DJAS., Vol. (4) (II): (42- 53) (2025) DOI: 10.21608/djas.2025.415957

Damietta Journal of Agricultural Sciences
https://djas.journals.ekb.eg
ISSN: 2812-5347(Print)- 2812-5355 (Online)

Combining Ability and Mode of Gene Action for The traits of Earliness, Growth and Biological Yield of Diallel Crosses of Sesame under Water Stress Conditions

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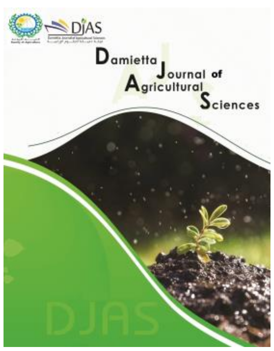

Abstract:

In this study, six parents and their fifteen hybrids were evaluated under drought conditions to study the combining ability and the type of gene action for some characters of sesame under normal irrigation and water stress conditions. These experiments were conducted at the Agronomy Department's Experimental Farm, Fac. of Agric., Mans. Uni., during the 2021 and 2022 summer seasons. The results indicated that the mean of squares of both GCA and SCA were high significantly for the analyzed qualities, referring to the importance of the additive and non-additive impacts in determining the performance of these traits. The ratio of GCA to SCA was less than unity for all the characteristics studied under both irrigation conditions, indicating that the non- additive effect being more essential and having a major influence on how these traits were inherited and therefore the selection procedure for these features were more effective in late segregating generations. Based on GCA estimates, it can be concluded that the best parents were P_3 (8-94-115 Hybrid) under normal conditions and P_2 (3-110-304 Imported) under both conditions for days to 1st flower. As for the number of days to maturity, P_2 (3-110-304 Imported) and P_1 (1-48-74 Hybrid) at normal conditions and P_4 (11-35-545 Imported) and P_5 (13-93-585 Imported) at water stress conditions. While the parents P_2 (3-110-304 Imported) and P_6 (Giza 32) for height to the 1st capsule under both conditions. P_2 (3-110-304 imported) under drought conditions, P_3 (8-94-115 hybrid), and P_6 (Giza 32) under normal irrigation were the best for plant height. According to SCA assessments, the optimal cross combinations were P_1 x P_2, P_1xP_4, P_4 x P_5, and P_4 x P_6 under normal irrigation, P_1 x P_3 and P_5 x P_6 under drought conditions and cross P_2 x P_3 in both circumstances for biomass yield/plant.

Key words: sesame, half-diallel, combining ability, gene action, drought

INTRODUCTION

Belonging to the Pedaliaceae family, sesame (*Sesamum indicum L*., 2n = 26) is one of the oldest oil crops cultivated worldwide. It has played a crucial role as a significant oil seed crop throughout history, serving as a valuable source of food and a commodity for trade among various human populations. Gedifew *et al.* (2023**)** revealed that genotypes of sesame significantly differed for plant height. Developing effective sesame breeding programs necessitates understanding the relative importance of broad and particular combining abilities. Choosing the correct parents entails combining ability analysis with knowledge on the kind and size of gene effects that regulate quantitative qualities of economic value, which is more reliable when applied to varied environments. To identify the main categories of gene effects that alter the desired features, it is required to correctly determine the quantity and relative proportions of the main element's variation in genes. For example, the variance of general combining ability is the additive effects and additive x additive epistatic interactions of a set of genes, while the variance the dominance and epistatic types of a set of gene actions are distinct combining abilities. Abd EL-Satar *et al.* (2016), observed that the primary factor in determining the inheritance of days was a certain combining ability to 1st flower, height of plant, height to 1st capsule and No. of branches per plant. One of the effects of climate change that is thought to be a significant barrier to global food output is drought. Farooq et al. 2012 Developed in tropical, subtropical in nature and southern the temperate zones of the globe, this warm-weather crop is extremely drought-tolerant and can adapt to and yield seed well in quite high temperatures, so breeding high-oil-production sesame genotypes, especially under drought conditions has become necessary for narrowing the wide gap between production of edible oils in Egypt and its consumption .Consequently, most breeding programs have long struggled to improve sesame genotypes for water stress tolerance. It can be achieved at the same time by developing drought- tolerant sesame genotypes with high- yielding potential. The current study aimed to evaluate the effects of combining abilities and types of gene action for all the traits in sesame being considered. Sesame was the subject of this investigation at the Department of Agronomy's Experimental Farm. Fac. of Agric., Mans. Uni., Dhakaliya Govern., Egypt, during two summers 2021 and 2022 seasons.

MATERIALS AND METHODS:

Plant material and cultivation methods

The genetic materials used in this study as six parental lines of sesame (*Sesamum indicum* L.), appearing a broad term of diverse for many agronomical traits. Seeds of the parental lines were got from the Oil Crops Research Section, Field Crops Research Institute, Agricultural Research Center (ARC), Giza, Egypt. The names and parents of the six parent sesame genotypes were listed in Table 1. In the summer of 2021, the parent varieties were introduced and seeded to yield 15 F_1 hybrids, while in the summer of 2022, 21 entries (15 F_1crosses and their 6 parents) were assessed in two different studies with different irrigation regimes.

The experimental design:

In the summer of 2022, two experimental plots (normal conditions and water stress conditions) were established with 3 replications using a randomized block design; twenty-one genotypes were evaluated using two different irrigation conditions. Ten waterings were made during the first experiment under normal circumstances., But the second experiment (water stress conditions) was watered only six times throughout the season. Each experimental unit contain of 4 lines with a length of 3.5 m, a width of 60 cm, and an area of 8.4 m^2, and each replication consisted of all genotypes. Seeds were manually placed in each mound with a spacing of 30 cm within the row, with three to four seeds per mound. All agricultural applications were carried out in accordance with the recommendations for sesame cultivation. In harvest, individual plants were taken at random from each dam; to record traits, 10 plants were chosen from each parent and F_1 hybrid.

Studied characteristics:

1) Days to 1^{st} flower: It was expressed the period of days between the date of sowing and the appearance of the first blossom.

2) Days to maturity: The amount of time following the date of sowing till maturity.

3) No. of branches/plant: By measuring the total amount of branches on each plant, this was ascertained.

4) Leaf count / plant: By counting the number of leaves / plant on the day of harvest.

5) Height to 1^{st} capsule (cm): It was taken starting from the plant's base at the soil surface to the first capsule in the stem of the plant.

6) Total chlorophyll content: The meter of portable chlorophyll (SPAD-502, Soil-Plant Analysis Development (SPAD) Section, Minolta Camera, and Osaka, Japan) was used to measure the greenness of leaf in SPAD values according to Castelli *et al.* (1996). These values were be linearly associated with the concentration of chlorophyll in several cases (Yadava, 1986).

7) Plant height (cm): At maturity, it was determined by measuring from the plant's base at the soil's surface to its uppermost tip.

8) Stem diameter (mm): It was measured at the third internode above the soil surface level by using a digital Vernier Caliper.

9) Biological yield / plant (g): After harvesting, the average dry weight of every plant part—aside from the roots—was used to estimate it.

Diallel analyses:

The impacts of GCA and SCA on the data were assessed by using Griffing (1956) method 2 model 1. It was believed that the parents were permanent. Table 2 provides the analysis of variance for each feature. The following is an expression of the relative relevance of GCA to SCA.:K^2 GCA / K^2 SCA = [M_s GCA –M^s e / (p +2)] / [M_s SCA –M_s e] Where: M_s = mean squares, P = No. of parents, K^2= mean squares of the effects. The formula was utilized to evaluate heritability in both broad and narrow senses of Mather and Jinks (1982).

Table 1: Parents names and their pedigree of the six parental sesame genotypes.

No.	Parental genotypes	Pedigree
P_1	1-48-74 Hybrid	NA98 x Local 2
P_2	3-110-304 Imported	USA 1975
P_3	8-94-115 Hybrid	NA432 x Giza 25
P_4	11-35-545 Imported	Alfan1986
P_5	13-93-585 Imported	1986Mexico
P_6	Giza 32	Local variety

Table 2: Analysis of variance from method 2 model 1 and the expectation of mean square:

S.V	D.F	SS	MS	EMS
GCA	P-1	Sg	M_g	σ^2e+ (P+2) (1/P-1) ∑g2i
SCA	P (P-1)/2	Ss	M_s	σ^2e+ 2/P (P-1) ∑i ∑j s2ij
Error	(r-1) (c-1)	Se	M_e	σ^2e

RESULT AND DISCUSSION

1- Analysis of variance:

Tables 3, 4, and 5 displayed the mean squares of sesame genotypes for each of the parameters under investigation, GCA/SCA ratio, together with general (GCA) and specific (SCA) combining abilities. Mean squares of GCA were extremely important for every attribute examined in both normal and water-stressed situations except total chlorophyll content (%) under normal conditions (Table 5), but SCA mean squares were non- significant for number of branches / plant under drought stress condition as showed in Table 4. Regarding Table 5, GCA and SCA were highly significant in terms of biological production in both normal and water-stressed conditions. The significance of these characteristics suggests both of which additive and non-additive GCA and SCA gene types are presented in the genetic system governing them. Either the GCA or SCA variants for the attributes under study were very significant in both scenarios, highlighting the importance of the two different additive and non-additive factors in influencing these qualities' performance. GCA mean squares were higher than these of SCA for days to 1st flower, days to maturity, total content of chlorophyll and stem diameter under normal conditions, as well as plant height under drought conditions. In addition to the quantity of leaves per plant, the number of branches each plant, and the biological yield in both scenarios. Thus, these characteristics were mostly controlled by additive gene action. Therefore, according to the accumulation of additive effects, it may be concluded that a recurrent selection strategy would prove superior in the early segregated generations But for height to the first capsule in both situations, No.of branches / plant, No. of leaves / plant, total content of chlorophyll , height of the plant, and biological output under drought conditions, SCA mean squares were greater than GCA mean squares, as well as for the number of days until the first blossom, days till maturity, and stem diameter under normal circumstances. In this regard, Hassan and Seedeck (2015) observed that for every attribute under study, the combining abilities of general and specific were highly significant. Abd EL-Satar *et al.* (2016) obtained that the primary factor in determining the inheritance of days to the first flower, height of plant, height to 1st capsule and No. of branches was SCA. Anyang *et al.* (2016) revealed that the effects of GCA was high for days to 1st flower, height to 1st capsule, and No. of branches/plant. According to the data gathered, for every attribute under study, the ratios of GCA to SCA were less than unity in both circumstances. showing that the variance of the dominance effect was more important and played a significant part in these features' inheritance, making the selection process for them more successful in the later segregating generations. These results were agreement with Parameshwarappa (2017), Abd Elaziz and Ghareeb (2018), Ibrahim *et al.*(2021), Parameshwarappa *et al.* (2021), Sandhya et al. (2021), Abd El -Kader *et al.* (2022) and Daba *et al* . (2022).

Table 3: Mean squares of sesame genotypes, the GCA/SCA ratio for earliness traits under normal and water stress circumstances, and general (GCA) and specific (SCA) combining abilities.

S.V	D.F	Days to 1st flower (days)		Days to maturity (days)	
		Normal	Stress	Normal	Stress
GCA	**5**	15.09**	4.36**	31.69**	16.44**
SCA	**15**	27.07**	23.71**	15.97**	28.55**
Error	**40**	0.35	0.31	0.31	0.30
GCA/SCA	**-**	**0.53**	**0.27**	**0.80**	**0.54**

Table 4: Mean squares of sesame genotypes, general (GCA) and specific (SCA) combining abilities, and GCA/SCA ratio for Plant height (cm), Height to 1st capsule (cm), No. branches / plant and No. leaves / plant under normal and water stress conditions.

S.V	D.F	Plant height (cm)		Height to 1st capsule (cm)		No. branches / plant		No.Leaves / plant	
		Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
GCA	**5**	80.26**	34.54**	34.54**	19.10**	0.44**	0.17**	160.07**	155.93**
SCA	**15**	141.77**	35.00**	35.00**	21.49**	0.21**	0.05	115.59**	97.78**
Error	**40**	1.83	2.37	2.37	0.93	0.08	0.03	2.34	2.44
GCA/SCA	**-**	**0.53**	**0.66**	**0.66**	**0.64**	**0.81**	**0.88**	**0.73**	**0.76**

***, ** significant at 0.05 and 0.01 level of probability, respectively.**

Table 5: Mean squares of sesame genotypes, general (GCA) and specific (SCA) combining abilities, and GCA/SCA ratio for Total chlorophyll, Stem diameter (mm) and biological yield (g/ plant) under normal and water stress conditions.

S.V	D.F	Total chlorophyll		Stem diameter (mm)		Biological yield (g/ plant)	
		Normal	Stress	Normal	Stress	Normal	Stress
GCA	**5**	**20.08**	**18.22****	**5.09****	**2.62****	**121.84****	**55.52****
SCA	**15**	**38.59****	**22.24****	**2.68****	**4.96****	**60.44****	**24.69****
Error	**40**	**7.27**	**3.64**	**0.62**	**0.06**	**0.11**	**0.11**
GCA/SCA	**-**	**0.51**	**0.62**	**0.79**	**0.51**	**0.80**	**0.82**

***, ** significant at 0.05 and 0.01 level of probability, respectively.**

The significance of these characteristics suggests both of which additive and non-additive GCA and SCA gene types are presented in the genetic system governing them. Either the GCA or SCA variants for the attributes under study were very significant in both scenarios, highlighting the importance of the two different additive and non-additive factors in influencing these qualities' performance. GCA mean squares were higher than these of SCA for days to 1st flower, days to maturity, total content of chlorophyll and stem diameter under normal conditions, as well as plant height under drought conditions. In addition to the quantity of leaves per plant, the number of branches each plant, and the biological yield in both scenarios. Thus, these characteristics were mostly controlled by additive gene action. Therefore, according to the accumulation of additive effects, it may be concluded that a recurrent selection strategy would prove superior in the early segregated generations But for height to the first capsule in both situations, No.of branches / plant, No. of leaves / plant, total content of chlorophyll , height of the plant, and biological output under drought conditions, SCA mean squares were greater than GCA mean squares, as well as for the number of days until the first blossom, days till maturity, and stem diameter under normal circumstances. In this regard, Hassan and Seedeck (2015) observed that for every attribute under study, the combining abilities of general and specific were highly significant. Abd EL-Satar *et al.* (2016) obtained that the primary factor in determining the inheritance of days to the first flower, height of plant, height to 1st capsule and No. of branches was SCA. Anyang *et al.* (2016) revealed that the effects of GCA was high for days to 1st flower, height to 1st capsule, and No. of branches/plant. According to the data gathered, for every attribute under study, the ratios of GCA to SCA were less than unity in both circumstances. showing that the variance of the dominance effect was more important and played a significant part in these features' inheritance, making the selection process for them more successful in the later segregating generations. These results were agreement with Parameshwarappa (2017), Abd Elaziz and Ghareeb (2018), Ibrahim *et al.*(2021), Parameshwarappa *et al*. (2021), Sandhya et al. (2021), Abd El -Kader *et al.* (2022) and Daba *et al* . (2022).

2- The effects of GCA:

A- The characteristics of Earliness:

Based on the number of days until the start of blossom and maturity, Table 6 displays the projected GCA effects of parental genotypes. The findings showed that the most effective general combiners for 1st flower date were P_3 (8-94-115 Hybrid) and P_2 (3-110-304 Imported) under normal condition, P_2 (3-110-304 Imported) at water stress condition and for maturity date were P_2 (3-110-304 Imported) and P_1 (1-48-74 Hybrid) at normal condition and P_4(11-35-545 Imported) and P_5 (13-93-585 Imported)they observed highly substantial and adverse GCA effects for these features under water stress conditions. Contrarily, P_4 (11-35-545 Imported), P_5 (13-93-585 Imported) and P6 (Giza 32) showed positive and significantly or high significantly effects of GCA for days to 1st flowering under normal condition, P6 (Giza 32) showed positive and high significantly impacts of GCA for maturity day at two conditions. Thus, for days leading up to the first flower and days leading up to maturity, the parents acted like the poor general combiners.

B- Growth characters and Biological Yield:

An examination of the general combinatorial impacts of all parental genotypes on growth characteristics and the yield of biomass under both water situations is provided in Tables 7 and 8. The data showed that P1 (1-48-74 hybrid) had an important or extremely important and favorable GCA effect on plant height under both conditions (suggesting that the greatest general combinatorial for this characteristic were these parents.) On the other side, P_4 (11-35-545Imported) and P_5 (13-93-585 Imported) recorded very important and negative GCA effects under both conditions.

Table 6: Evaluations of general combining ability (GCA) effects for parent genotypes for Earliness under normal and water stress conditions

Parents	Days to 1st flower (days)		Days to maturity (days)	
	Normal	Stress	Normal	Stress
P_1 (1-48-74) Hybrid	-0.31	1.04**	-2.17**	-0.17
P_2 (3-110-304) Imported	-1.39**	-0.96**	-2.54**	-0.71**
P_3 (8-94-115) Hybrid	-1.68**	-0.46*	-0.29	0.83**
P_4 (11-35-545) Imported	0.40*	0.17	1.29**	-1.42**
P_5 (13-93-585) Imported	1.44**	-0.37*	1.75**	-1.00**
P6 – Giza32	1.53**	0.58**	1.96**	2.46**
LSD gi 5%	0.38	0.36	0.36	0.36
LSD gi 1%	0.51	0.48	0.49	0.48
LSD gi-gj 5%	1.05	0.99	1.00	0.99
LSD gi-gj 1%	1.41	1.33	1.34	1.32

***, ** significant at 0.05 and 0.01 level of probability, respectively.**

Table 7: Evaluations of general combining ability (GCA) effects for Plant height (cm), Height to 1st capsule (cm), No. branches / plant and No.Leaves / plant for parent genotypes for under normal and water stress conditions

Parents	Plant height (cm)		Height to 1st capsule (cm)		No. branches / plant		No.Leaves / plant	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
P1 (1-48-74) Hybrid	1.04*	11.70**	-0.19	-2.73**	0.20*	0.05	3.87**	4.84**
P2 (3-110-304) Imported	-3.41**	6.28**	2.37**	1.29**	0.31**	0.27**	4.21**	4.84**
P3 (8-94-115) Hybrid	1.61**	-3.98**	-0.27	1.07**	-0.03	-0.07	2.55**	-0.51
P4 (11-35-545) Imported	-2.84**	-8.01**	-0.26	-0.73*	-0.36**	-0.10	-6.83**	-6.55**
P5 (13-93-585) Imported	-1.38**	-4.54**	-3.51**	0.03	-0.07	-0.11	-0.02	0.12
P_6 – Giza32	4.99**	-1.45*	1.86**	1.07**	-0.07	-0.04	-3.77**	-2.73**
LSD gi 5%	0.88	1.12	1.00	0.63	0.18	0.11	1.00	1.02
LSD gi 1%	1.18	1.50	1.34	0.84	0.24	0.15	1.33	1.36
LSD gi-gj 5%	2.42	3.08	2.76	1.73	0.50	0.31	2.74	2.80
LSD gi-gj 1%	3.24	4.12	3.69	2.32	0.67	0.42	3.67	3.75

*, ** significant at 0.05 and 0.01 level of probability, respectively.

Also, the parents P_2 (3-110-304 Imported) under normal conditions and P_6 (Giza 32) under drought condition demonstrated extremely strong and adverse GCA impacts on plant height, these parents were among the worst overall combiners for height at Harvest. P_2 (3-110-304 Imported) and P6 (Giza 32) had high significant and positive impacts of GCA for height to 1st capsule under both conditions, meanwhile P_2 (3-110-304 Imported) and P_6 (Giza 32) obtained high significantly and positive effects of GCA for heigh to 1st capsule so they are the worest general combiners for this trait. These outcomes were consistent with Anyanga *et al.* (2016), Abd El-Kader *et al.* (2017), Daba *et al.* (2017), Mungala *et al.* (2017), Abd Elaziz and Ghareeb (2018), Fazal *et al.* (2022), Gadhiya *et al.* (2023) and Mehana (2023). In this regard, the ideal universal combiner would be significant positive GCA values for No. branches/plant, No. Leaves/plant, total chlorophyll (%) and stem diameter. Data indicated that parent P_2 (3-110-304Imported) exhibited was highly significant and positive GCA influences of number of branches /plants, No. of leaves / plant and the yield of biological under both conditions. P3 (8-94-115 Hybrid), on the other hand, had the most significant and advantageous GCA impacts for chlorophyll content in both circumstances. In contrast, in drought conditions, P4 (11-35-545 Imported) and P_5 (13-93-585 Imported) showed significantly or high significantly and beneficial GCA impacts for diameter of stem, as did parents P3 (8-94-115 Hybrid). In this regard, P_4 (11-35-545 Imported) and P6 (Giza 32) under normal irrigation as well as P_3 (8-94-115 Hybrid) under water stress conditions for biological yield recorded highly significant positive GCA effects. These findings mostly concurred with those documented by Abd Elaziz and Ghareeb (2018), Abdel-Rhman *et al.* (2019), Abd-Elsaber *et al.*(2019), Ibrahim *et al.* (2021), Mehana (2023), Parameshwarappa *et al.* (2023) and Gore *et al.* (2024).

3- The SCA effects

A- Earliness characters:

For F_1 hybrids, as shown in Table 9, assessments of the impact of particular combining ability were computed for each feature under both normal and water-stressed circumstances. Days to first blossom and days to maturity would benefit most from significant negative SCA values.

According to the results, many crossed had unfavorable SCA effects that lasted for days and were severe or highly significant to 1st flower. Crosses namely; No.2 (P_1 x P_3), No.3 (P_1 x P_4), No.9 (P_2 x P_6), and No.10 (P_3x P_4) were the most effective combinations of specific crossings for this characteristic in both circumstances. In terms of days to maturity, only four crossovers receiving normal irrigation and five crossings experiencing drought shown negative and highly significant SCA impacts. These crosses namely; No.5(P_1xP_6), No.10(P_3xP_4), No.11(P_3xP_5) and No.12(P_3xP_6) under ordinary irrigation conditions, No.9(P_2xP_6), No.10(P_3xP_4), NO.13(P_4xP_5), NO.14(P_4xP_6) and No.15 (P_5xP_6) under drought conditions, Consequently, these crosses were the most popular combinations of crosses for days to maturity.

B-Growth characters and Biological Yield:

For plant height, positive SCA values that are substantial or highly significant would be preferred, as Table 10 illustrates. The results showed that three and six crosses had high particular combination values for plant height that were either substantial or very significant under both regular watering and drought. The best specific crosses combinations for this trait were; No.5 (P_1xP_6), No.6 (P_2xP_3) as well as No.13 (P_4xP_5) under natural conditions and hybrids; No.2 (P_1xP_3), No.3 (P_1xP_4), No.5 (P_1xP_6), No. 6(P_2xP_3), No.7 (P_2xP_4) and No.12 (P_3xP_6) at drought conditions. Regarding to height to 1st capsule, there were three crosses under both conditions, four crosses with drought and three intersections with frequent irrigation demonstrated significantly or high significantly negative SCA impacts for the pervious character. The best combinations of specific crosses were No.11 (P_3×P_5), No.14 (P_4xP_6) as well as No.15(P_5xP_6) under two irrigation conditions, No.3(P_1x P_4), No.8 (P_2xP_5) and No.12(P_3xP_6) under normal irrigation, as well as No.1(P_1xP_2), No.5(P_1xP_6), No.7 (P_2xP_4), No.10(P_3xP_4), No.11 (P_3xP_5), No 14 (P_4xP_6) and No.15(P_5xP_6) under drought conditions. For No. branches/ plant, there were one cross namely No.8 (P_2xP_5) under normal irrigation, No.9 (P_2xP_6) under water stress conditions and No.6 (P_2xP_3) determined that these crosses were the most effective cross combinations for the previous character under both conditions, yielding positive as well as significantly or high significantly impacts of SCA.

With respected to No. leaves/plant, the findings indicated that, under both normal and drought situations, there were crosses that demonstrated significantly or high significantly and positive SCA effects. Those hybrids namely; No.2 (P_1xP_3), No.5(P_1xP_6) and No.14(P_4xP_6) under natural watering regime, No.6(P_2xP_3) as well as No.9(P_2xP_6) under both conditions and No.4(P_1xP_5) showed that these particular cross combinations were the most effective for increasing the number of leaves per plant during drought circumstances. Table 11 displays the estimations of the particular combining ability effects of F1 crosses that were calculated for stem diameter under both normal and water stress circumstances. For stem diameter, significant or highly significant positive SCA values would be ideal. Results indicated the good hybrids combinations about this trait were No.6 (P_2xP_3) under both conditions, No.15 (P_5xP_6) under ordinary irrigation and five hybrids namely; No.3(P_1xP_4), No.4(P_1xP_5), No.5(P_1xP_6), No.10(P_3xP_4) as well as No.15(P_4xP_5) under drought conditions. Significant positive from the perspective of the breeder, SCA estimates may be the optimal crossings for total content of chlorophyll.

Table 8: Evaluations of general combining ability (GCA) effects for Total chlorophyll, Stem diameter (mm) and biological yield (g / plant) parent genotypes for under normal and water stress conditions.

Parents	Total chlorophyll		Stem diameter (mm)		Biological yield (g/ plant)	
	Normal	Stress	Normal	Stress	Normal	Stress
P1 (1-48-74) Hybrid	0.30	1.03	0.27	0.53**	-4.00**	-3.26**
P2 (3-110-304) Imported	-2.26*	-2.44**	-1.52**	-0.27**	6.53**	4.22**
P3 (8-94-115) Hybrid	2.08*	1.81**	0.08	-0.47**	-0.08**	0.01
P4 (11-35-545) Imported	-0.16	0.30	0.67*	0.68**	0.07**	0.23**
P5 (13-93-585) Imported	1.24	-0.96	0.58*	0.26**	-3.19**	0.17
P6 – Giza32	-1.20	0.27	-0.07	-0.73**	1.17**	-1.99**
LSD gi 5%	1.76	1.25	0.51	0.15	0.22	0.21
LSD gi 1%	2.35	1.67	0.69	0.21	0.29	0.28
LSD gi-gj 5%	4.83	3.42	1.41	0.42	0.60	0.58
LSD gi-gj 1%	6.47	4.58	1.89	0.56	0.80	0.78

***, ** significant at 0.05 and 0.01 level of probability, respectively.**

Table 9: Evaluations of specific combining ability (SCA) effects for F1 crosses for Earliness traits under normal and water stress conditions.

Crosses	Days to 1st flower (days)		Days to maturity (days)	
	Normal	Stress	Normal	Stress
1-P_1xp_2	1.49**	-4.85**	7.04**	6.26**
2-P_1xP_3	-7.22**	-6.01**	5.46**	6.71**
3-P_1xP_4	-1.97**	-1.64**	4.21**	3.96**
4-P_1xP_5	-2.01**	-0.76	1.08*	-0.45
5-P_1xP_6	-1.10*	0.28	-3.12**	2.09**
6-P_2xP_3	4.20**	4.99**	2.17**	5.26**
7-P_2xP_4	2.45**	4.36**	-0.42	2.51**
8-P_2xP_5	-1.26**	3.90**	0.13	0.09
9-P_2xP_6	-3.35**	-2.72**	2.25**	-1.70**
10-P_3xP_4	-2.60**	-3.14**	-4.67**	-4.04**
11-P_3xP_5	5.36**	-0.93*	-1.46**	5.55**
12-P_3xP_6	6.61**	7.45**	-1.33**	3.09**
13-P_4xP_5	5.61**	3.78**	1.29**	-2.20**
14-P_4xP_6	5.20**	2.82**	2.08**	-4.66**
15-P_5xP_6	5.15**	4.03**	1.29**	-1.74**
LSD Sij 5%	0.87	0.82	0.83	0.81
LSD Sij 1%	1.17	1.09	1.10	1.09
LSD sij-sik 5%	1.57	1.48	1.49	1.47
LSD sij-sik 1%	2.11	1.98	2.00	1.97
LSD sij-skl 5%	1.46	1.37	1.38	1.36
LSD sij-skl 1%	1.95	1.83	1.85	1.82

***, ** significant at 0.05 and 0.01 level of probability, respectively.**

Table 10: Evaluations of specific combining ability (SCA) effects for F1 crosses for Plant height (cm), Height to 1st capsule (cm), No. branches / plant and No.Leaves / plant under normal and water stress conditions .

Crosses	Plant height (cm)		Height to 1st capsule (cm)		No. branches / plant		No. leaves / plant	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
1-P_1xp_2	-2.22*	-5.25**	-1.74	-3.03**	0.01	-0.29*	-17.15**	-12.08**
2-P_1xP_3	-0.40	16.00**	0.07	4.96**	-0.19	-0.17	5.07**	1.04
3-P_1xP_4	-7.62**	7.21**	-2.44*	3.66**	-0.03	-0.15	-6.67**	0.42
4-P_1xP_5	-17.65**	-2.60*	-0.69	0.73	0.32	-0.04	-2.36*	3.75**
5-P_1xP_6	3.89**	10.31**	9.44**	-3.31**	0.29	-0.11	3.61**	-5.63**
6-P_2xP_3	3.11**	10.13**	8.11**	1.84*	1.01**	0.27*	24.17**	15.48**
7-P_2xP_4	-7.33**	4.12**	2.00	-8.19**	-0.53*	0.07	-0.35	-5.69**
8-P_2xP_5	-11.46**	-14.99**	-4.47**	0.31	0.58**	0.17	-14.38**	-7.36**
9-P_2xP_6	-15.66**	-21.67**	7.28**	0.84	0.21	0.40**	2.71*	6.04**
10-P_3xP_4	-14.48**	-55.28**	8.65**	-6.30**	0.37	-0.02	-4.24**	-9.24**
11-P_3xP_5	-0.47	-6.22**	-3.82**	-6.57**	0.05	-0.02	-12.71**	-14.24**
12-P_3xP_6	0.83	3.99**	-6.89**	1.28	-0.08	0.02	-9.51**	-9.17**
13-P_4xP_5	7.64**	-2.73*	0.27	0.46	0.06	-0.09	1.67	-0.42
14-P_4xP_6	-8.39**	-0.48	-4.99**	-3.63**	-0.15	-0.04	2.64*	-5.35**
15-P_5xP_6	-2.42**	-14.06**	-5.05**	-1.23**	-0.31	-0.05	1.39	-6.46
LSD Sij 5%	2.00	2.54	2.28	1.43	0.41	0.26	2.26	2.31
LSD Sij 1%	2.68	3.40	3.05	1.91	0.55	0.34	3.03	3.09
LSD sij-sik 5%	3.61	4.59	4.12	2.58	0.74	0.46	4.09	4.18
LSD sij-sik 1%	4.84	6.14	5.51	3.46	0.99	0.62	5.47	5.59
LSD sij-skl 5%	3.35	4.25	3.81	2.39	0.69	0.43	3.79	3.87
LSD sij-skl 1%	4.48	5.69	5.10	3.20	.092	0.57	5.06	5.18

***, ** significant at 0.05 and 0.01 level of probability, respectively.**

The optimal cross combinations for total chlorophyll could be determined using certain combining ability estimates value were genotypes; No.12(P_3xP_6) at both regimes, cross No.7(P_2xP_4) at normal conditions and crosses; No.8(P_2xP_5), No.9 (P_2xP_6), No.10(P_3xP_4) and No.15 (P_5xP_6) under drought conditions, where they found positive SCA effects on the previous attribute that were substantial or very significant. The results in Table 11 show that certain crossings had favorable and highly significant SCA impacts on biological yield attributes under both normal and drought conditions. These crosses namely; No.1(P_1xP_2), No.3 (P_1xP_4), No.13(P_4xP_5) and No.14 (P_4xP_6) under ordinary watering, No.2(P_1xP_3) and No.15(P_5 xP_6) under drought conditions and cross No.6 (P_2 xP_3) stating that these crosses were the most effective cross combination for raising the biomass output of sesame plants under both circumstances. The current study's findings were consistent with those obtained by Brima (2021) and Parameshwarappa *et al.* (2021).

4- Heritability estimates

A- Earliness characteristics:

The findings showed that for days to maturity in both scenarios, the additive genetic element (D) was significantly or highly significant and day's to1st flower under drought conditions, according to the component estimated using half-diallel as given in Table 12. This indicated that additive genetic factors had negligible role in defining these features. The fact that elements H_1 and H_2 were more significant than (D) indicated that dominance impacts were present for these characteristics. Most earliness traits showed significantly or extremely significant and positive F values under regular irrigation and water stress conditions, indicating an excess of the dominant gene for the majority of the traits being evaluated. This meant that they were more genes of dominant than genes of recessive, as evidenced by mean positive values of (F). During typical irrigation and drought conditions, h^2 component for the traits of earliness exhibited positive values and significantly or high significantly except the first flower days, whereas it was non-significant under water stress conditions. Under two watering conditions, parts of dominance H_1 and H_2 for earliness attributes were considerable or very important. Both of the highly significant hypotheses, H_1 and H_2, showed variance resulting from non-additive effects that had been adjusted for gene distribution. The (E) component had non-significant value for earliness characters suggested that environmental influences on these traits expression were negligible under both regular irrigation and water stress settings. The average dominates degree of every locus, as determined by $(H_1/D)^{1/2}$ was larger than unity for earliness characteristics, indicating over-dominance for these characteristics under study conditions. Between irrigation and water, stress conditions, the average allele frequency at loci exhibiting $H_2/4H_1$ measurements was less than 0.25 for the majority of earliness characters, indicating that the allelic frequency of the dominant gene's favorable and unfavorable impacts was symmetrical.

Table 11: Evaluations of specific combining ability (SCA) effects for F1 crosses for Total chlorophyll, Stem diameter (mm) and biological yield (g / plant) under normal and water stress conditions.

Crosses	Total chlorophyll		Stem diameter (mm)		Biological yield (g/plant)	
	Normal	Stress	Normal	Stress	Normal	Stress
1-P_1xp_2	-1.71	-0.32	-1.62**	-0.43*	9.37**	-2.35**
2-P_1xP_3	-4.45*	-2.17	0.11	-0.96**	-3.98**	4.90**
3-P_1xP_4	-7.71**	-2.64	0.52	0.88**	4.55**	-1.59**
4-P_1xP_5	-3.66	-6.66**	0.27	2.14**	-12.87**	-4.48**
5-P_1xP_6	-5.25*	-4.28**	0.55	2.30**	-1.19**	-3.21**
6-P_2xP_3	-6.61**	-4.92**	1.52*	4.03**	8.13**	8.67**
7-P_2xP_4	7.85**	-0.99	-2.08**	-3.15**	-13.88**	-5.50**
8-P_2xP_5	3.40	4.20**	-2.10**	-1.47**	-4.25**	-3.80**
9-P_2xP_6	-1.53	3.53*	-1.05	-2.91**	-2.81**	4.68**
10-P_3xP_4	3.15	5.00**	-0.78	0.88**	-0.19	-3.47**
11-P_3xP_5	1.06	-3.88**	-0.76	-1.70**	-9.81**	-4.09**
12-P_3xP_6	9.25**	3.19*	-2.71**	-0.54**	-2.84**	-6.80**
13-P_4xP_5	-3.14	-3.17*	0.21	1.32**	7.42**	-1.00**
14-P_4xP_6	-7.92**	-6.07**	-0.80	-1.86**	2.94**	-0.20
15-P_5xP_6	-1.77*	0.26**	1.79**	-1.44**	-2.43**	1.14**
LSD Sij 5%	3.99	2.82	1.16	0.35	0.49	0.48
LSD Sij 1%	5.34	3.78	1.56	0.47	0.66	0.65
LSD sij-sik 5%	7.21	5.10	2.11	0.63	0.89	0.87
LSD sij-sik 1%	9.65	6.83	2.82	0.84	1.20	1.17
LSD sij-skl 5%	6.68	4.73	1.95	0.58	0.83	0.81
LSD sij-skl 1%	8.93	6.32	2.61	0.78	1.11	1.08

*, ** significant at 0.05 and 0.01 level of probability, respectively.

That is mean that the parents' positive and negative allele frequencies were equal. Table (12) provided estimates for earliness traits under both irrigation conditions in both of them broad and narrow senses. Since most variance of genetic for the pervious characters were due to non-additive genetic effects, limited sense heritability estimates $h^2_{(n.s)}$. Under the experiment circumstances, earliness characteristics were shown to be substantially lower than wide sense traits, indicating that selection strategies proven effective in modifying the frequency of genes when both additive and non-additive factors were present should be utilized.

B- Growth characters and Biological Yield:

According to the findings, the additive genetic component (D) was important or extremely important for biological yield in typical circumstances and for height to 1st capsule and total chlorophyll content under water-stress conditions, according to the component estimated using half-diallel as given in Tables 13 and 14. This revealed that additive genetic factors had little influence on these qualities. H_1 and H_2 were more significant than (D), determining that the effects of dominance were strong for these variables. The majority of growth traits under both irrigation conditions had positive or negative and non-significant values of F except for total chlorophyll content under drought conditions, which was significant, indicating an excess of the dominant gene for the majority of the traits under evaluation. The mean positive value of (F) obtained that they were larger numbers of dominant genes than recessive genes. At natural irrigation and drought regimes, h^2 component was positive values for the traits of growth except for No. branches / plant and biological yield during stress from water circumstances had negative values, suggesting that the importance of dominant genes or for these qualities, dominant genes predominate over recessive genes. With the exception of No. of branches / plant in both cases, dominant H_1 and components of H_2 showed significantly or very significant for growth attributes under two regular irrigation and drought. After adjusting for gene distribution, both H_1 and H_2 showed variance due to non-additive effects, making them highly significant hypotheses. The (E) component had non-significant values for growth traits except for stem diameter under drought conditions was found highly significant suggested that environmental influences on these traits' expression were negligible under both irrigation conditions. At natural irrigation and water shortage conditions, the mean dominance degrees of each locus as evaluated by the ratio $(H_1/D)^{1/2}$ obtained greater than unity for growth characters, indicating over-dominance for these traits. Under both irrigation conditions, the average allele frequency at loci exhibiting $H_2/4H_1$ measurements was less than 0.25 for the majority of growth traits, indicating that the allelic frequency of the dominant gene's favourable and unfavourable impacts was symmetrical. That means that the parent's positive and negative allele frequencies were equal. Tables 13 and 14 provided estimates for growth traits under both irrigation conditions both broadly and specifically.

Table 12: The estimates of genetic variance and its components and genetic ratio for Earliness traits in F1's hybrids under normal irrigation (N) and water stress (S) conditions.

Genetic parameters	I	Days to 1^{st} flower	Days to maturity
E	N	0.44±5.08	0.37±2.67
	S	0.30±3.27	0.47±2.42
D	N	14.75±13.44	44.83±7.08**
	S	28.05±8.65**	33.70±6.39**
F	N	35.22±32.83	50.80±17.29**
	S	60.92±21.13**	68.44±15.62**
H_1	N	117.06±34.11**	64.37±17.97**
	S	108.18±21.96**	124.82±16.23**
H_2	N	83.19±30.47**	48.42±16.05**
	S	73.14±19.61**	79.17±14.50**
h^2	N	41.29±20.51*	38.51±10.80**
	S	20.09±13.20	64.63±9.76**
$(H_1/D)^{0.5}$	N	2.82	1.20
	S	1.96	1.92
$H_2/4H_1$	N	0.18	0.19
	S	0.17	0.16
h^2/H_2	N	0.50	0.80
	S	0.27	0.82
$h^2_{(n.s)}$	N	0.24	0.29
	S	0.06	0.21
$h^2_{(b.s)}$	N	0.98	0.98
	S	0.98	0.98

*, ** Significant and highly significant at 0.05 and 0.01 probability levels, respectively. D = additive variance, H_2 = proportion of positive and negative genes in the parents, H_1 = dominance variance, E= environmental variance F = Relative frequency of dominant and recessive alleles in the parents, H_1/D = mean degree of dominance, $H_2/4H_1$= the proportion of genes with positive and negative effects in the parents, h^2 = dominance effect (over all loci in heterozygous phase), Heritability in narrow sense $h^2_{(n.s)}$ h^2/H_2 = no. of effective genes, Heritability in broad sense $h^2_{(b.s)}$.

Table 13: The estimates of genetic variance and its components and genetic ratio for No.branches, No.leaves / plant, Height to 1st capsule (cm) and Total chlorophyll in F1's hybrids under normal irrigation (N) and water stress (S) conditions.

Genetic parameters	I	No.branches / plant	No. leaves/Plant	Height to 1^{st} capsule(cm)	Total chlorophyll
E	N	0.08±0.05	3.25±31.86	2.28±6.47	7.31±5.52
	S	0.03±0.01**	2.35±15.08	0.92±3.51	3.69±2.00
D	N	0.04±0.13	122.98±84.29	4.77±17.12	23.51±14.60
	S	0.05±0.03	43.08±39.90	24.38±9.30**	22.65±5.30**
F	N	-0.11±0.31	99.24±205.93	7.57±41.82	45.58±35.66
	S	0.02±0.07	-27.83±97.47	29.90±22.71	30.60±12.95*
H_1	N	0.64±0.32*	464.00±213.99*	149.23±43.46**	143.85±37.06**
	S	0.15±0.07*	335.35±101.28**	81.70±23.60**	78.22±13.46**
H_2	N	0.52±0.29	410.19±191.16*	118.44±38.82**	111.90±33.10**
	S	0.08±0.06	312.00±90.48**	68.81±21.08**	63.95±12.03**
h^2	N	0.34±0.20	101.31±128.66	3.70±26.13	50.89±22.28*
	S	-0.02±0.04	360.17±60.90**	49.39±14.19**	52.06±8.09**
$(H_1/D)^{0.5}$	N	3.92	1.94	5.59	2.47
	S	1.74	2.79	1.83	1.86
$H_2/4H_1$	N	0.20	0.22	0.20	0.19
	S	0.13	0.23	0.21	0.20
h^2/H_2	N	0.66	0.25	0.03	0.45
	S	-0.22	1.15	0.72	0.81
$h^2_{(n.s)}$	N	0.40	0.27	0.31	0.12
	S	0.50	0.37	0.17	0.14
$h^2_{(b.s)}$	N	0.78	0.98	0.95	0.82
	S	0.69	0.98	0.96	0.84

*, ** Significant and highly significant at 0.05 and 0.01 probability levels, respectively. D = additive variance, H_2 = proportion of positive and negative genes in the parents, H_1 = dominance variance, E= environmental variance F = Relative frequency of dominant and recessive alleles in the parents, H_1/D = mean degree of dominance, $H_2/4H_1$= the proportion of genes with positive and negative effects in the parents, h^2 = dominance effect (over all loci in heterozygous phase), Heritability in narrow sense $h^2_{(n.s)}$ h^2/H_2 = no. of effective genes, Heritability in broad sense $h^2_{(b.s)}$.

Table 14: The estimates of genetic variance and its components and genetic ratio for Plant height (cm), Stem diameter (mm) and biological yield (g/ plant) in F1's hybrids under normal irrigation (N) and water stress (S) conditions.

Genetic parameters	I	Plant height (cm)	Stem diameter(mm)	Biological yield
E	N	1.755±6.90	0.61±0.23**	0.12±7.68
	S	2.905±106.80	0.05±0.87	0.11±4.63
D	N	20.20±18.25	0.50±0.62	46.31±20.33*
	S	49.76±282.56	2.33±2.31	19.30±12.25
F	N	-7.07±44.59	-1.59±1.52	1.09±49.67
	S	-7.83±690.29	4.89±5.65	-0.55±29.92
H_1	N	438.68±46.33**	8.61±1.58**	242.79±51.61**
	S	1680.19±717.29*	21.83±5.87**	98.05±31.09**
H_2	N	413.85±41.39**	7.48±1.41**	215.46±46.11**
	S	1384.29±640.78*	17.16±5.25**	83.82±27.77**
h^2	N	796.49±27.86**	6.93±0.95**	72.04±31.03*
	S	772.02±431.29	1.24±3.53	44.03±18.69*
$(H_1/D)^{0.5}$	N	4.66	4.17	2.29
	S	5.81	3.06	2.25
$H_2/4H_1$	N	0.24	0.22	0.22
	S	0.21	0.20	0.21
h^2/H_2	N	1.92	0.93	0.33
	S	0.56	0.07	0.53
$h^2_{(n.s)}$	N	0.20	0.39	0.40
	S	0.34	0.20	0.45
$h^2_{(b.s)}$	N	0.99	0.85	1.00
	S	0.99	0.99	1.00

***, ** Significant and highly significant at 0.05 and 0.01 probability levels, respectively. D = additive variance, H_2 = proportion of positive and negative genes in the parents, H_1 = dominance variance, E= environmental variance F = Relative frequency of dominant and recessive alleles in the parents, H_1/D = mean degree of dominance, $H_2/4H_1$= the proportion of genes with positive and negative effects in the parents, h^2 = dominance effect (over all loci in heterozygous phase), Heritability in narrow sense $h^2_{(n.s)}$ h^2/H_2 = no. of effective genes, Heritability in broad sense $h^2_{(b.s)}$.**

Since most genetic variance for all growth traits were due to non-additive genetic effects, narrow sense heritability estimates $h^2_{(n.s)}$ for the characters of growth under ordinary irrigation and drought regimes, which were found to be much lower than those of broad sense, resulting in the utilization of selection procedures that were proven to be successful in changing the frequency of genes when two additive and dominance qualities were present. These consequences were in agreement with Shabana *et al.* (2015), Monpara and Khairnar (2016), Divya *et al.* (2018), Gedifew *et al.* (2023) and Mehana (2023).

CONCLUSION

Based on the previous findings, the P_2 (3-110-304 Imported) was the most effective universal combiner for biological output in both situations. Depending on specific merging ability estimations, the good combiner's hybrids for 1st flower days were No.2 (P_1xP_3), No.3 (P_1xP_4), No.9 (P_2xP_6) and No.10 (P_3xP_4) under both conditions. For days to maturity were No.5 (P_1xP_6), No.10 (P_3xP_4), No.11 (P_3xP_5), and No.12 (P_3xP_6) under normal conditions, as well as, No.10 (P_3xP_4), No.13 (P_4xP_5), No.14 (P_4xP_6) and No.15 (P_5xP_6) under drought conditions. For plant height were No.5 (P_1xP_6), No.6 (P_2xP_3), and No.13 (P_4xP_5) under natural watering conditions and crosses No.2 (P_1xP_3), No.5 (P_1xP_6), No.6 (P_2xP_3), No.7 (P_2xP_4), and No.12 (P_3xP_6) at drought conditions. For height to 1st capsule were No.14 (P4xP6) and No.15 (P_5xP_6) under two watering regimes and for biological yield were No.1 (P_1xP_2), No.3 (P_1xP_4), No.6 (P2xP3), No.15 (P_5xP_6) and No.14 (P_4xP_6) under normal irrigation. As well as, No.2 (P_1xP_3), No.6 (P_2xP_3), No.9 (P_2xP_6), and No.15 (P_5 xP_6) under drought conditions.

FUNDING:

This research did not receive any funding

CONFLICTS OF INTEREST:

The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTION

All authors developed the concept of the manuscript, checked and confirmed the final revised manuscript.

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القدرة على التآلف ونوع الفعل الجيني لصفات التبكير والصفات الخضرية والمحصول البيولوجي للهجن الدائرية لمحصول السمسم تحت ظروف الإجهاد المائي

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الملخص:

في هذه الدراسة تم تقييم ستة آباء والخمسة عشر هجينًا الناتجة منهم تحت ظروف الإجهاد المائي وذلك لدراسة القدرة على التآلف ونوع الفعل الجيني لبعض صفات السمسم تحت ظروف الري العادي والإجهاد المائي. حيث أجريت التجارب في المزرعة البحثية - قسم المحاصيل - كلية الزراعة - جامعة المنصورة خلال موسمي 2021 و2022. أشارت النتائج إلى أن متوسط مربعات كلًا من GCA وSCA كان معنوي جدًا للصفات المدروسة، مما يشير إلى أهمية التأثير المضاف وغير المضاف في تحديد أداء تلك الصفات. كانت نسبة GCA إلى SCA أقل من الواحد لجميع الصفات المدروسة لكلاً من ظروف الري مشيرًا إلى أن لتأثير السيادي كان أكثر أهمية ولعب دورًا رئيسيًا في وراثة تلك الصفات وبالتالي كان إجراء الانتخاب لهذه الصفات أكثر فاعلية في الأجيال الانعزالية المتأخرة. وبناءً على تقديرات GCA يمكن استنتاج أن أفضل الآباء كان P_3 في حالة الري الطبيعي وP_2 تحت كلا الظروف بالنسبة لصفة عدد الأيام حتى ظهور أول زهرة. أما بالنسبة لعدد الأيام حتى النضج كان P_2وP_1 في حالة الري الطبيعي وP_4 وP_5 في حالة الإجهاد المائي. بينما كان P_2 وP_6 الأفضل بالنسبة لصفة ارتفاع أول كبسولة لكلا ظروف الري. كان P_2 تحت ظروف الجفاف وP_6 تحت الري الطبيعي الأفضل بالنسبة لصفة ارتفاع النبات. ومن نتائج هذه الدراسة نجد أن أفضل الهجن في قدرتها الخاصة على التآلف كانت P_1xP_2، P_1xP_6، P_3xP_6، P_4xP_5، P_4xP_6 وP_5xP_6 تحت كلا الظروف وP_1XP_3 وP_2XP_3 تحت الري الطبيعي P_2xP_3 تحت كلا الظروف بالنسبة SCA للمحصول البيولوجي.