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GENETIC CONTROL OF DROUGHT TOLERANCE IN TWO MAIZE HYBRIDS

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ABSTRACT

This study delved into the genetic control and inheritance of physiological and quantitative traits in six populations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of two maize hybrids: cross I (Inb.8 x Inb.24) and cross II (Inb.86 x Inb.24) under normal (100%IR) and drought (70%IR) treatments. Results revealed that mean squares due to generations were highly significant for all studied traits in the two crosses under the two water regimes. Data also illustrated that at least one of the non-allelic interactions is significant or highly significant for all the studied traits either in Cross I or in Cross II under the two water treatments. Through generation mean analysis, we identified significant additive and non-additive gene effects for trait inheritance in varying water regimes. Heritability estimates ranged from low to moderate in a narrow sense and moderate to high in a broad sense in the two crosses under both treatments, indicating the substantial influence of non-additive gene effects. The expected genetic advance for the studied traits were found to be moderate to high with values which ranged from 7.73% for chlorophyll content at 100%IR in cross I to 72.66% for grain yield/plant at drought stress conditions in cross II. Our findings provide valuable insights for maize breeding programs targeting enhanced grain yield and drought tolerance.

Key Words: ***Zea mays, L., Drought stress, Generations mean analysis, Gene effects, Heritability, Genetic advance.***

INTRODUCTION

Water scarcity is considered significant environmental elements that affect in agriculture worldwide; especially in light of the increasing population density food need, and with the continuing challenges of drought which considered one of the manifestations resulting from climate change which has an impact on many countries of the world, including Egypt. Changes in climatic conditions have further increased the possibility of drought occurrence (Wang *et al* 2020), drought stress worldwide threatens maize production (Liu and Qin 2021) in all stages of plant growth, especially flowering and grain filling globally (Boyer and Westgate 2004, Lobell *et al* 2014).

Maize is the one of the three most important cereal crops (wheat, rice and maize) overall world and is cultivated for food, feed, and industrial materials (Emam *et al* 2023). The study on maize drought is important in understanding the effect of water stress on crop growth and yield (Wang *et al* 2021). The multiple-stress effects on plant physiology and gene expression are being intensively studied lately (Malenica *et al*

2021). Deficit irrigation negatively affected the physiological traits for maize likewise, relative water content (RWC), cell membrane stability (CMS) and chlorophyll pigments content (Abdelkader *et al* 2022). Soltani *et al* (2013) and Younis *et al* (2017) reported that a water deficiency induced significant decrease in chlorophyll content by causing some physiological changes. Moreover, leaf relative water content is closely linked to plant tolerance to osmotic stresses such as drought and salinity stress (Aljuaid *et al* 2022). Water stress-induced decrease in membrane stability indicates the extent of lipid peroxidation caused by ROS (Abdul *et al* 2016; Ashraf 2009).

Thus, producing drought tolerant cultivars has been a major goal of maize breeding. Moreover, inheritance of different plant traits under drought stress requires understanding the genetic control for adopting different breeding approaches (Ahsan *et al* 2013). The conventional breeding strategies considers a more direct, efficient, and accurate approach for trait improvement. Generation mean analyses have provided information on the importance of gene effects (Moharramnejad *et al* 2018), and considers a simple but useful technique for estimating gene effects for a polygenic trait (Said 2014) such as grain yield trait.

Therefore, it is necessary for maize breeders to continue to produce high-yielding and drought-stressed genotypes of maize that can be grown in sandy and newly reclaimed lands by estimating some statistical and genetic parameters in order to benefit from them as new genetic sources in maize breeding programs under normal and drought-stress conditions to mitigate this risk. This study aims to evaluation of the six populations (P_1, P_2, F_1, F_2, BC_1, BC_2) for agronomic and physiologic traits associated with drought tolerance by estimating some statistical and genetic parameters in order to benefit from them as new genetic sources in maize breeding programs under normal and drought stress conditions.

MATERIALS and METHODS

1. Plant materials and field experimental work

Three inbred lines i.e., Inb.8, Inb.24 and Inb.86 were selected based on their diversity to achieve this study. Names and pedigree of the parental inbreds are presented in Table 1.

Table 1. Names, pedigree and drought tolerance of the three inbred maize lines used as parents in the study.

No.	Name	Pedigree	Drought tolerance
1	**Inb. 8 (P_1)**	**Early whit composite**	**Sensitive**
2	**Inb. 24 (P_2)**	**loc.bred (H-230 1969,Miyco)**	**Tolerant**
3	**Inb. 86 (P_3)**	**g.s. (Sanjuan X307)(S.C.14)**	**Sensitive**

Source: Gene Bank of Maize Depart., FCRI, ARC, Giza, Egypt.

Seeds of the inbred lines were obtained from Maize Research Section, Field Crops Res. Instit., Agric. Res. Center, Giza, Egypt.

During summer 2020 growing seasons, parents were sown and crosses were done to obtain seeds of the F_1 of the two crosses; Cross I (Inb.8 x Inb.24) and Cross Π (Inb.24 x Inb.86). The F_1 seeds were planted during summer 2021 growing seasons; plants were advanced by selfing to obtain F_2 seeds also. Crossing between F_1 plants was made with their parents to develop backcrosses (BC_1 and BC_2) generations, respectively. Also, parents were selfed to maintain parental purity. In addition, crossing was made between the parental inbred lines again to produce additional new F_1 hybrid grains for each cross. The crossing in the two seasons was made in the Experimental Farm of the Fac. of Agri., Ain Shams Univ. at Shoubra El-Kheima, Kalubia Governorate, Egypt on the first week of June and the plants were harvested in the third week of September.

In 2022 summer growing season, two separate and adjacent field trials (two irrigation levels: 70% and as (a drought) 100% (as a normal) of irrigation requirements (IR) included the six populations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of the two crosses were conducted in sandy soil at the experimental station of Agric. Production and Res. Station, National Research Centre, El Nubaria region, El Behaira Governorate, Egypt (latitude30°301.4\N, longitude30°1910.9\E, and mean altitude 21 m above sea level). Each trial was devoted for one irrigation treatment. Sowing date was on June 3rd and the preceding winter crop was onion (*Alium cepa*, L.). The two field experiments were designed in a randomized complete blocks design (RCBD) with three replications. Each replicate consisted of one row for each parent and F_1 cross, four rows for each backcross and six rows for the F_2 population for each cross. The row was 4 m long and 0.80 m wide with a distance of 0.25 m between hills (15 plants/row). Plants were thinned at one plant/hill. The soil of the site was analyzed mechanically and chemically according to Black (1965) and Piper (1950), respectively. The soil properties are presented in Table 2. While Table 3 exhibits the metrological data of the site.

Table 2. Properties of experimental site soil in 0-30depth.

<table>
<tr><th colspan="2">Mechanical analysis</th><th colspan="4">Chemical analysis</th></tr>
<tr><td rowspan="2">Coarse sand (%)</td><td rowspan="2">17.87</td><td colspan="2">pH value</td><td colspan="2">8.3</td></tr>
<tr><td>EC</td><td>(ds/m)</td><td colspan="2">0.38</td></tr>
<tr><td rowspan="2">Fine sand (%)</td><td rowspan="2">75.9</td><td rowspan="8">meq /l</td><td rowspan="4">Cations</td><td>Ca^{++}</td><td>1.51</td></tr>
<tr><td>Mg^{++}</td><td>0.43</td></tr>
<tr><td rowspan="2">Silt (%)</td><td rowspan="2">4.37</td><td>Na^{+}</td><td>1.62</td></tr>
<tr><td>K^{+}</td><td>0.24</td></tr>
<tr><td rowspan="2">Clay (%)</td><td rowspan="2">1.86</td><td rowspan="4">Anions</td><td>Cl^{-}</td><td>1.27</td></tr>
<tr><td>CO_3^{--}</td><td>0</td></tr>
<tr><td rowspan="2">Soil texture</td><td rowspan="2">Sand</td><td>HCO_3^{-}</td><td>1.31</td></tr>
<tr><td>SO_4^{--}</td><td>1.22</td></tr>
</table>

Calculations of irrigation levels were done as the irrigation control was practiced *via* manual valves for each experimental plot. The amount of irrigation water was calculated by Food and Agricultural Organization (FAO), Penman- Monteith procedure (PM), FAO 56 method (Allen *et al* 1998). The seasonal irrigation quantities under two irrigation levels were amounted 2690 and 1884m^3/fed for 100% and 70% IR, respectively including the quantity of irrigation water supplied before and after applying irrigation treatments. Plants were irrigated by using drippers of 2 l/hr capacity. The fertigation technique was used; 37.5 kg fed^{-1} of calcium superphosphate (P_2O_5 15.5%) added during soil preparation; for the potassium element, it is added at rate of 25 kg fed^{-1} potassium sulfate (K_2O 48%), while nitrogen fertilizer was added as ammonium nitrate (N 33.5%) at rate of 8 equal doses so that fertilization ends at flowering. The recommended other cultural practices were followed for maize production in the region of the experiment. Plants were harvested at September19th.

Table 3. Meteorological data of experimental site during 2022 growing season.

Items		June	July	August	September
Air temperature [°C]	**avg**	**25.58**	**26.63**	**27.28**	**26.06**
	Max	**32.01**	**32.83**	**33.67**	**33.24**
	min	**20.09**	**21.08**	**21.75**	**20.4**
Solar radiation [MJ/m2]	**Avg**	**1.36**	**1.24**	**0.96**	**0.66**
Relative humidity [%]	**Avg**	**74.46**	**74.61**	**76.73**	**75.44**
	Max	**99.99**	**99.45**	**100**	**99.62**
	Min	**40.23**	**41.31**	**41.46**	**40.72**
Precipitation [mm]	**Sum**	**0.00**	**0.00**	**0.00**	**0.05**
Soil temperature [°C]	**avg**	**27.76**	**29.32**	**30.13**	**28.66**
	max	**29.34**	**31.02**	**31.67**	**30.02**
	min	**26.18**	**27.67**	**28.57**	**27.27**

Source: Central Laboratory for Agricultural Climate, Doki, Giza,Egypt.

2. Traits measurement

Traits were measured on individual guarded plant basis where data were recorded on 30 plants for each of P_1, P_2 and F_1, 180 plants for each of BC_1 and BC_2 and 270 plants for each of F_2 population from the three replications for each cross for earliness traits (days to anthesis, days to silking), physiological traits i.e., total chlorophyll content (SPAD unit) measured on flag leaf blades of 10 guarded plants taken from each plot in field by chlorophyll meter by Minolta (1989), Cell membrane stability (CMS) (%) calculated as described by Abd Elbar *et* *al* (2021) using the equation: CMS = [1 – (EC1 /EC2)] × 100 where some leaf discs (8) were incubated for 24 h in 10 mL deionized water on a shaker; then EC1 values of contents were measured by EC meters; samples were autoclaved at 120 ◦C for 20 min to determine the values of EC2. Relative water content (RWC) was calculated according to Schonfeld *et al* (1988) using the following equation: RWC (%)=[(Fresh weight-dry weight)/(Turgid weight-dry weight)]x100, as well as the agronomic traits; plant height in cm, ear height in cm, No. of rows/ear, No. of kernels/row, 100-kernel weight (g) and grain yield per plant (g).

3. Statistical and genetic analyses

Analysis of variance and mean comparison of the characters were performed according to Gomez and Gomez (1984) using SAS Software, (version 9.1). Generation means analysis was analyzed using six populations model and A, B and C scaling tests were estimated using Mather and Jinks (1982) method to compute the gene effects involved in the six parameters genetic model. In this method the mean of each character is indicated as follows: Y= m + α[d] + β[h] + α2 [i] + 2αβ[j] + β2 [l]; where: Y= observed mean for generation; m = the mean effect, d=average additive effects, h=average dominance effects, i=average interaction between additive effects, j=average interaction between additive and dominance effects, l=average interaction between dominance effects. The genetic parameters (m, [d], [h], [i], [j] and [l]) were tested by using t-test of significance. To estimate the parameters and to select the most suitable model the least squares method and the joint scaling test of Mather and Jinks (1982) were employed. Broad and narrow sense heritability were calculated according to Warner (1952) as follows:

$$\text{Broad sense heritability } (H_{bs}) = \frac{VF_2 - VE}{VF_2} = \frac{VG}{VF_2}$$

Where: VE = the average environmental variances for the two parents and the F_1 populations, VF_2= phenotypic variance of the F_2 population, VG=genotypic variance of the F_2 generation by subtract the environmental variance (VE) from the F_2 variance (VF_2) *i.e*. VF_2-VE.

Narrow sense Heritability (H_{ns}) $= \dfrac{2VF_2 - (VBC_1 + VBC_2)}{VF_2}$

Where: VBC_1 = variance of the backcross 1 population, VBC_2 = variance of the backcross 2 population.

Expected genetic advance after one generation of selection of the best of the F_2 population in percentage of F_2 mean (%GAM) was calculated according to Allard (1960): GAM% = G.S. / F_2 x 100; G. S. (Δg) = K x δg x H_{ns}

Where: G.S.= expected genetic advance from selection, K= selection differential with a value of 2.06 under 5% selection intensity. δg= genotypic standard deviation, H_{ns}= heritability value in the narrow sense, F_2 = mean of the F_2 population.

RESULTS AND DISCUSSION

1. Analysis of variance and mean performance

Results in Table 4. revealed that mean squares due to generations were highly significant for the studied traits in the two crosses; cross I (Inb.8 x Inb.24) and cross Π (Inb.24 x Inb.86) under the two water regimes {100% (normal) and 70% (drought) IR}, indicating the genetic variability among the six populations (P_1, P_2, F_1, F_2, BC_1 and BC_2) in the two hybrids.

Table 4. Mean squares for the studied traits using the six populations data of the two maize hybrids under 100% (N) and 70% IR (D) at El-Nubaria region, El Behaira Governorate, Egypt; 2022 growing season.

Treatments	N	D	N	D	N	D
SOV	Replications		Generations		Error	
Df	2		5		10	
Traits	Cross I (Inb.8 x Inb.24)					
Days to 50% anthesis	2.89	0.72	55.42**	60.46**	2.09	3.45
Days to 50% silking	3.56	1.5	57.16**	68.10**	4.09	5.5
Cell membrane stability (%)	1.1	1.63	48.63**	51.6**	0.95	0.89
Relative water content (%)	0.59	0.27	26.57**	23.37**	0.42	0.2
Chlorophyll content (Spad	0.8	1.19	45.38**	76.65**	0.64	1.15
Plant height (cm)	10.17	15.17	2451.83**	2553.43**	52.7	78.7
Ear height (cm)	17.17	12.67	2203.2**	1548.9**	46.57	19.67

Ear length (cm)	**0.17**	**0.17**	**8.8****	**2.77****	**1.17**	**0.23**
No. of rows /ear	**0.17**	**0.39**	**2.93****	**2.72****	**0.1**	**0.12**
No. of kernels/row	**2.17**	**2.06**	**39.43****	**44.75****	**2.3**	**1.46**
100-kernel weight (g)	**2.39**	**1.17**	**85.69****	**67.20****	**2.26**	**1.77**
Grain yield /plant (g)	**5.56**	**8.67**	**6106.19****	**4489.43****	**5.09**	**9.6**

Table 4. Continue.

Treatments	N	D	N	D	N	D
SOV	Replications		Generations		Error	
Df	2		5		10	
Traits	Cross Π (Inb.24 x Inb.86)					
Days to 50% anthesis	3.17	1.56	56.77**	61.79**	4.63	5.22
Days to 50% silking	2	0.89	56.13**	60.46**	2.93	2.09
Cell membrane stability (%)	0.92	1.149	54.60**	60.60**	0.99	0.94
Relative water content (%)	1.2	0.18	69.15**	49.78**	1.05	0.34
Chlorophyll content (SPAD unit)	1.11	0.55	50.32**	40.99**	0.7	0.69
Plant height (cm)	62.72	63.72	2449.12**	2519.02**	125.66	92.06
Ear height (cm)	12.39	20.22	2816.59**	4195.42**	49.72	53.29
Ear length (cm)	1.17	1.56	47.73**	49.29**	6.1	4.62
No. of rows /ear	0.167	0.22	2.00**	3.029**	0.167	0.16
No. of kernels/row	1.56	1.06	37.96**	47.69**	2.289	1.32
100-kernel weight (g)	4.06	0.39	62.46**	26.73**	3.46	1.27
Grain yield /plant (g)	6	2.89	9106.13**	9671.69**	7.13	18.89

**** significant at 0.01 probability level.**

Tables (5 and 6) revealed that water stress reduced all studied traits in the two crosses under normal and drought stress treatments. Results also showed that mean performances of the six populations of the two maize crosses under two water regimes tented towards their earlier parent in the first and second crosses, the F_1 means were lower than the earlier parent. The F_2 means were more than the F_1 mean. Furthermore, the means of F_1 in the cross I (Inb.8 x Inb.24) followed by BC_1 gave highest values for physiologic traits and most agronomic traits (Table 5). On the contrary, in cross Π (Inb.24 x Inb.86), the means of F_1 followed by BC_2 gave highest values for physiological and yield traits (Table 6).

Table 5. Mean performance of generations and standard error (SE) of the studied traits of maize Cross I (Inb.8 x Inb.24) under 100% (N) and 70% IR (D) at El-Nubaria region, El Behaira Governorate, Egypt; 2022 growing season.

Generations		P_1	P_2	F_1	F_2	BC_1	BC_2	LSD 5%
Days to anthesis	N	47.93 ±0.38	54.73 ±0.46	42.03 ±0.29	45.82 ±0.26	44.48 ±0.27	47.66 ±0.19	2.63
	D	40.87 ±0.32	47.20 ±0.42	35.00 ±0.40	37.76 ±0.29	35.60 ±0.25	39.18 ±0.23	3.38
Days to silking	N	57.70 ±0.47	64.50 ±0.35	52.50 ±0.38	55.61 ±0.35	52.78 ±0.36	58.00 ±0.25	3.68
	D	51.80 ±0.43	57.76 ±0.38	46.96 ±0.44	47.17 ±0.39	44.60 ±0.34	50.87 ±0.24	4.27
Cell membrane stability (%)	N	63.45 ±0.53	59.59 ±0.51	71.55 ±0.56	67.31 ±0.61	66.53 ±0.50	64.49 ±0.55	1.78
	D	55.1 ±0.56	52.41 ±0.62	63.89 ±0.59	60.44 ±0.61	60.59 ±0.54	57.91 ±0.59	1.72
Relative water content (%)	N	74.71 ±0.38	72.34 ±0.39	80.75 ±0.4	78.46 ±0.42	78.08 ±0.36	76.52 ±0.40	1.78
	D	62.74 ±0.19	58.87 ±0.30	67.44 ±0.35	64.55 ±0.36	63.84 ±0.30	62.92 ±0.32	0.9
Chlorophyll content (SPAD unit)	N	30.79 ±0.53	28.68 ±0.46	39.53 ±0.57	36.05 ±0.51	34.23 ±0.39	32.23 ±0.42	1.54
	D	25.56 ±0.72	23.21 ±0.60	37.1 ±0.80	32.75 ±0.68	30.32 ±0.51	27.57 ±0.55	1.94
Plant height (cm)	N	168.31 ±0.55	178.69 ±1.08	247.41 ±1.29	212.96 ±1.46	188.34 ±1.76	209.35 ±0.65	13.2
	D	145.61 ±0.89	158.15 ±1.11	227.23 ±1.14	192.55 ±1.64	166.93 ±1.76	184.34 ±0.80	16.14

Table 5. Cont.

Generations		P_1	P_2	F_1	F_2	BC_1	BC_2	LSD 5%
Ear height (cm)	N	72.40 ±0.64	85.81 ±1.00	145.87 ±0.87	124.20 ±1.45	98.82 ±0.44	121.16 ±1.73	12.41
	D	65.27 ±0.74	78.44 ±0.70	127.70 ±0.72	93.27 ±0.88	71.70 ±0.41	98.79 ±0.99	8.07
Ear length (cm)	N	13.76 ±0.34	15.20 ±0.33	18.40 ±0.81	17.10 ±0.31	15.82 ±0.37	16.07 ±0.37	1.97
	D	12.33 ±4.04	14.2 ±2.51	15.10 ±3.64	14.82 ±26.49	13.07 ±20.35	13.51 ±24.94	0.88
No. rows/ear	N	13.47 ±0.19	13.93 ±0.11	15.80 ±0.11	14.89 ±0.08	13.62 ±0.09	14.14 ±0.10	0.58
	D	11.40 ±0.17	11.87 ±0.13	13.87 ±0.13	12.93 ±0.09	11.55 ±0.18	11.85 ±0.10	0.64
No. of kernels/row	N	32.83 ±0.35	34.13 ±0.30	43.03 ±0.28	38.88 ±0.24	36.12 ±0.26	35.59 ±0.17	2.76
	D	26.73 ±0.28	28.23 ±0.30	37.33 ±0.35	32.42 ±0.21	29.05 ±0.24	29.46 ±0.20	2.28
100-kernel weight (g)	N	34.12 ±0.50	37.91 ±0.42	48.44 ±0.59	46.24 ±0.31	41.75 ±0.32	43.85 ±0.34	2.73
	D	32.74 ±0.48	34.58 ±0.43	45.89 ±0.56	41.02 ±0.24	37.85 ±0.26	37.59 ±0.26	2.42
Grain yield/plant (g)	N	110.66 ±0.6	116.81 ±0.55	217.20 ±0.45	198.40 ±0.75	183.05 ±0.31	194.34 ±0.33	4.11
	D	85.59 ±0.68	92.72 ±0.64	174.91 ±0.74	161.67 ±0.51	152.65 ±0.33	161.46 ±0.47	5.63

Table 6. Mean performance of generations and standard error (SE) of the studied traits of maize Cross Π (Inb.24 x Inb.86) under 100% (N) and 70% IR (D) at El-Nubaria region, El Behaira Governorate, Egypt; 2022 growing season.

Cross I (Inb.8 x Inb.24)								
Generations		**P_1**	**P_2**	**F_1**	**F_2**	**BC_1**	**BC_2**	**LSD 5%**
Days to anthesis	**N**	**54.23 ±0.43**	**47.63 ±0.36**	**41.73 ±0.28**	**54.53 ±0.26**	**47.23 ±0.20**	**44.11 ±0.27**	**3.92**
	D	**46.9 ±0.44**	**40.43 ±0.34**	**34.57 ±0.38**	**37.47 ±0.29**	**38.96 ±0.22**	**35.38 ±0.25**	**2.63**
Days to silking	**N**	**63.93 ±0.36**	**57.33 ±0.49**	**52.20 ±0.37**	**55.13 ±0.35**	**57.44 ±0.26**	**52.32 ±0.36**	**3.12**
	D	**57.27 ±0.34**	**51.40 ±0.43**	**46.63 ±0.43**	**46.75 ±0.38**	**50.47 ±0.23**	**44.21 ±0.33**	**4.16**
Cell membrane stability (%)	**N**	**66.82 ±0.54**	**63.05 ±0.5**	**75.4 ±0.56**	**71.82 ±0.62**	**70.85 ±0.51**	**69.2 ±0.55**	**2.03**
	D	**58.8 ±0.58**	**56.21 ±0.62**	**68.13 ±0.59**	**65.4 ±0.62**	**65.34 ±0.55**	**63.09 ±0.59**	**2.00**
Relative water content (%)	**N**	**79.03 ±0.59**	**74.61 ±0.57**	**88.35 ±0.61**	**84.94 ±0.66**	**83.64 ±0.55**	**81.65 ±0.60**	**2.08**
	D	**64.17 ±0.55**	**55.95 ±0.63**	**68.39 ±0.58**	**63.54 ±0.52**	**61.56 ±0.41**	**61.64 ±0.43**	**1.25**
Chlorophyll content (SPAD unit)	**N**	**32.28 ±0.55**	**29.46 ±0.50**	**41.2 ±0.53**	**37.27 ±0.52**	**35.46 ±0.41**	**33.59 ±0.45**	**1.23**
	D	**26.30 ±0.56**	**24.89 ±0.45**	**34.86 ±0.64**	**31.83 ±0.50**	**30.00 ±0.38**	**27.88 ±0.41**	**1.6**
Plant height (cm)	**N**	**177.92 ±1.13**	**167.60 ±0.54**	**246.73 ±3.33**	**212.27 ±1.46**	**187.61 ±1.76**	**206.94 ±0.62**	**10**
	D	**157.61 ±1.63**	**145.39 ±0.89**	**226.36 ±1.36**	**192.35 ±1.64**	**184.11 ±0.80**	**166.72 ±1.76**	**17.45**

Table 6. Cont.

Cross Π (Inb.24 x Inb.86)								
Generations		**P_1**	**P_2**	**F_1**	**F_2**	**BC_1**	**BC_2**	**LSD 5%**
Ear height (cm)	**N**	**95.77 ±0.82**	**71.81 ±0.64**	**166.67 ±1.39**	**123.11 ±1.43**	**125.18 ±1.74**	**116.87 ±0.53**	**10**
	D	**77.70 ±0.82**	**64.55 ±0.75**	**163.28 ±1.13**	**116.12 ±1.43**	**106.98 ±1.72**	**88.67 ±0.47**	**17.45**
Ear length (cm)	**N**	**13.30 ±0.32**	**11.90 ±0.33**	**21.29 ±0.69**	**19.86 ±0.35**	**19.51 ±0.40**	**18.62 ±0.40**	**4.49**
	D	**11.85 ±0.32**	**10.00 ±0.36**	**19.63 ±0.90**	**19.38 ±0.34**	**18.09 ±0.39**	**17.63 ±0.39**	**3.91**
No. rows/ear	**N**	**13.73 ±0.13**	**13.43 ±0.21**	**15.53 ±0.12**	**14.68 ±0.08**	**13.46 ±0.09**	**14.03 ±0.10**	**2.75**
	D	**11.83 ±0.14**	**11.37 ±0.22**	**13.77 ±0.17**	**12.76 ±0.09**	**11.48 ±0.10**	**11.83 ±0.10**	**2.09**
No. of kernels/row	**N**	**33.37 ±0.32**	**32.37 ±0.34**	**41.80 ±0.27**	**37.94 ±0.25**	**34.68 ±0.18**	**35.28 ±0.25**	**0.74**
	D	**27.93 ±0.33**	**26.53 ±0.29**	**36.80 ±0.32**	**32.03 ±0.21**	**29.06 ±0.17**	**26.66 ±0.24**	**0.72**
100-kernel weight (g)	**N**	**34.24 ±0.43**	**32.67 ±0.54**	**45.47 ±0.54**	**40.47 ±0.23**	**37.37 ±0.25**	**37.9 5±0.25**	**3.38**
	D	**34.19 ±0.430**	**32.42 ±0.38**	**45.41 ±0.39**	**40.71 ±0.25**	**37.98 ±0.26**	**37.38 ±0.1822**	**2.88**
Grain yield/plant (g)	**N**	**116.41 ±0.54**	**110.23 ±0.66**	**238.10 ±0.49**	**217.51 ±0.82**	**213.09 ±0.36**	**200.67 ±0.35**	**10**
	D	**92.04 ±0.86**	**84.99 ±0.76**	**215.65 ±0.85**	**194.51 ±0.81**	**194.12 ±0.67**	**180.09 ±0.43**	**7.91**

Results are in agreement with El-Shamarka *et al* (2019), Islam *et al* (2020) and Khan *et al* (2021), who revealed that sufficient genetic variations were found among genotypes for one or more of the studied traits in maize under normal or/and drought conditions.

2. Scaling test and types of gene action

The choice of breeding procedures for genetic improvement of maize depends on the knowledge of type of gene effects for different traits in plant materials under research (Melchinger *et al* 2013). So, six populations of maize can be analyzed using generation mean analysis to better understand the inheritance of important traits in maize.

The results of scaling test (A, B, C and D) in (Table 7, 8). under both water regimes showed significance of any of these tests for earliness, physiologic and agronomic traits. Data also illustrated that at least one of the non-allelic interactions is significant or highly significant for the studied traits either in cross I (Inb.8 x Inb.24) or cross Π (Inb.24 x Inb.86) under two water treatments, indicating the adequacy of the six parameters model to estimate the different types of gene action controlling the traits in the two crosses under both conditions.

The results of the nature of gene action controlling the inheritance of different traits under study using the method of generation mean analysis (six parameters model) revealed that the F_2 mean effect parameter (m) was found to be highly significant for all studied traits in the two crosses under investigation.

The estimated values of types of gene effects contributing to the genetic variability for the studied traits in the two crosses under 100% and 70%IR are presented in (Table 9, 10).

Results showed that the estimated F_2 mean effect parameter (m) which reflects the contributions due to the overall mean in addition to the locus effects and the interaction of the fixed loci was found to be highly significant for all studied traits in the two crosses under both conditions, indicating that all studied traits were quantitively inherited.

Additive gene effect (d) was significant for the studied traits except, Chl. content and ear height in Cross I (Inb.8 x Inb.24) at 100% and 70%IR and ear length at 70%IR likewise, ear length and 100-kernel weight in Cross Π (Inb.24 x Inb.86) at 100% and 70%IR and No. of kernels/row at 100%IR and relative water content at 70% IR.

Table 7. Estimates of scaling tests for the studied traits using the six populations data of maize Cross I (Inb.8 x Inb.24) under 100% (N) and 70% IR (D) at El-Nubaria region, El Behaira Governorate, Egypt; 2022 growing season.

Trait	100IR			
	A	B	C	D
Days to 50% anthesis	-1.00	-1.44*	-3.41*	-0.49
Days to 50% silking	-4.64**	-1.00	-4.74**	0.45
Cell membrane stability (%)	-1.94	-2.15	3.12	3.61*
Relative water content (%)	0.7	-0.05	5.30**	2.32*
Chlorophyll content (SPAD unit)	-1.86	-3.74**	5.67*	5.63**
Plant height (cm)	-39.04**	-7.4**	10.02	28.23**
Ear height (cm)	-20.61**	10.65**	46.88**	28.42**
Ear length (cm)	-0.5	-1.45*	2.63	2.29**
No. of rows /ear	-2.02**	-1.44**	0.56	2.01**
No. of kernels/row	-3.62**	-6**	2.49*	6.06**
100-kernel weight (g)	0.95	1.36	16.05**	6.87**
Grain yield /plant (g)	38.25**	54.68**	131.75**	19.41**
Trait	70%IR			
Days to 50% anthesis	-4.67**	-3.84**	-7.01**	0.75
Days to 50% silking	-9.59**	-2.99**	-14.85**	-1.14
Cell membrane stability (%)	2.2	-0.48	6.48**	2.39
Relative water content (%)	-2.5**	-0.47	1.71	2.34**
Chlorophyll content (SPAD unit)	-2.02	-5.16**	8.04*	7.61**
Plant height (cm)	-38.99**	-16.69**	11.98	33.83**
Ear height (cm)	-49.55**	-8.55**	-26**	16.05**
Ear length (cm)	-1.29	-2.28**	2.54	3.06**
No. of rows /ear	-2.18**	-2.04**	0.72	2.47**
No. of kernels/row	-5.96**	-6.64**	0.06	6.33**
100-kernel weight (g)	-2.94**	-5.29**	4.98**	6.60**
Grain yield /plant (g)	44.8**	55.27**	118.55**	9.24**

***,** significant at 0.05 and 0.01 probability levels, respectively.**

Table 8. Estimates of scaling tests for the studied traits using the six populations data of maize Cross Π (Inb.24 x Inb.86) under 100% (N) and 70% IR (D) at El-Nubaria region, El Behaira Governorate, Egypt; 2022 growing season.

Trait	100IR			
	A	B	C	D
Days to 50% anthesis	-0.52	-0.05	6.63*	3.60*
Days to 50% silking	-1.50*	-1.14	-3.23*	-0.29
Cell membrane stability (%)	-0.52	-0.05	6.63*	3.60*
Relative water content (%)	-0.09	0.34	9.41**	4.58**
Chlorophyll content (SPAD unit)	-2.57*	-3.48**	4.95*	5.50**
Plant height (cm)	-49.44**	-0.45	9.92	29.91**
Ear height (cm)	-45.08**	-1.35	-1.69	22.37**
Ear length (cm)	4.42**	4.05**	11.66**	1.6
No. of rows /ear	-2.36**	-0.91**	0.48	1.87**
No. of kernels/row	-5.80**	-3.61**	2.43*	5.92**
100-kernel weight (g)	-4.97**	-2.24*	4.04*	5.62**
Grain yield /plant (g)	71.68**	53.01**	167.2**	21.25**
	70%IR			
Days to 50% anthesis	-2.97**	-9.61**	-14.93**	-1.17
Days to 50% silking	-3.54**	-4.24**	-6.59**	0.6
Cell membrane stability (%)	3.74**	1.83	10.33**	2.38
Relative water content (%)	-9.44**	-1.06	-2.73	3.89**
Chlorophyll content (SPAD unit)	-1.16	-4.00**	6.39*	5.78**
Plant height (cm)	-15.75**	-38.31**	13.68	33.88**
Ear height (cm)	5.82	-53.88**	-11.11	18.48**
Ear length (cm)	4.71**	5.62**	16.41**	3.04**
No. of rows /ear	-2.63**	-1.48**	0.29	2.20**
No. of kernels/row	-6.61**	-10.01**	0.07	8.34**
100-kernel weight (g)	-2.34**	-1.96**	3.45**	3.87**
Grain yield /plant (g)	80.55**	59.54**	169.71**	14.81**

***, ** significant at 0.05 and 0.01 probability levels, respectively.**

Table 9. Gene effects for the studied traits using the six populations data of maize hybrid Cross I (Inb.8 x Inb.24) under 100% and 70% Eto at El-Nubaria; 2022 growing season.

Treatments	100IR					
Gene effects	M	d	h	i	j	i
Days to 50% anthesis	45.83**	-3.18**	-8.33**	0.97	0.22	1.47
Days to 50% silking	55.61**	-5.22**	-9.5**	-0.9	-1.82**	6.55**
Cell membrane stability (%)	212.96**	-21.01**	17.44*	-56.47**	-15.82**	102.92**
Relative water content (%)	124.2**	-22.34**	9.92	-56.84**	-15.63**	66.8**
Chlorophyll content (SPAD unit)	17.09**	-0.25	-0.66	-4.58**	0.47	6.52*
Plant height (cm)	14.89**	-0.52**	-1.92**	-4.02**	-0.29	7.49**
Ear height (cm)	38.88**	0.54	-2.56*	-12.11**	1.19**	21.74**
Ear length (cm)	46.24**	-2.1**	-1.32	-13.74**	-0.2	11.44**
No. of rows /ear	198.4**	-11.29**	64.64**	-38.82**	-8.21**	-54.1**
No. of kernels/row	67.31**	2.04**	2.81	-7.21*	0.11	11.3**
100-kernel weight (g)	78.46**	1.56**	2.58	-4.64*	0.37	3.99
Grain yield /plant (g)	36.05**	2.00**	-1.47	-11.27**	0.94	16.87**
Treatments	70%IR					
Gene effects	M	d	h	i	j	l
Days to 50% anthesis	37.76**	-3.58**	-10.53**	-1.5	-0.41	10.01**
Days to 50% silking	47.17**	-6.27**	-5.56**	2.27	-3.3**	10.30**
Cell membrane stability (%)	192.55**	-17.41**	7.69	-67.66**	-11.15**	123.34**
Relative water content (%)	93.27**	-27.09**	23.73**	-32.1**	-20.5**	90.2**
Chlorophyll content (SPAD unit)	14.82**	-0.44	-4.28**	-6.11**	0.50	9.68**
Plant height (cm)	12.93**	-0.3*	-2.71**	-4.94**	-0.07	9.16**
Ear height (cm)	32.42**	-0.41	-2.81*	-12.66**	0.34	25.26**
Ear length (cm)	41.02**	0.26	-0.98	-13.21**	1.17*	21.43**
No. of rows /ear	161.68**	-8.8**	67.29**	-18.47**	-5.23**	-81.6**
No. of kernels/row	60.44**	2.69**	5.36	-4.77	1.34	3.06
100-kernel weight (g)	64.55**	0.92*	1.95	-4.68**	-1.02*	7.66**
Grain yield /plant (g)	32.75**	2.74**	-2.5	-15.22**	1.57	22.39**

***, ** significant at 0.05 and 0.01 probability levels, respectively. m= mean, d = additive effects, h= dominance effects, i = additive × additive interaction, j= additive × dominance interaction, l= dominance × dominance interaction.**

Table 10. Gene effects for the studied traits using the six populations data of maize hybrid Cross Π (Inb.24 x Inb.86) under 100% and 70% Eto at El-Nubaria; 2022 growing season.

Treatments	100IR					
Gene effects	M	d	h	i	j	i
Days to 50% anthesis	55.13**	5.12**	-9.41**	-0.98	1.82**	7.13**
Days to 50% silking	45.53**	3.12**	-8.61**	0.59	-0.18	2.06
Cell membrane stability (%)	71.82**	1.65*	3.27	-7.2*	-0.24	7.77
Relative water content (%)	84.94**	2.00*	2.37	-9.16**	-0.21	8.91*
Chlorophyll content (SPAD unit)	37.27**	1.87**	-0.66	-10.99**	0.46	17.04**
Plant height (cm)	212.23**	-19.34**	14.16	-59.81**	-24.49**	109.7**
Ear height (cm)	123.11**	-9.89**	34.74**	-44.75**	-21.87**	91.18**
Ear length (cm)	19.86**	0.89	5.48**	-3.19	0.18	-5.27
No. of rows /ear	14.68**	-0.57**	-1.79**	-3.74**	-0.72**	7.01**
No. of kernels/row	37.94**	-0.59	-2.91*	-11.84**	-1.09**	21.25**
100-kernel weight (g)	40.47**	-0.58	0.78	-11.25**	-1.36**	18.45**
Grain yield /plant (g)	217.51**	12.42**	82.27**	-42.51**	9.33**	-82.19**
Treatments	70%IR					
Gene effects	M	d	h	i	j	l
Days to 50% anthesis	46.75**	6.26**	-5.35**	2.35	3.32**	10.23**
Days to 50% silking	37.47**	3.58**	-10.3**	-1.2	0.35	8.99**
Cell membrane stability (%)	65.4**	2.25**	5.87	-4.75	0.96	-0.83
Relative water content (%)	63.54**	-0.08	0.55	-7.77**	-4.19**	18.27**
Chlorophyll content (SPAD unit)	31.83**	2.12**	-2.28	-11.55**	1.42*	16.71**
Plant height (cm)	192.35**	17.39**	7.12	-67.74**	11.28**	121.8**
Ear height (cm)	116.12**	36.43**	58.58**	-36.96**	29.85**	85.02**
Ear length (cm)	19.38**	0.46	2.63	-6.08**	-0.46	-4.25
No. of rows /ear	12.76**	-0.34*	-2.23**	-4.4**	-0.58**	8.51**
No. of kernels/row	32.03**	2.4**	-7.12**	-16.69**	1.70**	33.31**
100-kernel weight (g)	30.55**	0.38	0.01	-7.75**	-0.19	12.04**
Grain yield /plant (g)	194.51**	14.04**	97.51**	-29.62**	10.51**	-110.47**

***, ** significant at 0.05 and 0.01 probability levels, respectively. m= mean, d = additive effects, h= dominance effects, i = additive × additive interaction, j= additive × dominance interaction, l= dominance × dominance interaction.**

Dominance gene action (h) was significant for earliness traits; for physiological traits, CMS was significant at 100%IR but not significant at 70%IR in contrary RWC and Chl. content; while most of agronomic traits were not significant such as ear length, No. of kernels/row, hundred kernel weight and grain yield/plant under the two irrigation regimes in Cross I (Inb.8 x Inb.24). In Cross Π (Inb.24 x Inb.86), all physiological traits (CMS, RWC, Chl. content) and the two agronomic traits (plant height and hundred kernel weight) were not significant under normal and drought treatments as well as ear length under drought treatments.

Significant epistatic effects were observed for all studied traits except for days to anthesis at 100%IR and No. of kernels/row at 70%IR in Cross I (Inb.8 x Inb.24), as well as days to silking and ear length at 100%IR and CMS at 70%IR in Cross Π (Inb.24 x Inb.86).

In Cross I (Inb.8 x Inb.24); additive × additive (i) interaction was significant for all studied traits, except earliness traits under both treatments and No. of kernels/row at 70%IR. The significant additive × dominance (j) effects were shown studied traits, except in days to anthesis, chlorophyll pigment, plant height, No. of kernels/row and grain yield/plant under both treatments as well as ear length and 100-kernel weight at 100%IR and ear height at 70%IR. Furthermore, significant dominance × dominance (l) interaction effects were observed for all studied traits, except No. of kernels/row under drought treatment and 100 kernels weight under normal treatment.

In Cross Π (Inb.24 x Inb.86); additive × additive (i) interaction was significant for all studied traits, except for earliness traits under both treatments as well as CMS at 70%IR and ear length at 100%IR. Additive × dominance (j) effects were significant for all studied traits, except days to silking, CMS and ear length under both treatments as well as RWC and Chl. content at 100%IR and 100 kernel weight at 70%IR. Dominance × dominance (l) interaction effects were significant for all traits, except for CMS under and ear length at 100% and 70%IR as well as days to silking at 100%IR.

The above results or some of them are in harmony with Sher *et al* 2012, Shahrokhi *et al*, 2013, Dorri *et al* 2014, Wannows *et al* 2015, Heakel and Hany 2019, Shankar *et al* 2022, Emam *et al* 2023.

3. Heritability estimates and expected genetic advance from selection

Heritability estimates and expected genetic advance from selection displayed in (Table 11, 12)

Table 11. Heritability estimates in broad (Hbs) and narrow (Hbn) sense and genetic advance after one generation of selection the best 5% of the F_2 population in percentage of F_2 mean (GMA%) for the studied traits using the six populations data of the two maize hybrid under 100% (N) and 70% IR (D) at El-Nubaria region, El Behaira Governorate, Egypt; 2022 growing season.

Traits	Cross I (Inb.8 x Inb.24)					
	N	D	N	D	N	D
	Heritability%				GMA%	
	Broad sense		Narrow sense			
Days to 50% anthesis	76.46	80.18	47.42	52.63	13.81	16.52
Days to 50% silking	84.93	87.19	46.33	62.61	17.13	21.35
Cell membrane stability (%)	90.55	91.94	64	63.45	28.06	14.14
Relative water content (%)	88.31	86.95	57.05	69.04	12.18	8.92
Chlorophyll content (SPAD unit)	89.35	86.15	59.51	69.49	7.73	34.35
Plant height (cm)	94.55	95.44	44.8	53.72	23.2	31.57
Ear height (cm)	96.18	92.58	49.28	50.44	49.93	51.22
Ear length (cm)	66.83	87.17	6.26	14.52	16.13	14.08
No. of rows /ear	64.85	67.67	4.57	5.03	11.97	15.23
No. of kernels/row	82.43	76.31	47.27	28.39	18.47	24.17
100-kernel weight (g)	70.21	54.58	22.36	25.58	24.82	24.02
Grain yield /plant (g)	94.27	79.26	87.7	57	54.48	57.42

Table 12. Heritability estimates in broad (Hbs) and narrow (Hbn) sense and genetic advance after one generation of selection the best 5% of the F_2 population in percentage of F_2 mean (GMA%) for the studied traits using the six populations data of the two maize hybrid under 100% (N) and 70% IR (D) at El-Nubaria region, El Behaira Governorate, Egypt; 2022 growing season.

Traits	Cross Π (Inb.24 x Inb.86)					
	N	D	N	D	N	D
	Heritability %				GMA%	
	Broad sense		Narrow sense			
Days to 50% anthesis	84.64	87.69	45.84	63.39	13.79	16.48
Days to 50% silking	78.33	79.51	43.3	54.23	17.08	21.3
Cell membrane stability (%)	90.77	83.84	63.8	66.51	12.19	14.29
Relative water content (%)	88.16	87.23	56.98	66.05	11.69	13.24
Chlorophyll content (SPAD unit)	89.88	84.89	61.38	69.16	23.52	25.15
Plant height (cm)	77.82	92.73	45.22	53.81	26.59	31.03
Ear height (cm)	95.79	94.29	47.87	47.3	53.92	70.45
Ear length (cm)	79.37	66.45	13.23	12.39	35.15	43.9
No. of rows/ear	59.16	50.5	8.71	9.38	11.9	14.52
No. of kernels/row	82.43	76.12	48.29	36.23	18.09	26.19
100-kernel weight (g)	47.04	70.18	22.71	45.44	22.18	23.38
Grain yield /plant (g)	94.65	88.35	87.73	67.3	62.03	72.66

Very high to moderate heritability estimates in broad sense were detected in most of the studied traits; values ranged from 54.58% for 100-kernels weight at 70%IR to 96.18% for ear height at 100%IR in cross I and from 47.04% for 100 kernels weight to 95.79% for ear height at 100%IR In cross Π. Low to very high heritability estimates in the narrow sense were detected in most of the studied traits with values ranging from 4.57% for No. of rows/ear to 87.70% for grain yield/plant at 100%IR in cross I. In cross II, the values ranged from 8.71% for No. of rows/ear to 87.73% for grain yield/plant at 100%IR.

For narrow sense heritability (H_{ns}) estimates; in cross I (Inb.8 x Inb.24), very high estimates were displayed for CMS, chlorophyll content under both treatments; grain yield/plant at 100%IR; days to silking and RWC at 70%IR. Moderately high estimates were found for days to anthesis, plant height, ear height under both regimes; days to silking, RWC, No. of kernels/row under normal treatment; grain yield/plant under drought treatment. Moderate H_{ns} estimates were displayed for 100-kernels weight under both treatments; No. of kernels/row at 70%IR. Low H_{ns} estimates were found for ear length and No. of rows/ear under both water treatments. In cross Π (Inb.24 x Inb.86), very high H_{ns} estimates were displayed for CMS, chlorophyll content and grain yield/plant under normal and drought stress, respectively; days to anthesis and RWC at 70%IR. Moderately high estimates of H_{ns} for days to silking, plant height, ear height under normal and drought water regimes, respectively; days to anthesis, RWC, No. of kernels/row at 100%IR; 100-kernel weight at 70%IR. Moderate H_{ns} estimates were shown for 100-kernel weight at 100%IR and No. of kernels/row at 70%IR. Low H_{ns} estimates were displayed for ear length and No. of rows/ear at 100% and 70%IR, respectively.

The expected genetic advance relative to the F_2 mean (GAM%) for studied characters were found to be moderate to high (Table 11, 12). Values which ranged from 7.73% for chlorophyll content at 100%IR to 57.42% for grain yield/plant at 70%IR in cross I. In cross II, the values ranged from 11.69% for relative water content at normal irrigation to 72.66% for grain yield/plant at drought stress conditions.

In this context, Katiyar *et al* (2020) mention that high heritability coupled with high genetic advance is mainly due to the additive gene action. On the other hand, high heritability with low genetic advance and moderate or low heritability with low genetic advance reflect non additive gene action. Some of the above results were agreements with (Moharramnejad *et al* 2018, Abe and Adelegan 2019, Islam *et al* 2020, Dorri *et al* 2021 and Shankar *et al* 2022).

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التحكم الوراثي لتحمل الجفاف في هجينين من الذرة الشامية

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أجري هذا البحث بهدف دراسة التحكم الوراثي وتوارث الصفات الفسيولوجية في العشائر الستة لهجينين من الذرة الشامية: الهجين الأول (Inb.8 x Inb.24) والهجين الثاني (Inb.86 x Inb.24) تحت ظروف الري العادي (١٠٠% من الاحتياجات المائية) واجهاد الجفاف (٧٠% من الاحتياجات المائية). اشتملت الدراسة على ثلاثة مواسم زراعية حيث تم زراعة الآباء في موسم ٢٠٢٠ والتهجين فيما بينها، ثم زراعة بذور الجيل الأول للحصول على نباتات الجيل الثاني مع إعادة تكوين هجن الجيل الأول مرة أخرى وكذلك عمل تلقيح ذاتي للآباء مع إجراء التهجين الرجعي لكلا الأبوين لكل هجين للحصول على الهجن الرجعية في موسم ٢٠٢١، وفي موسم ٢٠٢٢ تم زراعة العشائر الستة (الآباء والجيل الأول والجيل الثاني والهجن الرجعية لكلا الأبوين) لكل هجين تحت ظروف الري العادي (١٠٠% من الاختياجات المائية) وظروف الجفاف (٧٠% من الاحتياجات المائية). أوضح تحليل التباين وجود اختلافات عالية المعنوية بين العشائرالستة لمختلف الصفات تحت الدراسة لكلا الهجينين تحت كلا معاملتي الري مما يدل على وجود إختلافات وراثية بين الآباء المستخدمة فى الدراسة؛ أوضحت نتائج إختبار إسكيلنج (A, B, C and D) وجود تفاعل بين جينات غير آليلية أى وجود تأثيرات للفعل الجينى التفوقى epistasis gene action إضافة إلى تأثيرات الفعل الجينى المضيف additive والسيادى dominance فى وراثة الصفات للهجين الأول والثاني تحت كلا معاملتي الري. أظهرت النتائج الخاصة بطبيعة الفعل الجينى المتحكم فى وراثة الصفات المختلفة تحت الدراسة بإستخدام طريقة تحليل متوسط الأجيال Generation mean analysis (موديل الستة دلائل Six parameters model) أن المتوسط العام للجيل الثانى (m) mean effects كان عالى المعنوية لكل الصفات مما يشير إلى أنها صفات كمية فى وراثتها. كما أوضحت النتائج أيضاً أن الصفات المدروسة تأثرت بأنواع الفعل الجينى المختلفة ولكن بدرجات مختلفة من التأثر.

تراوحت قيم كفاءة التوريث بالمعنى الواسع من 64.85% لعدد الصفوف/الكوز إلى 96.18% لصفة ارتفاع الكوز تحت ظروف الري العادي، بينما تراوحت من 54.58% لوزن ١٠٠ حبة إلى 95.44% لصفة ارتفاع النبات تحت طروف الجفاف وذلك للهجين الأول. وبالنسبة للهجين الثاني تراوحت القيم تحت ظروف الري العادي من 47.04% لوزن ١٠٠ حبة إلى 95.79% لصفة ارتفاع الكوز ومن 50.50% لصفة عدد الصفوف/الكوز إلى 94.29% لصفة ارتفاع الكوز. تراوحت قيم كفاءة التوريث بالمعنى الدقيق من ٤٤,٥٧% لصفة عدد الصفوف/الكوزإلى 87.70% لصفة محصول النبات الفردي من الحبوب تحت ظروف الري العادي ومن ٥٠,٠٣% لصفة عدد الصفوف/الكوز إلى ٦٩,٤٩% لصفة محتوى الكلوروفيل تحت ظروف الجفاف للهجين الأول. بالنسبة للهجين الثاني تراوحت القيم ٨,٧١% لصفة عدد الصفوف/الكوز إلى ٨٧,٧٣% لصفة محصول الحبوب/النبات تحت ظروف الري العادي و من ٩,٣٨% لصفة عدد الصفوف/الكوز إلى ٦٩,١٦% لمحتوى كلوروفيل النبات تحت ظروف الجفاف. تراوحت قيم التقدم الوراثي المتوقع نتيجة انتخاب احسن ٥% من نباتات عشيرة الجيل الثانى F2 مقدرة كنسبة مئوية من المتوسط العام لنباتات F_2 من (٧,٧٣% و ٨,٩٢%) لمحتوى الكلوروفيل إلى (٥٤,٤٨% و ٨,٩٢%) لمحصول الحبوب/النبات للهجين الأول، وبالنسبة للهجين الثاني تراوحت القيم من (11.69% و 13.24%) لصفة المحتوى المائي النسبي بالاوراق إلى (62.03 و 72.66%) لمحصول الحبوب/النبات تحت كلا معاملتي الري على الترتيب.