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GENE ACTION AND HERITABILITY IN SOME CROSS POPULATIONS IN DURUM WHEAT UNDER NORMAL AND WATER STRESS CONDITIONS

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ABSTRACT

Six populations of three durum wheat (*Triticum turgidum* L. var durum) crosses namely 1) Mrb5 x ICAMOR-TA04-68-F4, 2) Bani suef-3 x Waha and 3) Korifa x Haurani were grown during 2009/2010, 2010/2011 and 2011/2012 at Ismailia Agricultural Research Station, Ismailia Governorate, Egypt. The six populations were evaluated in two adjacent experiments, one with irrigated by sprinkler system every week throughout the season (normal condition) and the other was irrigated by sprinkler system every three weeks throughout the season (water stress condition). The study aimed to determine the adequacy of genetic model and gene action controlling days to heading, days to maturity, grain yield/plant and its components, proline content, relative water content (RWC) and transpiration rate. Results indicated that, F_1 exceeded the better parent for yield and its components and some physiological characters in most studied crosses under both normal and water stress conditions. Genetic system and gene expression differed greatly from the normal condition to water stress treatment in most cases. Where, scaling tests (A, B and C) provide evidence for the suitability of simple additive-dominance genetic model for explaining the inheritance of days to heading in 1st and 3rd crosses, No. of spikes/plant in 1st and 2nd crosses, 100-grain weight, proline content and RWC in 2nd cross as well as transpiration rate in 1st one under normal condition, as well as days to heading and proline content in 1st cross, No. of spikes/plant in all studied crosses and 100-grain weight in 2nd and 3rd crosses under water stress condition. Otherwise, the complex genetic model was responsible for the inheritance of grain yield/plant and days to maturity in all crosses under both conditions, No. of spikes/plant in 3rd cross, No. of grains/spike and 100-grain weight in 1st and 2nd crosses, proline content and RWC in 1st and 3rd crosses as well as transpiration rate in 2nd and 3rd crosses under normal condition, also it responsible for days to heading and proline content in 2nd and 3rd crosses, No, of grains/spike, RWC and transpiration rate in all studied crosses under water stress condition. Additive gene effect (d) was significant for days to heading in 1st and 3rd crosses, No. of spikes/plant in 1st and 2nd crosses, 100-grain weight, proline content and RWC in 2nd cross and transpiration rate in 1st one under normal condition as well as days to heading and proline content in 1st cross, No. of spikes/plant in 1st, 2nd and 3rd crosses and 100-grain weight in 2nd and 3rd crosses under water stress condition. Both additive (d), dominance (h) and their interaction types, additive x additive (i) and dominance x dominance (l) were involved in the genetics of No. of grains/spike in 1st cross under normal condition and RWC in 1st and 3rd crosses, as well as grain yield/plant in 3rd cross under water stress condition. Additive (d), dominance (h), additive x additive (i), additive x dominance (i) and dominance x dominance (I) were significant for No. of grains/spike in 1st cross under normal condition and days to maturity in 1st cross and RWC in the 3rd one under water stress condition. Additive (D) genetic variance was important in the genetics of days to heading, days to maturity. No. of spikes/plant, proline content, RWC and transpiration rate in all studied crosses, under normal condition, as well as days to heading in 1st and 3rd crosses, days to maturly in 1st and 2nd crosses, proline content in 2nd and 3rd crosses as well as transpiration rate in 1st one under water stress condition. The dominance (H) genetic variance was found to be the prevailent type controlling the remaining crosses under both conditions. Heritability in narrow sense (Tn) was high (>50%) for days to heading, days to maturity, No. of spikes/plant. 100-grain weight, proline content. RWC and transpiration rate in most cases and ranges from low to moderate for grain yield/plant under both conditions.

Key words: Durum wheat, water stress, tolerance, genetic system, heritability.

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INTRODUCTION

Water deficit is the major constraint to rainfed durum wheat production worldwide (Kristin *et al.*, 1997; Androw *et al.*, 2000). Moreover, changing weather pattern and world wide water shortage will likely result in irrigated wheats being grown with low applied water, increasing the likelyhood or soil water deficit (Rebetzke *et al.*, 2006)

Durum wheat (*Triticum turgidum* L. var. durum Desf.) as a self pollinated tetraploid (2n= 4x= 28) is highly valued for production of semolina and pasta products. It is occupying about 30 million hectares and 8% of total production throughout the world (Sharma and Sain, 2004). Considering the lower potential yield in durum than that of bread wheat under both rainfed and irrigated conditions, more investigations and breeding programs for development of higher- yielding and best cultivars are necessary. Drought cause some deficits in plant characters like yield. Identification of drought tolerance as the ability of plants to grow satisfactorily when exposed to water defects has little direct applicability to either quantifying or breeding for the characters in crop species (Clarke *et al.*, 1992).

Plant breeders have been selected some physiological parameters *i.e.,* proline content, relative water content and transpiration rate, supplemented date to heading, date to maturity and grain yield/plant and its components for the purpose of identifying selection criteria which would be used to screen genotypes for drought tolerance.

Therefore, studying the type of gene action controlling physiological characters a long with durum wheat grain yield and its components accounted the major importance in durum wheat breeding programs. Since, decision making about the effective breeding procedure to be used is mainly dictated by the type of gene action controlling the physiological characters. Thus, the genetic information obtained from multigeneration are reliable compared with those based on one generation, thus six populations (P_1, P_2, F_1, F_2, BC_1 and BC_2) are considered the one which may give details information for the employed genotypes.

In turn, genetic improvement of grain yield under water limitations is a key objective for wheat breeders (Richards *et al.*, 2002). Eemphasis on selection for higher grain yield and improved performance under drought is not always successful (Cooper *et al.*, 1997). Genetic progress is slowed due to a large genotype × environment interaction arising from seasonal differences in rainfall and drought severity. This interaction reduces heritability and then restricting effectiveness of empirical selection and subsequent genetic gain for yield (Calhoun *et al.*, 1994, Farshadfar *et al.*, 2000 and Kahrizi *et al.*, 2010).

An understanding of physiological adaptation to water limited environment has identified number of drought tolerance characteristics with potential for genetic improvement of grain yield under drought (Zarei *et al.*, 2007). However, only very few of the nominated traits have been rigorously evaluated in a breed framework (Rebetzke *et al.*, 2006).

Assessment the type of gene action in wheat have been studied by many investigators of them, Dedio (1975) reported that water retention was inherited under simple genetic control and governed by genes with dominant effect. Whereas, Dhanda and Sethi (1998) and Farshadfar *et al.* (2011) concluded that additive gene action played a major role in determining the inheritance of relative water content and selection for this trait appeared to be more effective at anthesis. The transpiration efficiency was simply inherited and controlled mainly by additive genetic variation which was reflected in high (88 to 89%) narrow sense heritability (Malik *et al.*, 1999). Additive and dominance gene action and their digenic interaction (additive x additive), (additive × dominance) and (dominance × dominance) were more important in the inheritance of grain yield and its components (Awaad, 1996 and 2002, Salama 2002, El- Sebae *et al.*, 2008; Amin 2013). El- Sebae *et al.* (2008) reported the importance of additive genetic variance for No. of spikes/plant, grain weight/spike and 100-grain weight and narrow sense heritability value was high for yield components, while it was low in durum grain yield/plant. Moreover, the additive gene effect (d) was more importance in the genetic system controlling No. of spikes/plant, 100-grain weight, No. of grains/spike, grain weight/spike and grain yield /plant. Amin (2013) in their study on six populations using two durum wheat crosses grown under normal and heat stress conditions, reported that, additive dominance model was inadequate for the inheritance of days to heading, No. of spikes/plant, No. of grains/ spike, 100- grain weight and grain yield/plant for the two crosses under both conditions. Additive, additive × additive and additive × dominance gene effects were higher than the dominance and dominance × dominance gene effect, with low narrow sense heritability for No. of spikes/plant and No. of grains/plant under normal conditions, but it was moderate for all studied traits for the two crosses and environments except days to heading and 100 grain weight in some cases.

Proline could increase the tolerance of plants to abiotic stress (Hong *et al.*, 2000 and Salem *et al.*, 2003). Jaleel *et al.*, 2007 consider the proline content suitable for selection in stress conditions and proline content in tolerant plants is higher than in sensitive plants. Maleki *et al.* (2010) concluded that proline contant in leaves has additive gene effects and relatively high narrow sense heritability, therefore this trait relatively high genetic gain from selection can be expected and recommended for breeding of wheat populations to drought tolerance.

Low narrow sense heritability was observed for relative water content, proline content and plant yield (Naroui Rad *et al.*, 2013)

The objectives of the present investigation were to study the adequate genetic model, types of gene action as well as components of the genetic variance, for durum wheat grain yield, its components and some physiological characters under normal and water stress conditions.

MATERIALS AND METHODS

Crossing Technique and Experimental Layout

The present investigation was conducted during the three winter growing seasons: 2009/2010, 2010/2011 and 2011/2012 at Ismailia Agricultural Research Station, Ismailia Governorate, Egypt, to study the genetic system controlling drought tolerance. Six diverse parental durum wheat genotypes *i.e.* Mrb5, ICAMOR-TA04-68= F4, Bani Suef-3, Waha, Korifla and Haurani (Table 1) were selected according to their productivity as parental materials to build six populations of three durum wheat crosses 1) Mrb5X ICAMOR-TA04-68= F4, 2) Bani Suef-3 x Waha and 3) Korifla x Haurani.

In the first season of 2009/2010, the six parental durum wheat genotypes were grown in a randomized complete block design with three replications, at the same time, pair crosses were performed to obtain F_1 grains. In the second season 2010/2011, three F_1 cross grains were sown to produce F_1 plants. Each of the F_1 plants were crossed back to their respective parent to obtain first ($F_1 \times P_1$) and second ($F_1 \times P_2$) backcrosses. In the meantime pair crosses were made to produce more F_1 grains, also the F_1 plants were selfed to produce F_2 grains. In the third season 2011/2012, the obtained grains of six populations (P_1, P_2, F_1, F_2. BC_1 and BC_2) for each of the three crosses were evaluated using a randomized complete block design with three replications in two parallel experiments. The first experiment was irrigated by sprinkler system every week throughout the season (normal). The second experiment was irrigated by sprinkler system every three weeks throughout the season (severe drought stress by skipping two irrigations). Durum wheat grains were sown on the last week of November. Row was 2m long, row to row and plant to plant spacings were 20 and 5cm, respectively.

The recommended agricultural practices for wheat production under sandy soil conditions were performed. Date of days to heading was recorded at the time of full emergence of main spike, moreover at heading stage, relative water content (RWC) (Schonfeld *et al.*, 1988) transpiration rate (Stocker, 1956; Gosav 1960) and proline content (Bates *et al.*, 1973) were performed in penultimate leaf. At full maturity data of days to maturity was recorded. At harvest, grain yield and its components were estimated from individual plants.

Biometrical Assessment

A regular analysis of variance was firstly performed for the studied characters of the three durum wheat crosses.

Table 1.Pedigree of the evaluated durum wheat genotypes

No	Genotype	Perdigree	Origin
1	Mrb5	L0589-4L- 2AP-2AP-0AP	Syria
2	ICAMOR-TA04-68= F4	13/3/Artur 71/Lahn//Blk2/Lahn/4/Quarual	Syria
3	Bani Suaf-3	Corm "s"/rufo "s"	Egypt
4	Waha	CMI7904-B-3M-1Y-1Y-0SK-0AP	Syria
5	Korifla	CD523-3Y-1Y-2M-0Y-0AP	Syria
6	Haurani	Derived from different crosses in ICARDA	Syria

Testing the Genetic Models

The A, B and C scaling tests as outlined by Mather and Jinks (1982) were applied to test the presence of non-allelic interactions as follows; $A = 2\bar{B}_1 - \bar{P}_1 - \bar{F}_1, B = 2\bar{B}_2 - \bar{P}_2 - \bar{F}_1$ and $C=4\bar{F}_2 - 2\bar{F}_1 - \bar{P}_1 - \bar{P}_2$. Due to unknown biased effect of non-allelic interaction, the simple genetic model (m,d and h) was applied when epistasis was absent. Whereas, in the presence of non- allelic interactions, the analysis was proceeded to compute the interaction types involved using the six- parameters genetic model according to Jinks and Jones (1958). The significance of the genetic components were tested using the "t" test where:

$$\pm t = \frac{\text{Effect}}{\sqrt{\text{Variance of effect}}}$$

Components of the Genetic Variance

The components of genetic variance for each character in the studied crosses were partitioned into additive (D), dominance (H) genetic variance and environmental (E) one using Mather and Jinks (1982) formulae as follow:

$E = (1/3)\,(VP_1 + VP_2 + VF_1)$

$D = 4VF_2 - 2(VB_1 + VB_2)$ and

$H = 4\,(VF_2 - \tfrac{1}{2}VD - E)$

The genetic components of variance were used further to compute average degree of dominance $(H/D)^{1/2}$ and heritability in narrow sense (Tn) as follow:

$$Tn = \frac{1/2\,D}{1/2\,D + 1/4\,H + E}$$

RESULTS AND DISCUSSION

Mean Performance

The reliability of the genetic components estimates depends mainly on the amount of the genetic variability among the studied genotypes. Before proceeding to the biometrical analysis the "t" statistical test was applied to the studied genotypes for the different characters. The results revealed significant differences between parental genotypes, providing evidence for the presence of considerable amount of genetic differences among genotypes. Estimation of mean performance (Tables 2, 3 and 4) showed that, under normal conditions, the F_1's exceeded the better parent for No. of spikes/plant, 100-grain weight and proline content in 1st and 3rd crosses; No. of grains/spike in 1st and 2nd crosses as well as grain yield/plant and RWC in 1st one, showing heterotic effects and accumulation of favorable alleles for such characters. On the other hand, under water stress conditions, the F_1's exceeded the better parent for No. of spikes/plant in 3rd cross; No. of grains/spike and grain yield/plant in all studied crosses; 100-grain weight in 1st cross; proline content in 2nd and 3rd crosses and RWC in 1st and 3rd crosses. Whereas, the F_1's means of transpiration rate were less than the lowest parent in 1st cross under normal condition and in 1st and 2nd crosses under water stress conditions, providing evidence for the predominant of decreasing alleles in favor of drought tolerance. While the F_1's means were more than the lower parent under normal conditions for proline content and RWC in 2nd cross, providing evidence for the predominant of decreasing alleles and negative heterotic effect. The F_1's

Table 2. Generation means and standard errors for days to heading, days to maturity and No. of spikes/plant in the six populations of three durum wheat crosses under normal and water stress conditions

Characters cross populations	Days to heading (day)			Days to maturity (day)			No. of spikes/plant		
	1	2	3	1	2	3	1	2	3
Normal									
P_1	83.3±0.340	87.8±0.208	82.4±0.400	124.5±0.226	125.1±0.206	122.1±0.423	2.82±0.152	3.27±0.329	3.10±0.233
P_2	95.6±0.369	81.8±0.297	94.3±0.367	127.7±0.214	120.1±0.261	128.0±0.617	2.28±0.178	2.21±0.274	2.27±0.183
F_1	88.4±0.311	83.4±0.243	85.5±0.247	125.0±0.229	121.6±0.311	124.7±0.332	3.00±0.239	2.30±0.286	3.37±0.183
F_2	89.5±0.453	84.5±0.231	87.7±1.182	124.2±0.361	122.1±0.323	125.2±0.934	2.53±0.155	2.68±0.261	2.30±0.307
BC_1	85.2±0.402	86.5±0.231	85.3±0.925	124.5±0.287	122.8±0.289	121.9±0.642	3.15±0.174	2.94±0.259	3.00±0.275
BC_2	92.6±0.423	83.6±0.266	89.2±1.055	126.2±0.330	121.8±0.311	125.4±0.898	2.39±0.147	2.15±0.231	1.78±0.261
Water stress									
P_1	81.8±0.347	85.9±0.197	79.0±0.436	119.5±0.268	121.0±0.245	117.4±0.412	2.57±0.160	2.14±0.271	2.09±0.211
P_2	93.6±0.305	80.05±0.203	87.6±0.333	124.3±0.244	118.0±0.027	122.6±0.324	2.00±0.172	1.54±0.225	1.55±0.242
F_1	86.7±0.302	80.6±0.209	79.7±0.278	121.3±0.258	118.5±0.257	117.7±0.332	2.44±0.168	2.09±0.308	2.12±0.226
F_2	87.8±0.429	82.9±0.269	80.3±0.956	122.3±0.373	119.3±0.300	121.0±0.879	2.08±0.152	1.91±0.208	2.00±0.288
BC_1	83.8±0.445	84.4±0.261	80.6±0.884	121.8±0.379	121.3±0.288	118.1±0.690	2.78±0.213	2.10±0.211	2.10±0.233
BC_2	89.9±0.367	81.5±0.262	85.3±0.797	125.6±0.256	119.7±0.029	120.0±0.807	1.94±0.145	1.79±0.192	1.50±0.224

Table 3. Generation means and standard errors for No. of grains/spike, 100-grain weight and grain yield/plant in the six populations of three durum wheat crosses under normal and water stress conditions

Characters cross populations	No. of grains/spiks			100-grain weight (g)			Grain yield/ plant (g)		
	1	2	3	1	2	3	1	2	3
Normal									
P_1	30.01±0.319	36.7±0.968	30.5±0.652	3.20±0.119	3.17±0.114	3.20±0.015	2.70±0.091	3.89±0.040	2.98±0.024
P_2	33.0±0.345	26.9±0.917	20.7±0.773	3.73±0.122	3.98±0.107	3.01±0.038	2.82±0.094	2.37±0.125	1.62±0.022
F_1	36.4±0.309	39.2±1.005	24.4±0.476	4.22±0.115	3.24±0.083	3.31±0.008	4.05±0.164	3.02±0.127	2.56±0.031
F_2	30.7±0.362	28.4±0.828	26.1±1.489	3.40±0.144	3.33±0.231	3.08±0.068	3.12±0.152	2.64±0.203	1.89±0.177
BC_1	26.4±0.391	32.9±0.822	26.1±1.218	3.03±0.142	3.31±0.218	3.14±0.047	2.76±0.127	3.12±0.213	2.54±0.126
BC_2	30.8±0.426	31.2±0.604	21.0±0.763	3.37±0.123	3.74±0.204	2.94±0.055	2.61±0.119	2.41±0.179	1.46±0.158
Water stress									
P_1	23.2±0.317	26.3±0.536	22.7±0.738	2.18±0.083	2.11±0.096	2.93±0.025	1.41±0.093	1.15±0.023	1.31±0.026
P_2	24.9±0.335	19.4±0.520	15.3±0.352	2.12±0.096	2.68±0.110	2.51±0.018	1.04±0.062	0.95±0.023	0.86±0.044
F_1	27.7±0.317	29.2±0.601	23.7±0.326	3.02±0.126	2.25±0.093	2.82±0.014	1.97±0.095	1.33±0.018	1.88±0.029
F_2	26.2±0.335	22.2±0.643	20.9±1.018	2.61±0.133	2.72±0.287	2.76±0.056	1.45±0.119	1.21±0.106	1.07±0.065
BC_1	24.1±0.400	23.3±0.568	22.2±0.946	2.81±0.134	2.34±0.145	2.84±0.053	1.84±0.132	1.16±0.078	1.20±0.059
BC_2	33.7±0.435	22.1±0.663	17.5±0.813	2.87±0.133	2.71±0.230	2.65±0.041	1.18±0.106	0.98±0.060	0.84±0.063

Table 4. Generation means and standard errors for proline content, relative water content and transpiration rate in the six populations of three durum wheat crosses under normal and water stress conditions

Characters cross populations	Proline content (µ mols proline/g.f.w)			Relative water content (%)			Transpiration rate (mg H_2O/g.F.W./hr.)		
	1	2	3	1	2	3	1	2	3
Normal									
P_1	13.4±0.562	18.3±0.337	23.0±0.168	61.3±0.469	63.2±0.628	66.6±0.718	178.2±1.657	170.6±1.477	108.8±0.495
P_2	12.5±0.468	20.3±0.301	19.2±0.178	48.6±0.309	69.7±0.635	61.7±0.553	219.8±2.031	156.0±1.315	138.1±0.547
F_1	15.6±0.337	20.1±0.382	24.2±0.161	63.8±0.399	62.0±0.159	65.2±0.485	201.6±1.482	167.4±1.035	129.6±0.463
F_2	13.8±0.770	19.9±0.444	21.5±0.551	57.2±1.668	64.6±1.318	65.6±1.337	199.1±3.774	163.7±1.891	121.1±2.047
BC_1	14.4±0.702	19.6±0.403	21.9±0.359	58.1±1.399	63.8±0.959	68.9±1.061	185.4±2.943	164.9±1.758	113.4±1.109
BC_2	11.6±0.654	21.0±0.452	20.8±0.437	50.1±1.102	67.2±1.176	62.8±1.133	204.3±3.251	157.4±1.567	132.1±1.058
Water stress									
P_1	21.5±0.361	21.9±0.325	25.7±0.185	42.2±0.546	51.0±0.691	48.0±0.701	130.1±1.608	118.8±0.631	115.0±0.359
P_2	20.0±0.280	23.6±0.265	22.7±0.175	35.7±0.467	41.6±0.575	51.9±0.885	151.3±1.675	128.7±0.651	98.7±0.781
F_1	20.8±0.297	23.8±0.223	26.2±0.106	44.9±0.415	46.1±0.503	56.6±0.455	123.81±1.164	111.7±0.718	100.0±0.653
F_2	20.4±0.573	21.8±0.532	24.2±0.485	39.2±1.211	45.4±1.130	51.3±1.315	135.4±3.293	122.6±1.943	107.7±1.462
BC_1	21.0±0.533	21.1±0.531	24.5±0.416	41.8±1.116	46.8±1.001	50.2±1.091	130.5±2.134	115.4±1.404	111.8±1.320
BC_2	19.5±0.527	23.5±0.557	23.1±0.516	34.5±1.193	40.6±0.858	58.4±1.397	144.5±2.488	123.5±1.453	101.1±1.215

Adequacy Genetic Model and Gene Effects

Scaling tests (A, B and C) are presented in Tables 5, 6 and 7 under both normal and water stress conditions. Under normal condition, the results provide evidence for the suitability of a simple additive- dominance genetic model to explain the genetic mechanism controlling days to heading in 1st and 3rd crosses; No. of spikes/plant in 1st and 2nd crosses; No. of grains/spike in 3rd cross; 100-grain weight, proline content and RWC in 2nd cross as well as transpiration rate in the 1st one. These information's could be used to facilitate breeding of cultivars under normal irrigation condition. Similar observations were reported by Salem *et al.* (2003) who found that the simple additive-dominance genetic model was adequate to explain the inheritance of RWC in three crosses; transpiration rate in two crosses and proline content in one cross only out of five bread wheat cross populations studied.

Otherwise, the complex genetic model was found to be adequate for explaining the inheritance of days to heading in 2nd cross; No. of spikes/plant in 3rd cross; No. of grains/spike in 1st and 2nd crosses; 100-grain weight, proline content and RWC in 1st and 2nd crosses; transpiration rate in 2nd and 3rd crosses as well as days to maturily and grain yield/plant in 1st, 2nd and 3rd ones. Similar results were registered for proline content, RWC, transpiration rate and grain yield/plant (Salem *et al.*, 2003) and for days to heading, No. of spikes/plant, No. of grains/ spike. 100-grain weight and grain yield/ plant in durum wheat (El-Sebae *et al.*, 2008; Amin, 2013).

Additive gene effect (d) was significant and considered the main type controlling the inheritance of days to heading, days to maturity, No. of spikes/plant, 100-grain weight, proline content, RWC and transpiration rate in all studied crosses; No. of grains/spike in 1st and 3rd crosses as well as grain yield/plant in 2nd and 3rd ones. Meanwhile, the additive (d) and additive x additive (i) interaction type were important in the inheritance of days to maturity and No. of grains/plant in 1st ones, indicating that the superior genotypes could efficiently identified from its phenotypic expression. Therefore phenotypic selection was more effective for improving these characters in durum wheat under normal irrigation conditions. Similar results were reported by many investigators (Dhanda and Sethi, 1998; Malik *et al.*, 1999; Salem *et al.*, 2003; Salama, 2007; El-Sebae *et al.*, 2008; Farshadfar *et al.*, 2011).

Table 5. Scaling test (A,B and C) and adequacy genetic model for days to heading, days to maturity and No. of spikes/plant in three durum wheat crosses growing under normal and water stress conditions

Characters	Days to heading			Days to maturity			No. of spikes/plant		
Cross populations	1	2	3	1	2	3	1	2	3
Scaling test					**Normal**				
A	-1.30	1.80**	2.70	-0.50	0.40	-3.00*	0.48	0.31	-0.47
B	1.20	2.00**	-1.40	-0.30	1.90*	-1.90	-0.50	-0.21	-2.08**
C	2.30	2.40	3.10	-5.40**	0.00	1.30	-0.98	0.64	-2.91*
χ^2	NS	**	NS	**	**	*	NS	NS	**
Adequacy genetic model									
m	91.85**	84.70**	90.15**	124.20**	122.10**	125.20**	1.59*	3.28**	2.30**
d	-6.15**	2.90**	-5.95**	-1.70**	1.00*	-3.50**	0.27*	0.53*	1.22**
h	-5.95	0.00	-5.15	3.50*	-0.20	-6.55	2.35	-1.42	1.05
i		1.40		4.60**	0.80	-6.20			0.36
j		-0.10		-0.10*	-1.50**	-0.55			0.81*
l		-5.20**		-3.80	-1.60	11.10*			2.19
Scaling test					**Water stress**				
A	-0.90	2.30**	2.50	2.80**	3.10**	1.06	0.5	-0.03	-0.01
B	-0.50	2.35**	3.30*	5.60**	2.90**	-0.30	-0.56	-0.39	-0.67
C	2.40	4.45**	-4.80	2.80	1.20	8.60*	-1.13	-0.22	0.12
χ^2	n.s	**	*	**	**	**	NS	NS	NS
Adequacy genetic model									
m	91.50**	82.90**	80.30**	122.30**	119.30**	121.00**	1.16	2.04*	2.62*
d	-5.90**	2.90**	-4.70**	-3.80**	1.60**	-1.92	0.28*	0.30*	0.27*
h	-10.00*	-2.17	7.00*	5.00**	3.80*	-10.14**	2.38	0.45	1.98
i		0.20	10.60*	5.60**	4.80**	-7.84*			
j		-0.03	-0.40	-1.40**	0.10	0.68			
l		-4.85*	-16.40**	-14.00**	-10.80**	7.08			

Table 6. Scaling test (A, B and C) and adequacy genetic model for No. of grains/spike, 100-grain weight and grain yield/plant in three durum wheat crosses growing under normal and water stress conditions

Characters	No. of grains/spike			100- grain weight			Grain yield/plant		
Cross populations	1	2	3	1	2	3	1	2	3
Scaling test					**Normal**				
A	-13.68**	-10.10**	-2.70	-1.36**	0.21	-0.19*	-1.23**	-0.67	-0.46*
B	-7.81**	-3.70*	-3.10	-1.21**	0.26	-0.42**	-1.65**	-0.55*	-1.26**
C	-12.91**	-28.40**	4.40	-1.77**	-0.31	-0.51*	-1.14	-1.66*	-2.16**
χ^2	**	**	NS	**	NS	**	**	**	**
Adequacy genetic model									
m	30.76**	28.40**	35.80**	3.40**	2.79**	3.08**	3.12**	2.66**	1.89**
d	-4.43**	1.70	4.90**	-0.34*	-0.41**	0.20**	0.15	0.70**	1.08**
h	-3.62	22.00**	-27.40*	-0.05	1.70	0.04	-0.45	0.33	0.70
i	-8.58**	14.60**		-0.80		-0.16	-1.74**	0.44	0.44
j	-2.94**	-3.20**		-0.08		0.11	0.21	-0.06	0.40*
l	30.07**	-0.80		3.37**		0.83*	4.62**	0.78	1.28
Scaling test					**Water stress**				
A	-2.71	-8.90**	-2.00	0.42**	0.32	-0.07	0.30	0.22	-0.79**
B	-5.08	-4.40**	-3.80*	0.60**	0.49	-0.03	-0.65**	-0.32**	-1.06**
C	1.45	-15.30**	-1.80	0.10**	1.59	-0.04	-0.59	0.08	-1.65**
χ^2	**	**	*	**	NS	NS	**	**	**
Adequacy genetic model									
m	26.23**	22.20**	20.90**	2.61**	3.17**	2.78**	1.45**	1.21**	1.07**
d	0.34	1.20*	4.60**	-0.06	-0.28**	0.21**	0.66**	0.18*	0.36**
h	-5.63**	8.35**	0.70	1.79**	-0.89	-0.12	0.98*	-0.28	0.59*
i	-9.24**	2.00	-4.00	0.92			0.24	-0.56	-0.2
j	1.18	-2.25*	0.90	-0.09			0.48**	0.08	0.13*
l	17.08*	11.30*	10.30*	-1.94*			0.11	1.04*	2.05**

Table 7. Scaling test (A, B, and C) and adequacy genetic model for proline content, relative water content and transpiration rate in three durum wheat crosses growing under normal and water stress conditions

Characters	Proline content			Relative water content			Transpiration rate		
Cross populations	1	2	3	1	2	3	1	2	3
Scaling test					**Normal**				
A	-0.20	0.80	-3.40**	-8.90**	2.40	6.00**	-9.00	-8.20*	-3.70
B	-4.91**	1.60	-1.80*	-12.20**	2.70	-1.30	-12.80	-8.60*	-11.60**
C	-1.90	0.80	-4.60*	-8.70	1.50	3.70	-4.80	-6.60	-21.70**
χ^2	*	NS	**	**	NS	**	NS	*	**
Adequacy genetic model									
m	13.80**	17.70**	21.50**	57.20**	62.85**	65.60**	216.00**	163.70**	121.10**
d	2.83**	-1.00**	1.10*	8.00**	-3.25**	6.10**	-20.80**	7.51**	18.70**
h	-0. 55	6.40	2.50*	-3.55	7.85	2.05	-53.20	-6.10	12.75
i	-3.20		-0.60	-12.40		1.00		-10.20	6.60
j	2.35*		-0.80	1.65		3.65**		0.20	4.05**
l	8.30		5.82*	33.50**		-5.70		27.00*	8.50
Scaling test					**Water stress**				
A	-0.30	-3.50**	-2.90**	-3.50	-3.50	-4.20	7.10	0.30	8.60**
B	-1.80	-0.40	-2.70**	-11.60**	-6.50**	8.30**	13.90**	6.60*	3.50
C	-1.50	-5.90**	-4.00*	-10.90*	-3.20	-7.90	12.6	19.50*	17.10**
χ^2	NS	**	**	**	**	**	**	**	**
Adequacy genetic model									
m	21.35**	21.80**	24.20**	39.20**	45.40**	51.30**	139.20**	122.60**	107.70**
d	0.75**	-2.40**	1.40*	7.30**	6.20**	-5.70**	-14.00**	-8.10**	10.70**
h	-3.25	3.05	0.40	1.75*	-7.00	18.65**	-8.50	-24.65**	-11.80*
i		2.00	-1.60	-4.20	-6.80	13.00*	8.40	-12.60	-5.00
j		-1.55*	-0.1	4.05*	1.50	-6.25**	-3.40	-3.15	2.55
l		1.90	7.20*	19.30*	16.80*	-16.10*	-29.40	5.70	-7.10

The dominance (h) and its digenic interaction type dominance x dominance (I) were significant and involved in the inheritance of days to maturity and No. of grains/spike in 1st cross, suggesting that improving these characters could be achieved under normal irrigation conditions through hybrid breeding method. Similar results were detected by Awaad (2002); El-Sebae *et al.* (2008) and Amin (2013).

Meanwhile, the interaction type additive x dominance (j) was negative and significant for days to maturity and No. of grains/spike in 1st and 2nd crosses, suggesting that decreasing alleles were more frequent than the increasing ones, and vice versa was recorded for proline content in 1st cross as well as No. of spikes/ plant, RWC, transpiration rate and grain yield/ plant in the 3rd one which showed more frequent of increasing alleles over decreasing ones.

On the other hand, under water stress conditions the simple additive-dominance genetic model was adequate for explaining the inheritance of days to heading in 1st cross, No. of spikes/plant in 1st, 2nd and 3rd crosses; 100-grain weight in 2nd and 3rd crosses and proline content in 1st one. In this connection, Salem *et al.* (2003) found that the simple additive-dominant genetic model was adequate for explaining the inheritance of proline content in one cross of bread wheat. El-Sebae *et al.* (2008) concluded that the simple additive-dominant genetic model was adequate for explaining the inheritance of No. of spikes/plant in all studied crosses grain weight/spike and 100- grain weight in two crosses from four durum wheat crosses, sown under sandy soil conditions. Otherwise, the adequacy genetic model (Tables 5, 6 and 7) indicated that, the simple additive-dominance genetic model was not adequate to explain the inheritance of days to heading and proline content in 2nd and 3rd crosses, 100- grain weight in 1st cross, days to maturity, No. of grains/ plant, RWC, transpiration rate and grain yield/ plant in all studied crosses. These results reveal the presence of epistasis and the complex genetic model was adequate to explain the genetics of the above- mentioned characters in the corresponding crosses. Similar findings were reported by (Awaad, 2002) for morpho-physiological and grain yield/plant characters. Moreover, Amin (2013) revealed that additive-dominance model was inadequate for the inheritance of grain yield/plant and its components in two durum wheat crosses under normal and heat stress conditions.

It has been observed that, additive gene effect (d) was significant and expressed the main-type controlling the inheritance of No. of spikes/ plant in 1st, 2nd and 3rd crosses; 100-grain weight in 2nd and 3rd crosses and proline content in 1st one. Hereby phenotypic selection would be effective for improving these characters in durum wheat under water stress conditions.

Both additive (d) and dominance (h) gene effects were involved in the genetics of days to heading in 1st cross. Hereby pedigree method would be effective for improving tolerance of durum wheat to water stress.

Moreover under complex genetic model additive (d), dominance (h) and their digenic interaction types additive x additive (i) and dominance x dominance (1) was significant for days to maturity and No. of grains/spike in 2nd cross; RWC in 1st cross as well as days to heading and grain yield/plant in the 3rd one. Whereas, additive (d), dominance (h) and their digenic interaction types additive x additive (i), additive x dominance (j) and dominance x dominance (1) appeared to be highly significant and responsible in the inheritance of days to maturity and No. of grains/spike in 1st cross and RWC in the 3rd one. Dominance (h) and the digenic interaction typ additive x dominance (j) were significant for grain yield/plant in 1st cross, wherease additive (d) gene effect and its digenic interaction type additive x dominance (j) were significant for proline content in 2nd cross and grain yield/plant in 1st one. Additive, dominance and different types of their interactions were involved in the genetics of days to heading, proline content and grain yield/plant (Salem *et al.*, 2003), yield and its components under sandy soil condition in durum wheat (El-Sebae *et al.*, 2008) as well as yield and its components under both normal and heat stress conditions in durum wheat (Amin, 2013).

It is worth to note that under normal irrigation, days to heading and No. of grains/ spike in 3rd cross; proline content and RWC in

2nd cross as well as transpiration rate in 1st one, inherited under simple additive- dominance genetic model with the prevailed type of additive gene effect (d). Whereas, under water stress condition these crosses showed another behavior and inherited under complex genetic model with the prevailed type of epistasis and vice versa were recorded for No. of spikes/plant and 100-grain weight in 3rd cross and proline content in 1st one. This may be due to the effect of water stress on the gene expression of durum wheat crosses.

It is worth to note that, dominance (h) and its digenic interation type dominance x dominance (1) were significant and has different signs for No. of grains/spike in 1st cross and proline content in 3rd cross under normal irrigation, days to heading in 3rd cross: days to maturity and No. of grains/spike in 1st and 2nd crosses; 100-grain weight in 1st cross, grain yield/plant in 3rd cross as well as RWC in the 2nd one under water stress condition. This result indicate that interaction is predominantly of duplicate type.

Components of Genetic Variance and Heritability

Separate out the total genetic variance to its constituent parts; additive (D) and dominance (H) gene action has been done. Also, heritability in narrow (Tn) senses were calculated.

The results given in Tables 8, 9 and 10 clearly indicate that additive (D) genetic variance under normal condition was the predominant type controlling days to heading, days to maturity, No. of spikes/plant, proline content, RWC and transpiration rate in all studied durum wheat crosses; No. of grains/spike in 1st and 2nd crosses as well as 100-grain weight in 1st and 3rd ones. Otherwise, under water stress condition, additive component (D) was the predominant type controlling days to heading in 1st and 3rd crosses; days to maturity in 1st and 2nd crosses; No. of spikes/plant in 3rd cross; proline content in 2nd and 3rd crosses as well as transpiration rate in the 1st one, resulting in $(H/D)^{0.5}$ ratio was less than unity, reinforcing the importance role of phynotypic selection for improving these characters in the corresponding crosses under both normal and water stress conditions. Similar conclusion was reported for days to heading and yield and its components (Awaad, 2002 and El-Sebae *et al.*, 2008) as well as for days to heading, proline content, RWC and transpiration rate (Salem *et al.*, 2003; Maleki *et al.*, 2010).

Under normal condition, the dominance (H) genetic variance was found to be the prevailed type in the inheritance of No. of grains/spike in 3rd cross; 100-grain weight in 2nd cross and grain yield/plant in 1st, 2nd and 3rd crosses. Otherwise, under water stress condition dominance component (H) was found to be the prevailed type in the inheritance of days to heading in 2nd cross; days to maturity in 3rd cross; No. of spikes/plant, No. of grains/spike and grain yield/ plant in 1st, 2nd and 3rd crosses; proline content in 1st cross as well as RWC in 1st and 2nd crosses as well as transpiration rate in the 2nd and 3rd ones, resulting in $(H/D)^{0.5}$ ratio was more than unity, indicating the importance of over- dominance gene effects in the genetic control of these characters in those durum wheat crosses under both conditions. In this respect, hybrid breeding method could be used for improving these characters under both conditions. In this connection, dominance gene effect played an important role in the inheritance of proline content (Hassan 2002), relative water content, transpiration rate and proline content (Salem *et al.,* 2003); No. of spikes/plant, No. of grains/ spike, 100-grain weight and grain yield/plant in durum wheat (El-Sebae *et al.*, 2008 and Amin, 2013) as well as grain yield/plant (Awaad *et al.*, 2013).

Heritability estimates in narrow sense (Tn) under normal condition was high (> 50%) for days to heading in 1st and 3rd crosses, No. of spikes/plant in 1st cross, 100-grain weight in 3rd cross as well as days to maturity, proline content, RWC and transpiration rate in all the studied crosses. Meanwhile, under water stress condition, heritability was high (> 50%) for days to heading in 1st and 3rd crosses, days to maturity in 1st and 3rd crosses; No. of grains/spike in 3rd cross; 100-grain weight and proline content in 2nd and 3rd crosses as well as RWC in the 2nd one. These results allow for considerable progress for selection. In this concern, high “Tn” values have been reported for days to heading, proline content, RWC and transpiration rate

Table 8. Components of variance (D, H and E), degree of dominance $(\sqrt{H/D})$ and heritability in narrow sense (Tn) for days to heading, days to maturity and No. of spikes/plant in three durum wheat crosses under normal and water stress conditions

Characters	Days to heading			Days to maturity			No. of spikes/plant		
Crosses parameters	1	2	3	1	2	3	1	2	3
Normal									
D	95.308	3.532	30.693	5.286	3.698	16.140	1.224	0.800	1.202
H	-54.742	0.328	23.126	2.476	1.948	5.792	-0.889	-0.484	0.612
E	1.275	1.223	1.205	0.915	1.104	1.832	0.532	1.021	0.476
$\sqrt{H/D}$	0.394	0.304	0.868	0.684	0.725	0.599	0.851	0.778	0.713
Tn%	85.20	57.50	68.70	63.21	53.70	71.05	66.30	30.76	48.80
Water stress									
D	9.358	1.192	14.200	3.712	3.008	10.014	0.408	0.560	0.920
H	6.190	4.832	11.868	1.240	0.948	12.284	1.484	-0.800	3.260
E	1.121	0.814	0.893	1.186	1.319	1.194	0.353	0.910	0.475
$\sqrt{H/D}$	0.813	2.013	0.914	0.578	0.561	1.107	1.852	1.195	1.882
Tn%	63.68	23.07	64.70	55.30	49.20	54.00	21.90	30.00	26.28

Table 9. Components of variance (D, H and E), degree of dominance $\sqrt{H/D}$ and heritability in narrow sense (Tn) for No. of grains/spike, 100-grain weight and grain yield/plant in three durum wheat under normal and water stress conditions

Characters	No. of grains/spike			100-grain weight			Grain yield/plant		
Crosses parameters	1	2	3	1	2	3	1	2	3
Normal									
D	4.694	7.200	37.772	0.728	0.620	0.100	0.624	0.348	0.300
H	4.228	-0.340	47.568	0.644	0.628	0.007	0.768	0.708	0.593
E	2.363	6.097	3.330	0.268	0.065	0.004	0.374	0.061	0.006
$\sqrt{H/D}$	0.949	0.217	1.122	0.940	1.006	0.273	1.109	1.426	1.406
Tn%	40.60	37.45	55.30	45.90	58.3	89.30	35.50	42.23	49.18
Water stress									
D	6.220	3.894	18.126	0.280	0.624	0.073	0.360	0.172	0.056
H	67.464	6.064	19.264	0.876	0.700	0.114	0.468	0.508	0.077
E	4.580	3.169	2.656	0.241	0.063	0.003	0.240	0.005	0.011
$\sqrt{H/D}$	3.291	1.247	0.970	1.768	1.059	1.249	1.140	1.718	1.175
Tn%	12.66	29.30	54.80	23.33	56.72	52.97	33.52	39.45	48.27

Table 10. Components of variance (D, H and E), degree of dominance $\sqrt{H/D}$ and heritability in narrow sense (Tn) for proline content, relative water content and transpiration rate in three durum wheat crosses under normal and water stress conditions

Characters	Proline content			Relative water content			Transpiration rate		
Crosses parameters	1	2	3	1	2	3	1	2	3
					Normal				
D	13.00	3.374	6.620	57.482	37.454	25.648	234.756	38.314	85.492
H	-3.292	0.292	0.068	11.896	5.932	15.048	70.592	13.340	19.144
E	1.443	1.002	0.315	1.693	4.141	3.082	21.719	13.289	2.755
$\sqrt{H/D}$	0.503	0.294	0.0103	0.455	0.158	0.766	0.548	0.590	0.473
Tn%	91.29	61.07	90.88	86.03	76.90	65.20	74.88	53.54	85.00
					Water stress				
D	2.260	4.058	5.160	21.488	26.242	27.152	118.966	73.520	18.846
H	4.288	2.396	1.732	34.052	10.840	126.880	41.420	115.200	72.356
E	0.748	0.772	0.277	2.757	4.633	6.004	11.245	4.193	4.564
$\sqrt{H/D}$	1.377	0.768	0.579	1.258	0.643	2.161	0.590	1.251	0.473
Tn%	38.31	59.64	78.41	48.81	64.11	26.460	73.36	52.70	29.37

(Salem *et al*., 2003), 100-grain weight (El-Sebae *et al*., 2008 and Amin, 2013) and proline content (Awaad *et al*., 2013). Furthermore, heritability in narrow sense ranged from low to moderate for grain yield/plant under both normal and water stress conditions, where yield is quantitively and greatly affected by environmental changes. Also, low to moderate (Tn) estimates were registered in the remainig crosses for the various characters under both conditions. Similar results were recorded for morpho-physioliogical characters and grain yield/plant by Salem *et al.* (2003); Awaad *et al.* (2010 and 2013); El-Sebae *et al.* (2008); Maleki *et al.* (2010) and Amin (2013).

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الفعل الجينى وكفاءة التوريث فى بعض عشائر هجن قمح الديورم تحت الظروف الطبيعية والإجهاد المائى

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أجريت هذه الدراسة خلال المواسم الشتوية لأعوام ٢٠٠٩ / ٢٠١٠، ٢٠١٠ / ٢٠١١ و ٢٠١١ / ٢٠١٢ بالمزرعة التجريبية لمحطة البحوث الزراعية بالإسماعيلية محافظة الإسماعيلية بإستخدام تحليل العشائر الستة لثلاث هجن من قمح الديورم هى: (١) أم رابى ٥ × ICAMOR-TAO4-68=F4 (٢) بنى سويف ٣ × واحة و (٣) كوريفلا × حورانى فى تصميم قطاعات كاملة العشوائية فى تجربتين، الأولى ثم ريها بنظام الرى بالرش كل أسبوع خلال موسم النمو (ظروف الرى الطبيعى)، والثانية تم ريها بنظام الرى بالرش كل ثلاثة أسابيع خلال موسم النمو (ظروف الإجهاد المائى). وقد استهدفت الدراسة تقدير النظام الوراثى وطبيعة الفعل الجينى المتحكم فى صفات ميعاد طرد السنابل، النضج، عدد السنابل/نبات، عدد الحبوب/سنبلة، وزن الـ ١٠٠ حبة، محصول الحبوب/ نبات، محتوى الأوراق من البرولين، محتوى الأوراق النسبي من الماء ومعدل النتح فى الأوراق تحت معاملتى الظروف الطبيعية للرى والإجهاد المائى، وقد أظهرت نتائج متوسط السلوك تفوق الجيل الأول على متوسط الأب الأحسن للمحصول ومكوناته وبعض الصفات الفسيولوجية تحت الدراسة والمرتبطة بتحمل النباتات للجفاف فى معظم الهجن تحت الدراسة تحت ظروف التجريب. هذا وقد إختلف النظام الوراثى والتعبير الجينى من ظروف الرى الطبيعى إلى معاملة الإجهاد المائى للصفات تحت الدراسة فى معظم الحالات. فقد أظهرت نتائج إختبار المقياس (A, B and C) تحت ظروف المعاملة الطبيعية للرى بالرش ملاءمة الموديل الوراثى البسيط "المضيف – السيادى" فى تفسير ميكانيكية وراثة طرد السنابل / نبات فى الهجينين الأول والثالث وعدد السنابل/ نبات فى الهجينين الأول والثاني ووزن الـ ١٠٠ حبة ومحتوى الأوراق من البرولين والمحتوى النسبى للماء فى الأوراق فى الهجين الثانى وكذلك معدل النتح فى الهجين الأول، بينما تحت ظروف الإجهاد المائى كان الموديل الوراثى البسيط هو الملائم لتفسير وراثة ميعاد طرد السنابل ومحتوى أوراق النبات من البرولين فى الهجين الأول وعدد السنابل/ نبات فى كل الهجن تحت الدراسة ووزن الـ ١٠٠ حبة فى الهجينين الثانى والثالث، وعلى الجانب الأخر كان الموديل الوراثى المعقد هو الملائم لتفسير وراثة محصول الحبوب/ نبات وميعاد نضج السنابل فى كل الهجن تحت الدراسة تحت الظروف الطبيعية والإجهاد المائى، وعدد الحبوب/ السنبلة ووزن الـ ١٠٠ حبة فى الهجينين الأول والثانى ومحتوى الأوراق من البرولين والمحتوى النسبى للماء فى الأوراق فى الهجن الأول والثالث ومعدل النتح فى الهجينين الثانى والثالث تحت ظروف الري الطبيعية بينما كان الموديل الوراثى المعقد هو المتحكم فى وراثة صفات ميعاد الطرد ومحتوى الأوراق من البرولين فى الهجن الثانى والثالث وعدد الحبوب/ السنبلة والمحتوى النسبى للماء في الأوراق ومعدل النتج فى كل الهجن تحت الدراسة وذلك تحت ظروف الإجهاد المائى، لعب الفعل الجينى المضيف دوراً معنوياً فى وراثة ميعاد الطرد فى الهجينين الأول والثالث وعدد السنابل/نبات فى الهجينين الأول والثانى ووزن الـ١٠٠ حبة ومحتوى الأوراق من البرولين والمحتوى النسبى للماء فى الأوراق فى الهجين الثانى ومعدل النتح فى الهجين الأول تحت ظروف الرى الطبيعى، وميعاد طرد السنابل ومحتوى الأوراق من البرولين فى الهجين الأول وعدد السنابل/نبات فى الهجن الأول والثانى والثالث ووزن الـ١٠٠ حبة فى الهجن الثانى والثالث وذلك تحت ظروف الأجهاد المائى، كان الفعل الجينى المضيف والسيادى والتفاعل مضيف × مضيف وسيادى × سيادى هو المتحكم فى وراثة عدد الحبوب / السنبلة فى الهجنين الأول تحت ظروف الرى الطبيعى، والمحتوى النسبى للماء فى الأوراق فى الهجينين الأول والثالث ومحصول الحبوب/ نبات فى الهجين الثالث تحت ظروف الإجهاد المائى. بينما كان الفعل الجينى المضيف والسيادى والتفاعلات مضيف × مضيف ومضيف × سيادى وسيادى × سيادى دوراً هاماً ومعنوياً فى وراثة عدد الحبوب / السنبلة فى الهجين الأول تحت ظروف الرى الطبيعى، وميعاد نضج السنابل فى الهجين الأول والمحتوى النسبى للماء فى الأوراق فى الهجين الثالث تحت ظروف الإجهاد المائى، كان التباين الوراثى المضيف هو المكون الأعظم المتحكم فى وراثة ميعاد طرد السنابل وميعاد نضج السنابل وعدد السنابل/ نبات ومحتوى الأوراق البرولين والمحتوى النسبى للماء فى الأوراق ومعدل النتح فى كل الهجن تحت الدراسة وذلك تحت ظروف الرى الطبيعى، وميعاد طرد السنابل فى الهجن الأول والثالث وميعاد نضج السنابل فى الهجن الأول والثانى ومحتوى الأوراق من البرولين فى الهجينين الثانى والثالث معدل النتح فى الهجين الأول وذلك تحت ظروف الإجهاد المائى، وكانت تقديرات معامل التوريث فى المعنى الخاص عالية (< ٥٠%) لميعاد طرد السنابل وميعاد نضج السنابل وعدد السنابل/نبات ووزن الـ١٠٠ حبة ومحتوى الأوراق من البرولين والمحتوى النسبى للماء فى الأوراق ومعدل النتح فى الأوراق فى معظم الحالات، بينما تراوحت من منخفضه إلى متوسطة لمحصول الحبوب/ نبات فى جميع الهجن تحت كل من الظروف الطبيعية والإجهاد المائى.

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