	36.7	37.0	20.38	20.62
25 cm	20.1	18.7	70.3	71.3	72.7	72.2	0.869	0.860	36.2	36.6	20.65	20.84
30 cm	21.4	19.7	72.7	73.4	73.8	73.5	0.875	0.869	35.8	36.1	21.05	21.20
LSD at 0.05	0.25	0.24	0.41	0.15	0.36	0.24	0.005	0.004	0.15	0.15	0.08	0.08

(6.46 and 6.68%), and (2.58 and 2.96%) with regard to stem diameter, head diameter, 1000-seed weight, seed weight plant^{-1}, and daily seed weight plant^{-1} in 2019 and 2020 seasons, respectively.

This might be due to the sufficiency of environmental conditions such as light, space, nutrients, and soil moisture which have helped increasing the vegetative growth especially leaf area plant^{-1} and photosynthesis rate resulting in improved assimilation rate and dry matter accumulation in leaves thus increase yield components traits. Abd EL-Satar *et al*. (2017) stated that the greatest values of head diameter, 100-seed weight, and seed weight plant^{-1} were scored by sown sunflower at wider spacing. Kandil *et al*. (2017) observed that increasing hill spacing from 15, 20, and 25 cm produced thickness stem, the highest head diameter and weight of 1000-seed weight.

These results are in agreement with those obtained by Mahmood (2013), Viorel *et al*. (2015) and Emam and Awad (2017), Demir (2020) and Singh and Parajuli (2020).

3.2.3. Seed and oil yields traits:

Oil yield is the main indicator of obtaining the high productivity of sunflowers fed^{-1}. Seed and oil yields as affected significantly by plant spacing (Table 8 and fig. 2). The maximum seed yield (1024 and 1064 kg fed^{-1}) and oil yield (385.2 and 403.6 kg fed^{-1}) were obtained from the treatment P_1 (15 cm spacing) and the treatment P_4 (30 cm spacing) produced minimum seed yield (787 and 818 kg fed^{-1}) and oil yield (284.5 and 298.3 kg fed^{-1}) in the 1st and 2nd seasons, respectively.

Narrow spacing had obtained an increase of seed yield by (30.11 and 30.07%) and oil yield by (36.00 and 35.30%) compared with wider spacing in the first and second seasons, respectively. The increased oil yield is due to the increase in seed yield fed^{-1} regardless of the ratio in oil. Mahmood (2013) revealed that seed yield obtained from narrow plant spacing was significantly higher. Awais *et al*. (2015) reported that increasing plant density leads to increased seed yield due to increased total dry matter accumulation partitioned to seeds. The highest seed yield (5.627 ton ha^{-1}) and oil yields (2.632 ton ha^{-1}) were achieved in the higher plant density and the lowest seed yield (5.484 ton ha^{-1}) and oil yield (2.531 ton ha^{-1}) were obtained by lower plant density, have been reported by (Mijic *et al*., 2021).

Modanlo *et al*. (2021) indicated that a more dense sow (80000 plant ha^{-1}) as compared to a less dense sow (50000 plant ha^{-1}) could have resulted in an improvement in seed yield by 35.88% and oil yield by 33.62% due to increased photosynthesis and high leaf area index. There are authors (Awais *et al*., 2013; Viorel *et al*., 2015; Day and Kolsarici, 2016; Fakirah *et al*., 2017; Kandil *et al*., 2017 and Demir, 2020) found that increasing plant density (narrow

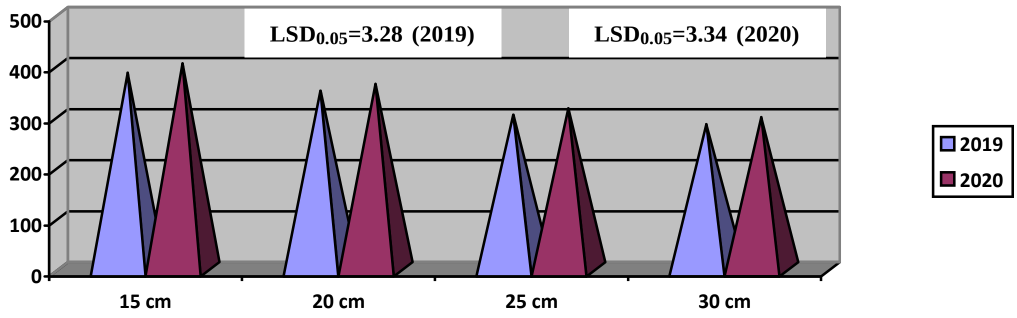

Fig 2. Effect of plant spacing on oil yield of sunflower during 2019 and 2020 seasons.

spacing) led to increased seed and oil yields under favorable conditions. Whereas other researchers reported that increasing plant density decreased seed yield and oil yield (Abd EL-Satar ***et al***., 2017; Emamand Awad, 2017 and Farweez ***et al***., 2020).

3.2.4. Quality traits:

Oil and protein traits are the most important component of sunflower seeds to measure their quality. It is apparent from the results given in Table 5, a significant impact of plant spacing was observed on oil and protein contents in both seasons. Maximum sunflower seeds oil content (37.2 and 37.5%) was obtained by sunflower plants which were sown at narrow spacing while statistically minimum oil content (35.8 and 36.1%) was attained at a wider spacing in the first and second seasons, respectively.

Gradually increasing plant spacing from 15, 20 up to 25 cm had a positive increase in seed oil content (Abd EL-Satar *et al*., 2017). Sunflower plants grown under higher density produced light seeds (1000-seed weight) as shown in Table 6 and this might be at the expense of carbohydrate storage rather than oil, which resulted in higher oil content. Seed oil content (%) depends on percentages of hull and oil content in the seed. The highest oil content was produced from the highest plant density (51.47%) as compared to the smallest plant density (50.68%), found these results by (Mijic *et al*., 2021). Awais *et al*. (2013); Day and Kolsarici (2016); Fakirah *et al*. (2017); Abido and Abo-El-Kheer (2020); and Farweez *et al*. (2020) supported these results. Contrary, plant spacing at 30 cm (low density, P_4) produced significantly higher protein content (21.05 and 21.20%) as compared to plant spacing 15 cm (dense plants, P_1) which produced statistically minimum protein content (20.03 and 20.14%) in the 1st and 2nd seasons, respectively. The minimum and maximum of seed protein content were recorded from 20 and 40 cm respectively (Day and Kolsarici, 2016). Sown plants at a wider spacing of 25 cm produced higher seed protein content (Abd EL-Satar *et al*., 2017).

3.3. Effect of interactions:

3.3.1. Crop phenology and vegetative growth traits:

Available results in Table 6 evident that all crop phenology and vegetative growth traits were influenced significantly with interaction among sowing dates × plant spacing. Early planting on 1st July SD_1 and plant spacing 30 cm P_4 between plants P_4 gave the highest values for the number of days to 50% flowering (65.1 and 66.2 days), number of days to maturity (90.3 and 90.8 days), number of leaves plant^{-1} (30.1 and 29.1 leaves), and leaf area plant^{-1} (197.1 and 199.3 cm) compared with other interactions in both seasons, but plant height recorded the maximum tallest (165.7 and 167.4 cm) from early planting on 1st July SD_1 with plant spacing 15 cm between plants P_1 in the 1st and 2nd seasons, respectively.

The minimum mean values of crop phenology, number of leaves plant^{-1} and leaf area plant^{-1} were attained by late planting date (15th August, SD_4) with 15 cm plant spacing between plants P_1 in both seasons, whereas, the shortest height of plant scored the minimum heights from $SD_4 \times P_4$ in both seasons. The tallest plant height (2.36 m) was recorded from early planting on 25th April with narrow plant spacing at 20 cm, and the shortest plant height (1.88 m) was obtained from late planting on 15th May with wider plant spacing at 43 cm (Ali *et al*., 2014).

3.3.2. Yield attributes:

Results in Tables (6 and 7) showed that the interaction between sowing date and plant spacing was significant for stem diameter, head diameter, 1000-seed weight, seed weight plant^{-1}, and daily seed weight plant^{-1} in both seasons.

Table 6. Effect of interaction between sowing dates and plant spacing on crop phenology, vegetative growth and yield attributes of sunflower during 2019 and 2020 seasons

Traits		Number of days to 50% flowering		Number of days to maturity (day)		Plant height (cm)		Number of leaves plant^{-1}		Leaf area plant^{-1} (cm)		Stem diameter (cm)	
Seasons		**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
SD × P													
SD1	P1	59.8	60.2	87.9	88.2	165.7	167.4	26.8	25.4	160.0	165.3	2.0	1.8
	P2	61.9	62.2	88.9	89.0	163.6	164.8	27.5	26.3	168.5	170.0	2.2	2.1
	P3	64.3	64.3	90.0	90.1	161.0	162.3	28.7	27.2	181.0	183.6	2.5	2.3
	P4	65.1	66.2	90.3	90.8	155.7	159.0	30.1	29.1	197.1	199.3	2.9	2.7
SD2	P1	52.8	53.5	82.2	82.8	161.8	163.1	23.5	21.9	140.0	141.0	2.0	1.9
	P2	54.9	55.0	83.8	84.0	160.5	161.0	24.9	22.9	150.0	152.0	2.0	1.7
	P3	57.3	57.8	84.6	84.9	159.8	160.7	26.2	24.2	157.0	160.0	2.4	2.1
	P4	59.6	60.3	85.6	86.1	151.0	151.8	27.4	25.7	176.7	179.8	2.6	2.4
SD3	P1	48.5	50.1	79.4	79.9	159.2	160.5	21.0	18.4	128.4	129.8	1.7	1.5
	P2	50.7	52.1	80.0	80.1	157.4	158.4	22.2	20.2	131.4	135.3	1.9	1.7
	P3	52.9	53.8	80.4	80.9	154.3	155.6	24.1	21.9	140.0	144.4	1.9	1.8
	P4	55.6	55.9	81.0	81.1	147.4	151.0	25.6	23.5	158.0	160.3	2.2	2.0
SD4	P1	45.7	46.0	74.1	74.7	154.5	156.8	15.3	13.8	120.5	123.1	1.3	1.1
	P2	46.8	47.7	75.4	75.7	155.3	154.2	17.8	15.7	126.5	128.2	1.4	1.3
	P3	48.1	49.6	78.6	78.9	151.0	151.9	19.9	17.9	131.0	133.8	1.5	1.4
	P4	50.9	52.4	79.5	79.7	145.1	146.4	21.6	19.7	139.0	140.9	1.7	1.6
LSD at 0.05		0.86	0.48	0.53	0.27	1.69	0.83	0.73	0.51	1.60	0.94	0.11	0.15

The maximum values of yield attributes were obtained with planting sunflower on 1st July SD_1 with 30 cm plant spacing P_4 in both seasons, stem diameter was 2.9 and 2.7 cm, head diameter was 24.0 and 22.0 cm, 1000-seed weight was 79.2 and 79.9 g, seed weight plant^{-1} was 84.9 and 84.3 g, and daily seed weigh plant was 0.940 and 0.928 g plant^{-1} in the first and second seasons, respectively. Conversely, the lowest values of all yield components traits were obtained with late planting (15th August, SD_4) plus with 15 cm plant spacing P_1. The maximum value for 1000-seed weight was produced from the early planting date on 15th March and with wider spacing at 25 cm (Mahmood, 2013).

3.3.3. Seed and oil yields traits:

The interaction between sowing date and plant spacing was significant on seed and oil yields by early sowing (1st July, SD_1) and narrow plant spacing (15 cm, P_1) in both seasons (Table 8 and fig. 3). The increase in the two growing seasons respectively was 160.0 and 154.7 % for seed yield and 204.44 and 197.47% for oil yield compared with late sowing (15th August, SD_4) and wider plant spacing (30 cm, P_4). This result s supported by Ali *et al.* (2014) clear that the early planting date and narrow row spacing at 20 cm gave the highest seed yield 2489 kg ha^{-1}.

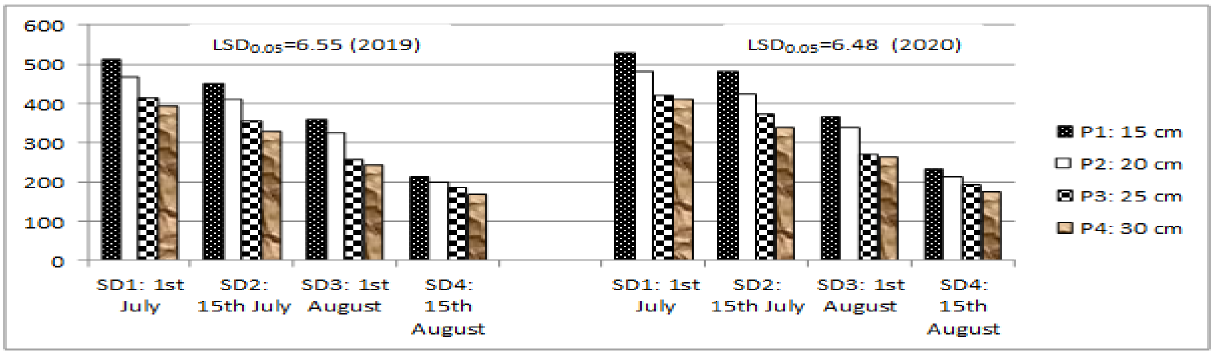

Fig 3. Effect of interaction between sowing dates and plant spacing on oil yield of sunflower during 2019 and 2020 seasons.

Table 7. Effect of interaction between sowing dates and plant spacing on vegetative growth traits and yield attributes of sunflower during 2019 and 2020 seasons

Traits		Head diameter (cm)		1000-seed weight (g)		Seed weight plant^{-1} (g)		Daily seed weight plant^{-1}		Seed oil content %		Seed protein content %	
Seasons		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
SD × P													
SD1	P1	20.9	18.5	72.4	73.9	79.6	79.2	0.906	0.898	39.6	39.9	21.8	22.0
	P2	22.0	20.0	75.3	76.1	81.9	81.1	0.921	0.911	38.8	39.0	21.9	22.3
	P3	22.8	21.2	77.6	78.5	83.3	82.3	0.925	0.913	38.0	38.3	22.0	22.3
	P4	24.0	22.0	79.2	79.9	84.9	84.3	0.940	0.928	37.7	37.9	22.8	22.9
SD2	P1	18.7	16.4	71.1	71.9	73.1	73.1	0.890	0.883	38.0	38.4	19.8	19.9
	P2	20.5	17.8	71.8	73.0	74.1	74.9	0.885	0.892	37.7	37.9	20.0	20.1
	P3	20.8	18.9	73.8	74.8	75.9	75.7	0.898	0.893	37.1	37.5	20.3	20.5
	P4	22.8	20.6	75.8	76.0	77.6	76.7	0.906	0.890	36.6	37.0	20.7	20.7
SD3	P1	17.3	16.0	63.9	64.4	66.9	66.0	0.842	0.826	36.2	36.5	19.4	19.4
	P2	18.3	17.4	66.5	67.3	67.9	67.5	0.849	0.843	36.0	36.2	19.6	19.9
	P3	19.4	18.4	69.2	70.3	71.4	70.4	0.887	0.871	35.7	36.0	20.1	20.3
	P4	20.6	19.0	71.9	72.9	72.0	72.1	0.888	0.889	35.0	35.4	20.3	20.5
SD4	P1	14.6	13.4	52.9	55.2	57.6	57.3	0.775	0.767	35.1	35.3	19.1	19.2
	P2	16.4	15.3	56.2	57.4	58.7	58.4	0.778	0.772	34.4	34.8	20.0	20.2
	P3	17.5	16.3	60.7	61.6	60.2	60.2	0.766	0.763	34.1	34.4	20.2	20.2
	P4	18.1	17.0	63.9	64.8	60.8	61.1	0.766	0.767	33.8	34.1	20.4	20.6
LSD at 0.05		0.51	0.48	0.83	0.29	0.71	0.49	0.009	0.008	0.29	0.29	0.17	0.17

3.3.4. Quality traits:

The data in Table 7 show that the effect of sowing dates × plant spacing interaction on oil and protein contents in both seasons.

The highest ratio in sunflower oil content 39.6 and 39.9% was recorded by early planting (1st July, SD_1) × plant spacing (15 cm, P_1), while the lowest ratio 33.8 and 34.1% was scored from late planting (15th August, SD_4) × plant spacing (30 cm, P_4) in the first and second seasons, respectively. The same Table illustrated that the maximum value of protein content 22.8 and 22.9% was achieved by early planting (1st July, SD_1) × plant spacing (30 cm, P_4) and the minimum value of protein content 19.1 and 19.2% were obtained from the planting of sunflower on 15th August (SD_4) combined with plant spacing 15 cm (P_1) in 2019 and 2020 seasons, respectively.

3.3.5. Effect of thermal indices:

Data in Table 8 point out that thermal indices at the physiological maturity stage were significantly correlated with sowing dates in both seasons.

Sowing date at 1st of July SD_1 recorded the highest values of GDD (2289 and 2334 ºC day), HTU (29483 and 29975 ºC day hour), HTUE (0.040 and 0.040 kg fed^{-1} C^{-1}), HUE (0.51 and 0.51 kg fed^{-1} ºC^{-1} day^{-1}), and PTI (25.6 and 26.1 ºC day duration) compared to all other sowing dates in the 1st and 2nd seasons, respectively.

The lowest values of these traits were achieved from the last sowing date on the 15th August SD_4 in both seasons. Thermal indices gradually decreased with delay in sowing date or with the advancement of plant age attributed to the gradual decline in temperature. The decrease in physiological maturity duration, GDD, HTU, PTI, and HUE for maize plants due to delay in sowing date but increased at the earlier sowing date (Ram et al., 2016). (Hulmani, 2021) illustrated that the maximum values of the GDD, HTU, and PTU at the physiological maturity stage were recorded early sowing compared to all other sowing dates. The HTUE from sowing to physiological maturity ranged between 0.026 to 0.040 kg fed^{-1} ºC^{-1} and HUE from 0.31 to 0.51 kg fed^{-1} ºC day^{-1}, HTUE and HUE were scored highest values when the crop was sown on 1st July and lowest on 15th August. Increases in HTUE and HUE could be attributed to increasing seed yield and higher GDD.

Dhilion ***et al***. (2017) revealed that the highest HUE for seed yield under early sowing and the least HUE produced the last sowing date.

Similarly, amongst the plant spacing, 30 cm plant spacing scored the highest values accumulated for GDD (2057 and 2149 ºC day) and for HTU (25653 and 26634 ºC day hour), and the lowest values for GDD (1993 and 2083 ºC day) and for HTU (24842 and 25908 ºC day hour) were obtained from narrow spacing at 15 cm 1st and 2nd seasons, respectively.

Table 8. Effect of sowing dates and plant spacing on thermal indices *viz*.,: Accumulated growing degree days (GDD), Heliothermal units (HTU), Heliothermal use efficiency(HTUE), Heat use efficiency (HUE), Photothermal index (PTI) at physiological maturity stage and se ed yield of Nili sunflower during 2019 and 2020 seasons.

Traits		GDD (ºC day)		HTU (ºC day hour)		HTUE (kg fed^{-1} ºC^{-1})		HUE (kg fed^{-1} ºC^{-1}day^{-1})		PTI (ºC dayduration)		Seed yield (kg fed^{-1})	
Seasons		**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
Sowing dates (SD)													
1st July		2289	2334	29483	29975	0.040	0.040	0.51	0.51	25.6	26.1	1160	1188
15th July		2106	2181	26535	27390	0.039	0.040	0.49	0.49	25.1	25.8	1037	1073
1st August		1938	2040	23810	25010	0.035	0.034	0.43	0.42	24.2	25.3	830	860
15thAugust		1781	1910	21300	22800	0.026	0.026	0.31	0.31	23.2	24.7	556	590
LSD at 0.05		7.06	4.12	93.18	41.19	0.0003	0.0003	0.004	0.004	0.10	0.05	6.92	7.79
Plant spacing (P)													
15 cm		1993	2083	24842	25908	0.040	0.040	0.51	0.51	24.6	25.6	1024	1064
20 cm		2020	2101	25150	26133	0.037	0.037	0.46	0.46	24.6	25.5	944	974
25 cm		2043	2131	25482	26500	0.033	0.031	0.40	0.40	24.5	25.4	829	855
30 cm		2057	2149	25653	26634	0.030	0.030	0.38	0.38	24.4	25.4	787	818
LSD at 0.05		7.30	2.38	85.**00**	34.74	0.0003	0.0003	0.003	0.003	0.07	0.03	6.70	8.06
SD × P													
SD1	P1	2257	2294	29115	29547	0.045	0.045	0.58	0.58	25.7	26.0	1300	1327
	P2	2281	2321	29242	29894	0.041	0.041	0.53	0.53	25.7	26.1	1204	1234
	P3	2305	2347	29735	30229	0.040	0.036	0.47	0.47	25.6	26.0	1090	1103
	P4	2313	2374	29838	30229	0.035	0.036	0.45	0.46	25.6	26.1	1043	1087
SD2	P1	2070	2147	26078	26966	0.046	0.047	0.58	0.59	25.2	25.9	1193	1260
	P2	2104	2169	26510	27243	0.041	0.041	0.52	0.51	25.1	25.8	1092	1115
	P3	2111	2192	26598	27532	0.036	0.035	0.46	0.46	25.0	25.8	963	998
	P4	2139	2215	26952	27820	0.033	0.033	0.42	0.41	25.0	25.7	900	918
SD3	P1	1920	2027	23530	24851	0.042	0.040	0.52	0.50	24.2	25.4	996	05
	P2	1934	2027	23788	24851	0.038	0.038	0.47	0.46	24.3	25.3	904	935
	P3	1941	2049	23874	25121	0.030	0.030	0.37	0.37	24.1	25.3	717	755
	P4	1955	2057	24047	25215	0.029	0.030	0.36	0.36	24.1	25.4	703	746
SD4	P1	1726	1865	20643	22268	0.029	0.030	0.35	0.36	23.3	25.0	605	666
	P2	1761	1888	21062	22543	0.027	0.027	0.33	0.32	23.4	25.0	574	609
	P3	1816	1936	21719	23116	0.025	0.024	0.30	0.29	23.1	24.5	545	564
	P4	1821	1949	21775	23271	0.023	0.022	0.28	0.27	22.9	24.5	500	521
LSD at 0.05		14.59	4.77	170.2	69.48	0.0006	0.0006	0.007	0.007	0.14	0.07	13.40	16.12

Accumulated thermal indices were calculated at the physiological maturity stage

The narrow spacing at 15 cm recorded the highest values for HUE (0.51 and 0.51 kg fed^{-1} ºC day) and for PTI (24.6 and 25.6 ºC day duration) in both seasons, respectively, due to higher seed yield, while the lowest values were gained from wider spacing at 30 cm. Narrow spacing led to higher HUE for seed yield due to the accumulation of dry matter by the plant (Dhilion ***et al.,*** 2017). Interaction impacts show that the highest values for GDD (2313 and 2374 ºC day) and for HTU (29838 and 30229 (ºC day hour) at physiology maturity were recorded from the sowing date on 1st July × wider spacing at 30 cm in 2019 and 2020 seasons, respectively. The interaction between sowing date and plant spacing revealed that maximum HTUE of 0.046 and 0.047 kg fed^{-1} ºC^{-1}and HUE of 0.58 and 0.59 kg fed^{-1} ºC^{-1} day^{-1} in the 1st and 2nd seasons, respectively were obtained when early sowing date (1st July) with narrow plant spacing (15 cm).

4. CONCLUSION

Based on the above results, delaying the sowing date from 1st July to 15th August resulted in gradually decreased vegetative growth traits, crop phenology, thermal indices, and yield and its attributes for sunflower *cv*. Sakha 53.

With respect to plant spacing, wider spacing at 30 cm recorded an increase both of vegetative growth, yield components traits, crop phenology, and GDD and HTU, whereas narrow spacing at 15 cm scored the lower number of days to crop phenology, tallest of plant height, and heaviest seed yield as well as the maximum of HTUE, HUE, and PTI. The highest seed yield was obtained at 15 cm plant spacing (1024 and 1064 kg fed^{-1}) in the 1st and 2nd seasons, respectively which was significantly higher over other spacing's.

Generally, thermal indices utilization of the crop improved the early sowing date on 1st July with 15-cm plant spacing resulting in the maximized seed and oil yields and increase resource use efficiency besides requiring an average of accumulated heat units 2312 ºC day^{-1} to complete the physiological maturity stage for Sakha-53 cultivar under Aswan conditions.

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الملخص العربي

تأثر أداء دوار الشمس صنف سخا ٥٣ بالوحدات الحرارية المتجمعة تحت مواعيد زراعة و مسافات نباتية مختلفة تحت ظروف محافظة أسوان

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أجريت الدراسة الحالية خلال موسمي ٢٠١٩ و ٢٠٢٠ بالمزرعة التجريبية بكلية الزراعة والموارد الطبيعية بجامعة أسوان لتقدير النمو والإنتاجية والوحدات الحرارية المتجمعة لدوار الشمس صنف سخا–٥٣ باستخدام تصميم القطاعات كاملة العشوائية بتجربة القطع المنشقة مرة واحدة في ثلاث مكررات.

وطبقت لأربع مواعيد زراعة الميعاد الأول : ١ يوليو ، الميعاد الثاني: ١٥ يوليو ، الميعاد الثالث: ١ أغسطس و الميعاد الرابع: ١٥ أغسطس الذي وضعت بالقطع الرئيسية وأربعة مسافات نباتية هي ١٥ سم ، ٢٠ ، ٢٥ و ٣٠ سم وزعت بالقطع الشقية. نفذت التجربة باستخدام تصميم القطع المنشقة مره واحدة في ثلاثة مكررات.

أشارت النتائج إلى وجود تأثير معنوي لمواعيد الزراعة والمسافات بين النباتات وتفاعلها على جميع صفات الدراسة في كلا الموسمين.

أعطى ميعاد الزراعة ١ يوليو أعلى متوسطات القيم لجميع الصفات محل الدراسة. الزراعة المبكرة في ١ يوليو أعطت زيادة معنوية بالمؤشرات الحرارية ووزن محصول البذور المصاحب للصفات المحصولية الأخرى.

كما أوضحت النتائج بأن زيادة المسافة بين النباتات من ١٥ و ٢٠ و ٢٥ وحتى ٣٠ سم أدت إلي زيادة تدريجية في عدد الايام للوصول إلى ٥٠% تزهير و النضج الفسيولوجي ، عدد الاوراق لكل نبات ، مساحة الورقة للنبات ، قطر الساق ، قطر الرأس ، وزن ١٠٠٠ بذرة ، وزن البذور للنبات و وزن البذور اليومي للنبات وزيادة عدد تراكم GDD and HTU في حين أدى التباعد الضيق عند ١٥ سم إلى أطول نباتات ، أعلى محصول للبذور والزيت و أعلى تراكم HTUE, HUE and PTI.

جميع التفاعلات بين مواعيد البذر والمسافات النباتات كان لها تأثير معنوي لعوامل الدراسة ، حيث تبين أن أثقل محصول بذور (١٣٠٠ و ١٣٢٧ كجم فدان$^{-١}$) تم الحصول عليه من المعاملة $SD_1 \times P_3$ في كلا الموسمين.

<u>الخلاصة</u> : بشكل عام ، زراعة محصول عباد الشمس صنف سخا ٥٣ في ١ يوليو مع تباعد ١٥ سم بين النباتات قد أعطت زيادة في محصول البذور والزيت وزيادة كفاءة استخدام الموارد المتاحة بالإضافة إلى الحاجة إلى متوسط ٢٣١٢ GDD لإكمال مرحلة النضج الفسيولوجي تحت ظروف محافظة أسوان.