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Estimation of some genetic parameters of the sunflower genotypes under drought stress

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Abstract

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A field experiment was carried out in the fields of the College of Agriculture- University of Baghdad with the aim of improving some of the characteristics of the sunflower crop. Selecting for drought tolerance using two sunflower varieties Shamous and local was done by adopting selection criteria including early flowering plant height, and disc diameter under the intensity of 10% selection and under three irrigation periods (5 days, 8 days, 10 days). The experiment was designed using the split plot design with replications during the growing seasons spring 2019 and spring 2020. The results of the statistical analysis showed that the selection was efficient in improving the qualities of the sunflower in addition to increasing the tolerance to drought stress, where the S1 progeny (SHD) gave the highest yield of grains/plants (114.33), as well as it gave the highest disc diameter of 22.86 cm. The difference of heterogeneity and phenotypic variation were not significant at 50% flowering stage (10.21 and 10.92), however, heritability of the broad sense and genetic progress was high for two selected traits at early flowering and stem height. It was found that the S1 progeny (LD) and (SHD) gave the highest grain yield of 8.240 t/ha and 7.341 t/ha respectively. The two varieties Shamous and local showed a high response to the selection and that the selection led to the improvement of most of the qualities and increased tolerance to drought stress, and a decrease in the height of the plant will lead to an increase in its tolerance to drought stress.

Keywords: Sunflower; drought; heritability

Introduction

Seeds of sunflower contains unsaturated fatty acids and lack of cholesterol, as well as its oil contains several soluble vitamins such as A, E and K, and the sunflower is used as fodder for livestock because it contains a high protein content (Ahmad et al., 2009; Yasir & Abed,2024). Biotic and abiotic stresses are key factors causing huge losses in agricultural production in Iraq (Adhab & Alkuwaiti, 2022; Khalaf et al., 2023a, b; Mohammed et al., 2021; Adhab et al., 2018; 2019). Drought is one of the main obstacles that limit the cultivation of crops and the expansion of agriculture (Adhab, 2021; Adhab et al., 2021; Al-Assafi & Abed, 2014; Abed & Abed, 2010; Abed, 2011). There have been many attempts to confront the stress resulting from drought, among which is spraying crops with proline acid, desalination and drip irrigation, as well as adding fertilizers such as nitrogen and potassium, which help reduce stress damage (Abed et al., 2018; Khezzani et al., 2016). These practices remain less effective compared to the correct breeding methods that lead to increasing the efficiency of the crop to tolerate stress and the stability of its yield under stress conditions (Okab & Abed, 2023). Due to high cost and labor, drought-induced stress is one of the main aspects of loss and appears to be an active threat to constrain crop productivity in the future with climate change and global warming increase (Abed et al., 2018; Obaid & Adhab, 2025; Elis & Yildirim, 2021). Plant physiologists classify drought tolerance as the persistence of plant growth during drought stress and accelerating healing at the end of drought stress. Similarly, the agronomists explanation for stress tolerance is stability in the yield performance of a crop in environments under water deficiency (Keneni et al., 2016; Alogaidi et al., 2024). This study aims to improve two varieties of sunflower by selection according to three selection criteria, namely the least number of days from planting to flowering, the height of the plant and the largest diameter of a disc with the possibility of determining which criteria are more efficient, and then evaluate the performance of the selected genotypes under three levels of water deficiency to find out which genotype has high yield and drought tolerance.

Materials and Methods

A field experiment was carried out during the spring seasons of 2019 and 2020 in the field of experiments, College of Agriculture, University of Baghdad for the aim of improving two varieties of sunflower crop by selection according to three selection criteria: early flowering, the plant height and the largest plant disc diameter with a selection intensity 10% to determine which genotypes are the most tolerant to drought.

Season one (Spring 2019)

The land of the experiment was plowed, leveled and divided with distance between the farrows (0.75 cm), the seeds were planted at the rate 3–5 seeds/hole and the distance between the holes (0.25 cm) for each of the two varieties. Urea fertilizer (N46%) was supplied at a rate of 60 kg.h^{-1} (Ashri, 2006). Urea was supplied twice, the first application at four-leaves-stage; the second application was at the flowering stage.

Second (Spring Season 2020)

A field experiment was carried out at the College of Agriculture, University of Baghdad, for the purpose of evaluating the performance of genotypes under nitrogen levels. The experiment was designed using the RCBD design and in the arrangement of split plot design, where the main plots were period of irrigation in (5, 8, 10 days), and sub-plots were genotypes (8 genotypes) (Table 1).

The studied traits

1 – Number of days from planting to 50% flowering;

2 – Disc diameter, cm;

3 – Plant height, cm;

4 – Genetic parameters: Genetic progression, genotypic coefficient of variation and phenotypic coefficient of variation;

5 – Total plant yield ton/ha: Sunflower genotypes were harvested in every experiment unit and then, the individual plant yield was multiplied in plant density.

Table 1. Selected genotypes with their parents of sunflower

Numbers	Genotypes	Details
1	LF	selected for early flowering of the local variety
2	LD	Selected of the discus diameter from the common variety
3	LS	Selected of plant height of the common variety
4	LC	The origin of the local variety
5	SHF	Selected of early flowering of the Shamous variety
6	SHD	Selected of disc diameter of Shamous variety
7	SHS	Selected of plant height of Shamous variety
8	SHC	The Shamous variety

Results and Discussion

The early flowering leads to improvement of fertility and increase of total yield of seeds. The results of Table 2 indicate that there are significant differences between the genotypes in the period from planting to flowering, as this period decreased in all selected genotypes compared to the parents and the S1-progeny (SHF) gave the minimum period of 64.11 days. It did not differ significantly from the S1-progeny (SHS), while the S1-progeny (SHC) gave the highest number of days from planting to flowering about 75.56 days, the selection showed its effectiveness in reducing the period from planting to flowering to the lowest possible period in the genotypes compared to the original (Shamous variety). As the biological and physiological activities are increase of large amounts of CO_2 molecules, as well as reducing the time required for flowering. The early flowering is one of the clear indicators of the crop's resistance to stress. Our results are in the same trend with previous results found by (Buriro et al., 2015; AL-Behadili & Abed, 2019). It is noted that there is a significant effect of irrigation periods in the interval between planting to 50% flowering, as the irrigation period of 10 days gave the least period to about 64.00 days compared to the irrigation period of 5 days, which gave the highest period to flowering about 76.71 days, the reason for reducing the period to flowering stage with increased drought stress was inducible of flowering hormones that accelerated of plants in the flowering stage (Jones & Phillips, 1966). There was a significant difference between irrigation periods and S1-progenies, as each of the S1-progenies (SHF) (SHS) (SHD) (LF) (LS) (LD) gave in the irrigation period 10 days the least period to flowering about to 60.00 days, 60.67 days, 63.33 days, 64.00 days, 64.00 days and 62.00 days, respectively, while the parent (LC) gave the highest period to flowering (87.00 days) in the irrigation period of 5 days. The results show that all genetic variations are higher than the environmental variations for the duration from planting to 50% flowering and the heritability of broad sense of all genotypes under irrigation periods was about 74.58, 72.54 and 83.03 for the three irrigations respectively. The values P.V.C and G.C.V about to 6.90 and 5.19 for the first irrigation and 8.85, 7.45 for the second irrigation and 6.25 and 5.70 to the third irrigation. This indicates homogeneity in 50% flowering and the heritability narrow sense was low about to 23.40 and the genetic progress of the three irrigations 2.52, 2.48 and 1.64 respectively, and these results refer to the possibility of improving flowering via selection.

Plant height

The importance of selecting plants with short stems is to protect plants from logging down and breaking with getting the optimal distribution of leaves**.** The results of Table 3 show significant differences between the S1-progenies, as the S1-progenies (LS) and (SHS) gave the lowest plant height of 160.7 cm and 163.0 cm respectively, while the parent (LC) gave the highest value of the trait of 184.7 cm and did not differ significantly from each of the S1-progenies (LD), (LF) and (SHD). The difference of genotypes in plant height is due to its genetic nature separated from the genetic and environmental interaction, as well as the selection for short stem (Schoeman, 2003). The period of 5 days gave the highest value of the plant height (199.7 cm). The water stress led to a decrease in the height of the plant, as the irrigation period gave 10 days the lowest value of the plant height (144.0 cm) that the decrease in the plant height under insufficient water, which leads to breakdown of water content in the stem cells. There were significant differences between the genotypes and irrigation periods due to the different genetic nature of the genotypes, as the S1-progenies (SHS) and (LS) at the duration of irrigation gave 10 days the lowest value of the trait amounted to 132.7 cm and 136.6 cm respectively, while the S1-progenies (LF), (LC), (LD) and (SHD) (SHC) in the irrigation period of 5 days gave the highest values of the trait amounted to 212.3 cm, 208.7 cm, 205.2 cm, 204.4 cm and 201.3 cm, respectively.

The results showed that the heterogeneity is higher than the environmental variations, so the value of heritability increased in the broad sense and amounted to 73.75 for the first irrigation and 60.65 for the second irrigation, while the heritability was average for the third irrigation and amounted to 54.51, the values of P.C.V and G.C.V about to 6.34 and 5.44, 7.30 and 5.68 respectively for the second irrigation, 5.70 and 4.21 for the third irrigation, the heritability of narrow sense was 16.79 while the genetic progress of S1-progenies under three irrigation periods are 3.72, 3.87 and 2.42. This indicates that the additive genes were effective in this trait, so other selection cycles could be effective in further improving this trait (Houmanat et al., 2016; Okab & Abed, 2023).

Table 2. Effect of irrigation durations in the period from planting to flowering 50% in selected genotypes and their parents from the sun flower for the spring season 2020

Period Irrigation	LF	LD	LS	LC	SHF	SHD	SHS	SHC	Mean
5	73.76	81.33	75.33	87.00	69.33	76.33	72.00	78.67	76.71
8	63.33	70.00	76.00	71.00	63.00	69.33	63.00	76.00	69.00
10	64.00	62.00	64.00	66.00	60.00	63.33	60.67	72.00	64.00
lsd 5%	4.53								2.40
Mean of genotypes	67.00	71.11	71.78	74.78	64.11	69.67	65.22	75.56	69.90
lsd 5%	2.59								
Genetic variation	$\sigma^2 g_1 = 27.61$		$\sigma^2 e_1 = 10.08$		$\sigma^2 p_1 = 37.69$				
	$\sigma^2 g_2 = 26.47$		$\sigma^2 e_2 = 10.02$		$\sigma 2 p_2 = 36.49$				
	$\sigma^2 g_3 = 13.31$		$\sigma^2 e_3 = 2.72$		$\sigma 2 p_3 = 16.03$				
Percentage of genetic values	PCV% = 6.9	G.C.V% = 5.19	P.C.V% = 8.75	G.C.V% = 7.45	G.C.V% = 7.45	P.C.V% = 8.75	P.C.V% = 6.25	G.C.V% = 5.70	
Heritability and gain from selection	GA_1=2.52	GA_2=2.48	GA_3=1.64	$h^2_{b.s1}$%=74.58	$h^2_{b.s}$2%=72.54	$h^2_{b.s}$3%=83.03	$h^2_{n.s}$% = 23.40		

Disc diameter

The diameter of disc is one of the most important factors that helps increase the yield of seeds. The results of Table 4 indicate that there are significant differences between the S1-progenies in the diameter of the disc, as it gave the S1-progeny (SHD) the highest value of 22.86 cm, superior to all genotypes, while the S1-progeny (SHS) gave the lowest value of the trait about to 19.02 cm and did not differ significantly of parent (LS), which gave a value of 19.62 cm, the genotype differ in their ability to justify of osmotic and the stability of the cell wall, which makes them differ in their ability of photosynthesis, the increase in disc diameter in selected S1-progenies is due to their ability to optimize water use and raise net representation, as well as increasing the number of leaves in the plant being responsible for photosynthesis (Shaker & Mohammed, 2011). The results showed significant differences between the irrigation periods in the disc diameter, as the irrigation period of 5 days gave the highest value of 24.20 cm, while the irrigation period of 10 days gave the lowest value of 17.24 cm. These results are consistent with the results of Nezami et al. (2008).

There were significant differences in the interaction between irrigation periods and genotypes due to the inability of all genotypes to resist stress due to the difference in their genome, the parent (SHS) in the irrigation period of 5 days gave the highest value of the trait reached 27.09 cm, while the genetic structure itself in the irrigation period gave 10 days the lowest value of the trait amounted to 16.28 cm. The results show a significant of genetic variations from the environmental variations of the first and second irrigation, while the environmental variations were higher than the genetic variations in the third irrigation, so this was reflected in the percentage of inheritance, which was average for the first irrigation, as it amounted to 62.53 and was low for the second and third irrigation, amounting to 44.04 and 7.96 respectively, although the genetic variations were higher than the environmental, even by a small percentage, but the selection and its success does not depend only on genetic variation, but depends on the heritability (Al-Temimi & Abed, 2016; Jessup et al., 2020).

Plant yield, g/ plant

The results of Table 5 indicate that there are significant differences between the genetic structures in the plant yield for the whole and the selected genetic structure for the diameter of the disc (LD) gave the highest yield of the plant amounted to (155.47 g/plant), superior to all genotypes and superior to its parent, while the S1-progeny for short stem (LS) gave the lowest yield of the plant amounted to (29.80 g/plant) and did not differ significantly from each of the genotypes (SHS) and (SHC). The genetic structures differ among themselves in their yield and this difference is due to the difference in the components of the yield that contribute to its formation and the reason for the increase in the yield in the selected genetic structure (LD) is due to the efficiency of selection in increasing the diameter of the disk due to the increase in the process of photosynthesis and the increase in the number of seeds in the disk, which reflects positively

Table 3. Effect of period irrigation on Plant Height of Selected genotypes and Their Sunflower Parents for the Spring Season 2020

Period Irrigation	LF	LD	LS	LC	SHF	SHD	SHS	SHC	mean
5	212.3	205.2	179.4	208.7	201.4	204.4	184.9	201.3	199.7
8	185.8	194.3	166.1	195.2	181.1	183.8	171.5	167.7	180.7
10	144.9	143.9	136.6	150.2	148.9	152.5	132.7	148.4	144.8
lsd 5%	12.6								9.1
Mean of genotypes	181.0	181.1	160.7	184.7	177.1	180.2	163.0	172.4	175.0
lsd 5%	6.5								
Genetic variation	$\sigma^2 g_1$ =1 18.72		$\sigma^2 e_{1=}$ = 42.1		$\sigma^2 p_1$ = 160.37				
	$\sigma^2 g_2$ = 105.41		$\sigma^2 e_2$ = 68.38		$\sigma 2 p_{2=}$ = 173.79				
	$\sigma^2 g_3$ = 37.15		$\sigma^2 e_3$=31.01		$\sigma 2 p_3$ = 68.16				
Percentage of genetic values	G.C.V% = 5.44	G.C.V% = 5.68	G.C.V% = 4.21	P.C.V% = 6.34	P.C.V% = 7.30	P.C.V% = 5.70			
Heritability and gain from selection	GA_1 = 3.72	GA_2 = 3.87	GA_3 = 2.42	$h^2_{b.s1}$% = 73.75	$h^2_{b.s}$2% = 60.65	$h^2_{b.s}$3% = 54.51	$h^2_{n.s}$% = 16.79		

Table 4. Effect of period irrigation on disc dimeter of Selected genotypes and their sunflower parents for the spring season 2020

Period Irrigation	LF	LD	LS	LC	SHF	SHD	SHS	SHC	mean
5	23.20	24.96	20.25	26.30	24.61	25.81	21.20	27.09	24.20
8	20.08	21.85	20.60	19.19	19.53	23.69	19.05	18.07	20.25
10	17.46	17.60	18.11	16.43	16.36	19.09	16.60	16.28	17.24
lsd 5%	2.87								1.74
Mean of genotypes	20.25	21.47	19.62	20.64	20.17	22.86	19.02	20.48	20.56
lsd 5%	1.58								
Genetic variation	$\sigma^2 g_1 = 5.80$		$\sigma^2 e_1 = 3.51$		$\sigma^2 p_1 = 9.38$				
	$\sigma^2 g_2 = 2.22$		$\sigma^2 e_2 = 2.82$		$\sigma 2p_2 = 5.02$				
	$\sigma^2 g_3 = 0.11$		$\sigma^2 e_3 = 1.36$		$\sigma 2p_3 = 1.47$				
Percentage of genetic values	G.C.V% = 10.06	G.C.V% = 7.37	G.C.V% = 2.00	P.C.V% = 12.72	p.C.V% = 11.10	P.C.V% = 7.08			
Heritability and gain from selection	$GA_1 = 0.64$	$GA_2 = 0.46$	$GA_3 = 0.25$	$h^2_{b.s1}\% = 62.53$	$h^2_{b.s}2\% = 44.04$	$h^2_{b.s}3\% = 7.96$	$h^2_{n.s}\% = 11.98$		

Table 5. Effect of period irrigation interval on plant yield (g/plant) of selected genotypes and Their Sunflower Parents for the Spring Season 2020

Period Irrigation	LF	LD	LS	LC	SHF	SHD	SHS	SHC	mean
5	118.49	155.47	107	144.52	110.75	138.49	107	119.2	125.11
8	110.10	91.69	91.69	112.75	98.30	116.98	85.47	88.67	91.53
10	74.76	86.03	29.80	73.58	74.71	87.54	68.67	69.62	62.96
L.SD 5%	N.S								0.109
Mean of genotypes	84.50	111.06	76.16	110.28	94.58	114.33	87.04	92.46	93.2
L.sd 5%	3.47								
Genetic variation	$\sigma^2 g = 2.96$		$\sigma^2 e = 0.515$		$\sigma^2 p = 3.229$				
	P.C.V%=17.21		G.C.V%=13.55		$h^2_{b.s\%} = 64.62$				

on the yield. The results of Table 5 indicated that there are significant differences between the irrigation periods, as the plant yield decreased with the increase in the period between the two irrigations, as the irrigation period of 5 days gave the highest yield of the plant amounted to (125.11 g/plant), compared to the irrigation period of 10 days, which gave the lowest yield of the plant amounted to (62.96 g/plant), the lack of water in the soil leads to the lack of water absorbed by the plant, which leads to the closure of stomata, lack of paper space and lack of carbon metabolism, which results in a lack of materials. These results are consistent with the results of Meena (2021). There were no significant differences between irrigation periods and their effect on genotypes, as all genotypes behaved similarly. The results show that the genetic variations were higher than the environmental variations, so the heritability in the broad sense was high and about to (64.62%), P.C.V and G.C.V were (17.21%) and (13.55%) and this indicates that most of the phenotypic variation is a genetic variation and these results are consistent with Elsahookie & Abed (2008).

Conclusion

This study showed that period of irrigation enhanced the of sunflower traits and eventually led to a significant increase in yield. Also, the S1-progeny SHS gave the highest of plant yield under 5 day of irrigation. We also showed that increase of interval irrigation led to a decrease of productivity in selected progenies of sunflower.

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