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Genetic Analysis for Heterotic Traits in Bread Wheat (*Triticum aestivum* L.) Using Six Parameters Model

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A B S T R A C T

The assessment of nature of gene effect for yield and its contributing traits and detection of epistasis in wheat was studied in five crosses involving seven parents through generation mean analysis. Scaling test and joint scaling test were showed significant for almost traits all crosses. Additive gene effects (d) were positively significant for days to maturity and tillers per plant in cross II; for seed per plant in cross IV. Dominance gene effects (h) were highly significant for days to 75% heading in cross II, III and IV; for days to maturity and grains per spike in cross II, for grain yield per plant and grains per spike in cross I. Additive x additive type of gene (i) were positive significant effect for days to 75% heading in cross II, III and IV; for days to maturity in cross II and grains per spike in crosses I, II; for 1000 grain weight in cross II and IV; for grain yield per plant in cross I. Additive x dominance type of gene effect (j) was positive significant for days to 75% heading in cross III; for days to maturity in cross II and III; for plant height in cross III; tillers per plant in cross II; for grain per spike and seed per plant in cross III and grain yield in cross IV. Dominance x dominance effect (l) were positively significant for days to 75% heading, plant height in cross I; for plant height in cross III, IV and V; for tillers per plant in cross II and for grains per spike in cross IV and V; seed per plant, grain yield in cross IV.

Introduction

Wheat is one of the most important food grain crops of the world including India, which belong to the family Poaceae and genera *triticum*. The breeders are concentrating to improve the yield potential of wheat by developing new varieties/new genotypes with desirable genetic makeup in order to overcome the consumption pressure of ever increasing population (Memon *et al.,* 2007). Grain yield in wheat is a complex character determined by several traits; therefore, direct selection may not be effective. Yield potential of wheat can be enhance through indirect selection of its contributing traits. Increase in one component trait might have positive or negative effect on other components trait (Chandra *et al.,* 2004).

Generation mean analysis belongs to the biometric methods based on the measurements of phenotypic performances for different quantitative traits of different breeding population (Parental, F_1s, back cross and segregation generations). This is one of the most important technique used in plant breeding for estimating main gene effects (additive and dominance) and their interactions (additive x additive, additive x dominance, dominance x dominance) provided the pattern inheritance of yield and other plant associated characters. In the earlier study, Gamble (1962) clearly indicated the role of epistatic gene action (both additive and dominance gene action) in controlling the inheritance of yield and yield associated traits in different crops. Cavalli (1952) reported that accuracy of gene effect increases with increasing number of segregating generation and number of observational plants.

Materials and Methods

A field experiments were conducted at Agricultural Research Station, S.D. Agricultural University, Ladol, Ta-Vijapur, Gujarat, during successive wheat crop season. Seven bread wheat genotypes were used as parents for attempting the cross combinations. In first growing season, the parental genotypes were inter-crossed to produce five F_1s cross combinations. The crosses were designated as follows:- Cross I- GW 03-05 / FLW 4, Cross II-PBW343 / PBW 502, Cross III- GW 03-05 /CMH 84,Cross IV- GW 273/FLW4, Cross V-PBW443/CMH 84. The F_1 generations of all above five combinations were advanced at Ladol & Vijapur (Gujarat).

In addition, the backs cross populations (BC_1 and BC_2) of each combination were also obtained. The six populations, i.e. P_1, P_2, F_1, F_2, BC_1 and BC_2 of the five wheat crosses were grown during the third season 2012-13 in a randomized complete blocks design with three replicates in a two row for parents and F_{1s}, 4 row for F_2 generation, one row for each back cross 2.5 m long were planted. Ten plants were selected at random from P_1, P_2, F_1, BC_1, BC_2 and 60 plants from each F_2 generation in each replication to record the data on individual plant (Table 1). All recommended cultural practices were following to raise a normal healthy crop.

The mean value of each generation for each character was subjected to standard statistical analysis to test the difference among various generations studied as per standard procedures (Panse and Sukhatme 1985). Scaling test was used to check the adequacy of the additive-dominance model for different traits in each cross (Hayman and Mather 1955). The significance of any one of these scales was taken to indicate the presence of epistasis i.e. non-allelic interaction. In the presence of non-allelic interaction, various gene effects were estimated using 6 parameter model (Hayman, 1958). Cavalli (1952) devised the method "joint scaling test" which includes any combination of families at a time. The "un weighted least square method" developed by Hayman (1960) was followed to estimate the parameters: (m), (d) and (h). Here the weights are defined as the reciprocal of standard error. From these estimates, the expected generation means were calculated and compared with observed generation mean values using a Chi square test. A significant Chi square value indicates that model is not adequate and the non-allelic interactions are to be added in model. Expected means of all the generation were computed using the estimates of parameters from observed and expected value of each generation, the value of chi- square was calculated. When the Chi square value was with the acceptable probability limit (0.05) the model was considered as adequate.

Further, analysis of data was performed following six-parameter model (Hayman, 1958). At least, six generations are required for estimation of six parameters (m), (d), (i), (j) and (l). These were provided by the mean values of parents, F_1, F_2, B_1 and B_2 generations. Based on the direction of "h" and "l", we can classify the interaction as complementary or duplicate (Hayman and Mather, 1955) Complete dominance is indicated when potence ratio is equal to (+1) or (-1). Partial dominance is the case, when ratio between (+1) and (-1). Over-dominance indicated if ratio exceeds (± 1).

Results and Discussion

The values of potence ratio (Table 1), ranged from less than one (0.00) for tillers per plant in cross I and II, for spike length in cross II to more than one (112) for grain yield per plant in cross II, indicating the presence of over dominance and partial dominance respectively, for all the studied traits in all the five cross combinations. Data of mean of six populations (P_1, P_2, F_1, F_2, BC_1 and BC_2) for yield and yield contributing traits are presented in Table 3.

The results of generation mean for all the studied traits in all the five cross combinations showed significant difference among all six generation, indicating the existence of sufficient amount of genetic variability for these traits in the studied material. The mean values of F_1 population was higher than the respective parents for five traits namely days to maturity, tillers per plant, spike length seeds per plant, grain yield per plant in cross I and II; for three traits namely days to maturity, tillers per plant, spike length in cross III; for four traits plant height, tillers per plant, spike length, seed per plant in cross IV and for two traits days to maturity and spike length in cross V. The superior performance of F_1 population over the parents for mean value was also reported by Rahman and Hammad, 2009 and Zaazaa *et al.,* (2012). The mean value of the F_2 population was also higher than their better parent for four traits plant height, tillers per plant, spike length and seed per plant in cross I, II and III; for grain yield per plant in cross I and II; for days to 75% heading in cross I; for tillers per plant in cross IV and for spike length in cross V. The mean value of BC_2 population was higher than BC_1 population in all the five cross combinations for almost all the studied traits, indicating existence of appreciable amount of genetic variability for these character in the corresponding crosses.

Significant results of scaling tests parameters indicate inadequacy of the additive-dominance model to interpret the gene effects involved in the materials investigated (Mather and Jinks 1982). The Scaling test (A, B, C, D) and joint scaling test for five wheat cross combinations presented in Table 2.

The scaling test for all studied traits in the five crosses were statistically significant except days to 75% heading, days to maturity, 1000-grain weight and grain yield per plant in cross V; for tillers per plant in cross III, IV, cross V; for spike length and grain weight per spike in all five crosses showed non-significant of scaling test and also chi-square value of joint scaling test also indicated the six parameter model is valid to explain the nature of gene action for concerned traits. Meanwhile, A, B, or C, D scaling test were non-significant ones. Indicating the interactive model failed to explain the type of gene action in this case.

These results are similar to the earlier results reported by Zaazaa *et al.,* (2012) and Said (2014) for grain per spike, tiller per plant and grain yield per plant and Moussa, 2010 for days to 75% heading, days to maturity and plant height, seed per plant and 1000 grain weight by Lal *et al.,* 2013.

Table.1 Mean performance of P_1, P_2, F_1, F_2, BC_1, BC_2 for yield and its contributing traits in bread wheat (*Triticum aestivum* L.)

Cross	Generation	75 % DH	Days to maturity	Plant Height	Tiller/Plant	Spike Length	Grain/spike	Grain wt / spike	Seed/ plant	TGW	Grain Yield
I	P1	57.00 ± 0.58	117.00 ± 0.58	79.33 ± 2.73	8.00 ± 0.58	9.00 ± 0.58	49.33 ± 2.03	1.98 ± 0.14	351 ± 4.10	41.00 ± 1.15	13.66 ± 0.04
	P2	80.00 ± 20.8	123.00 ± 0.58	85.00 ± 0.58	8.00 ± 0.58	10.00 ± 0.58	44.33 ± 1.86	1.71 ±0.05	310.33 ± 8.35	39.00 ± 2.08	11.60 ±0.50
	F1 (P1xP2)	78.67 ± 0.88	125.00 ±0.58	83.00 ±1.15	11.33 ± 0.88	11.00 ± 0.58	45.00 ±1.15	1.26 ± 0.05	447.33 ±4.91	28.00 ± 0.58	12.58 ± 0.06
	F2	81.67 ±1.86	120.67 ± 0.88	89.00 ±3.06	12.67 ± 0.88	11.33 ± 0.67	47.67 ±0.33	1.24 ±0.03	565.33 ± 3 7.12	31.00 ± 0.58	14.19 ± 0.53
	F1xP1 (BC1)	63.67 ± 1.76	116.00 ± 1.00	80.67 ± 1.33	11.67 ± 0.88	11.00 ± 0.58	48.33 ±0.88	1.06 ±0.03	546.00 ±34.43	32.00 ±0.58	13.92 ±0.26
	F1xP2 (BC2)	81.33 ±1.76	126.33 ± 1.45	82.33 ±0.88	10.33 ± 0.33	10.67 ± 0.88	52.67 ± 1.76	1.39 ± 0.14	519.00 ±29.48	32.33 ± 0.88	17.59 ± 0.30
	LSD 0.05	4.78	3.04	5.51	1.84	2.22	4.90	0.25	77.35	3.26	1.15
	Potence ratio	0.88	1.66	0.29	0.00	3.00	-8.73	-4.14	5.72	-12.0	-0.048
II	P1	79.00 ± 0.58	124.33 ± 1.76	78.33 ± 1.45	10.33 ± 0.33	9.00 ± 0.58	43.00 ± 2.02	1.34 ± 0.11	422.67 ± 6.17	32.67 ± 0.33	13.60 ± 0.19
	P2	84.00 ± 0.58	125.00 ± 0.58	82.67 ± 2.33	10.33 ± 0.33	9.00 ± 0.58	41.00 ± 1.53	1.46 ± 0.06	386.00 ± 6.51	36.00 ± 0.58	13.62 ± 0.30
	F1 (P1xP2)	80.67 ± 1.20	128.00 ± 1.00	81.00 ± 3.21	13.00 ± 0.58	11.00 ± 0.58	41.33 ± 1.20	1.27 ±0.07	472.33 ± 2.40	31.33 ± 0.88	14.73 ± 0.35
	F2	76.00 ±0.58	125.00 ± 0.58	94.00 ± 1.53	15.67 ± 1.20	12.00 ± 0.58	35.00 ± 1.15	1.00 ± 0.01	488.33 ± 3.53	28.67 ± 0.67	13.70 ± 0.12
	F1xP1 (BC1)	78.67 ± 0.88	131.00 ± 0.58	84.00 ± 1.53	12.00 ± 0.58	10.00 ± 0.58	43.00 ± 0.58	1.08 ± 0.04	455.33 ± 8.84	30.67 ± 0.88	11.33 ± 0.12
	F1xP2 (BC2)	86.33 ± 1.86	126.67 ± 0.88	88.00 ± 3.61	11.00 ± 0.58	11.00 ± 0.58	50.00 ± 3.21	1.26 ± 0.07	467.20 ± 19.61	31.67 ± 0.88	11.87 ± 0.74
	LSD 0.05	3.60	3.15	7.54	1.74	1.72	5.10	0.15	30.20	1.90	1.04
	Potence ratio	-3.33	3.13	-1.67	0.00	0.00	-0.67	-2.16	3.70	-1.79	112.0
III	P1	58.67 ± 0.88	117.67 ±0.88	82.00 ± 1.73	11.33 ± 0.33	9.67 ± 0.33	44.33 ± 0.88	1.72 ±0.01	467.33 ± 11.62	38.67 ± 0.33	18.43 ± 0.36
	P2	84.00 ± 1.15	124.67 ± 1.20	105.67 ± 1.45	11.00 ± 0.58	8.00 ± 0.58	40.67 ± 0.33	1.24 ± 0.09	404.67 ± 21.42	29.67 ± 0.69	11.34 ±0.88
	F1 (P1xP2)	78.33 ± 0.88	127.33 ± 0.88	99.00 ± 1.15	12.67 ± 0.33	11.00 ± 0.58	36.67 ± 1.20	0.95 ± 0.03	428.00 ± 6.56	31.67 ± 0.33	11.15 ± 0.19
	F2	76.00 ± 0.58	128.33 ± 0.88	111.33 ± 1.20	12.33 ± 0.67	10.00 ± 0.58	41.67 ± 1.45	1.06 ± 0.03	468.33 ± 9.35	31.67 ± 0.33	11.74 ± 0.34
	F1xP1 (BC1)	77.33 ± 0.88	126.33 ± 0.88	95.67 ± 1.86	11.33 ± 0.88	10.00 ± 0.58	43.67 ± 2.40	1.05 ± 0.06	464.33 ± 8.41	31.00 ± 1.00	11.70 ± 0.30
	F1xP2 (BC2)	87.00 ± 0.58	126.00 ± 0.58	93.00 ± 1.53	13.33 ± 1.20	10.00 ± 0.33	38.67 ± 4.26	1.07 ± 0.12	466.33 ±5.36	32.67 ± 1.20	12.36 ± 0.10
	LSD 0.05	2.88	2.85	4.62	1.83	1.50	7.04	0.20	34.79	2.65	0.85
	Potence ratio	-5.66	2.66	-17.0	8.88	2.58	-3.18	-2.20	-0.25	-0.55	-1.05

Cross I: GW 03-05/FLW 4, II: PBW 343/PBW502, III: GW 03-05/CMH84

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Cross	Generation	75 % DH	Days to maturity	Plant Height	Tiller/Plant	Spike Length	Grain/spike	Grain wt / spike	Seed/ plant	TGW	Grain Yield
IV	P1	80.00 ± 2.52	127.33 ± 0.88	89.67 ± 2.33	9.67 ± 0.88	8.33 ± 0.88	38.33 ± 0.67	1.05 ± 0.06	339.67 ± 21.15	27.67 ± 1.20	8.91 ± 0.21
	P2	81.33 ±0.88	124.67 ± 0.33	86.67 ± 0.88	11.00 ± 0.58	10.67 ± 0.33	45.00 ± 1.53	1.54 ± 0.05	464.00 ± 4.04	33.67 ± 0.33	15.36 ± 0.05
	F1 (P1xP2)	81.33 ± 0.88	124.00 ±0.58	91.00 ±0.58	13.00 ±0.58	12.00 ± 0.58	39.00 ± 0.58	1.14 ± 0.33	470.33 ± 31.42	29.33 ± 0.33	13.74 ± 0.68
	F2	76.00 ± 0.58	125.33 ± 1.20	89.33 ± 1.20	12.00 ± 0.58	10.67 ± 0.33	38.00 ± 1.15	1.08 ± 0.03	430.67 ± 20.85	29.00 ± 0.33	12.17 ± 0.40
	F1xP1 (BC1)	82.00 ± 0.58	126.67 ± 0.88	86.67 ± 0.88	11.33 ± 0.33	11.00 ± 0.58	38.00 ± 2.31	0.91 ± 0.05	405.00 ± 7.51	30.00 ± 1.15	9.69 ± 0.11
	F1xP2 (BC2)	84.33 ± 1.20	128.00 ± 0.58	85.33 ± 1.20	11.67 ± 0.88	12.00 ± 0.58	35.33 ± 1.76	1.19 ± 0.09	338.00 ± 3.51	33.67 ± 0.88	11.31 ± 0.14
	LSD 0.05	4.18	2.46	4.24	1.78	1.22	3.95	0.16	51.80	2.69	0.90
	Potence ratio	0.01	-3.33	1.33	3.81	2.13	-0.79	-0.60	1.09	-0.45	0.49
V	P1	83.00 ± 1.53	125.13 ± 0.47	79.67 ±1.20	10.33 ± 0.33	7.67 ±0.33	35.33 ±2.60	1.10 ±0.08	349.00 ± 16.48	31.00 ± 1.00	10.16 ± 0.18
	P2	84.67 ± 1.45	125.80 ± 1.17	106.00 ± 1.53	12.00 ±0.58	8.67 ± 0.88	40.33 ± 0.67	1.15 ±0.01	442.33 ± 14.50	28.67 ± 0.33	12.24 ± 0.22
	F1 (P1xP2)	84.67 ±0.88	126.20 ± 0.81	81.00 ± 1.15	11.67 ± 0.33	10.67 ± 0.88	36.00 ± 2.00	1.05 ± 0.07	386.33 ± 3.53	29.00 ± 0.58	10.89 ± 0.11
	F2	82.33 ± 0.88	125.73 ± 0.87	94.33 ± 2.91	11.33 ± 0.88	11.00 ± 0.58	37.00 ± 2.08	1.07 ± 0.08	361.33 ± 12.88	29.33 ± 1.33	10.19 ± 0.18
	F1xP1 (BC1)	83.00 ± 1.53	125.20 ± 0.53	68.67 ± 0.67	11.67 ± 0.88	10.00 ± 0.58	31.33 ± 1.20	0.97 ± 0.04	341.33 ± 22.92	30.33 ± 0.33	10.18 ± 0.64
	F1xP2 (BC2)	86.67 ± 0.88	125.47 ± 0.87	105.33 ± 0.88	12.67 ± 0.88	10.67 ± 0.88	34.33 ± 1.45	0.99 ± 0.03	408.00 ± 13.11	29.33 ± 0.33	11.69 ± 0.45
	LSD 0.05	4.13	2.56	4.96	1.84	2.47	5.62	0.18	51.19	2.56	1.13
	Potence ratio	0.01	0.58	-24.99	0.61	0.00	-0.73	-2.33	-0.19	-0.70	-0.29

Cross IV: GW273/ FLW 4, V: PBW 443/ CMH 84

Table.2 Estimation of scaling test for yield and its contributing traits in bread wheat (*Triticum aestivum* L.)

Traits	Crosses		Scaling test				Joint scaling test		
		A	B	C	D	m	d	h	^{2}
75 Days to	I	-8.00* ± 3.68	4.00 ± 4.18	32.33** ± 7.93	18.33** ± 4.47	69.19** ± 0.64	-12.73** ± 0.63	10.86** ± 1.18	76.720**
heading	II	-2.33 ± 2.21	8.00* ± 3.94	-20.33** ± 3.43	-13.00**± 2.35	81.23** ± 0.64	-3.53**± 0.63	-1.09 ± 1.18	39.638**
	III	17.66** ± 2.16	11.66**± 1.85	4.66 ± 3.24	-12.33** ± 1.56	73.19** ± 0.64	-12.06**± 0.63	8.86** ± 1.18	68.276 **
	IV	2.66 ± 2.90	6.00* ± 2.70	-20.00** ± 3.94	-14.33** ± 1.76	80.58** ± 0.64	-1.00* ± 0.63	0.58 ± 1.20	35.421**
	V	-1.66 ± 3.52	4.00 ± 2.44	-7.66 ± 4.47	-5.00* ± 2.49	83.74** ±0.64	-1.39* ± 0.63	0.74 ± 1.18	7.466
Days to	I	-10.00** ± 2.20	4.67 ± 3.01	-7.33 ± 3.80	-1.00 ± 2.49	119.47** ± 0.64	-4.46 ± 0.63	4.47** ± 1.18	24.854**
Maturity	II	9.66** ± 2.33	0.33 ± 2.10	-5.33 ± 3.57	-7.66** ± 1.56	125.09** ± 0.64	0.60 ± 0.63	3.76** ± 1.18	20.616**
	III	7.66** ± 2.16	0.00 ± 0.00	16.33** ± 4.21	4.33* ± 2.05	122.09** ± 0.64	-2.73** ± 0.63	7.09** ± 1.18	18.838 **
	IV	2.00 ± 2.05	7.33**± 1.33	1.33 ± 5.03	-4.00 ± 2.62	126.58** ± 0.64	0.80 ± 0.63	-1.41 ± 1.19	9.432*
	V	-0.93 ± 1.41	-1.06 ±2.24	-0.40 ± 4.02	0.80 ± 2.00	125.34** ± 0.64	-0.32 ±0.63	0.60 ± 1.19	0.298
Plant height	I	-1.00 ± 3.98	-3.33 ±2.18	25.67* ±12.74	15.00* ± 6.31	82.66** ± 0.64	-2.60** ± 0.63	1.33 ± 1.18	40.877**
	II	8.66 ±4.66	12.33 ± 8.23	53.00** ± 9.28	16.00** ± 4.96	83.29** ± 0.64	-2.53** ± 0.63	3.29** ± 1.18	132.491**
	III	10.33* ± 4.25	-18.66** ± 3.57	59.66** ± 5.79	34.00** ± 3.39	95.09** ± 0.64	-8.93** ± 0.63	6.43** ± 1.18	294.894 **
	IV	-7.33* ± 2.98	-7.00* ± 2.62	-1.00 ± 5.53	6.66* ± 2.82	87.29** ± 0.64	1.46* ±0.63	1.96* ± 1.19	16.047**
	V	-23.33** ± 2.13	23.66** ± 2.60	29.66* ±12.00	14.66* ± 5.91	93.72** ± 0.64	-17.86** ± 0.63	-10.94** ± 1.18	265.772**
Tiller / plant	I	4.66** ± 1.56	2.00* ±0.94	12.00** ± 3.82	2.66 ± 1.88	8.07** ± 0.64	0.26 ± 0.63	3.41** ± 1.18	8.188*
	II	0.66 ± 1.37	-3.00* ± 1.24	13.66** ± 2.51	8.00 ** ± 1.41	9.76** ± 0.64	0.53 ± 0.63	2.43* ± 1.18	12.805*
	III	-0.66 ± 1.33	2.66 ± 2.53	2.00 ± 1.88	0.00 ± 1.49	10.50** ± 0.64	0.019 ± 0.63	1.84 ± 1.18	1.464
	IV	-0.33 ± 1.05	-2.33 ± 1.33	2.00 ± 2.98	2.33 ± 1.49	9.56** ± 0.64	-0.46 ± 0.63	2.23 ± 1.20	1.416
	V	1.33 ±1.91	3.33 ± 1.97	-1.33 ± 2.74	-3.00 ± 1.69	10.56** ± 0.64	-0.86 ±0.63	0.23 ± 1.18	2.527
Spike length	I	2.00 ± 1.41	0.33 ± 1.94	4.33 ± 3.01	1.00 ± 1.69	9.76** ± 0.64	-0.33 ± 0.63	1.76 ± 1.18	1.238
	II	0.00 ± 0.00	2.00 ± 1.41	8.00** ± 2.70	3.00* ± 1.41	9.35** ± 0.64	-0.20 ± 0.63	2.35 ± 1.18	3.311
	III	0.66 ± 1.33	1.00 ± 0.81	0.33 ± 2.66	0.00 ± 1.29	8.86** ± 0.64	0.66 ± 0.63	2.19 ± 1.18	0.287
	IV	1.66 ± 1.56	1.33 ± 1.33	-0.33 ± 2.00	-1.66 ± 1.05	9.66** ± 0.64	-1.13* ± 0.63	2.66** ± 1.18	0.788
	V	1.66 ± 1.49	2.00 ± 2.16	6.33* ± 3.05	1.33 ± 1.56	8.56** ± 0.64	-0.53 ± 0.63	2.90** ± 1.21	2.138

A and B = presence of all three type of gene interaction), C= D x D type interaction, D = A x A type interaction, m= mean effect, d= additive gene effect, h= dominance gene effect

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Traits	Crosses	Scaling test				Joint scaling test			
		A	**B**	**C**	**D**	**m**	**d**	**h**	l
Grains / spike	I	2.33 ± 2.92	16.00** ± 4.14	7.00 ±3.82	-5.66** ± 2.08	48.11** ± 0.64	1.13 ± 0.63	-0.54 ± 1.18	42.723**
	II	1.66 ± 2.62	17.66* ± 6.71	-26.66** ±5.79	-23.00** ± 4.00	42.35** ± 0.64	-0.60 ± 0.63	-0.31 ± 1.18	115.178**
	III	6.33 ± 5.03	0.00 ± 0.0	8.33 ± 6.35	1.00 ± 5.68	43.11** ± 0.64	2.46** ± 0.63	-5.21** ± 1.18	8.501*
	IV	-1.33 ± 4.70	-13.33** ±3.88	-9.33 ± 5.04	2.6 ± 3.71	40.52** ± 0.64	-2.13** ± 0.63	-3.80** ± 1.19	30.243**
	V	-8.66* ± 4.06	-7.66* ± 3.59	0.33 ± 9.62	8.33 ± 4.57	36.88** ± 0.64	-2.60** ± 0.63	-2.78** ± 1.19	21.923**
Grain weight/ spike	I	-1.12** ± 0.16	-0.20 ± 0.29	-1.24** ± 0.21	0.04 ± 0.15	1.72**± 0.64	0.04 ± 0.63	-0.69 ± 1.18	0.232
	II	-0.45** ± 0.15	-0.21 ± 0.16	-1.32** ± 0.19	-0.32** ±0.08	1.32* ± 0.64	0.085 ±0.63	-0.21 ± 1.19	0.093
	III	6.33 ± 5.03	0.00 ± 8.60	8.33 ± 6.35	1.00 ± 5.68	1.42** ± 0.64	0.18 ± 0.63	-0.59 ± 1.18	0.061
	IV	-0.37** ± 0.11	-0.27 ± 0.18	-0.55 ± 0.14	0.05 ± 0.12	1.23* ± 0.64	-0.23 ± 0.63	-0.19 ± 1.19	0.034
	V	-0.21 ± 0.14	-0.21 ± 0.10	-0.07 ± 0.37	0.17 ± 0.17	1.09* ± 0.64	-0.025 ± 0.63	-0.099 ± 1.18	0.0138
Seed/ plant	I	293.33**± 69.15	280.33** ± 59.75	704.99**± 149.10	65.66 ± 86.98	385.31** ± 0.64	21.80** ± 0.63	170.98** ± 1.19	34374.200**
	II	15.66 ±18.87	76.06 ±39.82	200.00**± 17.39	54.13* ±22.63	415.61** ± 0.64	12.29** ±0.63	79.27** ±1.18	2294.853**
	III	33.33 ± 21.47	100.00** ± 24.83	145.33**± 46.52	6.00 ± 21.19	448.11** ± 0.64	24.66** ± 0.63	4.117** ± 1.19	2114.602**
	IV	0.00 ± 0.00	-258.33**± 32.45	-21.67 ± 106.63	118.33**± 42.51	385.99** ± 0.64	-36.33** ± 0.63	52.67** ± 1.19	11848.610**
	V	-53.00 ± 48.84	-12.67 ± 30.17	-119.00*± 56.42	-26.67 ± 36.88	388.47** ± 0.64	-50.53** ± 0.63	-16.86** ± 1.18	895.576**
1000 grain weight	I	-5.00** ± 1.73	-2.33 ± 2.78	-12.00** ± 3.51	-2.33 ±1.56	39.21** ± 0.64	0.73 ±0.63	-12.78** ± 1.19	8.590*
	II	-2.66 ±2.00	-4.00* ± 1.97	-16.66** ±3.21	-5.00** ±1.82	33.45** ± 0.64	-1.53* ± 0.63	-3.88** ± 1.19	13.167*
	III	-8.33** ± 2.05	4.00 ± 2.58	-5.00* ± 1.76	-0.33 ± 1.69	33.76** ± 0.64	3.26** ±0.63	-2.90** ± 1.19	17.060**
	IV	3.00 ± 2.62	4.33** ± 1.82	-4.00** ± 1.41	-5.67** ± 1.45	30.98** ± 0.64	-3.13** ± 0.63	-1.02 ± 1.20	6.645*
	V	0.67 ± 1.33	1.00 ± 0.94	-0.33 ± 5.55	-1.00 ± 2.70	29.92** ± 0.65	1.13* ±0.63	-0.74 ± 1.18	0.266
Grain yield per plant	I	1.59** ± 0.53	10.99** ±0.78	6.35** ± 2.17	-3.12** ± 1.13	13.55** ± 0.64	0.09 ± 0.63	0.88 ± 1.18	20.198**
	II	-5.67**± 0.46	-4.62** ± 1.54	-1.90* ± 0.92	4.19** ± 0.78	12.95** ± 0.64	-0.114 ± 0.63	0.458 ± 1.18	8.000*
	III	-6.18** ± 0.72	2.23** ±0.39	-5.11** ±1.46	-0.58 ± 0.74	14.50** ± 0.64	2.70** ± 0.63	-4.12** ± 1.20	8.794*
	IV	3.27** ± 0.74	-6.49** ± 0.73	-3.09 ± 2.10	3.33** ± 0.82	11.46** ± 0.64	-2.90** ± 0.63	0.94 ± 1.18	7.909*
	V	-0.70 ± 1.29	0.24 ± 0.92	-3.43** ± 0.80	-1.49 ± 0.85	11.07** ± 0.64	-1.13* ± 0.62	-0.43 ± 1.19	0.644

A and B = presence of all three type of gene interaction), C= D x D type interaction, D= A x A type interaction, m= mean effect, d= additive gene effect,h= dominance gene effect

Table.3 Estimation of gene effect for yield and its contributing traits in bread wheat (*Triticum aestivum* L.)

Traits	Crosses	Genetic parameters					
		m	**[d]**	**[h]**	**[i]**	**[j]**	**[l]**
75 Days to heading	I	81.66**± 1.85	-17.66 ** ± 2.49	-26.49** ± 9.05	-36.66** ± 8.94	-6.16* ± 2.71	40.99** ± 12.74
	II	76.00**± 0.57	-7.67** ± 2.05	25.17** ± 4.88	26.00** ± 4.71	-5.17* ± 2.09	-31.67** ± 8.90
	III	76.00**± 0.57	-9.67** ± 1.05	31.67** ± 3.32	24.67** ± 3.12	3.00* ± 1.28	-54.00** ± 5.32
	IV	76.0** ± 0.58	-2.33* ± 1.33	29.33** ± 3.87	28.67** ± 3.52	-1.67 ± 1.88	-37.33** ± 6.63
	V	-	-	-	-	-	-
Days to Maturity	I	120.66** ± 0.88	-10.33** ± 1.76	7.00 ± 5.03	2.00 ± 4.98	-7.33** ± 1.81	3.33 ± 8.01
	II	125.00** ± 0.58	4.33** ± 1.05	18.67** ± 3.41	15.33** ± 3.12	4.67** ± 1.40	-25.33** ± 5.53
	III	128.33** ± 0.88	0.33 ± 1.05	-2.50 ± 4.26	-8.67* ± 4.10	3.83** ± 1.29	0.99 ± 5.96
	IV	125.33** ± 1.20	-1.33 ± 1.05	5.99 ± 5.30	7.99 ± 5.24	-2.67 ± 1.15	-17.33** ± 6.56
	V	-	-	-	-	-	-
Plant height	I	89.00** ± 3.05	-1.67 ± 1.59	-29.16 ± 12.76	-30.00* ± 12.63	1.16 ± 2.12	34.33* ± 14.25
	II	94.00** ± 1.52	-4.00 ± 3.91	-31.50** ± 10.53	-32.00** ± 9.93	-1.83 ±4.14	11.00 ± 18.20
	III	111.33** ± 1.20	2.67 ± 2.40	-62.83** ± 6.98	-68.00** ± 6.79	14.50** ± 2.65	76.33** ± 11.22
	IV	89.33** ± 1.20	1.33 ± 1.49	-10.50* ± 5.28	-13.33* ± 5.65	-0.16 ±1.94	27.67** ± 8.13
	V	94.33** ± 2.90	-36.67** ± 1.10	-41.17** ± 11.92	-29.33** ± 11.83	-23.50** ± 1.47	29.00** ± 12.79
Tiller / plant	I	11.67** ± 0.88	1.33* ± 0.67	-2.67 ± 3.84	-5.33 ± 3.77	1.33 ± 0.81	-1.33 ± 4.67
	II	14.00** ± 0.58	2.00* ± 0.82	-13.83** ± 2.87	-16.00** ± 2.82	1.83* ± 0.89	18.33** ± 4.12
	III	-	-	-	-	-	-
	IV	-	-	-	-	-	-
	V	-	-	-	-	-	-
Spike length	I	-	-	-	-	-	-
	II	-	-	-	-	-	-
	III	-	-	-	-	-	-
	IV	-	-	-	-	-	-
	V	-	-	-	-	-	-

Cross I: GW 03-05/FLW 4, II: PBW 343/PBW502, III: GW 03-05/CMH 84, IV: GW273/ FLW 4, V: PBW443/CMH 84
*, ** Significant at 5% and 1% respectively

Contd…

Traits	Crosses	Genetic parameters					
		m	[d]	[h]	[i]	[j]	[l]
Grains / spike	I	47.67** ± 0.33	-4.33* ±1.97	9.49* ±4.53	11.33** ± 4.16	-6.83** ± 2.40	-29.67** ± 8.76
	II	35.00** ± 1.15	-7.00* ± 3.26	45.33** ± 8.18	46.00** ± 8.00	-8.00** ± 3.50	-65.33** ± 14.29
	III	41.66** ±1.45	5.00 ± 4.88	-7.83 ± 11.44	-2.00 ± 11.37	3.17 ± 4.91	-4.33 ± 20.55
	IV	38.00** ± 1.15	2.67 ± 2.90	-8.00 ± 7.49	-5.33 ± 7.42	6.00* ± 3.02	20.00* ± 12.67
	V	37.00** ± 2.08	-2.99 ± 1.88	-18.50* ± 9.45	-16.67* ± 9.14	-0.50 ± 2.31	33.00** ± 12.22
Grain weight / spike	I	-	-	-	-	-	-
	II	-	-	-	-	-	-
	III	-	-	-	-	-	-
	IV	-	-	-	-	-	-
	V	-	-	-	-	-	-
Seed/ plant	I	56.53**± 37.12	27.00 ± 45.32	-14.83 ± 174.10	-131.33 ± 173.97	6.50 ± 45.56	-442.33** ± 234.74
	II	488.33** ± 3.52	-11.87 ± 21.51	-40.27 ± 45.56	-108.27* ± 45.27	-30.19 ± 21.97	16.53 ± 87.78
	III	468.33** ± 9.35	-2.00 ± 9.97	-20.00** ± 44.59	-12.00 ± 42.39	-33.33* ± 15.74	-121.33* ± 61.30
	IV	430.67** ± 20.85	67.00** ± 8.28	-168.17**± 91.29	-236.67** ± 85.03	129.17**± 13.58	495.00** ± 111.67
	V	361.33** ± 12.87	-67.66** ± 26.41	43.83 ± 74.67	53.33 ± 73.77	-20.17 ± 28.59	12.33 ± 119.76
1000 grain weight	I	31.00** ± 0.58	-0.33 ± 1.05	-7.33* ± 3.39	4.67 ± 3.12	-1.33 ± 1.58	2.67 ± 5.48
	II	28.66** ± 0.67	-1.00 ± 1.24	7.00 ± 3.76	10.00** ± 3.65	0.67 ± 1.25	-3.33 ± 5.93
	III	31.66** ±0.33	-1.67 ± 1.56	-1.83 ± 3.44	0.67 ± 3.39	-6.17** ± 1.63	3.67 ± 6.49
	IV	29.00** ± 0.33	-3.67** ± 1.45	10.00** ± 2.99	11.33** ± 2.90	-0.67 ± 1.58	-18.67** ± 5.98
	V	-	-	-	-	-	-
Grain yield per plant	I	14.19** ± 0.53	-3.67** ± 0.40	6.19** ± 2.27	6.24** ±2.26	-4.69** ± 0.47	-18.83** ± 2.70
	II	13.69**± 0.12	-0.53 ± 0.74	-7.27** ± 1.61	-8.38** ± 1.56	-0.52 ± 0.76	18.68** ± 3.12
	III	11.74** ± 0.34	-0.67* ± 0.31	-2.59 ± 1.51	1.15 ± 1.48	-4.21** ± 0.38	2.80 ± 1.93
	IV	12.16** ± 0.40	-1.62** ± 0.17	-5.06** ± 1.77	-6.67** ± 1.64	1.61** ± 0.20	16.43** ± 2.21
	V	-	-	-	-	-	-

Cross I: GW 03-05/FLW 4, II: PBW 343/PBW502, III: GW 03-05/CMH 84, IV: GW273/ FLW 4, V: PBW443/CMH 84
*, ** Significant at 5% and 1% respectively

Estimates of the six parameters *i.e.* additive (d), dominance (h), additive x additive (i), additive x dominance (j) and dominance x dominance (l) and F_2 mean (m) are presented in Table 3. The results indicated that the mean effect (m) were highly significant for all studied traits in all five wheat crosses, indicating that these characters are quantitatively inherited. The value of additive gene effects (d) were positive significant for days to maturity and tillers per plant in the cross II; for tillers per plant in cross I, for seed per plant in the IV cross. The present results indicated that selection could be effective for these traits in early generations. Meanwhile, the negative significant value were reported for grain yield per plant in all crosses except cross II; for days to 75% heading in all five crosses; days to maturity in the cross I; for plant height in the cross V; grains per spike in the cross I and II; for seeds per plant and 1000 grain weight in the cross V and cross IV respectively.

These results indicated that the breeding materials used in this study have decreasing alleles for these traits and selection to improve it could be effective except for plant height if shorter cultivars are desired (Lal *et al.*, 2013). With regard to the dominance gene effect (h) were found to be positive and highly significant for days to 75% heading in cross II, III and IV; days to maturity and grains per spike in cross II, for grain yield per plant and grains per spike in cross I. These results indicated the presence of dominance gene effect in the inheritance of these characters. The negative values of (h) were recorded for plant height and seed per plant in the all five crosses; for days to 75% heading and 1000 grain weight in cross I; tillers per plant and grain yield per plant in cross II; grains per spike in cross V and for grain yield per plant in cross IV. These results indicated that the dominance gene action is responsible for the inheritance of these traits. The similar results were also reported by Khattab *et al.,* 2010 and Lal *et al.,* 2013. With respect to additive x additive type of gene effect (i) positive significant to positive highly significant effect were detected for days to 75% heading in cross II, III and IV; for days to maturity in cross II therefore, early generation selection for these traits might be effective for improvement of wheat crop. Positive significant value of gene effect (i) were recorded for grains per spike in cross I and II; for 1000 grain weight in cross II and IV; for grain yield per plant in cross I. Similar results to the present study were earlier reported by Zaazaa *et al.,* 2012. Positive and significant values of additive x dominance type of gene effect (j) was recorded for days to 75% heading in cross III; for days to maturity in cross II and III; for plant height in cross III; for tillers per plant in cross II; for grain per spike and seed per plant in cross III and grain yield per plant in cross IV.

However, the negative sign of interaction in same cases also suggested dispersion of gene in the parents. Similar findings have been reported by Said, 2014 for grain yield per plant and (Rahman and Hammad, 2009) for grains per spike and other traits. Concerning the type of dominance x dominance (l) positively significant effect were observed for days to 75% heading, plant height in cross I; for plant height in cross III, IV and V; for tillers per plant in cross II; for grains per spike in cross IV and V; seed per plant, grain yield per plant in cross IV. Positive and significant results confirm the importance of dominance x dominance gene interaction in the genetic system which controls these characters. Negative and significant value were recorded for days to 75 % heading in cross II, III and IV; for days to maturity in cross II and IV; for grains per spike in all crosses except cross IV and V; seed per plant and grain yield per plant in cross I and for seed per plant in cross III. These results suggest the scope of heterosis breeding for the development of superior populations. The above results are conformity with the finding of Zaazaa *et al.,* 2012 and Said, 2014 and Ataei *et al.,* 2017

The genetic analysis based on present investigation revealed that both additive and non-additive components of genetic variance are important. All the characters studied were under the control of both additive and dominance gene effects for most of the crosses. Whenever, traits are reflecting by both additive and non-additive gene action from one generation to others might be due to coupling or repulsion linkage. This may be helpful to accumulate desirable genes and facilitate breaking of undesirable linkage in wheat crop.

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