IMPACT OF CLIMATE CHANGE ON THE GROWTH, YIELD, AND SUNFLOWER CULTIVAR PERFORMANCE UNDER THE INFLUENCE OF PLANT DENSITY.

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ABSTRACT

To determine the impact of climate change on the growth and yield of sunflower when planted at two different climatic times, a field experiment was conducted in Anbar Governorate, specifically in the Ramadi district, in the fields of one of the farmers. Five cultivars were used: "Aqmar", "Haysen", "Isaqi", " Flami a and "Tarzan", at three plant densities of 88,900, 66,670, and 53,300 plants ha^{-1}. A randomized complete block design (R.C.B.D) was used with three replications, in a split plot arrangement, where plant densities occupied the main plots and cultivars occupied the sub plots. The results indicated the superiority of the cultivar "Flami" with the shortest flowering duration at 66.78 and 62.51 days for the spring and autumn seasons, respectively. Additionally, the selected cultivar "Haysen" exhibited superior leaf area 5690 and 5300 cm² for the spring and autumn seasons, respectively. Furthermore, the cultivar "Tarzan" surpassed others by providing the highest disc area at 355.0 and 327.4 cm² for the spring and autumn seasons, respectively. Moreover, the same cultivar outperformed in terms of seed number per disc and seed yield, with 1186 and 1164 seeds, and 5.665 and 5.409 grams disc^{-1} for the spring and autumn seasons, respectively. The high plant density exhibited superiority in seed yield, providing the highest yield of 6.100 and 5.936 µg ha^{-1} for the spring and autumn seasons, respectively, compared to the low plant density of 4.571 and 4.338 µg ha^{-1} for the spring and autumn seasons, respectively. Regarding the interaction between cultivars and plant density, the cultivar "Tarzan" outperformed with the highest yield of 6.528 and 6.385 µg ha^{-1} for the spring and autumn seasons, respectively, with an increase of 50.17% and 55.66% compared to the cultivar "Isaqi" for the spring and autumn seasons, respectively, at a plant density of 55,30 plants ha^{-1}.

Key words: GDD, CAT, Climate action, food security

تأثير التغيرات المناخية في نمو وحاصل تراكيب وراثية من زهرة الشمس تحت الكثافة النباتية

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المستخلص

لمعرفة تأثير التغيرات المناخية على نمو وحاصل زهرة الشمس عند زراعته بموعدين مختلفتين مناخيا، اجريت تجربة حقلية في محافظة الانبار قضاء الرمادي في حقول احد المزارعين استخدمت فيها خمسة تراكيب وراثية وهي اقمار، هايسين، اسحاقي، سخا و في ثلاث كثافات نباتية 88.90 ،66.67 و53.30 الف نبات .هـ$^{-1}$.وبتصميم القطاعات العشوائية الكاملة RCBD وبثلاث مكررات وبالتجربة العاملية بترتيب الالواح المنشقة حيث وضعت الكثافات النباتية بالألواح الرئيسية والتراكيب الوراثية بالألواح الثانوية. اشارت النتائج الى تفوق التركيب الوراثي فلامي باقل مدة للتزهير بلغت 66.78 و 62.51 يوم وللعروتين الربيعية والخريفية على التوالي، كذلك تفوق التركيب المنتخب هايسين بإعطائهـ اعلى مساحة ورقية بلغت 0.5690 و 5300 سم^2 للموسمين الربيعي والخريفي على التوالي وتفوق التركيب الوراثي طرزان بإعطائه اعلى مساحة قرص بلغت 355.0 و 327.4 سم^2 بالعروتين الربيعية والخريفية على التوالي وكذلك تفوق نفس التركيب في صفة عدد البذور في القرص وحاصل البذور حيث 1186 و 1164 بذرة و 5.665 و 5.409 ميكا غرام هـ$^{-1}$ وللعروتين الربيعية والخريفية على التوالي، وتفوقت الكثافة العالية في صفة حاصل البذور حيث اعطت اعلى حاصل بلغ 6.100 و 5.936 ميكا غرام .هـ$^{-1}$ للعروتين الربيعية والخريفية على التوالي مقارنتا بالكثافة الواطئة 4.571 و 4.338 طن .هـ$^{-1}$ ميكا غرام .هـ$^{-1}$ للعروتين الربيعية والخريفية على التوالي، اما التداخل بين التراكيب الوراثية والكثافة النباتية فق تفوق التركيب الوراثي طرزان اذ اعطى اعلى حاصل بلغ 6.528 و6.385 ميكا غرام هـ$^{-1}$ للعروتين الربيعية والخريفية على التوالي وبنسبة زيادة بلغت 50.17% و55.66% عن الصنف اسحاقي وللعروتين الربيعية والخريفية على التوالي في الكثافة النباتية 55.30 الف نبات .هـ$^{-1}$.

الكلمات المفتاحية: درجات الحرارة التجميعية، انزيم الكاتليز، العمل المناخي، الامن الغذائي.

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INTRODUCTION

The significant increase in the world's population has led to a doubling of the need to search for means to increase the productivity per unit area, improve crop quality, and reduce production costs. Sunflower (*Helianthus annuus* L.) is a member of the daisy family (Compositae). It has various uses, including oil extraction from oilseed cultivars and fodder. In Iraq, sunflowers are cultivated on an area of 748 hectares with a production of 1909 tons. The global cultivation area is 27.87 million hectares with a production of 50.2 million tons. Sunflower oil is the fourth largest source of oil in the world after palm oil, soybeans, and rapeseed. According to FAO statistics (2020), the oil content in sunflower seeds can reach 55%.Sunflower seeds also contain a percentage of vitamins such as (K, E, D, A) (23). The growth of the sunflower crop is determined by a set of factors, including environmental factors and factors related to genetic traits and their relationship to soil and crop service operations. The choice of plant density and cultivars is one of these factors. Plant density is a suitable way to control the proportion and efficiency of intercepting effective sunlight in the photosynthesis process. Increasing plant density with favorable growth conditions may increase the yield, but after exceeding the optimum density, increasing the density leads to a decrease in the yield. The catalase enzyme is usually found in all living organisms that live in the presence of oxygen and is one of the important enzymes that remove free radicals (ROS). It is one of the enzymes that have been crystallized and purified (21). The most important function of the catalase enzyme in plants is to protect tissues from the toxic effects of hydrogen peroxide (H_2O_2). It also removes the electrons that lead to the production of (O_2). Catalase works to decompose hydrogen peroxide H_2O_2 into oxygen and water. In a study conducted by (19), superoxide radicals are characterized by their damaging effect on cells and their ability to stimulate a series of reactions that generate reactive oxygen species (ROS), which in turn increase cell damage (3). Despite the suitability of the Iraqi environment for sunflower cultivation, its productivity remains below the required level in Iraq. This is attributed to the lack of proper attention to crop management practices. The productivity of cultivars in recent years in Iraq is low compared to the global average due to genetic mixing of cultivars and their deterioration. This necessitates the implementation of a suitable program for sunflower plants, including introducing new cultivars to assess their genetic and productive potential through cultivation at different plant densities and assessing their response to climate change (7).

MATERIALS AND METHODS

A field experiment was conducted during the spring and autumn seasons of 2023 in the fields of a farmer on the right bank of the Euphrates River in the city of Ramadi, Anbar Governorate. Five cultivars of sunflower were used: "Flami," "Haysen," "Isaqi," "Aqmar," and "Tarzan." The experiment aimed to assess the impact of three plant densities (53,300; 66,670; and 88,890 plants ha^{-1}) with fixed distances between rows of 75 cm and variable distances between plants (15, 20, 25 cm) on field traits, grain yield, and its components for the different sunflower cultivars. A randomized complete block design (R.C.B.D) was used with three replications, in a split plot arrangement, where plant densities occupied the main plots and cultivars occupied the sub plots. The experimental plot had dimensions of 3×4 meters and consisted of 5 rows, each with a length of 3 meters. **Crop management operations, including fertilization, weed control, and irrigation, were carried out according to scientific recommendations.**. The following traits were studied: number of days from planting to 95% flowering, leaf area (cm^2), disc area (cm^2), seed number per disc, grain yield (Mg ha^{-1}), catalase enzyme (CAT) activity, and accumulated heat units from emergence to 95% maturity (degree days Celsius). The accumulated heat units were calculated by estimating the daily heat units, which are the average daily temperature minus the base temperature (8°C), as suggested by Sadras and Hali (1988), and then summing the daily heat units from emergence to 95% maturity, as estimated by (2). The statistical analysis of the studied traits was conducted using the analysis of variance (ANOVA) method for the split-plot design within the randomized complete block design. The least significant difference (LSD) test was used to compare the means at a significance level of 5%.

RESULTS AND DISCUSSION

The number of days required for 95% flowering (days): Flowering is a quantitative genetic trait controlled by a large number of genes, thus it is influenced by climate change. The most important factors affecting flowering are photoperiod and temperature, with temperature being the most significant environmental factor controlling flowering. Since yield depends on the duration of seed filling, flowering significantly affects yield for each cultivar due to its association with both reproductive and vegetative stages, and the suitable conditions for flowering, pollination, and seed formation. The results revealed significant differences between cultivars and plant densities (Table 1). The cultivar "Aqmar" exhibited the longest flowering duration at 71.33 days, and did not differ significantly from the cultivar "Tarzan," which had a flowering duration of 70.78 days. On the other hand, the cultivar "Flami" stood out for early flowering, with a duration of 66.78 days for the spring, while for the autumn crop, "Flami" also distinguished itself by having the shortest flowering duration of 62.51 days, whereas the cultivar "Tarzan" showed delayed flowering, with the highest number of days to flowering at 67.14 days. The increase in flowering duration provided a greater opportunity for larger leaf area formation, which reflected in increased yield due to the larger source size providing more nutrients to the plant and seeds. This result is consistent with studies by (4 , 5, 12). Plant density showed significant differences as the density of 88,900 plants per hectare resulted in the shortest duration at 67.53 days to achieve 95% flowering, compared to 69.07 and 70.60 days for the densities of 66,670 and 53,300 plants per hectare, respectively, for the spring crop. In the autumn crop, the density of 66,670 plants per hectare stood out with the shortest duration to reach 95% flowering, and did not differ significantly from the high density of 88,900 plants per hectare, while the low plant density was delayed in flowering, resulting in a longer duration of 66.53 days. The early flowering with increased plant density is attributed to reduced radiation and increased competition for nutrients, prompting the plant to flower earlier. This result is consistent with studies by (10 , 14 , 20, 22). Regarding the interaction between cultivars and plant density, the "Flami" cultivar gave the shortest duration at 65.67 days at a plant density of 88,900 plants per hectare, while the two cultivars "Aqmar" and "Tarzan" exhibited the longest duration at 73.00 days at a plant density of 53,300 plants hectare^{-1} for the spring season. In the autumn season, the cultivar "Haysen" recorded the shortest duration to flowering, at 61.33 days with a high plant density of 88,890 plants hectare^{-1}, while the cultivar "Tarzan" recorded the longest duration to flowering, at 69.15 days with a low plant density of 53,300 plants per hectare.

Table 1. The effect of cultivars and plant density on the number of days required for 95% flowering

cultivar	Plant density (Thousand plant ha^{-1})			
	53.30	66.67	88.90	
Flami	68.00	66.67	65.67	66.78
	63.55	62.14	61.85	62.51
Haysen	69.00	67.67	66.33	67.67
	65.06	62.75	61.33	63.05
Isaqi	70.00	68.00	68.33	68.78
	66.66	64.37	64.88	65.3
Aqmar	73.00	72.00	69.00	71.33
	68.22	57.47	65.37	63.69
Tarzan	73.00	71.00	68.33	70.78
	69.15	67.24	65.04	67.14
L.S.D %5		1.874		0.540
		1.502		0.389
Mean	70.6	69.07	67.53	
	66.53	62.79	63.69	
L.S.D %5		0.985		
		0.834		

The leaf area (cm²): The importance of leaf area lies in its impact on plant yield, as leaves perform the process of dry matter manufacturing in various parts of the plant. An increase in leaf area leads to an increase in photosynthetic representation. Leaves manufacture the majority of materials in the plant. Leaf area can also be used as a selection criterion for high yield due to the positive relationship between leaf area and plant yield (9). The results indicate significant differences between cultivars and plant density (Table 2). The "Haysen" cultivar outperformed with highest leaf area at 5690 cm², while the "Isaqi" cultivar recorded the lowest leaf area, at 4993 cm² for the spring season. In the autumn season, the "Haysen" cultivar was distinguished with the highest leaf area, at 5300 cm², while the "Tarzan" cultivar recorded the lowest leaf area, at 4589 cm². The average leaf area increases as the plant matures, and this result is consistent with (4, 5, 17). The morphological traits have a positive relationship with absorption, photosynthetic representation, and growth for the purpose of forming dry matter that is converted into the reproductive part. The plant density differed significantly for the leaf area trait. The plant density of 53,300 plants ha^{-1} provided the highest leaf area at 6057 cm², with an increase of 17.33% and 29.59% compared to the densities of 66,670 and 88,890 plants ha^{-1}, respectively, for the spring season. Similarly, for the autumn season, the lower plant density of 53,300 plants ha^{-1} also outperformed with the highest leaf area, at 5660 cm², with an increase of 18.85% and 30.20% compared to the densities of 66,670 and 88,890 plants ha^{-1}, respectively. The increase in leaf area in the lower plant density of 53,300 plants ha^{-1} is attributed to the greater distance between plants and the absence of competition among them. This result is consistent with studies by Abdul-Hamed and Abood (2021), Ma *et al.* (2022), and Ibrahim and Abdulhamed (1, 11, 16). The interaction between cultivars and plant density resulted in the cultivar "Haysen" providing the highest leaf area, at 6687 cm², at a plant density of 53,300 plants ha^{-1}. In contrast, the cultivar "Tarzan" yielded the lowest leaf area, at 4104 cm², for the spring season. Similarly, for the autumn season, the cultivar "Haysen" exhibited the highest leaf area, at 6167 cm², at a plant density of 53,300 plants ha^{-1}, while the cultivar "Tarzan" yielded the lowest leaf area, at 3567 cm².

Table 2. The effect of cultivars and plant density on leaf area (cm^2)

Cultivar	Plant density (Thousand plant ha^{-1})			
	53.30	66.67	88.90	
Flami	5828	5095	5014	5312
	5600	5000	4867	5156
Haysen	6687	5392	4991	5690
	6167	4967	4767	5300
Isaqi	5692	4829	4458	4993
	5367	4433	4233	4678
Aqmar	6084	5489	4803	5459
	5567	4867	4300	4911
Tarzan	5994	5007	4106	5036
	5600	4600	3567	4589
L.S.D %5		426		107
		644		161
Mean	6057	5162	4674	
	5660	4773	4347	
L.S.D %5		233		
		285		

The catalase enzyme (CAT) activity

The catalase enzyme (CAT) activity varied significantly among cultivars and plant densities, as shown in Table 3. The cultivar "Flami" exhibited the highest activity of the antioxidant enzyme CAT, with the highest average absorption units at 10.80 and 11.30, respectively, for the spring and autumn seasons. In contrast, the cultivar "Aqmar" showed the lowest CAT enzyme activity, with an average of 8.48 and 8.86 AU for the spring and autumn seasons, respectively. Studies suggest that exposure to stress increases the activity of antioxidant enzymes as a response to neutralize harmful effects, which is consistent with findings by (19). The results of

Table (3) indicate a significant effect of plant density on the activity of the CAT enzyme. The low plant density treatment recorded the lowest average for the at 9.49 and 9.86 AU for both the spring and autumn seasons, respectively. Conversely, the high plant density yielded the highest average activity of the CAT enzyme, with values of 10.20 and 10.62 AU for the spring and autumn seasons, respectively. In the autumn season, there was no significant difference in enzyme activity between the medium and high plant densities. The results indicate significant interaction between study factors. The plant density of 88,890 plants ha^{-1} yielded the highest absorption units with the "Flami" cultivar, with values of 11.20 and 11.70 AU for the spring and autumn seasons, respectively. Conversely, the "Aqmar" cultivar with the low plant density of 53,300 plants ha^{-1} recorded the lowest average catalase enzyme activity, with values of 8.02 and 8.26 AU for the spring and autumn seasons, respectively. It is worth noting that catalase enzyme activity was higher in the autumn season, possibly due to higher temperatures during this season.

Table 3. The effect of cultivars and plant density on catalase enzyme (CAT) activity

Cultivar	Plant density (Thousand plant ha^{-1})			
	53.30	66.67	88.90	
Flami	10.22	10.98	11.20	10.80
	10.98	11.23	11.70	11.30
Haysen	9.82	10.08	10.24	10.05
	10.12	10.33	10.91	10.45
Isaqi	9.51	9.71	9.85	9.69
	9.83	10.04	10.23	10.03
Aqmar	8.02	8.47	8.96	8.48
	8.26	8.99	9.33	8.86
Tarzan	9.87	10.14	10.77	10.26
	10.11	10.47	10.94	10.51
L.S.D %5		0.55		0.26
		0.61		0.30
Mean	9.49	9.88	10.20	
	9.86	10.21	10.62	
L.S.D %5		0.40		
		0.42		

Area of the disc (cm^2): The area of the disc is one of the most important traits that affect seed yield, and climatic variations are among the factors that control yield. This trait is positively correlated with disc yield (6). Table 4 demonstrates significant differences among cultivars and plant density, where the "Tarzan" cultivar gave the largest disc area, at 355.0 and 327.4 cm^2 for the spring and autumn seasons, respectively. While, the "Flami" cultivar in the spring season and the " Haysen " cultivar recorded the smallest disc area, of 277.9 and 266.8 cm^2, respectively. Increasing the disc area in sunflower plants is of great importance in increasing *y*ield, a result consistent with (4 , 5). The result indicates significant differences in plant density, where a plant density of 53.30 thousand plants hectare^{-1} gave the highest disc area, at 344.9 and 366.0 cm^2 for the spring and autumn seasons, respectively, compared to plant densities of 66.7 and 88.9 thousand plants per hectare, which gave the lowest disc area of 299.6 and 284.0 cm^2 for the spring season and 284.3 and 263.3 cm^2 for the autumn season, respectively. The reason for the increase is attributed to intense competition among plants in high density, leading to a reduction in leaf area, which in turn increases the disc area. This result is consistent with Hassan *et al.,* (2019), Khattab (2020), and Marwa *et al*., (11 , 15 , 20). The interaction between cultivars and plant density showed that the Tarzan cultivar excelled by providing the highest disc area, at 375.7 and 355.4 cm^2 at a plant density of 53.33 thousand plants ha^{-1} for both the spring and autumn seasons, respectively. This represented an increase of 50.6% compared to the Haysen cultivar at a plant density of 88.89 thousand plants hectare^{-1} for the spring season, while the increase for the autumn season was 44.23% compared to the Isaqi cultivar at the high plant density of 88.89 thousand plants hectare^{-1}.

Table 4. The effect of cultivars and plant density on disc area (cm^2)

cultivar	Plant density (Thousand plant ha^{-1})			Mean
	53.30	66.67	88.90	
Flami	321.8	256.4	255.4	277.9
	319.5	260.8	257.7	279.3
Haysen	313.8	277.7	249.5	280.3
	308.8	262.8	228.9	266.8
Isaqi	360.5	273.8	267.9	300.7
	348.3	261.8	246.4	285.5
Aqmar	352.8	338.9	308.8	333.5
	347.9	310.5	283.8	314.1
Tarzan	375.7	351.1	338.3	355.0
	355.4	325.7	301.2	327.4
L.S.D %5		42.9		16.8
		48.2		19.4
Mean	344.9	299.6	284.0	
	336.0	284.3	263.6	
L.S.D %5		23.1		
		20.7		

Number of seeds per disc: The number of seeds per disc is considered a major component of yield and significantly affects plant yield. Improving any trait related to yield leads to an increase in plant yield (5). Table 5 shows significant differences between cultivars and plant density. The Tarzan cultivar outperformed with the highest number of seeds per disc at 1186 and 1164 seeds for the spring and autumn seasons, respectively. There was no significant difference compared to the Flamy cultivar for the spring season and with all cultivars for the autumn season, except for the Aqmar cultivar. The increase in the number of seeds per disc can be attributed to the increase in disc area, resulting in more seeds per disc. This result is consistent with the findings of (1, 4, 23). The plant density of 53.30 thousand plants ha^{-1} gave the highest number of seeds $disc^{-1}$ at 1208.0 seeds, with an increase of 4.95% and 13.64% for densities of 66.67 and 88.88 thousand plants ha^{-1}, respectively. In the autumn season, the plant density of 53.30 thousand plants ha^{-1} also outperformed, with the highest number of seeds $disc^{-1}$ at 1192 seeds, with an increase of 6.33% and 14.4% compared to densities of 66.67 and 88.88 thousand plants ha^{-1}, respectively. The decrease in seed number can be attributed to the decrease in disc area due to higher densities, leading to increased competition for available growth resources. This result is consistent with the findings of (11, 15, 18). the cultivar Tarzan resulted with highest number of seeds per disc at 1243.7 and 1221.5 seeds at a plant density of 53.30 thousand plants ha^{-1} for both the spring and autumn seasons, respectively. While, the cultivar Haysen gave the lowest number of seeds per disc, with 1028.0 and 1004.2 seeds at a plant density of 88.9 thousand plants per hectare for both the spring and autumn seasons, respectively.

Table 5. The effect of cultivars and plant density on number of seeds per disc

cultivar	Plant density (Thousand plant ha^{-1})			Mean
	53.30	66.67	88.90	
Flami	1201.9	1165.0	1076.7	1148
	1203.4	1129.8	1050.6	1128
Haysen	1175.6	1085.3	1028.0	1096
	1159.6	1054.3	1004.2	1073
Isaqi	1213.7	1159.3	1041.3	1138
	1201.3	1123.9	1022.8	1116
Aqmar	1206.3	1153.3	1047.2	1136
	1173.4	1134.1	1021.8	1110
Tarzan	1243.7	1193.3	1120.1	1186
	1221.5	1161.2	1108.5	1164
L.S.D %5		82.8		41.3
		58.2		28.1
Mean	1208	1151	1063	
	1192	1121	1042	
L.S.D %5		47.5		
		30.1		

Total seed yield (µg ha^{-1})

Seed yield is a field-scale measure that provides the final value for the cultivar and is considered a function of individual plant yield and the number of plants per unit area, greatly influenced by climatic variations (5). The result shows significant differences between cultivars and plant density for the seed yield (Table 6). The cultivar Tarzan gave the highest yield at 5.665 and 5.409 µg ha^{-1} for both the spring and autumn seasons, respectively, which was not significantly different from the cultivar Flami. However, it differed significantly from the other cultivars for both seasons. The high yield can be attributed to the positive relationship between seed yield per unit area and plant seed yield, as well as the superiority of the cultivar Tarzan in yield components. On the other hand, the cultivar Haysen gave the lowest yield at 4.836 and 4.582 µg ha^{-1}, despite not having the smallest disc area or the lowest number of seeds. This may be due to the smaller size and lower weight of the seeds. These results are consistent with (4, 13).

Table 6. The effect of cultivars and plant density on total seeds yield (µg ha^{-1})

cultivar	Plant density (Thousand plant ha^{-1})			Mean
	53.30	66.67	88.90	
Flami	4.515	5.335	6.374	5.408
	4.324	5.217	6.311	5.284
Haysen	4.560	4.795	5.900	5.085
	4.415	4.634	5.717	4.922
Isaqi	4.347	4.469	5.693	4.836
	4.102	4.212	5.431	4.582
Aqmar	4.516	5.205	6.006	5.242
	4.222	5.092	5.837	5.050
Tarzan	4.919	5.548	6.528	5.665
	4.627	5.214	6.385	5.409
L.S.D %5		0.55		0.26
		0.38		0.17
Mean	4.571	5.070	6.100	
	4.338	4.874	5.936	
L.S.D %5		0.25		
		0.20		

Plant density varied significantly for the total seed yield. The plant density of 88.89 thousand plants per hectare outperformed with highest seed yield of 6.10 and 5.936 µg ha^{-1} for both the spring and autumn seasons, respectively. This indicates that higher plant density compensated for the decrease in yield per individual plant and its components. On the other hand, the plant density of 53.30 thousand plants per hectare resulted in the lowest yield at 4.571 and 4.338 µg ha^{-1}. These results are consistent with studies by (8, 11, 16, 18, 25). The results revealed a significant interaction between study factors. Where the cultivar Tarzan outperformed others, with the highest seed yield of 6.528 and 6.385 µg ha^{-1} for 88.88 thousand plants per hectare both in the spring and autumn seasons, respectively. This represented an increase of 50.17% and 55.66% compared to the Isaqi cultivar for the respective seasons, at a plant density of 55.30 thousand plants per hectare.

Accumulated Growing Degree Days (GDD)

Temperature is one of the most critical elements of climate that directly and indirectly affects the growth and yield of agricultural crops. It determines the distribution of plants, as well as their planting and maturation seasons. Additionally, temperature affects physiological processes within plants such as photosynthesis, respiration, growth, nutrient and water absorption, and transpiration rate. Temperature also has an indirect impact through its influence on soil organisms, which create conditions for supplying crops with nutrients and spreading diseases that affect the crops. The result indicates that the cultivar Aqmar had the lowest accumulated growing degree days, totaling 1360.1 degrees Celsius, while the cultivar Isaki recorded the highest number of growing degree days at 1571.9 degrees Celsius for the spring season. For the autumn season, the cultivar Tarzan showed the lowest accumulated growing degree days at 1449.5 degrees Celsius, whereas the cultivar Ishaki had the highest number of accumulated growing degree days at 1612.9 degrees Celsius. The variation between cultivars can be attributed to their different responses to prevailing environmental conditions during the study. Furthermore, cultivar Aqmar accelerated flowering in the spring season, while cultivar Tarzan did so in the autumn season (Table 1). As for plant densities, the high plant density of 88.90 thousand plants $hectare^{-1}$ exhibited the lowest heat accumulation, totaling 1533.4 degrees Celsius, compared to the medium density of 66.67 thousand plants $hectare^{-1}$ and the low density of 53.30 thousand plants $hectare^{-1}$, which recorded 1541.6 and 1555.0 degrees Celsius, respectively, for the autumn season. This is attributed to the high-density plants flowering earlier. This finding is consistent with the research conducted by Hamad and Abdulhamed (3, 8, 20, 24). The response of cultivars to plant density treatments varied, with the lowest heat units recorded at 1356.8 degrees Celsius for the "Aqmar" cultivar at a plant density of 88.90 thousand plants $hectar^{-1}$, representing a decrease of 13.98% compared to the "Isaqi" cultivar at a plant density of 53.30 thousand plants per hectare during the spring season. As for the autumn season, the "Tarzan" cultivar exhibited the lowest accumulated heat units at 1487.7 degrees Celsius when planted at a density of 88.89 thousand plants $hectar^{-1}$, indicating an 8.44% decrease compared to the "Isaqi" cultivar at a plant density of 53.30 thousand plants $hectar^{-1}$. The decrease in cumulative heat units at high plant densities resulted from a reduction in the number of days to flowering, leading to lower heat unit accumulation.

Table 7. The effect of cultivars and plant density on accumulated growing degree days (GDD)

Cultivar	Plant density (Thousand plant ha^{-1})			Mean
	53.30	66.67	88.90	
Flami	1496.6	1490.7	1485.0	1490.8
	1556.8	1544.7	1536.0	1545.8
Haysen	1505.6	1493.9	1482.5	1494.0
	1546.9	1537.1	1529.6	1537.9
Isaqi	1577.3	1569.2	1569.2	1571.9
	1624.8	1611.4	1602.5	1612.9
Aqmar	1364.8	1358.8	1356.8	1360.1
	1530.8	1519.8	1511.3	1520.6
Tarzan	1461.1	1451.9	1448.8	1453.9
	1515.6	1495.2	1487.7	1499.5
L.S.D %5		52.11		22.13
		44.57		18.93
Mean	1481.1	1472.9	1468.5	
	1555.0	1541.6	1533.4	
L.S.D %5		N.S		
		20.12		

CONCLUSION

1- Clear variations among cultivars of sunflower were found in response to climatic changes, as indicated by cumulative heat units.
2- The increase in yield is a result of both an increase in the disc area and the number of seeds per disc.
3- The use of plant density helps in exploring the genetic potential of cultivars.
4- It is recommended to use the cultivar "Tarzan" and "Flami" due to their superiority in yield and its components in both spring and autumn seasons.

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