GENETIC ANALYSIS IN DURUM WHEAT USING GRIFFING AND HAYMAN'S APPROACH UNDER STRESS AND NON-STRESS WATER

Ismail Hussain Ali
College of Agriculture/Salahaddin University
E-mail:dr.ismail@ymail.com

ABSTRACT

A full-diallel cross of five durum wheat genotypes[Simeto (1), Ofanto (2), Acsad 65 (3), Miman-9 (4) and CRAK-10 (5)] was made in the growing season 2010-2011 at the Research Field of the College of Agriculture, Salahaddin University in Erbil, Iraq. Grains of 20 F1s and their five parents were planted on 15 November 2011 in two separate experiments, rainfall (stress) and irrigated (non-stress) using a randomized complete block design with three replications in order to study the genetic properties of days to flowering, plant height, flag leaf area, spike length, no. of spikes/plant, no. of grains/spike, 1000-grain weight, biomass yield/plant, grain yield/plant and harvest index by using Griffing, Hayman and Jinks-Hayman approaches. The results revealed that some parents exhibited positive and high general combining ability, while some hybrids showed specific combining ability for the majority of these traits. Important role of additive genetic component (*D*) was found for days to flowering, flag leaf area spike length, no. of spikes/plant, no. of grains/spike and biomass yield/plant under stress conditions and days to flowering, spike length, no. of spikes/plant, 1000-grain weight, biomass yield/plant, grain yield/plant and harvest index under non-stress conditions.The non-additive component *(H1)* was found to be important for the genetic control of all the traits under stress and non-stress conditions excluding grain yield/plant under stress conditions. The average degree of dominance $(H1/D)^{½}$ was>1 for all traits in both cases. The narrow sense heritability $H_{n.s}$ .was low for flag leaf area, moderate for no. of grains/spike and 1000-grain weight, high for remaining traits under stress conditions. While low for no. of grains/spike, moderate for days to flowering, flag leaf area and grain yield/plant, high for remaining traits under non-stress conditions.Under stress conditions high heterosis was exhibited by cross [1×4] for most traitswhile by cross [5×3]under non-stress conditions.It could be concluded that generated of these genotypes will serve for the breeders to develop high yielding of durum wheat under water stress und non-stress conditions by employing individual or mass selection breeding.
Keywords: Durum wheat, Full-diallel cross, Genetic properties.

Received: 7/5/2013, Accepted 30/12/2013

INTRODUCTION

The developments of improved cultivars of wheat have always remained a focalpoint for wheat breeders all over the world. For the improvement purpose, breeders have to rely upon the selection of suitable parents and crosses. Therefore, estimation ofavailable genetic variances in the early generations of crosses could be very helpful for aplant breeder. The knowledge about heritability of quantitative traits is also important forevery plant improvement program. Diallel cross technique is the one used mostcommonly to estimate inheritance and behavior of quantitative characters. Application of Griffing (1956), Hayman (1954) and Jinks (1954) models in F_1 generation provides information regarding nature and magnitude of the gene-action involved in the inheritance of acharacter. This information would be useful to plant breeders for typesof genetic variations in the traits for which selection is intended and rapid evaluation of yielding capacity by identifying crosses which will produce superior genotypes (Ejaz-ul-Hassan and Khaliq, 2008). Previous studies of the inheritance of different characters in wheat were mostly based on diallel analysis. Yield has prime importance in any breeding program. Thus, ultimate goal of breeder is to increase yield. Habib and Khan (2003), Mahmood *et al.* (2003) and Riaz and Chowdhry (2003) describe additive type of gene action with partial dominance controlling this trait. While Inamullah *et al.* (2005), Dere and Yildirim (2006) and Hassan *et al.* (2008) showed that over dominance type of gene action controls this parameter.On the other hand Golabadi *et al.* (2005) observed highest genetic variance under drought stress for grain yield while for harvest index under irrigation conditions. Ahmad *et al.* (2006) reported that additive component was significant for all the traits studied except no. of spikes/ plant and grain yield/plant. Dominant component was significant for spike length, no. of spikes/ plant and grain yield/plant. Ullah *et al.* (2010) observed additive type of gene action with partial dominance for plant height, number of spikes/plant, spike length and grain yield/plant.

The aim of this investigation was to study the gene action of some agromomic traits in durum wheat using Griffing, Hayman and Jinks-Hayman approaches under water stress and non-stress conditions which provide a fairly reliable mechanism to properly understand its nature.

MATERIALS AND METHODS

Five durum wheat genotypes (Table, 1) were crossed in a full diallel fashion during the season 2010-2011. Grains of 20 F1s and their parents was planted on 15 November 2011 in two experiments; stress (173 mm precipitation) and non-stress using randomized complete block design with three replications atthe Research Field of the College of Agriculture, Salahaddin University in Erbil, Iraq located on 36^o 10' N Latitude, 43^o E longitude and 415 m above sea level.

Table (1) Pedigree of durum wheat genotypes used as parents in the study

No.	Pedigree
1	Simeto: Capeiti 8 / Valnova
2	Ofanto: Appulo / Adamello
3	Acsad 65: STORK CM 470-1M-2y-CMXGDAV2 490-AA'SS"
4	MIMAN-9/LDTUS-1 CDSS928207-1M-0Y-0M-0Y-2B-0Y
5	CRAKE-10 RISSA CDSS93 Y20-1Y-2Y-0B-0Y-2B-0B

The grains of each genotype were planted in a plot which consisted of single 3m rows (one per genotype) spaced 20 cm apart, with an intra-row spacing of 10 cm between plants. At maturity, a ten plants was taken randomly from each experimental unit for recording data on individual plant basis for days to flowering, plant height (cm), flag leaf area (calculated at flowering stage using the equation (leaf length × width × 0.95), (Thomas, 1975) (cm^2), spike length (cm), number of spikes per plant, number of grains per spike, 1000-grain weight (g), biomass yield/plant (g), grain yield/plant (g) and harvest index (%).

Genetic statistical analysis: An ordinary analysis of variance was performed to determine whether the genotypic differences were significant for the characters under consideration or not. Then estimates of combining ability were computed by using the method as described by Griffing (1956) Method I, random model. Heritability in broad and narrow senses, average degree of dominance, expected genetic advance and heterosis over mid parents were computed according to equationsmentioned by Singh and Chaudhary (1985).

The data also analyzed according to Hayman approach (Hayman, 1954) (Table, 2). The underlying model in this analysis is:

$$y_{rs} = \mu + Jr + Js + Jrs + \int + \int r + \int s + \int rs + 2Kr + 2Ks + 2Krs$$

Where, y_{rs}=entry in *r*th row and *s*th column, μ=grand mean, *Jr*=mean deviation or *r*th parents from grand mean, *Jrs*=remaining discrepancy due to *rs*th reciprocal sum, ∫=mean dominance deviation, ∫*r*=dominance deviation (additional) due to *r*th parent, ∫*s*=dominance deviation (additional) due to *s*th parent, ∫*rs*=remaining discrepancy in *rs*th reciprocal sum, *2Kr*=difference when *r*th line (row) is used as male and female, *2Ks*=difference when *s*th line (column) is used as male and female, and *2Krs*= discrepancy in *rs*th reciprocal differences.

In this technique, the total sum of squares is partitioned into various components namely: a (additive), b non-additive, which is further subdivided into b_1, b_2 and b_3, *c* (maternal) and *d* (reciprocal differences other than *c*. Significance of test of item *a* suggests the significance of additive effects of genes and of item *b*, the dominance effects. Significance of b_1 indicates that the dominance is unidirectional. It is in fact a comparison of mean of F_1 and the mid-parental value. Asymmetry of gene distribution is indicated by the item b_2, whereas item $b_3$tests that part of dominance deviation which are not attributable to b_1 and b_2. Item c tests the presence of maternal effects whereas item *d* tests the reciprocal differences other than *c*. (Singh and Chaudhary, 1985).

Diallel cross analysis method developed by Hayman (1954), Jinks (1954), Jinks and Hayman (1953) and applied by Singh and Chaudary (1985) was also used to determine gene action and genetic components of variation. Finally, genetic correlation between studied characters was calculated according to equations that have been mentioned by Walter (1975).

Table (2) Analysis of variance according to Hayman's approach

SOV	df	SS	Constants
A	$n-1$	$\frac{\sum(y_{r.}+y_{.r})^2}{2n}-\frac{2y_{..}^2}{n^2}$	$\int Ti$
B	$\frac{1}{2}n(n-1)$	$\frac{\sum(y_{rs}+y_{sr})^2}{2}-\frac{\sum(y_{r.}+y_{.r})^2}{2n}+\frac{y_{..}^2}{n^2}$	$\int Jrs$
b_1	1	$\frac{(y_{..}-ny_{.})^2}{n^2(n-1)}$	$\int$
b_2	$n-1$	$\frac{\sum(y_{r.}+y_{.r}-ny_{r})^2}{n(n-2)}-\frac{(2y_{..}-ny_{.})^2}{n^2(n-2)}$	r
b_3	$\frac{1}{2}n(n-3)$	$b-b_1-b_2$	rs
C	$n-1$	$\frac{\sum(y_{r.}-y_{.r})^2}{2n}$	Kr
D	$\frac{1}{2}(n-1)(n-2)$	$\frac{\sum(y_{rs}-y_{sr})^2}{2}-\frac{\sum(y_{r.}-y_{.r})^2}{2n}$	Krs
Total	n^2-1	$\sum y_{rs}^2-\frac{y_{..}^2}{n^2}$	

RESULTS AND DISSCUSION

1. Parents, F1 and reciprocals performance: There were high significant differences for all studied characters under stress and non-stress conditions among genotypes (parents, F1s and reciprocals) (Table,3). Based on each character the responseof genotypes at each condition differed. Days to flowering varied from (151.0 to 157.0) under stress conditions and from (156.0 to 163.3) under non-stress conditions. The crosses showed lower value than their parental. [3×4] had the lowest days to flowering under both conditions. Under stress condition the highest plant height was observed for [1×4] (70.0) and the lowest value for [1×2] (53.7)while under non-stress condition highest plant height was assigned to [4×3] (102.0) and the lowest was observed in parent [2] (89.0).The largest flag leaf area was found in [1×5] (17.0 cm^2) and in [1×3] under stress and non-stress conditions, respectively.Longest spike length was observed in [3×2] (8.1 cm) under stress condition and for [2×5] under non-stress condition.The highest no. of spikes/plant understress condition was observed for parent [2] (5.3)andunder non-stress condition the highestvalues were for [5×3] (8.6). Highest no. of grains/spike was observed for [3×4] (50.0) under stress condition and for [2×5] (71.0) under non-stress condition. [5×3 and 5×4] had the highest 1000-grain weight (32.5 g) under stressconditions and [5×1 (49.2 g)followed by [3×1] (49.1 g]

Table (3) Mean performance of parents and hybrids for the studied characters

	Days to flowering		Plant height (cm)		Flag leaf area (cm^2)		Spike length (cm)		No. of spikes/plant	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
Parents										
1	156.0	158.0	61.7	96.7	12.5	23.8	7.0	8.0	4. 3	6.0
2	152.7	160.0	66.0	89.0	14.7	25.9	7.4	8.1	5.3	5.8
3	153.3	157.7	66.7	90.7	14.4	24.0	7.3	7.6	4.8	7.3
4	156.3	161.0	64.0	89.3	13.9	24.6	6.9	8.6	4.9	7.8
5	151.7	158.7	61.0	95.0	16.5	24.5	8.2	8.1	5.1	6.5
F1 hybrids										
1 × 2	156.7	161.3	53.7	91.3	13.5	23.7	6.9	8.4	4.0	6.5
1 × 3	156.7	157.7	68.7	95.7	12.7	28.7	7.4	8.2	4.1	6.8
1 × 4	151.0	156.7	70.0	97.0	15.8	25.5	7.4	8.5	4.8	7.3
1 × 5	153.3	162.0	61.7	95.0	17.0	26.7	7.0	7.7	4.4	6.5
2 × 3	154.3	158.0	65.3	99.7	12.1	19.8	7.1	8.9	4.1	7.7
2 × 4	153.0	162.0	66.0	95.3	13. 7	21.4	7.8	8.3	4.1	8.0
2 × 5	152.7	158.7	68.3	99.7	14.3	24.1	6.6	9.2	3.7	7.7
3 × 4	151.0	156.0	66.7	98.7	14.7	23.9	7.5	8.5	5.0	8.3
3 × 5	151.7	157.0	57.0	100.0	13.2	23.6	7.4	8.5	3.6	6.7
4 × 5	157.0	158.7	63.0	97.3	12.2	21.8	7.2	8.2	3.8	6.4
Reciprocals										
2 × 1	154.3	161.3	67.7	95.3	13.0	24.6	7.2	8.4	4.5	8.3
3 × 1	154.3	158.7	68.3	89.7	14.1	21.4	7.2	7.8	3.3	6.7
4 × 1	153.3	163.3	63.7	93.0	13.8	25.0	7.1	7.1	4.0	6.8
5 × 1	156.0	160.7	63.7	99.0	13.7	25.4	7.5	8.2	3.5	6.7
3 × 2	154.3	156.3	67.0	97.7	15.6	22.3	8.1	9.0	3.6	7.5
4 × 2	154.7	163.3	61.7	92.7	14.7	24.7	7.3	8.3	4.0	8.1
5 × 2	153.0	160.0	63.0	97.3	14.7	22.3	7.2	8.4	4.2	6.5
4 × 3	153.0	157.0	62.7	102.0	13.0	23.3	7.0	9.0	4.5	7.6
5 × 3	156.0	157.0	59.3	95.7	14.8	28.3	8.0	8.5	4.0	8.6
5 × 4	155.0	158.7	56.3	97.7	15.2	23.3	8.0	8.9	4.1	8.5
G. M.	154.1	159.2	63.7	95.6	14.2	24.1	7.3	8.4	4.2	7.2
L.S.D 1%	3.1	3.0	7.4	10.6	2.3	3.5	0.7	0.6	1.0	1.8

	No. of grains/spike	1000-grain weight (g)	Biomass yield/plant	Grain yield/plant	Harvest index (%)

					(g)		(g)			
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
Parents										
1	38.7	60.7	20.8	46.3	15.8	39.0	5.9	15.9	37.5	40.8
2	40.7	60.0	27.8	40.4	19.9	36.9	7.0	14.6	35.3	39.6
3	44.7	58.0	24.0	34.4	18.4	40.7	6.5	12.8	35.3	31.6
4	35.3	53.0	25.3	40.2	13.9	42.7	5.1	16.1	36.7	37.6
5	47.0	50.0	27.4	40.6	20.9	39.2	8.1	15.3	38.9	39.1
F1 hybrids										
1 × 2	47.3	55.0	23.9	40.8	17.0	38.6	6.8	15.3	39.8	39.5
1 × 3	49.0	55.7	31.4	47.4	16.4	43.8	6.6	16.8	40.1	38.4
1 × 4	46.3	62.0	27.9	42.2	22.0	42.4	9.3	17.8	41.9	42.1
1 × 5	35.7	48.7	30.9	44.2	21.3	40.7	8.8	14.5	41.3	35.6
2 × 3	35.0	63.3	24.3	44.7	14.2	43.4	4.8	19.6	33.6	45.1
2 × 4	45.7	64.0	24.8	43.2	18.0	44.0	6.5	20.0	36.2	45.7
2 × 5	36.3	71.0	24.4	48.5	15.7	47.0	6.1	22.5	38.7	48.0
3 × 4	50.0	60.3	28.6	43.2	23.2	47.0	10.0	19.6	43.0	41.5
3 × 5	47.3	65.0	23.8	45.4	19.6	43.0	8.3	18.2	42.5	43.0
4 × 5	48.7	48.0	21.6	39.0	18.1	39.1	7.4	15.2	41.2	39.0
Reciprocals										
2 × 1	43.0	63.3	29.6	45.9	18.3	46.4	6.1	22.2	34.1	48.0
3 × 1	37.0	53.0	29.7	49.1	16.6	44.0	6.2	18.5	37.4	42.0
4 × 1	43.0	43.0	31.9	43.5	20.6	41.5	5.9	14.9	28.1	35.8
5 × 1	39.3	58.0	27.3	49.2	16.8	46.6	5.1	19.4	30.9	42.0
3 × 2	49.0	70.0	29.3	47.8	16.8	45.7	5.7	21.9	34.3	47.9
4 × 2	44.7	61.0	28.3	42.4	18.4	47.3	5.5	22.4	30.1	47.5
5 × 2	48.0	60.3	31.2	45.4	18.4	43.4	7.3	17.0	39.5	39.3
4 × 3	40.7	60.7	27.7	47.3	18.5	44.5	5.9	19.8	32.5	44.4
5 × 3	50.0	57.7	32.5	47.5	19.8	49.2	7.6	23.5	38.6	47.7
5 × 4	50.0	57.0	32.5	46.0	20.6	48.8	7.9	23.0	38.2	47.1
G. M.	43.7	58.3	27.5	44.2	18.4	43.4	6.8	18.3	37.0	41.9
L.S.D 1%	3.0	5.7	2.5	3.2	2.6	5.5	1.4	3.1	6.3	4.7

S= Stress; NS= Non-stress; G. M. = Grand mean.

and [2×5] (48.5 g) under non-stress conditions. Heaviest biomass yield/plant was observed for [3×4] (23.2 g) under stress condition and for [5×3] (47.5) and [4×3] (47.3) under non-stress condition. The highest grain yield/plant under stress condition was observed for [3×4] (10.0 g) and under non-stress condition the highest values were for [5×3] (23.5 g) followed by [5×4] (23.0 g). Among all genotypes, [3×4] had the highest harvest index value (43.0%) under stress condition; the same was true for [2×5] and [2×1] (48.0%) under non-stress condition.

It can be concluded that parent [5] exceeded over the other parents in most characters; it was the earliest in days to flowering, and better in plant height, flag leaf area, spike length, no. of grains/spike, biomass yield/plant and grain yield/plant. Parent [2] exceeded for no. of spikes/plant and 1000-grain weight under stress conditions. While under non-stress conditions, parent [1] was better in plant height, no. of grains/spike, 1000-grain weight and harvest index and parent [4] for flag leaf area, spike length, no. of spikes/plant, biomass yield and grain yield. Regarding the crosses, hybrid [3×4] was earlier to flowering and better in no. of spikes/plant, no. of grains/spike, biomass yield, grain yield and harvest index under stress conditions. While under non-stress conditions, the hybrid [2×5] exceeded in spike length, no. of grains/spike and harvest index.

2. Combining ability: Estimates of GCA effects for individual parent for each trait under stress(S) and non-stress (NS) condition are presented in Table (4). The parents and crosses which have negative significant GCA and SCA effects, respectively are desirable in case of days to flowering and plant height. Parent [1] showed desirable GCA effects for plant height, no. of grains/spike, 1000-grain weight, grain yield/plant and harvest index under stress conditions and for days to flowering, flag leaf areaand 1000-grain weight under non-stress condition. Parent [2] had a desirable effect for days to flowering, plant height and no. of spikes/plant under stress conditions and for plant height, spike length, no. of grains/spike, grain yield and harvest index under non-stress conditions. Parent [3] had a desirable effects for days to flowering, spike length and no. of grains/spike under stress conditions and for days to flowering, spike length, no. of spikes/plant, no. of grains/spike and biomass yield/plant under non-stress conditions. Parent [4] showed desirable GCA effects for no. of spikes/plant and no. of grains/spike and harvest index under stress conditions and for spike length, no. of spikes/plant, no. of grains/spike, 1000-grain weight, biomass yield/plant, grain yield/plant and harvest index under non-stress conditions. Parent [5] had a desirable effect for days to flowering, flag leaf area, biomass yield and grain yield/plant under stress conditions and for 1000-grain weight under non-stress conditions. It can be noted that parent [1] showed desirable GCA effects for maximum number of traits (5 traits) consists of plant height, no. of grains/spike, 1000-grain weight, grain yield/plant and harvest index under stress conditions and parent [4] for (7 traits) consists of spike length, no. of spikes/plant, no. of grains/spike, 1000-grain weight, biomass yield/plant, grain yield/plant and harvest index under non-stress conditions.

The data regarding SCA effects presented in Table (5) showed that the cross [1×4] had a desirable SCA effects for the maximum number of traits (8 traits) (days to flowering, flag leaf area, no. of spikes/plant,no. of grains/spike, 1000-grain weight, biomass yield/plant, grain yield/plant and harvest index) followed by [3×4] in 7 traits(days to flowering, spike length, no. of grains/spike, 1000-grain weight, biomass yield/plant, grain yield/plant and harvest index)and [1×2] in 6 traits (plant height,no.of grains/spike, 1000-grain weight, biomass yield, grain yield and harvest index)under stress conditions. While under non-stress conditions the cross [3×4] showed desirable SCA effects for 7 traits (days to flowering, spike length, no. of grains/spike, 1000-grain weight, biomass yield/plant, grain yield/plant and harvest index) followed by [1×3] for 6 traits (flag leaf area, no. of spikes/plant, 1000-grain weight, biomass yield/plant, grain yield and harvest index).

Table (4) Estimates of GCA effects for studied characters in a 5 × 5 diallel cross of durum wheat

parents	Days to flowering		Plant height (cm)		Flag leaf area (cm^2)		Spike length (cm)		No. of spikes/plant	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
1	0.91*	-0.19*	-1.75*	0.59*	0.10	1.02*	-0.01	-0.06*	-0.07*	-0.29*
2	-0.25*	1.05*	-0.75*	-0.78*	-0.19*	-0.41*	-0.07*	0.09*	0.07*	0.03
3	-0.25*	-1.9*	1.11*	0.52	-0.25*	-0.19*	0.08*	0.03*	-0.05	0.23*
4	0.05	0.45*	1.58*	-0.51	0.07	-0.53*	-0.01	0.13*	0.15*	0.37*
5	-0.45*	0.58*	-0.19	0.19	0.27*	0.11	0.01	-0.19*	-0.11*	-0.34*
$S.E.(g_i - g_j')$	0.16	0.16	0.39	0.56	0.12	0.18	0.04	0.03	0.05	0.09

parents	No. of grains/spike		1000-grain weight (g)		Biomass yield/plant (g)		Grain yield/plant (g)		Harvest index (%)	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
1	0.61*	-0.78*	0.45*	1.34*	0.01	-0.24	0.29*	-0.36*	1.53*	-0.62*
2	-1.30*	1.15*	-0.12	-0.47*	-0.08	-0.52*	-0.49*	0.40*	-2.27*	1.33*
3	1.04*	1.82*	0.05	-0.07	-0.19*	0.83*	-0.01	0.08	0.23	-0.58*
4	0.91*	1.15*	-0.29*	-1.23*	-0.26*	0.66*	0.002	0.56*	0.35*	0.68*
5	-1.26*	-3.35*	-0.09	0.43*	0.52*	-0.73*	0.21*	-0.68*	0.16	-0.81*
$S.E.(g_i - g_j')$	0.15	0.30	0.13	0.17	0.14	0.28	0.07	0.16	0.33	0.25

The data in Table (6) showed that the cross [5×3] had a desirable reciprocal effects for the largest number of traits (8 traits), (days to flowering, plant height,spike length, no. of spikes/plant, no. of grains, biomass yield/plant, grain yield/plant and harvest index) followed by [4×1 and 5×1] for 7 traits (days to flowering, flag leaf area, spike length, no. of spikes/plant, biomass yield/plant, grain yield/plant and harvest index) (days to flowering, plant height, no. of spikes/plant, 1000-grain weight, biomass yield/plant, grain yield/plant and harvest index), respectivelyand [4×3] for 6 traits (days to flowering, no. of spikes/spike, no. of grains/spike, biomass yield/plant, grain yield/plant and harvest index) under stress conditions. While under non-stress conditions the cross [5×2] showed a desirable SCA effects for 7 traits (days to flowering, no. of spike/plant, no. of grains/spike, 1000-grain weight, biomass yield/plant, grain yield/plant and harvest index), followed by [4×1] for 6 traits (days to flowering, flag leaf area, no. of spikes/plant, no. of grains/spike, grain yield/plant and harvest index). The significant result of GCA and SCA suggests that both additive and non-additive gene effects were involved in the expression of these indices.

The results of combining ability revealed that the parents [1 and 4] proved as a best general combiner for higher values of traits (5 and 7 traits) under stress and non-stress conditions, respectively. These two parents can be used in hybridization program for obtaining desirable combinations, while in case of hybrids the results of SCA and reciprocal effects revealed that the hybrids [1×4, 5×3]had a best specific combiner in desirable direction for eight traits followed by [3×4,4×1 and 5×1] for seven traits under stress conditions, while under non-stress conditions, the results indicated that the cross [3×4 and 5×2] had a best specific combiner in desirable direction forseven traits followed by [1×3 and 4×1] for six traits. Other researchers also obtained parents which showed a desirable GCA and SCA or reciprocal effects of hybrids for different traits using different genotypes (Kashif and Khan, 2008, Mahpara *et al.,* 2008, Adel and Ali, 2013).

Table (5) Estimates of SCA effects for studied characters in a 5 × 5 diallel cross of durum wheat under stress conditions

F_1	Days to flowering		Plant height (cm)		Flag leaf area (cm^2)		Spike length (cm)		No. of spikes/plant	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
1 × 2	1.12*	-0.05	-6.21*	-0.92	0.31*	-1.20*	0.17	0.27*	-0.21*	0.53*
1 × 3	1.62*	0.22	0.92	-1.05	-0.24	3.30*	0.29*	0.04	-0.09	0.55*
1 × 4	-3.01*	-1.11*	2.95*	1.48*	0.94*	-0.66*	-0.03	0.04	0.21*	-0.43*
1 × 5	0.15	1.75*	0.89	0.61	0.81*	0.86*	-0.11*	-0.11	-0.09	0.02
2 × 3	0.12	-0.85*	-0.08	5.48*	-1.17*	-1.95*	-0.29*	0.51*	0.00	0.16
2 × 4	-0.01	1.99*	-0.71	-0.32	0.18	-0.29	0.30*	-0.27*	-0.38*	0.39*
2 × 5	-0.35	0.19	3.22*	0.81	-0.20	0.81*	-0.40*	-0.07	-0.36*	0.38*
3 × 4	-1.18*	-1.58*	0.42	3.05*	1.22*	-0.21	0.36*	0.25*	-0.06	0.11
3 × 5	-0.35	-0.05	-1.98*	-1.49*	-0.52	-1.48*	-0.15*	-0.00	-0.50*	-0.40*
4 × 5	2.02*	-0.21	0.22	1.05	-1.89*	-0.44*	-0.16*	0.02	-0.10	0.08
$S.E.(g_i - g'_j)$	0.40	0.38	0.95	1.37	0.30	0.44	0.09	0.08	0.13	0.23

F_1	No. of grains/spike		1000-grain weight (g)		Biomass yield/plant (g)		Grain yield/plant (g)		Harvest index (%)	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
1 × 2	5.66*	-2.72*	0.43*	-1.64*	0.51*	1.08*	0.70*	0.82*	2.70*	0.68*
1 × 3	4.16*	-2.72*	3.97*	1.98*	-0.13	2.53*	-0.00	2.19*	0.59	2.36*
1 × 4	1.96*	2.45*	1.91*	-0.53*	2.08*	-0.95*	1.15*	-1.07*	1.82*	-1.29*
1 × 5	-5.54*	-0.89*	1.25*	0.78*	0.15	1.25*	-0.37*	-0.28	-2.59*	-1.87*
2 × 3	-5.61*	0.68	-1.41*	2.36*	-1.74*	0.24	-0.96*	0.93*	-1.95*	2.11*
2 × 4	1.86*	1.85*	-0.52*	0.33	0.21	2.07*	-0.31*	2.00*	-1.97*	2.68*
2 × 5	-1.47*	0.85	0.89*	1.84*	-0.66*	2.06*	-0.57*	0.69	-1.55*	-0.53
3 × 4	3.86*	3.85*	1.72*	2.62*	2.07*	1.49*	1.06*	1.85*	1.03*	2.70*
3 × 5	-1.31*	2.18*	-0.72*	2.72*	-0.59*	0.02	0.24*	0.63*	2.51*	1.96*
4 × 5	2.49*	-0.49	-1.48*	-0.93*	-0.43*	-0.59	-0.19*	0.55*	0.10	1.60*
$S.E.(g_i - g'_j)$	0.38	0.73	0.33	0.41	0.34	0.70	0.18	0.40	0.81	0.61

Table (6) Estimates of reciprocal effects for studied characters in a 5 × 5 diallel cross of durum wheat

Reciprocals	Days to flowering		Plant height (cm)		Flag leaf area (cm^2)		Spike length (cm)		No. of spikes/plant	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
2 × 1	0.83*	1.33*	-1.33	-	-	0.27	-	-	-0.07	-
3 × 1	0.33	0.33	4.67*	3.17*	0.85*	-0.13	0.53*	0.23*	0.03	1.00*
4 × 1	-	-	3.50*	0.00	-	1.63*	-	-	0.30*	-
5 × 1	1.00*	1.67*	-	-0.17	1.03*	0.68	0.33*	0.15*	0.43*	0.88*
3 × 2	-	0.67*	1.00*	-	0.57*	-	0.10*	0.02	-	0.38*
4 × 2	1.33*	0.50*	1.33*	2.00*	1.67*	1.70*	-	-	0.20*	-0.08
5 × 2	0.67*	-	2.17*	-1.17	-0.45	-	0.27*	0.25*	0.05	0.02
4 × 3	-	0.67*	2.33*	1.33*	-0.55	1.42*	0.07	-0.03	-	-0.05
5 × 3	0.83*	-	-0.17	2.83*	0.23	-0.45	0.27*	-0.02	0.12*	0.43*
5 × 4	-0.33	2.33*	-	1.00	-	0.82*	-	1.03*	0.72*	0.40*
	-	-0.17	5.67*	5.17*	0.45*	1.12*	0.25*	-	0.28*	0.02
	1.67*	-	-	1.00	-	-	-	0.25*	-	-
	-	0.83*	2.33*		0.45*	1.35*	0.28*	0.35*	0.35*	0.97*
	1.33*	-			-		0.12*	-		
	1.33*	1.33*			0.43*		-0.02	0.13*		
$S.E.(r_{ij}-r_{ij}')$	0.37	0.38	0.87	1.25	0.27	0.40	0.08	0.07	0.12	0.21

Reciprocals	No. of grains/spike		1000-grain weight (g)		Biomass yield/plant (g)		Grain yield/plant (g)		Harvest index (%)	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
2 × 1	-	-	-	-	-	-	-	-	0.83*	-
3 × 1	1.33*	1.00*	4.30*	2.62*	1.82*	5.12*	0.55*	3.87*	0.74*	3.79*
4 × 1	-	-	-	-0.03	-	-	-	-	1.21*	-
5 × 1	0.50*	1.00*	0.56*	-	1.70*	2.72*	0.53*	3.35*	5.23*	4.65*
3 × 2	-	0.83*	-	1.60*	1.83*	-0.50	1.01*	0.38*	0.53	1.39*
4 × 2	0.83*	-	1.69*	-	2.22*	-	1.85*	-	3.05*	-
5 × 2	-	4.67*	1.82*	2.50*	-	2.95*	-	2.43*	5.29*	2.96*
4 × 3	1.83*	1.33*	-	-	2.16*	-0.58	0.588	-0.12	4.35*	0.31
5 × 3	-	1.50*	1.72*	1.30*	-0.19	-	0.48*	-	2.55*	-0.89
5 × 4	2.83*	1.40*	-	0.42*	-	1.65*	0.10	1.20*	3.53*	6.07*
	0.50*	-	1.71*	2.48*	2.48*	2.68*	2.13*	3.82*		-
	-	4.83*	-	-	3.22*	0.65*	1.07*	-		3.25*
	3.33*	6.00*	3.78*	2.30*	1.48*	-0.48	0.59*	1.17*		0.51
	0.50*	-	-	-	-0.14	-		-0.15		-
	5.17*	7.67*	0.36*	1.85*		3.65*		-		4.55*
	2.83*		-	-				3.52*		
			2.96*	3.45*						
			-							
			4.02*							
$S.E.(r_{ij}-r_{ij}')$	0.34	0.66	0.30	0.37	0.31	0.63	0.17	0.36	0.74	0.56

3. Gene action:

A. Hayman analysis: Mean square values of the Hayman genetic analysis are presented in Table (7). Component *a*, which is an estimation of additive variance and *b* which is non-additive has beenhighly significant for all studied traits except for flag leaf area, no.of spikes/plant and 1000-grain weight under stress conditions and for no. of spikes/plant under non-stress conditions. Based on the method proposed by Hayman (1954), this component of variance was divided into *b1*, *b2*, *b3*. Component *b1* means the comparison of parents with crosses. Component *b1* has been significant for no. of spikes/plant, no. of grains/spike and 1000-grain weight under stress conditions. While it is significant for all traits under non-stress conditions excluding days to flowering and flag leaf area, which means that highly significant of this item displaying the importance of dominance effects (Uni-directional) while non- significant indicated the absence of directional dominance of the genes. Component *b2* shows the special heterosis of each parent. The significance of this component determines if the deviation of F_1 from the average parents changes from one parent to another. This happens when the frequency of dominant allele are different (Aghamiri *et al.,* 2012). This component was significant for days to flowering, no. grains/spike, 1000-grain weight, biomass yield/plant and grain yield/plant under stress conditions. While for all traits under non-stress conditions excluding plant height, no. of grains/spike and biomass yield/plant, which means scattering in dominant allele's distribution for these traits. Important role of specific dominant deviation of genes was indicated by significant *b3* item. This component has been significant for all traits under stress conditions. While it is significant only for no. of grains/spike, 1000-grain weight and harvest index under non-stress conditions. Significant *c* and *d* items indicated the presence of maternal and reciprocal effects, respectively. Those two components were significant for all traits under stress conditions excluding harvest index in item *d* and for flag leaf area and no. of spike/plant in item *c* under non-stress conditions, while for plant height in both items under non-stress conditions. Mather and Jinks (1982) reported that the advantage of ANOVA components Hayman method are their validity irrespective of whether there are maternal or reciprocal differences among the progeny families and whether the parental lines are a fixed sample or a random sample of a population of inbred lines.

B. Jinks -Hayman analysis: The estimates of genetic components of variation are given in Table (8); these components consists of variance of parent (*i*) and its offspring (*Vp*), mean variance of F_1 arrays ($\bar{V}r$), variance of means of F1 arrays ($\bar{V}r$), mean of covariance between parents and F_1 arrays ($\bar{W}r$) and different square between grand mean and mean of parents $(ML_1 - ML_0)^2$, then by using the equations which are suggested by Ferreria (1988) components of variation were computed and genetic constants and tests according to Singh and Choudhary (1985) method for further elaboration of the genetic system controlling the studied traits in durum wheat (Table, 9). The results revealed a significant role of additive genetic component *(D)* for the inheritance of days to flowering, flag leaf area spike length, no. of spikes/plant, no. of grains/spike and biomass yield under stress conditions

Mesopotamia J. of Agric. ISSN: 2224 - 9796 (Online) مجلة زراعة الرافدين
Vol. (46) No. (3) 2018 ISSN: 1815 - 316 X (Print) المجلد (46) العدد (3) 2018

and days to flowering, spike length, no. of spike/plant, 1000-grain weight, biomass yield/plant, grain yield and harvest index under non-stress conditions. The positive values of *F* (mean of variance of additive and dominance effects) for all traits excluding for plant height under stress conditions and for days to flowering and no. of grains/spike under stress and non-stress conditions indicated that there were more dominant than recessive alleles regardless of positive or negative direction; in other words, this component indicates unequal distribution of dominant and recessive gene frequencies in the parents. These results supported by the ratio of dominant to recessive alleles *KD/KR* which was more than one showing the importance and greater proportion of dominant gene. The non-additive component *(H1)* was found to be important for the genetic control of all the traits under stress and non-stress conditions excluding grain yield/plant under stress conditions. Additive and non-additive genetic components were significant for all traits, except for flag leaf area and grain yield/plant under stress only. However, the relative magnitude of dominant component *(H2)* was higher as compared to additive

Table (7) Analysis of variance according to (Hayman, 1954) method

SOV	df	Mean Squares									
		Days to flowering		Plant height (cm)		Flag leaf area (cm^2)		Spike length (cm)		No. of spikes/plant	
		S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
a	**4**	5.143*	38.260**	53.643**	29.627^{ns}	4.257^{ns}	9.164*	0.548*	0.949**	0.395^{ns}	3.675*
b	**10**	13.755**	10.718**	46.771*	62.611*	3.037*	11.36**	0.454**	0.707**	1.268**	1.207^{ns}
b₁	**1**	0.053^{ns}	0.270^{ns}	0.403^{ns}	227.07**	0.998^{ns}	4.588^{ns}	0.001^{ns}	1.387*	7.395**	5.769*
b₂	**4**	12.262*	14.984**	15.029^{ns}	59.073^{ns}	3.608^{ns}	15.92**	0.556^{ns}	1.028**	0.571^{ns}	0.948^{ns}
b₃	**5**	17.689**	9.394**	81.439**	32.550^{ns}	2.988**	9.067^{ns}	0.463**	0.314^{ns}	0.600**	0.502^{ns}
c	**4**	13.983*	9.367^{ns}	52.717*	12.267^{ns}	8.442**	10.50^{ns}	0.883*	0.364*	0.604**	2.395^{ns}
d	**6**	3.956*	7.394*	53.883*	22.128^{ns}	5.925**	15.419*	0.225**	0.632**	0.421**	1.783*
Total	**24**										
Ba	**8**	1.203	1.430	3.948	12.357	1.851	1.572	0.098	0.087	0.559	0.607
Bb	**20**	2.853	1.184	14.355	23.245	1.127	2.252	0.108	0.086	0.189	0.647
Bb₁	**2**	5.773	1.110	62.413	8.680	3.629	0.883	0.110	0.030	0.043	0.217
Bb₂	**8**	1.952	1.981	4.382	19.277	1.318	0.748	0.191	0.065	0.363	0.963
Bb₃	**10**	2.989	0.561	12.722	29.333	0.474	3.729	0.040	0.113	0.080	0.479
Bc	**8**	2.183	4.017	9.892	31.217	0.817	2.786	0.140	0.074	0.054	1.035
Bd	**12**	1.072	1.711	12.183	25.411	0.860	3.138	0.032	0.066	0.109	0.394
SOV	**df**	No. of grains/spike		1000-grain weight (g)		Biomass yield/plant (g)		Grain yield/plant (g)		Harvest index (%)	
		S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
a	**4**	50.357**	273.2**	2.189^{ns}	30.68**	10.966**	20.497*	5.558**	14.75**	41.85**	52.0**
b	**10**	79.852**	81.00**	30.022**	59.66**	25.602**	33.38**	3.828**	32.24**	20.223*	72.6**
b₁	**1**	110.41**	76.00**	109.49*	272.1*	6.539^{ns}	254.8**	1.652^{ns}	207.34*	1.471^{ns}	324.63*

				*	*						
b_2	**4**	70.304**	151.8**	40.644**	66.84**	48.429**	13.54^{ns}	5.893**	24.54**	12.435^{ns}	84.30**
b_3	**5**	81.378**	25.35^{ns}	5.630**	11.43**	11.154**	4.951^{ns}	2.612**	3.374^{ns}	30.205*	12.85*
c	**4**	132.82**	98.45**	50.612**	25.24**	11.967**	47.581*	13.60**	29.72**	168.7**	36.87**
d	**6**	65.567**	141.1**	52.863**	19.71**	8.537**	34.476*	2.443**	33.79**	15.908^{ns}	61.36**
Total	**24**										
Ba	**8**	3.027	2.235	0.770	1.713	1.279	4.384	0.182	0.889	6.415	3.650
Bb	**20**	1.298	7.008	1.204	2.162	1.994	5.443	0.424	2.035	7.988	4.540
Bb_1	**2**	1.653	0.103	1.735	0.015	2.086	2.531	0.493	2.525	6.973	8.354
Bb_2	**8**	1.068	5.890	0.610	3.290	2.402	7.889	0.365	2.247	7.940	5.006
Bb_3	**10**	1.411	9.283	1.574	1.689	1.649	4.070	0.458	1.767	8.229	3.405
Bc	**8**	0.567	13.575	1.018	1.585	1.444	11.791	0.749	2.165	12.228	4.353
Bd	**12**	2.483	4.144	2.130	2.424	0.518	4.297	0.301	2.493	6.888	5.801

component *(D)* in all the traits in both cases, indicating the preponderance of dominant gene effects in controlling the inheritance of these traits. Unequal values of *(H1)* and *(H2)* indicated the presence of positive and negative alleles in unequal frequencies. This was also supported by the ratios of *(H2/4H1)* that were less than 0.25 for all traits except plant height in both cases, it was suggested that when the genes are equally distributed among the parents, this value is equal to 0.25 (Singh and Chaudhary, 1985). The value of h^2 was significantfor plant height, no. of spikes/plant and 1000-grain weight under stress conditions and for plant height, spike length, no. of spikes/plant, 1000-grain weight, biomass yield/plant, grain yield/plant and harvest index under non-stress conditions showing the presence of overall dominant gene effects due to heterozygous loci affecting the expression of those traits. Expected environmental component of variation *E* was found non-significant for all traits except no. of spikes/plant under stress conditions and biomass yield/plant under non-stress conditions indicating the influence of environment on those traits. The average degree of dominance $(H1/D)^{1/2}$ was >1 for all traits in both cases indicating that these traits were controlled by over-dominance of genes. The component $h^2/H2$ measures the number of groups of genes which control the trait and exhibited dominance. In this study, the value of genetic ratio $h^2/H2$ estimated for studied traits indicates that it's at least one genetic group involved in the control of heredity. The narrow sense heritability $H_{n.s.}$ was low for flag leaf area, moderate for no. of grains/spike and 1000-grain weight, high for remaining traits under stress conditions. While low for no. of grains/spike, moderate for days to flowering, flag leaf area and grain yield/plant, high for remaining traits under non-stress conditions, indicating that selection for improvement of these traits would be effective. Similar results were also reported by Rabbani *et al.* (2009).

Table (8) Values of statistical constants values according to Jinks and Hayman (1953) analysis for studied characters

Statistics	Days to flowering		Plant height (cm)		Flag leaf area (cm^2)		Spike length (cm)		No. of spikes/plant	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
Vp	5.133	2.633	8.367	15.967	3.026	1.484	0.414	0.209	0.676	1.194
$\bar{V}r$	4.853	5.460	26.860	28.240	2.282	6.274	0.228	0.263	0.406	0.931
$\bar{W}r$	1.077	1.540	5.487	-0.270	0.608	-0.061	0.131	0.019	0.161	0.179
Vr^{-}	0.727	1.704	2.481	5.841	0.567	0.432	0.039	0.069	0.081	0.367
$(ML_1 - ML_0)^2$	0.619	0.133	6.679	13.036	0.440	0.339	0.012	0.077	0.399	0.331
	No. of grains/spike		1000-grain weight (g)		Biomass yield/plant (g)		Grain yield/plant (g)		Harvest index (%)	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
Vp	23.533	23.067	8.430	19.177	10.414	9.202	1.456	3.047	8.182	17.234
$\bar{V}r$	28.073	51.660	13.702	14.759	6.809	15.315	1.641	12.467	16.628	26.679
$\bar{W}r$	9.367	11.627	1.484	0.800	1.174	0.847	0.278	-0.580	2.450	1.419
Vr^{-}	5.412	5.996	1.174	2.528	0.972	3.064	0.845	0.834	8.893	1.223
$(ML_1 - ML_0)^2$	6.065	4.065	6.025	14.513	0.571	13.862	0.141	11.327	0.822	18.204

Table (9): Genetic constants ratio, genetic parameters and heritability in narrow sense for studied characters

	Days to flowering		Plant height (cm)		Flag leaf area (cm^2)		Spike length (cm)		No. of spikes/plant	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
$\widehat{D}$	3.568* ± 1.695	1.619* ± 1.061	3.671 ± 6.518	6.560 ± 12.67	2.120* ± 1.374	0.534 ± 4.941	0.307* ± 0.084	0.146* ± 0.080	0.485* ± 0.074	0.784* ± 0.273
$\widehat{F}$	4.121 ± 4.233	-1.300 ± 2.650	-7.798 ± 16.28	18.954 ± 31.65	2.534 ± 3.432	1.785 ± 12.34	0.213* ± 0.209	0.249* ± 0.199	0.500* ± 0.186	1.133* ± 0.681
$\widehat{H}_1$	18.152* ± 4.576	17.02* ± 2.865	83.12* ± 17.60	91.88* ± 34.22	8.115* ± 3.710	25.28* ± 13.34	0.754* ± 0.226	0.989* ± 0.215	0.974* ± 0.201	3.009* ± 0.737
$\widehat{H}_2$	15.489* ± 4.151	14.68* ± 2.598	87.86* ± 15.97	63.27* ± 31.04	6.008* ± 3.365	22.91* ± 12.10	0.734* ± 0.205	0.673* ± 0.195	0.723* ± 0.182	1.556* ± 0.668
$\widehat{h}^2$	1.237 ± 2.802	0.266 ± 1.754	13.36* ± 10.78	26.07* ± 20.95	0.881 ± 2.272	0.678 ± 8.171	0.024 ± 0.139	0.155* ± 0.132	0.798* ± 0.123	0.662* ± 0.451
$\widehat{E}$	0.674 ± 0.692	0.610 ± 0.433	3.778 ± 2.661	7.767 ± 5.172	0.376 ± 0.561	0.816 ± 2.017	0.031 ± 0.034	0.026 ± 0.033	0.069* ± 0.030	0.214 ± 0.111
$\sqrt{H_1/D}$	2.256	3.242	4.758	3.742	1.956	6.880	1.567	2.603	1.417	1.959
$\bar{p}\bar{q}=H_2/4H_1$	0.213	0.216	0.264	1.172	0.185	0.227	0.243	0.170	0.186	0.129
KD/KR	1.688	0.780	0.635	2.258	1.879	1.642	1.568	1.976	2.143	2.168
h^2/H_2	0.080	0.018	0.152	0.412	0.147	0.030	0.033	0.230	1.104	0.425
$H_{n.s.}$	0.532	0.237	0.000	0.534	0.643	0.264	0.558	0.646	0.712	0.737
	No. of grains/spike		1000-grain weight (g)		Biomass yield/plant (g)		Grain yield/plant (g)		Harvest index (%)	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**

$\hat{D}$	18.357* ± 9.046	16.696 ± 26.11	6.389 ± 5.726	14.79* ± 4.270	7.954* ± 2.405	5.752* ± 2.107	1.056 ± 1.143	1.909* ± 1.880	4.370 ± 5.051	12.450* ± 6.171
$\hat{F}$	7.117 ± 22.60	-2.408 ± 65.23	8.312 ± 14.30	27.47* ± 10.67	12.46* ± 6.007	10.081* ± 5.263	1.310 ± 2.856	6.097* ± 4.697	2.642 ± 12.62	21.538* ± 15.41
$\hat{H}_1$	93.365* ± 24.43	184.6* ± 70.52	50.11* ± 15.46	52.06* ± 11.53	30.7* ± 6.494	43.42* ± 5.690	5.861* ± 3.088	39.91* ± 5.078	52.54* ± 13.64	93.758* ± 16.66
$\hat{H}_2$	87.475* ± 22.16	185.2* ± 63.96	44.57* ± 14.03	31.52* ± 10.46	23.24* ± 5.890	29.93* ± 5.161	2.948* ± 2.800	33.27* ± 4.606	26.69* ± 12.37	81.334* ± 15.12
$\hat{h}^2$	12.130 ± 14.96	8.129 ± 43.18	12.05* ± 9.469	29.03* ± 7.06	1.143 ± 3.977	27.72* ± 3.484	0.281 ± 1.891	22.65* ± 3.109	1.645 ± 8.353	36.41* ± 10.21
$\hat{E}$	0.587 ± 3.693	2.197 ± 10.66	0.444 ± 2.338	0.685 ± 1.743	0.471 ± 0.982	2.013* ± 0.860	0.136 ± 0.467	0.660 ± 0.768	2.719 ± 2.062	1.559 ± 2.519
$\sqrt{H_1/D}$	2.256	3.325	2.800	1.876	1.965	2.747	2.356	4.572	3.467	2.744
$\bar{p}\bar{q}=H_2/4H_1$	0.234	0.249	0.222	0.151	0.189	0.172	0.126	0.208	0.127	0.217
KD/KR	1.188	0.985	1.605	2.959	2.325	1.937	1.714	2.073	1.191	1.916
h^2/H_2	0.139	0.044	0.270	0.921	0.049	0.926	0.059	0.681	0.062	0.448
$H_{n.s.}$	0.411	0.124	0.466	0.786	0.689	0.606	0.752	0.449	0.636	0.515

*=The $H_{n.s.}$ value was set to zero when estimated turned out to be a negative.

A comparison of dominance degree for parents with mean values in each trait was shown in the Table (10); it can be noticed that the convergence matching some parents in terms of this comparison, such as parent 5 in harvest index, and it means the possibility to get advantage of this parent to improve these traits, while the other traits and parents differed in the sequence of degree of dominance and means, indicating other effects had an impact in different mean values of the parents. But that does not diminish the importance to refer for some outstanding parents in both sequence degree of dominance or means of traits, for instance: The parent 1 had a first rank in the degree of dominance in the days to flowering, spike length, no. of grains/spike, biomass yield/plant and grain yield/plant under stress conditions and parent 5 in plant height, no. of spikes/plant, biomass yield/plant and grain yield/plant under non-stress conditions, furthermore in 1000-grain weight and harvest index under stress conditions, while the parent 5 had a first rank in sequence means in all traits except no. of spikes/plant and 1000-grain weight under stress conditions; and parent 4 in spike length, no. of spikes/plant, biomass yield/plant and grain yield/plant under non-stress conditions, indicating possibility to get advantage of these two parents in hybridization breeding programs.

Table (10) Sorting of parents according to degree of dominance and its means for studied characters

Characters		Sorting parents according to degree of dominance Dominance → → →Recessive					Sorting parents according to means Highest→ → → Lowest				
Days to flowering	**S**	1	3	2	4	5	5	2	3	1	4
	NS	3	5	1	2	4	4	2	5	1	3
Plant height (cm)	**S**	3	1	5	4	2	5	1	4	2	3
	NS	5	3	2	4	1	1	5	3	4	2
Flag leaf area (cm^2)	**S**	4	2	1	3	5	5	2	3	4	1
	NS	4	2	1	5	3	2	4	5	3	1
Spike length (cm)	**S**	1	2	4	5	3	5	2	3	1	4
	NS	2	1	4	5	3	4	5	2	1	3
No. of spikes/plant	**S**	4	1	5	3	2	2	5	4	3	1
	NS	5	1	3	2	4	4	3	5	2	1
No. of grains/spike	**S**	1	2	5	3	4	5	3	2	1	4
	NS	3	2	4	1	5	1	2	3	4	5
1000-grain weight (g)	**S**	5	4	2	3	1	2	5	4	3	1
	NS	2	1	4	5	3	1	5	2	4	3
Biomass yield/plant (g)	**S**	1	2	3	5	4	5	2	3	1	4
	NS	5	1	3	4	2	4	3	5	1	2
Grain yield/plant (g)	**S**	1	5	2	3	4	5	2	3	1	4
	NS	5	1	4	2	3	4	1	5	2	3
Harvest index (%)	**S**	5	4	1	3	2	5	1	4	3	2
	NS	2	5	4	1	3	1	2	5	4	3

4. Heterosis: The mid-parent heterosis values at stress and non-stress conditions are presented in Table (11). The crosses of negative significant heterosis values were days to flowering and plant height. Also, there were significant positive heterosis values for the other traits. The best crosses at stress conditions for days to flowering were [1×4] (-5.17); for plant height were [1×2] (-10.2); for flag leaf area were [1 × 4] (2.63); for spike length were [3×2] (0.98); for no. of grains/spike were [5×2] (11.00); for 1000-grain weight were [5×3] (10.10); for biomass yield/plant [1×4] (7.18); for grain yield/plant and harvest index were [3×4] (4.2) and (6.97), respectively. While the best crosses at non-stress conditions were [3×4] (-3.33); for flag leaf area, grain yield and harvest index were [5×3] (4.42), (9.17) and (11.51), respectively; for spike length were [4×3] (1.17); for no. of spike/plant and biomass yield were [5×4], (2.6) and (10.8), respectively; for no. of grains/spike were [3×2] (14.50); for 1000-grain weight were [3×1] (11.60). The results of heterosis revealed that maximum number of crosses showed heterosis for 1000-grain weight (12 and (14) crosses at stress and non-stress conditions, respectively; no. of grains/spike (9) at both conditions; grain yield/plant (12), biomass yield/plant and harvest index (10) at non-stress conditions. Generally number of crosses and magnitude of heterosis was greater under non-stressconditions as compared to stress conditions. Under stress conditions high heterosis were exhibited by cross combinations [1×4] for days to flowering, flag leaf area and biomass yield followed by [3×4] for grain yield/plant and harvest index. While under non-stress conditions the high heterosis were exhibited by cross combinations [5×3] for flag leaf area, grain yield/plant and harvest index suggest the usefulness for developing durum wheat cultivars for each conditions by utilizing the potential of these crosses to give transgressive segregates. These results are in agreement with those obtained by Hassan (2004), Sharief *et al.* (2006) and Abdel-Moneam (2009).

5. Genetic correlation: Genetic correlation coefficients, calculated from the data obtained for parental and their F1 hybrids and reciprocals are presented in Table (12). GY were highly positive correlated with NS, NG, BY, HI at both conditions. No significant positive genotypic correlation existed between yield components (SN, GN and GW), except between NG and NS at non-stress conditions. The negative correlation of GY with DF at stress and PH at non-stress conditions in addition to positive correlations between GY and other traits. Generally, among the measured traits, GY exhibited the highest value of genetic correlation with BY in both stress (0.860) and non-stress (0.930) conditions followed with HI (0.781) and (0.962) under stress and non-stress conditions, respectively. Also other researchers established the importance of biological yield for the GY increase in wheat (Reynolds *et al.,* 2007, Yani and Rashidi, 2012), especially under stress conditions. Also, Kirigwi *et al.* (2004) reported positive and significant correlation for GY with BY and HI under various regimes of moisture stress. These results suggest that these traits therefore deserve better attention in future breeding programs for evolving better durum wheat.

Table (11) Mid- parent heterosis of studied characters in durum wheat

Crosses	Days to flowering		Plant height (cm)		Flag leaf area (cm^2)		Spike length (cm)		No. of spikes/plant	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
1 × 2	2.33*	2.33*	-10.2**	-1.5	-0.07	-1.13	-0.32	0.38	-0.84*	0.60
1 × 3	2.00	-0.17	4.50	2.0	-0.72	4.15**	0.22	0.42**	-0.47	0.22
1 × 4	-5.17**	-2.83**	7.17**	4.0	2.63**	1.33	0.47*	0.20	0.26	0.37
1 × 5	-0.50	3.67**	0.33	-0.83	2.48**	2.57*	-0.62**	-0.32	-0.28	0.32
2 × 3	1.33	-0.83	-1.00	9.83**	-2.42**	-5.1**	-0.23	1.10**	-0.99**	1.12
2 × 4	-1.50	1.5	1.00	6.17	-0.60	-3.8**	0.68**	-0.05	-0.97**	1.13
2 × 5	0.50	-0.67	4.83*	6.67	-1.32	-1.07	-1.17**	1.10**	-1.47**	1.58**
3 × 4	-3.83**	-3.33**	1.33	9.67**	0.62	-0.35	0.42	0.42*	0.18	0.78
3 × 5	-0.83	-1.17	-6.83**	7.17*	-2.23**	-0.65	-0.33	0.67**	-1.06**	-0.13
4 × 5	3.00**	-1.17	0.50	5.17	-3.02**	-2.7*	-0.35	-0.18	-1.13**	-0.78
2 × 1	0.33	1.5	5.17*	3.17	-2.15**	0.00	-0.32	0.08	-0.43	1.15*
3 × 1	1.83	0.5	4.50	-3.17	-1.33	-2.88*	-0.57*	-0.03	-1.63**	-0.17
4 × 1	1.17	4.0**	0.17	1.0	-1.78*	-0.17	-0.67**	-0.97**	-1.23**	0.72
5 × 1	2.17*	2.33*	2.33	3.17	-0.85	1.20	-0.08	0.18	-1.14**	0.48
3 × 2	-0.50	-3.0**	1.67	7.67*	1.52*	-1.98	0.98**	0.92**	-1.26**	-0.02
4 × 2	0.17	2.83**	-3.33	3.5	0.50	-0.97	0.15	-0.02	-1.07**	1.23*
5 × 2	-3.17**	0.5	0.17	4.33	1.50	-1.93	0.27	0.17	-0.34	-0.4
4 × 3	0.00	-1.83	-3.67	12.2**	-1.52*	-1.72	-0.37	1.17**	-0.59	1.08
5 × 3	1.33	-0.83	-4.83*	2.0	1.35	4.42**	0.88**	0.72**	-0.53	1.98**
5 × 4	0.67	-0.33	-7.50**	4.83	1.63*	-1.57	0.75**	0.85**	-0.71*	2.6**

Crosses	No. of grains/spike		1000-grain weight (g)		Biomass yield/plant (g)		Grain yield/plant (g)		Harvest index (%)	
	S	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
1 × 2	7.67**	-5.33**	-0.41	-2.52*	-0.85	0.65	0.32	0.00	3.42	-0.71
1 × 3	7.33**	-3.67	8.98**	7.08**	-0.72	3.92*	0.37	2.47*	3.69	2.21
1 × 4	9.33**	5.17**	4.82**	-1.08	7.18**	1.52	3.75**	1.82	4.79*	2.88

1 × 5	-7.17**	-6.67**	6.82**	0.78	2.91**	1.63	1.78**	-1.08	3.14	-4.31**
2 × 3	-7.67**	4.33*	-1.65*	7.33**	-4.93**	4.53*	-1.94**	5.83**	-1.72	9.45**
2 × 4	7.67**	7.50**	-1.72*	2.93**	1.14	4.17*	0.45	4.68**	0.19	7.12**
2 × 5	-7.5**	16.0**	-3.23**	7.97**	-4.74**	8.85**	-1.49**	7.52**	1.6	8.60**
3 × 4	10.0**	4.83*	3.97**	5.9**	7.07**	5.30**	4.2**	5.15**	6.97**	6.86**
3 × 5	1.5	11.0**	-1.92*	7.9**	-0.06	3.05	1.03*	4.08**	5.39*	7.62**
4 × 5	7.5**	-3.50	-4.72**	-1.43	0.64	-1.85	0.80	-0.50	3.35	0.48
2 × 1	1.83	11.83*	3.33**	5.47**	0.92	5.45**	-0.38	6.53**	-3.70	9.59**
3 × 1	-8.83**	-1.00	3.99**	11.6**	-3.02**	4.02*	-1.11*	4.38**	0.28	6.60**
4 × 1	-0.83	-12.0**	4.32**	3.00**	0.22	3.48	-1.68**	-0.12	-8.98**	-3.55**
5 × 1	-3.5**	2.67	3.17**	5.78**	-1.53	7.53**	-1.92**	3.78**	-7.31**	1.62
3 × 2	9**	14.5**	4.68**	10.5**	0.63	4.00*	-0.06	7.48**	-1.74	13.4**
4 × 2	6.67**	4.50*	1.70*	2.10*	1.52	7.47**	-0.51	7.08**	-5.92**	8.89**
5 × 2	11.0**	3.50	8.20**	2.12*	3.52**	2.52	1.73**	1.05	2.37	0.10
4 × 3	-2.0*	1.67	1.78*	9.93**	-0.61	5.70**	-0.79	6.07**	-2.77	8.84**
5 × 3	8.33**	-1.67	10.1**	7.15**	2.68**	9.35**	1.44**	9.17**	2.20	11.51*
5 × 4	10.3**	-3.33	8.20**	2.72*	2.79**	10.8**	1.42**	7.73**	1.76	6.87**

* Significant (P = 0.05), ** Significant (P = 0.01)

Table (12) Genetic correlation coefficients between studied characters

		HI	GY	BY	GW	NG	SL	NS	FLA	PH
DF	S	-.204	-.57**	-.66**	-.100	-.038	-.086	-.51**	-.61**	-.224
	NS	-.153	-.146	-.141	-.155	-.407*	-.475*	-.043	.102	-.81**
PH	S	-.098	-.161	-.190	.045	-.296	-.208	.185	-.140	
	NS	.767**	.686**	.552**	.796**	.671**	.915**	.193	-.254	
FLA	S	.321	.645**	.689**	.562**	.175	.513**	.425*		
	NS	-.228	-.074	.125	.001	-.272	-.281	.076		
NS	S	.274	.434*	.411*	-.036	.015	-.025			
	NS	.767**	.864**	.866**	.211	.397*	.514**			
SL	S	.078	.309	.399*	.390*	.686**				
	NS	.791**	.701**	.493*	.409*	.746**				
NG	S	.368	.532**	.515**	.267					
	NS	.713**	.614**	.422*	.355					
GW	S	-.137	.211	.438*						
	NS	.601**	.648**	.668**						
BY	S	.353	.860**							
	NS	.796**	.930**							
GY	S	.781**								
	NS	.962**								

* Significant (P = 0.05), ** Significant (P = 0.01)

DF= days to flowering; PH=plant height; FLA=flag leaf area; NS= no. of spikes/ plant; SL= spike length; NG= no. of grains/spike; GW=1000-grain weight; BY=biomass yield/plant; GY=grain yield/plant; HI= harvest index.

تحاليل وراثية في الحنطة الخشنة باستخدام تطبيقات كرفنك وهايمان تحت قلة وكفاية الماء

اسماعيل حسين علي
كلية الزراعة/جامعة صلاح الدين/أربيل/ العراق
E-mail:dr.ismail@ymail.com

الخلاصة

أجــري تهجــين تبــادلي كامــل بــين خمســة تراكيــب وراثيــة مــن الحنطــة الخشــنة هــي (Simeto (1), Ofanto (2), Acsad 65 (3), Miman-9 (4) and CRAK-10 (5)) خلال موسم النمو 2010-2011 في حقل تجارب كلية الزراعة بجامعة صلاح الدين في أربيل/العراق. زرعت حبوب 20 هجيناً فردياً مع الآباء الخمسة في 15 تشرين الثاني 2011 في تجربتين منفصلتين واحدة تحت الظروف الديمية (الشد) والأخرى تحت ظروف الري (عدم الشد) باستخدام تصميم القطاعات العشوائية الكاملة بثلاثة مكررات من أجل دراسة الخصائص الوراثية لعدد الأيام للتزهير وارتفاع النبات ومساحة ورقة العلم وطول السنبلة وعدد السنابل/نبات وعدد الحبوب/سنبلة ووزن 1000 حبة والحاصل البيولوجي/نبات وحاصل الحبوب/نبات ودليل الحصاد باستخدام طرائق كرفنك وهايمان وجنكز-هايمان. أظهرت النتائج اعطاء بعض الآباء قدرة ائتلاف موجبة عالية، بينما أظهرت بعض الهجن قدرة ائتلاف خاصة في معظم هذه الصفات. ظهرأهمية المكون الوراثي الاضافي (*D*) في التحكم بعدد الأيام للتزهير ومساحة ورقة العلم وطول السنبلة وعدد السنابل/نبات وعدد الحبوب/سنبلة والحاصل البيولوجي/نبات تحت ظروف الشد ولعدد الأيام للتزهير وطول السنبلة وعدد السنابل/نبات ووزن 1000 حبة والحاصل البيولوجي/نبات وحاصل الحبوب/نبات ودليل الحصاد تحت ظروف عدم الشد. أظهر المكون غير الاضافي (*H1*) أهمية في التحكم الوراثي لجميع الصفات تحت ظروف الشد وعدمه باستثناء حاصل الحبوب/نبات تحت ظروف الشد. كان معدل درجة السيادة $(H1/D)^{½}$ أكبر من واحد في الحالتين. كانت قوة التوريث بالمعنى الضيق منخفضة لمساحة ورقة العلم ومتوسطة لعدد الحبوب/سنبلة ووزن 1000 حبة وعالية لبقية الصفات تحت ظروف الشد في حين كانت منخفضة لعدد الحبوب/سنبلة ومتوسطة لعدد الأيام للتزهير ومساحة ورقة العلم وحاصل الحبوب/نبات وعالية لبقية الصفات تحت ظروف عدم الشد. كان عدد الهجن المتفوقة ومقدارها أكبر تحت ظروف عدم الشد مقارنة بظروف الشد. أظهرالهجين [1×4] اعلى قوة هجين في معظم الصفات تحت ظروف الشد، بينما للهجين [5×3] تحت ظروف عدم الشد.ويمكن الاستنتاج بامكانية وضع هذه التراكيب الوراثية في خدمة المربي للاستمرار بها للأجيال اللاحقة واختبارها لتطوير حاصل الحنطة الخشنة تحت ظروف قلة وكفاية الماء باستخدام الانتخاب الفردي او الاجمالي.

تاريخ تسلم البحث:2013/5/7، وقبوله2013/12/30

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