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Influence of plant densities and sowing conditions on Sunflower cultivars yield under semi-arid conditions

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Abstract

A field experiment was conducted to determine the influence of two plant densities Pd1 (50400) and Pd2 (62500) plant ha^{-1}, two cultivars C_1 (Samsun-3) and C_2 (Funtua), and six sowing conditions Sc_1 (Sowing at 22 Feb.-covered), Sc_2 (Sowing at 7 Mar.-covered), Sc_3 (Sowing at 30 Mar.-free cover), Sc_4 (Sowing at 22 Feb.-greenhouse), Sc_5 (Sowing at 7 Mar.-greenhouse) and Sc1 (Sowing at 30 Mar.-free cover plus two irrigations) on yield contributing traits of sunflower under rainfed condition. Results showed that the effects of plant densities, cultivars, sowing conditions, and their interaction on the studied yield parameters, disk weight, disc diameter (cm), 1000- seed weight (g), number of seed disc^{-1} and seed yield (t h^{-1}) were highly significant ($P \leq 0.01$). Maximum mean values were recorded for the disk weight (g) and number of seed disc^{-1} in Sc_3 (Mar-30) with Samsun-3 and Pd1(50400 plants ha^{-1}), disc diameter in Sc_4 (Feb-22) with Samsun-3 and Pd1(50400 plants ha^{-1}), 1000- seed weight (g) in Sc_4 (Feb-22) with Samsun-3 and Pd1(50400 plants ha^{-1}), and seed yield (t h^{-1}) in Sc_4 and Sc_2 (Feb-22) with Samsun-3 and Pd1 (50400 plants ha^{-1}). According to the seed yield, Samsun-3 surpassed Funtua by 23%, while Pd2 surpassed Pd2 by 17%. Yield reduction was large under Sc_3 late spring sowing (22 %) compared with too early sowing Sc_4. Based on the results, it is concluded that high quantity production was obtained on the Feb-22 date of sowing with Samsun-3 under a high population (62500 plants ha^{-1}). Favorite or Performer variety can be grown for their high seed under climate conditions in Sulaimany-Kurdistan-Iraq or other similar areas.

Keywords industrial crops**,** *Helianthus annuus* L., yield characteristics, treatment interactions, seed yield.

Introduction

Sunflower (*Helianthus annuus* L.) constitutes a significant oilseed crop on a global scale. It occupies the third position in oil production, following soybean and rapeseed, with respective production volumes of 345.97, 68.52, and 45.36 million tons as reported by FAOSTAT in 2017. The sunflower is indigenous to North America. Historical settlers cultivated sunflowers within their gardens for sustenance and ornamental purposes [1]. Implementing practices such as planting dates, variety selection, and plant density aims to optimize both yield and the overall quality of the crop. Both agricultural methodologies and the employment of high-yielding cultivars are critical determinants of sunflower cultivation's maximal productivity [2]. Various factors, including plant density and cultivar selection, significantly influence the productivity of sunflower crops [3]. The density of plants per unit area will establish the ideal above-ground conditions that enable the plant to access essential growth factors (such as CO_2 and light), which consequently affect productivity and, ultimately, seed yield [4]. The density of discs per unit area resulted in a 23% increase in seed yield when the plant density was maintained at 100,000 plants per hectare [5], whereas [6] observed that the optimal seed yield was achieved at a density of 60,000 plants per hectare, albeit with a concomitant decrease in the values of head yield components. Conversely, investigations indicated that a planting density ranging from 40,000 to 50,000 plants per hectare was associated with the highest seed yields per hectare [7].

The sunflower is recognized as an advantageous agricultural crop in both irrigated and rainfed regions of Kurdistan-Iraq, regardless of the presence of supplementary irrigation. The overall cultivated land area dataset, alongside the aggregate seed production yield per unit area in Iraq, positions it as a leading nation, both nationally and globally (refer to Table 1). Findings from various studies elucidate the significance of sowing time and cultivar selection on the seed yield of different sunflower genotypes [8, 9, and 10], however, the existing literature concerning variations in seed quantity attributable to different varieties and associated agronomic environmental factors remains limited, inconsistent, and inadequately explored. Consequently, in light of the emergence of novel sunflower hybrids characterized by diverse growth traits and maturation periods, it is imperative to assess the genetic variability concerning potential productivity and quality attributes when cultivated under varying environmental conditions.

Lawal *et al.* [10], indicated that various cultivars of sunflowers exhibit distinct optimal sowing dates concerning traits such as head diameter, head weight, and seed yield in the southern region of Nigeria, a phenomenon termed cultivar and sowing dates interaction. The timing of sunflower planting significantly affected grain yields more than any other agronomic trait [11]. The planting date greatly impacted vegetative characteristics, yield, and associated components [12,13,14]. Mahmood [15], reported that an early planting date of March 15th resulted in a notably positive influence on plant height, stem diameter, head size, and seed weight compared to the later planting date of April 15th, based on an average across both locations within the Sulaimani province of Kurdistan-Iraq for the "Flame" variety of sunflower.

In Florida, it has been documented that delays in the planting schedule adversely impact the yield of sunflower crops [16]. Anjum *et al*., [17], indicated that data on various parameters, specifically the count of seeds per head and the weight of seeds per head (measured in grams), were gathered, revealing that the hybrids (Soraj and Roshan) sown at an earlier date exhibited exceptional performance, yielding seed weights per head of 19.60 and 23.4 grams respectively, in contrast to the same hybrids cultivated later, which resulted in seed weights per head of 11 and 12.1 grams. This investigation aimed to assess the performance of sunflower cultivars in conjunction with population density in rain-fed regions under various sowing conditions, encompassing early and late spring planting schedules. The sowing dates spanned from the third week of February (designated as too early sowing) to mitigate water stress during the later growth phases, culminating in late sowing conducted during the final week of March for sunflowers in rain-fed environments. The influence of varying densities and sowing dates on spring sunflower cultivars was examined under rain-fed conditions to determine the optimal timing, density, or variety, along with their interactions, within the specific context of Sulaimani-Kurdistan-Iraq.

Table(1): Area, production, and yield of sunflower in Iraq, a top country and the world for the years (2012-2016).

Year	Area (ha)			Production (ton)			Productivity (t ha^{-1})		
	Iraq	The top country	The world	Iraq	The top country	The world	Iraq	The top country	The world
2016	0.520	7.294	26.205	0.914	13.627	47.345	1.758	7.118	1.807
2015	0.453		25.456	0.800		44.369	1.766	5.414	1.743
2014	0.845		25.256	1.822		42.584	2.156	7.127	1.686
2013	1.902		26.160	3.707		45.296	1.949	8.555	1.732
2012	2.168		25.071	4.216		36.608	1.945	8.415	1.460

Source Agricultural Statistics of FAOSTAT (2016)

Materials and Methods

The field experiment was conducted on the Experimental Farm of the College of Agriculture Sciences –University of Sulamani in 2017 at Bakrajo, which is located in the southwest of Sulaimani city (latitude35 33 N longitude 45 27 E at an altitude of approximately 830 m above sea level). It contained three factors, first Six Sowing conditions were used in that investigation Table 2. The climate of the region is semiarid mediterranean winter is mild and not long followed by a hot and dry long summer. The rainfall distribution and Physical and chemical properties of the studied soil data during the planting period for the season were collected and presented in Tables 3a and 3b, respectively.

Table(2): Sowing condition, irrigation technique, and Symbol

No	Sowing condition	Water supply	Symbol
1	Sowing on 22 Feb.-covered with transparent plastic cover until 25 Mar (too early)	Rain-fed	Sc_1
2	Sowing on 7 Mar.-covered with transparent plastic cover until 25 Mar (early)	Rain-fed	Sc_2
3	Sowing on 30 Mar.-free cover (drought condition)	Rain-fed	Sc_3
4	Sowing on 22 Feb.-greenhouse then transplanted to field on 25 Mar (too early sowing)	Rain-fed	Sc_4
5	Sowing on 7 Mar.-greenhouse then transplanted to field on 25 Mar (early sowing)	Rain-fed	Sc_5
6	Sowing on 30 Mar.-free cover (normal condition)	Rain-fed and two-furrow supplementary irrigation	Sc_6

Second two cultivars of sunflower Samsun-3 (C_1) and Funtua (C_2) and third two plant densities 50403 (D_1) and 62500 (D_2) plant ha^{-1} to evaluate the performance of two sunflower cultivars as affected by different sowing conditions and plant densities. The field was laid out according to a Randomized Complete Block Design (RCBD) factorial experiment with three replications. Each block contained 24 uniform experimental plots of 5.5552 m^2 (2.48 × 2.24) m and 4.480 m^2 (2.00 × 2.24) m for the two plant densities D_1 and D_2, respectively, and 0.5 m apart. Each plot included four rows, 2.24 m in length and 0.62 (D_1) and 0.50 (D_2) m apart with 0.32 m between plants in rows. The too-early (Sc_1) and early (Sc_2) sowing date plots were covered with a transparent plastic cover which will help to keep the soil and seeds warm to avoid low-temperature damage. Later, the plots were hand-thinned to one plant per hill when the plants were at the four to six-leaf stages. The treatment plots were uniformly fertilized with 120 kg N and 80 kg P_2O_5 ha^{-1} through urea (46% N) and diammonium phosphate (18% N, 46% P_2O_5), respectively. Half the dose of N and full dose of P were drilled at the time of sowing while the remaining half dose of N was top dressed 40-45 days after sunflower planting. The soil of the experiment was prepared for cultivation by ploughing the field using a mold broad plow and harrow. Weeds were controlled manually whenever necessary, and all other cultural practices were conducted uniformly as needed for all treatments. The data were recorded on disk weight (g), number of seed $disk^{-1}$, 1000- seed weight (g), biological yield (t h^{-1}), and seed yield (t h^{-1}) and analyzed statistically using MSTATC computer software.

Table (3a) : Average air temperature and rainfall during the growing seasons of 2016-2017 at Qlyasan Location.

Months	Average Air Temperature (°C)		Rainfall (mm)
	Max.	Min.	
November	21.3	7.6	44.5
December	11.1	3.0	158.0
January	11.10	1.46	59.2
February	13.02	0.26	96.5
March	17.73	7.45	111.5
April	23.89	10.97	54.5
May	31.63	13.48	27.7
Total			551.9

Table (3b): Physical and chemical properties of the studied soil

Soil Properties	Bakrajo location
P.S.D	Clay
Sand (g Kg^{-1})	41.00
Silt (g Kg^{-1})	430.50
Clay (g Kg^{-1})	528.50
E.C. (dS m^{-1})	0.61
pH	7.32
O.M (g Kg^{-1})	11.60

Total N (mg Kg^{-1})	1.07
Available Phosphate (mg Kg^{-1})	5.95
$CaCO_3$ (g Kg^{-1})	107.00

Results and Discussions

The final results of sunflower plant traits showed that sowing conditions, cultivars, and plant population had a significant effect on almost all plant traits ($P\leq 0.01$). However, cultivars on disc diameter had a non-significant effect, while the plant densities effect was significant on 1000 seed weight ($P\leq 0.05$). Therefore, our outcomes denoted an expressive improved seed yield, number of seed $disk^{-1}$, 1000 seed weight disc weight, and biological yield, performance. In addition, there were significant interactions between sowing conditions and cultivars on almost all plant traits ($P\leq 0.01$) except disc diameter which had a non-significant effect. This means that not all sowing conditions responded the same way to the two sunflower cultivars. Both sowing conditions with plant densities interaction and varieties with plant densities interaction and their tri-interaction had a significant effect on all plant traits ($P \leq 0.01$). This means that not all sowing conditions responded the same to the different plant densities, and not all plant densities responded the same to the two varieties of sunflower (Table 4). These results are consistent with those of Baghdadi *et al*. [18] for plant densities and sowing time and their interaction and Ibrahim [3], for sunflower hybrids and plant densities and their interaction.

Table (4) : Mean square of ANOVA's of disc weight (g), Disc diameter (cm), number of seed $disk^{-1}$, 1000- seed weight, (g) and seed yield (t h^{-1}) in sunflower.

S.O.V	d.f	Disc weight	Disc diameter	No seed $disc^{-1}$	1000-seed weight	seed yield
Replicates	2					
Sowing conditions (A)	5	2189.290**	5.087**	13707.16**	473.336**	0.809**
Cultivars (B)	1	1027.404**	0.161^{ns}	6105.125**	2691.82**	4.817**
(A × B)	5	169.959**	0.514^{ns}	52409.89**	612.450**	0.099**
Plant densities (C)	1	126.617**	1.869**	63308.68**	44.023*	2.634**
(A × C)	5	40.069**	1.240**	8356.247**	222.883**	0.093**
(B × C)	1	66.010**	9.102**	58653.13**	132.248**	0.935**

(A × B × C)	5	41.753**	4.055**	18415.96**	133.366**	0.080**

ns Non-significant, *and ** Significant at 0.05 and 0.01 levels, respectively.

Disc weight plus seeds (g)

Disk weight relied on a genotype and the environment during crop growth. Results showed that the effect of sowing conditions, cultivars, and plant densities, along with their di and tri-interactions presented in (Tables 4 and 5) were highly significant. This indicates that Sunflower cultivars are varied in their performance and sensitive to plant densities and sowing conditions. As regards sowing conditions (Sc), a significant maximum disc weight (97.22g) was observed in the case of early sowing Sc_2 as compared to the minimum (67.45g) disc weight recorded from too early sowing condition (Sc_1). Sunflower cultivar Samsun-3 produced a significantly higher weight of disc (86.719 g) than Funtua (79.164 g), significantly there is a progressive increase in the weight of disc with a decrease in plant population from 62500 (81.615 g) to 50403 (84.267 g) plant ha^{-1}. Chajjro *et al.*, [19], pointed out that, genotypes significantly affected the head weight of sunflowers. The effect of plant density was highly significant and the low population 50400 plant ha^{-1} resulted in significantly more disc's weight (84.267 g) compared with high population 62500 plant ha^{-1} (79.164 g). The Samsun-3 cultivar sown at a plant density of 50403 plant ha^{-1} produced a maximum weight of disc (89.002 g) while the Funtua cultivar at a plant density of 62500 plant ha^{-1} produced the minimum weight (78.795 g). The decreased weight of the disc with increasing plant density might be due to a more competitive state among plants in situations of light, moisture, and nutrients due to less wideness.

These results are supported by Oshundiya *et al,* [20], who concluded that head diameter and head weight were significantly affected by the sowing date x variety interaction effect with the Funtua cultivar giving higher values. The interactive effect of sunflower cultivars and sowing conditions showed that the Samsun-3 cultivar sown early on 7 Mar. sowing conditions (Sc_2) produced a maximum weight of disc (105.447 g), while the Funtua cultivar too early on 22 Feb. sowing conditions (Sc_1) produced the minimum weight (66.162 g). The head weight of sunflowers across six sowing conditions almost decreased gradually with the increasing plant density. The significant interactive effect revealed that sowing conditions behaved differently for their head weight at different population levels. A maximum head weight of 99.282 g was noted for Sc_2, followed by 98.398 g in the case of Sc_3 at 50400 plant ha^{-1}(Pd_1), respectively. In return, a minimum head weight of 64.798 g was noted in the case of Sc_1, where plant density was 62500 plant ha^{-1} (Pd_2) (Table 5). This might be because sunflower plants grown with a thin plant population minimize the almost competition between disc plants and thus, Provide them with more efficacious utilization of obtainable resources for more growth and to maximize yield components of sunflower plants [21]. A very significant interaction of these factors, sowing conditions of the six levels, cultivars, and plant density (Tables 4, 5). A maximum head weight of 109.890 g was noted for early sowing covered (Sc_2) at 50400 plant ha^{-1}(Pd_1) and Samsun-3 cultivar (C_1), while the minimum value of 64.667 g was noted for too early sowing covered (Sc_1) at 62500 plant ha^{-1}(Pd_2) and the same cultivar (Samsun-3).

Table (5): Effect of plant density, cultivars, and sowing conditions on Sunflower disc weight (g).

Sowing Conditions (Sc)	Cultivars (C)	Plant density plant ha^{-1} (Pd)		C × Sc
		50403 (Pd_1)	62500 (Pd_2)	
Sc_1	Samsun-3 (C_1)	72.813 hi	64.667 k	68.740 g
	Funtua (C_2)	67.393 jk	64.930 k	66.162 h
Sc_2	Samsun-3 (C_1)	107.820 a	103.073 b	105.447 a
	Funtua (C_2)	90.743 e	87.247 f	88.995 d
Sc_3	Samsun-3 (C_1)	109.890 a	99.323 c	104.607 a
	Funtua (C_2)	86.907 f	88.263 ef	87.585 d
Sc_4	Samsun-3 (C_1)	77.160 g	74.087 gh	75.623 e
	Funtua (C_2)	69.763 ij	67.153 jk	68.458 g
Sc_5	Samsun-3 (C_1)	93.673 de	92.580 d	93.127 b
	Funtua (C_2)	85.313 f	95.627 d	90.470 c
Sc_6	Samsun-3 (C_1)	72.657 hij	72.880 hi	72.768 f
	Funtua (C_2)	77.073 g	69.550 j	73.312 f
LSD ($p \leq 0.05$)		*3.262*		*1.830*
Sc_1		70.103 e	64.798 f	67.45 d
Sc_2		99.282 a	95.160 b	97.22 a
Sc_3		98.398 a	93.793 b	96.10 a
Sc_4		73.462 d	70.620 e	72.04 c
Sc_5		89.493 c	94.103 b	91.80 b
Sc_6		74.865 d	71.215 e	73.04 c
L.S.D, 0.05		*1.883*		*2.150*
Samsun-3 C_1		89.002 a	84.435 b	86.719 a
Funtua C_2		79.532 c	78.795 c	79.164 b
LSD ($p \leq 0.05$)		*1.332*		*0.789*
PD means		84.267 a	81.615 b	

LSD $_{(p\leq0.05)}$	0.769	

Means followed by a different letter(s) in a column and rows are significant at a 5% level of probability, $LSD_{0.05}$

Disc (head) diameter (cm)

The disc diameter is one of the ingredients that impact yield. The head diameter of a sunflower was significantly affected by variant environmental factors like light, temperature, and soil moisture and different cultivation applications such as cultivars, sowing conditions, and plant population. Our Results showed that the effects of two of the three factors sowing conditions, cultivars, and plant densities, along with their di, except (Sc × C) and tri-interactions are presented in (Tables 4 and 6) which were highly significant ($p\leq0.01$). The head diameter obtained from the two cultivars was alike. According to the sowing condition (Sc), the highest value of disc diameter (13.42cm) was produced on normal sowing conditions with irrigation (Sc_6), while the minimum value (11.73cm) was obtained on early sowing covered (Sc_2) (Table 6), this might due to the efficiency of the two irrigation in Sc_6 was reflected in the size of the head diameter. Subsequently adequate soil moisture content enables roots to absorb excess nutrients for plant growth [10]. However, Buriro *et al.*, [22], pointed out that the discontinuation of the water supply resulted in a marked reduction in head diameter. As regards plant density (Pd), increasing plant density from 50400 (12.547cm) to 62500 (12.869cm) plant ha^{-1} led to a significant decrease in head diameter from 12.869 to 12.547cm.

These results could be clarified based on the interplant contest in various plant populations, wherever competition among plants for growth factors is rising with increasing crowdedness. The findings were in agreement with those options by Allam *et al.*, [13] and Ibrahim *et al.*,[23]. The data for sowing condition × plant density interaction furthermore confirmed the superiority of Sc_4 (13.567cm) at 50400 plant ha^{-1} (Pd_2), compared to the other Sc × Pd interactions, while the least value of 11.083 cm was recorded for Sc_1 at 62500 plant ha^{-1}(Pd_2). Similar results were also reported by Ahmad & Quresh, [24], while Mahmood [15], noticed, that no significant interaction between three sowing dates with three plant spaces under two different environments in Sulaimani-Iraq. According to the cultivars, × plant density interaction shown, Samsun-3 at (Sc_2) produced the maximum disc diameter (13.272cm), while the same cultivar at Sc_1 produced the minimum diameter (12.239cm). Our findings are also supported by Shayanfar *et al.*, [25], when they pointed significant influence of interaction between four plant densities and three sunflower cultivars on head diameter. Hladni *et al.*, [26], explained that the sunflower head has a changeable diameter dependent on the variety, environmental factors, and their interaction. A very significant influence of the three factors interaction. A maximum head diameter of 14.700 cm was noted for too early sowing greenhouse (Sc_4) at 50400 plant ha^{-1} (Pd_1) and Samsun-3 (C_1), while the minimum value of 10.833 cm was noted for early sowing covered (Sc_2) at 62500 plant ha^{-1}(Pd_2) and the same cultivar (Samsun-3).

Table (6): Effect of plant density, cultivars, and sowing conditions on Sunflower disc diameter (cm).

Sowing Conditions (Sc)	Cultivars (C)	Plant density plant ha^{-1} (Pd)		C × Sc
		50403 (Pd_1)	62500 (Pd_2)	
Sc_1	Samsun-3 (C_1)	13.667 b	11.000 ij	12.333
	Funtua (C_2)	11.833 h	13.000 cd	12.417
Sc_2	Samsun-3 (C_1)	12.600 d-g	10.833 j	11.717
	Funtua (C_2)	12.167 gh	11.333 i	11.750
Sc_3	Samsun-3 (C_1)	12.467 efg	13.533 b	13.000
	Funtua (C_2)	13.467 b	12.667 d-g	13.067
Sc_4	Samsun-3 (C_1)	14.700 a	12.700 def	13.700
	Funtua (C_2)	12.433 efg	13.367 bc	12.900
Sc_5	Samsun-3 (C_1)	11.900 h	12.500 dfg	12.200
	Funtua (C_2)	12.600 d-g	12.567 def	12.583
Sc_6	Samsun-3 (C_1)	14.300 a	12.867 de	13.583
	Funtua (C_2)	12.300 fg	14.200 a	13.250
LSD $_{(p\leq0.05)}$		*0.798*		*n.s*
Sc_1		12.750 cde	12.000 g	12.38 c
Sc_2		12.383 efg	11.083 h	11.73 d
Sc_3		12.967 bcd	13.100 bc	13.03 b
Sc_4		13.567 a	13.033 bc	13.30 ab
Sc_5		12.250 fg	12.533 def	12.39 c
Sc_6		13.300 abc	13.533 a	13.42 a
LSD $_{(p\leq0.05)}$		*0.460*		*0.366*
Samsun-3 C_1		13.272 a	12.239 d	12.756
Funtua C_2		12.467 c	12.856 b	12.661
LSD $_{(p\leq0.05)}$		*0.326*		*n.s*
PD means		12.869	12.547	
LSD $_{(p\leq0.05)}$		*0.188*		

Number of seed disc^{-1}

The number of seed heads^{-1} is influenced by environmental conditions during the pollination period [27]. Zaffaroni and Schneider [28] pointed out that the seed number head^{-1} is an influential component of the seed yield in sunflowers. Our results showed that the effect of cultivars on the number of seed disc^{-1} was highly significant ($P \leq 0.01$) (Tables 4 and 7). The C_1 had a higher number of seed disc^{-1} (755.417) than C_2 (737.00) (Table 7). The superiority of Samsun-3 (C_1) may be due to its capability to make preferable use of available resources, compared to Funtua (C_2). These results are consistent with those of [29]. Differences between studied sowing conditions were significant for this trait, in which Sc_5 gave the highest number (799.25) compared with the lowest of Sc_1 (706.75). The data regarding plant density ha^{-1} of crop sown with 50400 (Pd_1) recorded a significantly higher value of number of seed disc^{-1} (775.861) than those sown with 62500 (Pd_2, 716.556). It was because of utilizing entire environmental conditions in lower population, and also the spaces between plants were not convenient to supplement benefiting the sun's light, therefore plants could produce seeds correctly.

The results regarding Sc × C interaction, It was observed that the highest number of seed disc^{-1} (887.500) was obtained under treatment $Sc_5 \times C_1$, and the lowest number of seed disc^{-1} was related to Sc_1 x C_1 (659.500). The significant interaction differences between variety and plant density showed, that the highest number of seed disc^{-1} was related to C_1 x Pd_1 (813.611), and the lowest was achieved in $C_1 \times Pd_2$ (697.222). Emami-Bistghani *et al.*, [30], also reported that significant interaction effect between plant densities and cultivars with seed number m^{-2}. According to the significant effect of Sc × Pd interaction on this trait. However, the maximum number of seed disc^{-1} was achieved with early sowing condition (7 Feb –greenhouse Sd_5) and Pd $_2$ (816.000), and the minimum was observed at too early sowing condition (22 Feb –covered Sd_1) and Pd $_2$ (659.167) (Table 7). In the case of highly significant Sc x C x Pd interaction, the maximum number of seeds head^{-1} was achieved with a delay of planting time, C_1 and Pd2 (988.333), and the minimum was observed at too early planting time, C_1 and Pd 2 (606.667) (Tables 4, 7).

Table (7): Effect of plant density, cultivars, and sowing conditions on a number of seed discs^{-1} of Sunflower.

Sowing Conditions (Sc)	**Cultivars (C)**	**Plant density plant ha^{-1} (Pd)**		**C × Sc**
		50403 (Pd_1)	**62500 (Pd_2)**	
Sc_1	Samsun-3 (C_1)	712.333 fg	606.667 i	659.500 i

	Funtua (C2)	796.333 d	711.667 fg	754.000 e
Sc2	Samsun-3 (C1)	772.333 d	743.333 e	757.833 e
	Funtua (C2)	729.667 e	695.333 g	712.500 f
Sc3	Samsun-3 (C1)	988.333 a	729.333 ef	858.833 b
	Funtua (C2)	641.667 h	732.667 ef	687.167 g
Sc4	Samsun-3 (C1)	722.667 ef	636.667 h	679.667 h
	Funtua (C2)	797.000 d	746.000 e	771.500 d
Sc5	Samsun-3 (C1)	940.000 b	835.000 c	887.500 a
	Funtua (C2)	625.000 hi	797.000 d	711.000 f
Sc6	Samsun-3 (C1)	746.000 e	632.333 h	689.167 g
	Funtua (C2)	839.000 c	732.667 ef	785.833 c
LSD $(p \le 0.05)$		*25.508*		*13.905*
Sc1		754.333 c	659.167 f	706.75 d
Sc2		751.000 c	719.333 d	735.17 c
Sc3		815.000 a	731.000 d	773.00 b
Sc4		759.833 c	691.333 e	725.58 c
Sc5		782.500 b	816.000 a	799.25 a
Sc6		792.500 b	682.500	737.50 c
LSD $(p \le 0.05)$		*14.727*		*14.230*
Samsun-3 C1		813.611 a	697.222 c	755.417 a
Funtua C2		738.111 b	735.889 b	737.00 b
LSD $(p \le 0.05)$		*10.413*		*5.993*
PD means		775.861 a	716.556 b	
LSD $(p \le 0.05)$		*6.012*		

1000-Seed weight (TSW) (*g*)

Seed weight is the most important quantity factor. This factor varies between plant species, varieties, and hybrids within one species and conditions of growing [23]. Our findings in Tables 4 and 8 demonstrated the following results. The comparison of the mean values of TSW for the sunflower plant variety showed that C_1 (Samsun-3) had a higher (70.617g), while C_2 (Funtua) had a lower value (58.388g). The superiority of Samsun-3 may be due to its ability to make greater use of obtainable resources, compared to other cultivars, to give more dry matter and better translocation to its seeds performing in better TSW. This result was in agreement with those notified by[23]. Sowing condition effects were highly significant for this trait, in which the highest TSW was related to Sc_6 (72.96g), and the lowest TSW was achieved in Sc_2 (57.78g).

The accretion in the TSW for the late sown with supplementary irrigation can be attributed to a suitable increase in temperature and soil moisture content. Gomes *et al.,* [31], debated that obtainable water is one of the main factors in seed production for sunflower crops by irrigation. Amin El Sir *et al.,* [32], also declared that 1000-seed weight recorded significant differences among four sowing times. The effect of plant density was highly significant and the high population of 62500 plant ha^{-1} resulted in significantly more seed weight (65.285 g) compared with the low population of 50400 plant ha^{-1} (63.721 g). However, Soleymani *et al.,* [33] stated that the difference between 12 (48.95g) and 14 (51.27g) plants m^{-2} was not significant for the TSW of sunflower crop, while Ibrahim [3], claimed that increasing plant crowdedness would lead to decrease in TSW. The result for cultivar × sowing condition interaction furthermore confirmed the superiority of C_1 at Sc_4 (82.570g), compared to the other C × Sc interactions, but its difference with C_1 at Sc_6 was not significant, while the least value of 50.635 g was recorded for C_2 at Sc_2. The superiority of C_1, compared to the second variety, where it recorded consistently the highest values, at most sowing conditions, may be due to valuable soil moisture and its ability to make better use of available resources, to give higher dry matter and translocate it to its seeds resulting in heavier TSW. According to significant sowing condition × plant density interaction on TSW of the sunflower plant. At the too-early covered (Sc_1) and late supplementary irrigation (Sc_6) planting, no differences in TSW were shown between planting density (Table 8). At the late supplementary irrigation planting (Sc_6), TSW was highest (73.125, 72.797g) at the Pd_1 and Pd_2 respectively, but for the earlier covered planting (Sc_2) TSW was lowest (48.748g) at Pd_1 (Table 8).

Westgate [34], pointed out that the main reason for the reduction of grain weight is a decrease in the grain filling period due to stress. Mahmood [13], concluded that there was a significant interaction between three sowing dates with three plant spaces under two different environments in Sulaimani-Iraq for the TSW trait of the sunflower plant. Regarding Tables 4 and 8, the highly significant interaction ($P \leq 0.01$) differences between cultivar and plant density showed, that the highest number of TSW was related to $C_1 \times Pd_1$ (71.191g), and the lowest was achieved in $C_2 \times Pd_1$ (56.251g). Furthermore, the superiority of C_1, compared to the second variety, where it recorded consistently the highest values, at all plant densities, for TSW. Ibrahim, [3] also declared that 1000-seed weight recorded significant differences in five sunflower hybrids among four plant densities.

The results revealed that TSW from sunflowers was significantly affected by sowing condition × cultivars × plant density interactions between these factors. Maximum TSW of 86.693, 85.317, and 84.850 g were noted for too early sowing greenhouse (Sc_4), too early sowing covered (Sc_1) and late sown with supplementary irrigation (Sc_6), respectively at 50400 plant ha^{-1}(Pd_1) and Samsun-3 (C_1), which were no significant differences among them. While the minimum value of 42.217 g was noted for early sowing covered (Sc_2) at 50400 plant ha^{-1} (Pd_1) and the second cultivar (Funtua). It was noted there are TSW differences between varieties about sowing conditions and plant density. These differences are determined by the hybrid features and environmental statuses, and on the other hand, the nutrition space, and soil fertility [35].

Table (8) : Effect of plant density, cultivars, and sowing conditions on 1000 seed weight (g) of Sunflower

Sowing Conditions (Sc)	**Cultivars (C)**	**Plant density plant ha^{-1} (Pd)**		**C×Sc**
		50403 (Pd_1)	**62500 (Pd_2)**	
Sc_1	Samsun-3 (C_1)	85.317 a	75.540 b	80.428 a
	Funtua (C_2)	50.513 g	58.327 ef	54.420 c
Sc_2	Samsun-3 (C_1)	55.280 f	74.553 b	64.917 c
	Funtua (C_2)	42.217 h	59.053 def	50.635 d
Sc_3	Samsun-3 (C_1)	57.783 ef	55.957 f	56.870 d
	Funtua (C_2)	67.467 c	56.803 f	62.135 c
Sc_4	Samsun-3 (C_1)	86.693 a	78.447 b	82.570 a
	Funtua (C_2)	49.777	63.147 cd	56.462 d
Sc_5	Samsun-3 (C_1)	57.220 ef	57.320 ef	57.270 d
	Funtua (C_2)	66.133 c	58.677 ef	62.405 c
Sc_6	Samsun-3 (C_1)	84.850 a	78.447 b	81.648 a
	Funtua (C_2)	61.400 de	67.147 c	64.273 c
LSD $_{(p \leq 0.05)}$		*4.428*		*3.641*
Sc_1		67.915 b	66.933 b	67.42 b
Sc_2		48.748 e	66.803 b	57.78 c
Sc_3		62.625 c	56.380 d	59.50 c
Sc_4		68.235 b	70.797 a	69.52 b
Sc_5		61.677 c	57.998 d	59.84 c
Sc_6		73.125 a	72.797 a	72.96 a
LSD $_{(p \leq 0.05)}$		*2.556*		*2.885*
Samsun-3 C_1		71.191 a	70.044 a	70.617 a
Funtua C_2		56.251 c	60.526 b	58.388 b
L.S.D, 0.05		1.808		*1.569*
PD means		63.721 b	65.285 a	
LSD $_{(p \leq 0.05)}$		*1.044*		

Seed yield (t h^{-1})

Results showed that the effect of sowing condition, cultivars, and plant density, as well as all their interaction on the seed yield (t h^{-1}), were highly significant ($P \leq 0.01$) (Tables 4 and 9). The comparison of the values of the seed yield (t h^{-1}) for sunflower plants of sowing condition showed that too early sowing greenhouse (Sc_4 22 Feb) had the highest (2.740 t h^{-1}), while the late sowing (Sc_3 Mar.-30) had the lowest seed yield (2.131t h^{-1}). Furthermore, earliness in planting by five weeks caused an increase in seed yield of 29%. Early season planting allows the plants a full season growth and often yields higher as they have an extended growth period. Ahmed *et al.*, [36], pointed out that were significantly influenced by sowing dates. Concerning the performance of varieties, the C1 (Samsun-3) was superior (2.736 t h^{-1}) to the other cultivar (2.219 t h^{-1}) and surpassed it by 23% concerning seed yield. In addition, that cultivar had high values of TSW, disk weight, and number of seed $disc^{-1}$. On the other hand, late sowing moves the growth and development of plants in a warm and dry period of season which leads to a shortened growing season. These results are inconsistent with those of [29]. The data revealed that increasing plant density from 50400 to 62500 plant ha^{-1} led to significant increases in seed yield from 2.287 to 2.669 t ha^{-1} and significant overtaking by 17%.

Li *et al.*, [37] also reported that the seed yield of sunflowers increased in response to the increase in plant density (five densities). However, Soleymani [38], stated that increasing plant density, resulting more competition for light between plant, which lead to a depression in the vegetative and reproductive plasticity of a single plant, while a lower plant density, results in the least light absorption by the plants and decrease in seed yield $area^{-1}$ [9]. Also, the interaction between sowing conditions and varieties exerted a highly significant influence on seed yield. The highest yield (3.121t h^{-1}) was obtained from Samsun-3 when sown at too early sowing -greenhouse (Sc_4), while the variety Funtua obtained the lowest seed yield with1.923 t h^{-1} at late sowing condition (Sc_3) and significant overtaking by 62%. The increase in seed yield here is mainly due to the increase in thousand seed weight under the same condition (table 9).

Moreover, the superiority of C_1, compared to C_2, where it recorded consistently the highest seed yield values, at all sowing conditions. However, Sc_4 x C_1 surpassed $Sc_3 \times C_1$ by 34%. For interaction, these findings are in harmony with those noted by [9, 13]. The result for the sowing condition × plant density interaction. The highest value of seed yield (2.985t h^{-1}) was obtained by planting on Feb 22-greenhouse with the highest plant density (62500 plant h^{-1}), due mainly to the higher thousand seed weight attributed to these interactions, while the lowest value (2.030 t h^{-1}) was obtained by late planting on Mar 30 with the lowest plant density (50400 plant h^{-1}) and significant overtaking by 47%, due mainly to the lower thousand seed weight, low number of seed disc^{-1} and disc diameter along with attributed to these interactions. Our data in terms of this interaction were similar to those of [15, 18, 39]. The data for cultivar × plant density interaction confirmed the superiority of Samsun-3, compared to the Funtua cultivar, where it recorded consistently achieving the highest values, at all plant densities, for seed yield ha^{-1}. Our findings are consistent with those of [3].

A significant interaction of these factors, sowing conditions, cultivars, and plant densities is presented in (Tables 4, 9). Maximum yields of 3.299 and 3.205 t ha^{-1} were noted for too early sowing greenhouse (Sc_4) and early sowing –covered(Sc_2), respectively at 62500 plant ha^{-1} (Pd_2) and Samsun-3 cultivar (C_1), which were no significant differences among them, due mainly to relatively higher thousand seed weight attributed to these interactions and it seemed that more plant ha^{-1} compensated for the low value of yield plant^{-1} leading to a high value of yield ha^{-1}, while the minimum value of 1.662 t ha^{-1} was noted for late sowing condition (Sc_3) at 50400 plant ha^{-1} (Pd_1) and the second cultivar (Funtua) and significant overtaking by 99 and 93%, respectively. However, $Sc_4 \times C_1 \times Pd_2$ and $Sc_2 \times C_1 \times Pd_2$ surpassed $Sc_3 \times C_1 \times Pd_2$ (late sowing) which is the following date in the region by 45 and 41%, respectively. Our data in terms of seed yield were similar to those of [40] for this tri-interaction, while Allam *et al.,* [13], pointed out that no significant effects for this tri-interaction.

According to the comparison between too early or early sowing (Pc_1, Pc_2, Pc_3, Pc_4) which was the aim of the study, versus late sowing (Pc_3) to avoid the drought and late sowing plus supplementary irrigation (Pc_6 locally followed method) to avoid the cost and availability of irrigation, along with seed yield. Concerning performer Samsun-3 cultivar (C_1) and superior plant density (Pd_2) we could be discussed that Sc_4 surpassed Pc_6 and Pc_3 by 4 and 29%, respectively, while for the sowing condition x plant density interaction, $Sc_4 \times Pd_2$ surpassed $Sc_6 \times Pd_2$ and $Sc_3 \times Pd_2$ by 6 and 34%, respectively. For the sowing condition x variety interaction, $Sc_4 \times C_1$ surpassed $Sc_6 \times C_1$ and $Sc_3 \times C_1$ by 6 and 33%, respectively, while in case of sowing condition × cultivar x plant density interaction, $Sc_4 \times C_1 \times Pd_2$ and $Sc_2 \times C_1 \times Pd_2$ surpassed $Sc_6 \times C_1 \times Pd_2$ and $Sc_3 \times C_1 \times Pd_2$ by 9, 45 and 6 and 41%, respectively. It was clear that the desired effect on seed yield was due mainly to too early sowing under greenhouse conditions and to a lesser extent to early sowing covered.

Table (9): Effect of plant density, varieties, and sowing conditions on Seed yield t ha^{-1} of Sunflower.

Sowing Conditions (Sc)	Cultivars (C)	Plant density plant ha^{-1} (Pd) 50403 (Pd_1)	Plant density plant ha^{-1} (Pd) 62500 (Pd_2)	C × Sc
Sc_1	Samsun-3 (C_1)	2.944 bc	2.831 c	2.888 b
	Funtua (C_2)	2.019 k	2.581 de	2.300 c
Sc_2	Samsun-3 (C_1)	2.504 ef	3.205 a	2.855 b
	Funtua (C_2)	2.020 k	2.658 d	2.339 c
Sc_3	Samsun-3 (C_1)	2.399 fg	2.278 ghi	2.338 c
	Funtua (C_2)	1.662 l	2.184 ij	1.923 e
Sc_4	Samsun-3 (C_1)	2.943 bc	3.299 a	3.121 a
	Funtua (C_2)	2.045 k	2.672 d	2.358 c
Sc_5	Samsun-3 (C_1)	2.325 gh	2.241 hi	2.283 c
	Funtua (C_2)	1.684 l	2.427 fg	2.056 d
Sc_6	Samsun-3 (C_1)	2.840 c	3.028 b	2.934 b
	Funtua (C_2)	2.055 jk	2.624 de	2.340 c
LSD ($p \leq 0.05$)		*0.141*		*0.095*
Sc_1		2.481 d	2.706 c	2.594 b
Sc_2		2.262 ef	2.932 a	2.597 b
Sc_3		2.030 g	2.231 f	2.131 c
Sc_4		2.494 d	2.985 a	2.740 a
Sc_5		2.004 g	2.334 e	2.169 c
Sc_6		2.448 d	2.826 b	2.637 b
LSD ($p \leq 0.05$)		*0.082*		*0.065*
Samsun-3 (C_1)		2.659 b	2.814 a	2.736 a
Funtua (C_2)		1.914 d	2.524 c	2.219 b
L.S.D, 0.05		0.058		*0.041*
PD means		2.287 b	2.669 a	
LSD ($p \leq 0.05$)		*0.033*		

The findings revealed that the yield of seeds and their associated components from Helianthus annuus was substantially influenced by the date of sowing, the cultivar, and the density of planting, in addition to the majority of interactions among these variables. The investigation indicated that the sowing conditions, genotype, plant density, and the interaction of genotype with climatic parameters significantly impact the overall seed yield. Nevertheless, the optimal yield was achieved on February 22 under transparent plastic coverings or within a greenhouse environment, facilitated by early sowing at elevated plant densities. In the face of challenging environmental conditions, particularly in rainfed settings where supplementary irrigation may be limited after the recommended sowing date, agricultural practitioners in Sulaimany-Kurdistan-Iraq, as well as in other analogous regions, could consider late February (22) under transparent plastic coverings or early March (7) in greenhouse settings as viable alternative sowing dates at high plant densities (62.500 plants ha^{-1}) that may yield satisfactory or at least acceptable seed productivity.

References

1) Susan, S., Alan, B. S., Karen, L. B. G., Judith, A. O. M., Ned, A. T., & Robert, B. (1993). Commercial Speciality Cut Flower Production. Cooperative Extension Services, Kanas State University, Manhattam, Kanas. MF-1084. KSU.

2) Beg, A., Pourdad, S.S., Alipour, S., 2007. Row and plant spacing effects on agronomic performance of sunflower in warm and semi-cold areas of Iran. Helia, 30 (47), 99-104.

3) Ibrahim, H. M. (2012). Response of some sunflower hybrids to different levels of plant density. Apcbee Procedia, 4, 175-182.

4) Basha, H. A. (2000). Response of two sunflower cultivars to hill spacings and nitrogen fertilizer levels under sandy soil conditions. Zagazig Journal of Agricultural Research (Egypt), 27(3).

5) Esechie, H. A., Elias, S., Rodriguez, V., & Al-Asmi, H. S. (1996). Response of sunflower (*Helianthus annuus*) to planting pattern and population density in a desert climate. The Journal of Agricultural Science, 126(4), 455-461.

6) Ion, V., Dicu, G., Basa, A. G., Dumbrava, M., Temocico, G., Epure, L. I., & State, D. (2015). Sunflower yield and yield components under different sowing conditions. Agriculture and Agricultural Science Procedia, 6, 44-51.

7) Sarmah, P. C., Katyal, S. K., & Faroda, A. S. (1994). Response of sunflower (*Helianthus annuus*) cultivars to fertility level and plant population, 39 76-78.

8) Asbag, F. T., Gorttapeh, A. H., Fayaz-Moghadam, A., Saber-Rezaie, M., Feghnabi, F., Eizadkhah, M., ... & Moghadam-Pour, S. N. (2009). Effects of planting date and irrigation management on sunflower yield and yield components. Research Journal of Biological Sciences, 4(3), 306-308.

9) Ali, B. M., Behrouz, A. A., & Mahdi, A. M. (2013). Study the effect of varieties and planting date on sunflower production (*Helianthus annuus* L.), 4 41– 46.

10) Lawal, B. A., Obigbesan, G. O., Akanbi, W. B., & Kolawole, G. O. (2011). Effect of planting time on sunflower (Helianthus annuus L.) productivity in Ibadan, Nigeria. African Journal of Agricultural Research, 6(13), 3049-3054.

11) Sheoran, P., Sardana, V., Chahal, V. P., Sharma, P., & Singh, S. (2015). Effect of sowing time on the yield and quality parameters of sunflower (Helianthus annuus) hybrids under semiarid irrigated conditions of northern India. Indian Journal of Agricultural Sciences, 85(4), 549-54.

12) Elsahookie M. M, Uraha F. and Shihab A. 1996. Chang in Growth and Yield of Sunflower as Influenced by Cultivars and Planting Date. (In Arabic). The Iraqi Journal of Agricultural Sciences – 27(2) 77-89.

13) Allam, A. Y., El-Nagar, G. R., & Galal, A. H. (2003). Response of two sunflower hybrids to planting dates and densities. Acta Agronomica Hungarica, 51(1), 25-35.

14) Olowe, V. I. O., & Adeyemo, A. Y. (2009). Enhanced crop productivity and compatibility through intercropping of sesame and sunflower varieties. Annals of Applied Biology, 155(2), 285-291.

15) Mahmood, H. N. (2013). Effect of planting dates and plant spacing on growth, yield, and yield components of sunflower (*Helianthus annuus* L.) in Iraqi Kurdistan Region. J. Zankoy Sulaimani, 15(4), 59-71.

16) Robertson, J. A., & Green, V. E. (1981). Effect of planting date on sunflower seed oil content, fatty acid composition and yield in Florida. Journal of the American Oil Chemists' Society, 58(6), 698.

17) Anjum, A. S., Muhammad, S. H. E. R., Imran, M., & Arshadullah, M. (2012). Performance of early and late sown sunflower hybrids under an organic farming system in the rainfed area. Science Technology and Development, 31(1) 26-28.

18) Baghdadi, A., Halim, R. A., Nasiri, A., Ahmad, I., & Aslani, F. (2014). Influence of plant spacing and sowing time on yield of sunflower (Helianthus annuus L.). Journal of Food, Agriculture & Environment, 12(2), 688-691.

19) Chajjro, M. A., Zia-ul-Hassan, S. A., & Kubar, K. A. (2013). Sunflower hybrids differentially accumulate potassium for growth and achene yield. Pak J Agri Agril Engg Vet Sci, 29(1), 31-43.

20) Oshundiya, F. O., Olowe, V. I. O., Sowemimo, F. A., & Odedina, J. N. (2014). Seed yield and quality of sunflower (Helianthus annuus L.) as influenced by staggered sowing and organic fertilizer application in the humid tropics. Helia, 37(61), 237-255.

21) Radwan, F. I. (1996). Effect of mycorrhizae inoculation, phosphorus and potassium fertilization on growth, yield and its components of sunflower plants. Journal of Agricultural Research, Tanta Univ.(Egypt), 22(3).

22) Buriro, M., Sanjrani, A. S., Chachar, Q. I., Chachar, N. A., Chachar, S. D., Buriro, B., & Mangan, T. (2015). Effect of water stress on growth and yield of sunflower. *Journal of Agricultural Technology*, *11*(7), 1547-1563.

23) Ibrahim, H. M., & El-Genbehy, M. M. (2009). Response of some sunflower hybrids to different hill spacings and N-fertilization levels. Minufiya Journal of Agricultural Research, 34, 641-659.

24) Ahmad, G., & Qureshi, Z. (2000). Plant population of sunflower under different planting dates. Pakistan Journal of Biological Sciences (Pakistan), 3(11).

25) Shayanfar, M., Soleymani, A., & Shahrajabian, M. H. (2011). Effect of plant densities on solar radiation absorption and depreciation, leaf area index, and crop growth rate of different cultivars of sunflower. Research on Crops, 12(3), 728-730.

26) Hladni, N., Miklič, V., Jocić, S., Kraljević-Balalić, M., & Škorić, D. (2014). Mode of inheritance and combining ability for plant height and head diameter in sunflower (*Helianthus annuus* L.). Genetika, 46(1), 159-168.

27) Villalobos, F. J., Hall, A. J., Ritchie, J. T., & Orgaz, F. (1996). OILCROP-SUN A development, growth, and yield model of the sunflower crop. Agronomy Journal, 88(3), 403-415.

28) Zaffaroni, E., & Schneiter, A. A. (1991). Sunflower production as influenced by plant type, plant population, and row arrangement. Agronomy Journal, 83(1), 113-118.

29) Fetri, M., Ghobadi, M. E., Asadian, G., & Rajabi, M. (2013). Effect of sowing date on yield and yield components of sunflower (*Helianthus annus* L.). Ann. Biol. Res, 4(2), 90-93.

30) Emami-Bistghani, Z., Siadat, S. A., Torabi, M., Bakhshande, A., Alami, S. K., & Shiresmaeili, H. (2012). Influence of plant density on light absorption and light extinction coefficient in sunflower cultivars. Res. Crop, 13, 174-179.

31) Gomes, E. P., Fedri, G., Ávila, M. R., Biscaro, G. A., Rezende, R. K., & Jordan, R. A. (2012). Produtividade de grãos, óleo e massa seca de girassol sob diferentes lâminas de irrigação suplementar. Revista Brasileira de Engenharia Agrícola e Ambiental, 16(3), 237- 246. doi 10.1590/S1415-43662012000300 001

32) Amin El Sir A. I.1, Abubaker A. Abdallah1, Adlan M. Ahmed1, Ezeldeen A. Banaga1 and Omima B. Haj. 2017. Effects of sowing date on sunflower (*Helianthis annuus* L.) yield and yield components under rainfed conditions in Blue Nile State, Sudan. Journal of Agricultural Science and Soil Sciences, 5(3) 060-063.

33) Soleymani, A., Shayanfar, M., Golparvar, A. R., Shahrajabian, M. H., & Naranjani, L. (2011). Response of different sunflower cultivars to various planting densities. Res. Crop, 12, 134-138.

34) Westgate, M. E. (1994). Water status and development of the maize endosperm and embryo during drought. Crop science, 34(1), 76-83.

35) de La Vega, A. J., & Hall, A. J. (2002). Effects of Planting Date, Genotype, and Their Interactions on Sunflower Yield I. Determinants of Oil-Corrected Grain Yield. Crop Science, 42(4), 1191-1201.

36) Ahmed, B., Sultana, M., Zaman, J., Paul, S. K., Rahman, M. M., Islam, M. R., & Majumdar, F. (2015). Effect of sowing dates on the yield of sunflower. Bangladesh Agronomy Journal, 18(1), 1-5.

37) Li, J., Qu, Z., Chen, J., Yang, B., & Huang, Y. (2019). Effect of planting density on the growth and yield of sunflower under mulched drip irrigation. Water, 11(4), 752.

38) Soleymani, A. (2017). Light response of sunflower and canola as affected by plant density, plant genotype and N fertilization. Journal of Photochemistry and Photobiology B Biology, 173, 580-588.

39) Barros, J. F., de Carvalho, M., & Basch, G. (2004). Response of sunflower (Helianthus annuus L.) to sowing date and plant density under Mediterranean conditions. European Journal of Agronomy, 21(3), 347-356.

40) Miller, B. C., Oplinger, E. S., Rand, R., Peters, J., & Weis, G. (1984). Effect of Planting Date and Plant Population on Sunflower Performance 1. Agronomy Journal, 76(4), 511-515.