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HETEROSIS ESTIMATES IN F_2 DIALLEL POPULATION OF SPRING WHEAT AT TWO DIFFERENT CULTURAL CONDITIONS

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Abstract

Spring wheat *(Triticum aestivum* L.) varieties Gaurab, Kanchan, Balaka, Sonora, Protiva, Pavon, and Anza were used as parent materials to estimate heterosis in a set of 7 × 7 diallel crosses. The diallel trial was carried out for seven parental material and their 21 F_2 progenies under two contrasting cultural conditions for different yield and yield contributing characters. Cultural conditions I is provided by the BARI recommended doses of fertilizer and irrigation, and 2 have no fertilizer but two irrigations once at crown root initiation stage and twice at panicle initiation stage. Heterosis was measured as i) Relative heterosis and ii) Heterobeltiosis. The result of relative heterosis revealed cross Sonora × Anza exhibited superior performance for grain yield/plot in environment-i. Desirable negative heterosis was observed in cross Balaka × Anza in environment-I and Pavon x Anza in environment-2 for days to 50% heading character. For days to maturity, desirable negative heterosis was found in cross Pavon x Anza in both cultural environments. Estimate of heterobeltiosis for different yield contributing characters showed that cross Sonora x Anza exhibited highest heterosis for grain yield/plant in environment-1 and Kanchan x Balaka in environment-2. Cross Pavon x Anza exhibited superior relative heterosis and heterobeltiosis for 100-grain weight in both cultural environments. By comparing two cultural conditions, it was found that 1 is better than 2 for all the characters.

Keywords: Relative heterosis, heterobeltiosis, spring wheat, F_2 generation, GxE interaction.

Introduction

In Bangladesh, wheat *(Triticum aestivum* L.) is an important cereal crop next to rice in both acreage and production constituting 15.2% of the staple cereal food. In the year 2003, wheat was cultivated in 208765 thousand hectares around the world with a total production of 556349 thousand mt with an average yield being 2.67 t/ha (FAO, production Yearbook, 2003). In Bangladesh, wheat has been cultivated in an area of 988 thousand acres with the total production of 737

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thousand mt in the year 2006-2007 (BBS, 2008). The average yield of wheat in Bangladesh is 3.8 t/ha, which is very low compared to other wheat growing countries like UK, France, and Belgium where average yields are 6.4, 6.8, and 8.19 t/ha, respectively (FAO Statistical Yearbook, 2007-2008). The climate and geographical location (environments) of Bangladesh favours wheat cultivation. So, it has immense scope in Bangladesh context as its cultivation not only plays role in crop diversification but also reduce water requirement for irrigation and to eradicate malnutrition within the country. In a plant breeding programme, potential genotypes are usually evaluated in different environments before selecting desirable ones. To identify such genotype, G × E interaction is of major concern to a breeder, because such interaction confounds their relative productiveness in different environments (Eagles and Frey, 1977). Heterosis helps to identify the potential genotypes or crosses to develop high potential cultivars for different agronomic traits. The present research work, therefore, was undertaken to estimate the magnitude and direction of relative heterosis and heterobeltiosis with the purpose of utilizing the information in wheat breeding programme.

Materials and Method

The research work was carried out at the experimental farm of the Department of Genetics and Plant Breeding, Bangladesh Agricultural University (BAU), Mymensingh during the period from 15th November 2005 to 19th March 2006 under two cultural environments. Seven spring wheat genotypes, such as Gaurab, Kanchan, Balaka, Sonora, Protiva, Pavon, Anza and their 21 F_2 progeny, derived from F_1 diallel without reciprocals were included in the experiment. The experiment was set up in a Randomized Complete Block Design (RCBD) with three replications. Seeds of each genotype were sown in one-meter long row representing a plot. Row to row distance was 40 cm and plants were maintained as continuous. The experimental site was differentiated by cultural practices, one representing environment-1 with recommended doses of fertilizers (viz., urea@220 kg/ha, TSP@ 180kg/ha, MP@50 kg/ha, Gypsum@110 kg/ha and compost@ 9 t/ha) and irrigation (viz., two times at crown root initiation stage and at panicle initiation stage) as recommended by BARI. The other was environment-2 which had no fertilizer but one time irrigation only at panicle initiation stage. Considering the poor growth of the plants, only urea @ 110 kg/ha was applied as top dressing in environment-2. All the plants from each plot in each replication were considered for collecting data. Heading and maturity data were recorded from the standing crops and other characters were recorded in the field laboratory after harvest. The mean value of mid parent was calculated by adding the value of two parental lines, which is divided by two. The amount of heterosis was calculated by comparing the mean of F_2 progeny/generation over mid parental value and over better parental value in respect of a particular character using the formula (Falconer and Mackay, 1996).

Table 1a. Mean values of yield and associated characters recorded in parental and F_2 population of a 7 × 7 diallel cross in wheat grown in cultural Env-1.

Genotypes	Days to 50 % heading	Days to maturity	Spikes/ plant	Plant height (cm)	Spikelets/ spike	Grains/ spike	100-grain wt (g)	Grain yield/ plant (g)	Harvest index
Gaurab	51.33	99.00	4.00	73.94	14.67	23.33	5.08	4.28	28.79
Kanchan	67.00	102.67	6.33	79.61	18.00	33.33	3.43	4.39	22.59
Balaka	52.33	98.00	5.33	66.89	16.33	28.00	4.13	4.00	26.64
Sonora	48.33	96.33	3.67	68.68	16.67	33.33	3.21	2.70	24.24
Protiva	70.33	102.00	5.67	84.68	17.00	33.67	3.69	4.61	24.29
Pavon	68.00	103.33	6.33	78.43	15.33	34.67	3.40	3.97	23.38
Anza	84.00	117.67	5.67	72.46	17.00	26.00	2.52	2.86	15.27
Gaurab×Kanchan	56.00	100.33	4.67	79.54	15.67	26.00	4.64	4.27	23.79
Gaurab×Balaka	47.00	100.00	6.00	71.26	14.67	26.33	4.31	4.41	28.20
Gaurab×Sonora	51.00	98.33	5.67	73.60	15.33	34.00 -	4.21	4.68	25.88
Gaurab×Protiva	54.67	99.67	5.33	76.53	15.33	25.33	4.69	5.32	26.94
Gaurab×Pavon	53.67	99.67	4.67	72.72	14.67	30.00	4.19	3.61	25.28
Gaurab×Anza	59.00	102.00	6.00	75.12	15.67	29.33	3.57	4.23	23.04
Kanchan×Balaka	51.67	102.33	6.33	76.14	17.67	34.67	3.58	4.64	23.37
Kanchan×Sonora	54.33	102.00	5.00	77.25	16.00	31.33	3.49	3.97	23.43
Kanchan×Protiva	64.00	102.00	6.33	83.89	17.00	30.33	3.38	5.01	23.49
Kanchan×Pavon	64.33	101.67	7.00	84.67	18.00	32.33	3.58	4.81	23.88
Kanchan×Anza	6133	102.00	5.67	78.20	15.33	27.67	3.64	3.77	21.28
Balaka×Sonora	50.33	100.00	4.67	68.09	16.00	31.67	4.01	3.13	23.36
Balaka×Protiva	57.33	100.33	6.00	77.26	16.67	28.00	3.55	4.16	21.88
Balaka×Pavon	54.33	100.00	5.00	83.96	17.00	31.33	3.74	3.67	21.63
Balaka×Anza	54.00	101.33	6.33	74.29	14.67	27.00	3.79	4.06	20.83
Sonora×Protiva	61.67	100.67	6.33	76.14	16.67	33.33	3.40	4.58	24.13
Sonora×Pavon	62.00	100.67	5.00	78.37	18.00	39.33	2.79	3.50	17.96
Sonora×Anza	55.00	101.67	6.33	76.94	15.33	32.00	2.95	4.24	23.74
Protiva×Pavon	64.33	102.33	6.00	79.80	17.00	29.67	3.27	3.45	20.23
Protiva×Anza	66.00	99.67	6.33	76.06	16.00	27.67	2.84	3.21	20.01
Pavon×Anza	70.33	98.33	5.33	68.36	15.67	28.33	3.76	3.64	24.47
SE(±)	1.31	1.10	0.55	4.83	0.58	1.69	0.06	0.29	2.20
Mean	59.06	100.14	5.61	76.17	16.19	30.29	3.67	4.04	23.29

Table 1b. Mean values of yield and associated characters recorded in parental and F_2 population of a 7×7 diallel cross in wheat grown in cultural Env-2.

Genotypes	Days to 50 % heading	Days to maturity	Spikes/ plant	Plant height (cm)	Spikelets/ spike	Grains/ spike	100-grain wt (g)	Grain yield/ plant (g)	Harvest index
Gaurab	59.67	101.00	4.00	66.62	12.67	22.00	3.36	2.30	21.69
Kanchan	73.67	103.00	4.67	72.26	15.67	22.33	2.46	2.33	15.42
Balaka	62.67	99.00	5.00	59.05	13.67	21.00	3.07	2.22	19.44
Sonora	54.00	99.67	5.00	59.43	14.00	29.67	2.87	2.00	21.47
Protiva	73.33	104.33	4.67	67.92	15.33	20.33	2.63	2.15	17.40
Pavon	72.67	104.00	4.33	71.68	15.00	27.33	2.64	2.13	18.51
Anza	81.67	117.00	5.67	65.69	16.00	27.33	2.24	2.40	16.22
Gaurab×Kanchan	62.67	101.00	5.00	67.14	14.00	20.33	3.65	2.31	18.52
Gaurab×Balaka	50.33	99.67	5.33	62.61	11.67	16.67	3.72	2.99	23.35
Gaurab×Sonora	54.33	100.67	5,33	66.42	14.00	30.00	3.58	2.95	22.12
Gaurab×Protiva	60.00	101.67	5.00	68.99	14.00	22.00	3.61	2.62	20.26
Gaurab×Pavon	60.67	l02.33	5.33	67.81	14.67	25.67	3.43	2.96	20.08
Gaurab×Anza	61.00	101.33	5.33	64.93	15.33	25.67	2.91	3.10	22,36
Kanchan×Balaka	55.00	100.00	4.33	65.18	15.33	24.33	3.04	3.26	20.86
Kanchan×Sonora	62.33	101.33	5.00	66.28	14.67	29.00	3.34	3.16	20.50
Kanchan×Protiva	68.00	104.67	4.67	69.19	17.67	26.67	2.79	2.56	17.75
Kanchan×Pavon	70.33	103.67	5.00	71.18	16.00	21.00	2.42	2.17	16.67
Kanchan×Anza	70.33	103.67	5.33	69.56	13.67	26.67	2.35	2.38	16.92
Balaka×Sonora	53.00	100.33	5.00	63,52	16.00	32.33	3.01	2.93	23.04
Balaka×Protiva	65.00	103.00	4.00	65.10	17.00	25.67	2.72	2.24	16.53
Balaka×Pavon	63.00	102.33	4.00	70.28	14.33	26.00	3.11	2.59	19.60
Balaka×Anza	56.33	102.00	5.33	62.66	12.33	20.67	3.31	2.45	20.61
Sonora×Protiva	64.00	100.67	4.67	67.85	14.67	27.33	2.94	2.88	24.84
Sonora×Pavon	65.00	103.00	3.33	67.04	15.67	32.67	2.61	2,16	20.31
Sonora×Anza	64.67	100.33	3.67	65.87	15.00	30.33	2.46	2.11	18.67
Protiva×Pavon	69.33	103.33	3.33	74.46	15,33	28.33	2.84	2,45	18.58
Protiva×Anza	68.33	102.67	5.33	68.62	15.00	24.33	2.51	2.14	15.75
Pavon×Anza	58.00	99.67	4.67	62.40	14.33	27.67	3.37	2.62	22.62
SE (±)	1.05	0.67	0.27	4.48	0.56	6.77	0.05	0.14	2.35
Mean	63.65	102.33	4.73	66.77	14.75	25.48	2.96	2.52	19.65

i) Percent of heterosis over mid parent (MP)

$$\text{Relative heterosis} = \frac{F_1 - \overline{MP}}{\overline{MP}} \times 100$$

ii) Percent of heterosis over better parent (BP)

$$\text{Heterobeltiosis} = \frac{F_1 - \overline{BP}}{\overline{BP}} \times 100$$

Results and Discussion

Relative heterosis in spring wheat

Relative heterosis was estimated for individual crosses in different yield contributing characters over mid parent (MP) under two contrasting cultural environments are presented in Table 2.The result showed cross Balaka x Anza (-20.78%) in environment-1 and Pavon x Anza (-24.84%) in environment-2 exhibited superior relative heterosis for days to *50%* heading as negative heterosis is desirable for heading. Deshpandae and Nayeem (1999) studied relative heterosis in spring wheat and reported -13.5 to 10.2% for days to flowering. For days to last flowering and days to maturity characters, Pavon x Anza performed as the best crosses in both environments.

Regarding other characters, the crosses exhibited superior performance (relative heterosis) in F_2 generation were Gaurab × Sonora in environment-I and Gaurab × Pavon in environment-2 for spikes/plant. Garuab × Sonora in environment-1 and Sonora × Anza in environment-2 for spike length; Balaka × Pavon in both environments for plant height; Sonora x Pavon in environment-I and Balaka x Protiva in environment-2 for spikelets/spike, Gaurabx Sonora in environment-I and Balaka × Sonora in environment-2 for grains/spike; Pavon × Anza in both environments for 100-grain weight; Sonora × Anza in environment-1 and Kanchan × Sonora in environment-2 for grain yield/plant, Sonora × Anza in environment-I and Gaurab × Pavon in environment-2 for grain yield/plot and Pavon × Anza in both environments for harvest index. Rahman *et al.* (2000) estimated significant average heterosis only for harvest index.

Heterobeltiosis in spring wheat

By estimating the heterosis in F_2 generation over better parent (Table 3), it was found Kanchan × Anza in environment-I and Pavon × Anza in environment-2 exhibited superior heterobeltiosis for days to 50% heading. In case of days to last flowering, Kanchan × Anza in environment-I and Pavon x Anza in environment-2 were the best crosses. For days to maturity, Pavon x Anza exhibited desirable negative heterobeltiosis in both environments.

Table 2. Estimates of heterosis in F_2 generation over mid parents (relative heterosis) for yield and yield contributing characters in two environments.

Cross	Days to 50% heading		Days to maturity		Spikes/plant		Plant height	
	E-1	E-2	E-1	E-2	E-1	E-2	E-1	E-2
Gaurab×Kanchan	-5.35*	-6.00	-0.50	-0.98	-9.58	15.34*	3.60	3.31
Gaurab×Balaka	-9.32***	-17.72	1.52	-0.33	28.62*	18.44***	1.20	-0.36
Gaurab×Sonora	2.35	-4.41***	0.68	0.33	47.84**	18.44	3.21	5.39
Gaurab×Protiva	-1013***	-9.77***	-0.83	-0.97	10.24	15.34	-3.51	2.56
Gaurab×Pavon	-10.05’	-8.31**	-1.48	-0.17	-9.58	27.97***	-4.58	-1.94
Gaurab×Anza	-1281***	-13.68	-5.85***	-7.04***	24.10*	10.24***	2.62	-1.85
Kanchan×Balaka	-13.40***	-19.32*	1.99	-0.99	8.58	-10.44	3.95	-0.72
Kanchan×Sonora	-5.78*	-2.36***	2.51*	-0.005	0.00	3.41	4.19	0.66
Kanchan×Protiva	-6.79***	-7.48**	-0.33	0.97	5.50	0.00	2.12	-1.28
Kanchan×Pavon	-470*	-3.88***	-1.29	0.16	10.58	11.11	7.15	-1.09
Kanchan×Anza	-18.77***	-9.45	-74***	-5.75***	-5.50	3.09	2.85	0.85
Balaka×Sonora	0.00	-9.15*	2.92*	1.00	3.78	0.00	0.45	7.22
Balaka×Protiva	-6.52**	-4.41	0.33	1.31*	9.09	-17.27**	1.95	2.54
Balaka×Pavon	-9.69***	-6.90	-0.66	0.82	-14.24	-1426*	15.55*	7.52
Balaka×Anza	-20.78***	-21.95*	-60***	-5.56***	15.09	-0.09	6.62	0.46
Sonora×Protiva	3.94	0.53*	1.52	-1.30*	35.55**	-3.41	-0.70	6.56
Sonora×Pavon	6.59**	2.63**	0.84	1.14	0.00	-28.62***	6.55	2.27
Sonora×Anza	-16.87***	-4.67*	-4.98***	-7.39***	35.55	-31.21***	9.03	5.29
Protiva×pavon	-6.99***	-5.03*	-0.33	-0.80	0.00	-26.00	-2.15	6.68
Protiva×Anza	-14.47***	-11.83	-9.25***	-7.22***	11.64	3.09	-3.19	2.72
Pavon×Anza	-7.46	-24.84***	-11.01’	-9.80***	-11.17	-6.6	-9.39	-6.05

Table 2. Cont'd.

Cross	Spikelets/spike		Grains/spike		100-grain weight		Grain yield/plant		Harvest index	
	E-1	E-2	E-1	E-2	E-1	E-2	E-1	E-2	E-1	E-2
Gaurab×Kanchan	-4.07	-1.20	-8.22	-8.28	9.05***	25.43***	-1.50	-0.22	-7.40	-0.19
Gaurab×Balaka	-5.35	-11.39	2.59	-22.47	-6.41***	15.71***	6.52	32.30***	1.75	13.54
Gaurab×Sonora	-2.17	4.99	20.01**	16.12	1.57	14.93***	34.10***	37.31***	-2.39	2.50
Gaurab×Protiva	-3.19	-16.46	-11.12	3.95	6.96***	20.53***	19.69**	17.75**	1.51	3.66
Gaurab×Pavon	-2.20	1.19	3.45	4.07	-1.18	14.33***	-12.48	33.63***	-3.09	-0.10
Gaurab×Anza	-1.04	-2.34	18.91**	4.07	6.05***	3.93*	18.49*	31.91***	4.58	17.96
Kanchan×Balaka	2.94	4.50	13.06*	12.30	5.29***	9.95***	10.61	43.30***	-5.06	19.68
Kanchan×Sonora	7.70*	-1.11	-6.00	11.54	5.12**	25.33***	11.99	45.96***	0.00	11.14
Kanchan×Protiva	-2.86	14.00***	-9.46	25.04	5.06**	9.63***	11.35	14.29*	0.21	8.17
Kanchan×Pavon	8.01*	4.34	-4.91	-15.42	4.83**	-5.10*	15.07*	-2.69	3.89	-1.74
Kanchan×Anza	-12.40***	-13.67***	-6.73	7.41	22.35***	0.00	4.00	0.63	12.41	6.95
Balaka×Sonora	-3.03	15.65***	3.28	27.61	9.26***	1.35	-6.57	38.86***	-8.18	12.64
Balaka×Protiva	0.03	17.24***	-9.19	24.22	9.21***	4.56*	-3.37	2.52	-14.08	-10.26
Balaka×Pavon	7•39*	-0.03	-0.02	7.59	-0.66	-8.93***	-7.90	19.08**	-13.51	3.29
Balaka×Anza	11.97**	16.89***	0.00	-14.46	13.98***	24.67***	18.37*	6.06	-0.60	12.72
Sonora×Protiva	-0.98	0.03	-0.51	9.32	-1.45	6.91***	25.31**	38.80***	0.56	27.81*
Sonora×Pavon	12.5**	8.07*	15.68**	14.63	15.58***	5.26**	4.95	4.60	24.57*	1.30
Sonora×Anza	-8.94*	0.00	7.87	6.42	2.97	-3.72	52.52***	-4.09	20.17	-0.93
Protiva×pavon	5.17	1.09	13.17**	18.88	7.76***	7.78***	..19.58**	14.49*	-15.12	3.48
Protiva×Anza	-5.88	-4.25	-7.26	2.09	8.53***	3.08	-14.06	-5.93	1.16	-6.31
Pavon×Anza	3.12	755**	-6.61	1.24	27.03***	38.11***	6.59	15.67*	26.62*	30.26*

*p<0.05**p<0.01;***p<0.001

Table 3. Estimates of heterosis in F_2 generation over better parents (heterobeltiosis) for yield and yield contributing characters in two environments.

Cross	Days to *50%* heading		Days to maturity		Spikes/plant		Plant height	
	E-1	E-2	E-1	E-2	E-1	E-2	E-1	E-2
Gaurab×Kanchan	9.10***	5.03**	1.34	0.00	-26.22**	7.07	-0.09	-7.09
Gaurab×Balaka	-8.44**	-15.65***	2.04	0.68*	12.57	6.60	-3.62	-6.69
Gaurab×Sonora	5.52*	0.61	2.08	1.00**	41.75**	6.60	-0.46	-0.30
Gaurab×Protiva	6.51*	0.55	0.68	0.66*	-6.00	7.07	-9.62	1.58
Gaurab×Pavon	4.56	1.68	0.68	1.31	•26.22**	23.09***	-7.28	-5.40
Gaurab×Anza	14.94***	2.23	3.03**	0.33	5.82	-6.00	1.60	-2.50
Kanchan×Balaka	-1.26	-12.24***	4.42***	1.01*	0.00	13.40*	-4.36	-9.79
Kanchan×Sonora	12.41***	15.43***	5.89***	1.67*	-21.01*	0.00	-2.96	-8.28
Kanchan×Protiva	-4.48*	-7.27***	0.00	1.62	0.00	0.00	-0.93	-4.24
Kanchan×Pavon	-3.99*	-3.22*	-0.97	0.65	10.58	3.07	6.36	-1.49
Kanchan×Anza	8.46***	-4.53**	-0.65	0.65	-10.43	-6.00	-1.77	-3.74
Balaka×Sonora	4.14	-1.85	3.81**	1.34*	-12.38	0.00	-0.86	-6.88
Balaka×Protiva	9.55***	3.72*	2.38*	4.04***	5.82	-20.00***	-8.76	-4.15
Balaka×Pavon	3.82	0.53	2.04	3.36***	-21.01*	-20.00***	7.05	-1.95
Balaka×Anza	3.19	-10.12***	3.40**	3.03***	11.64	-6.00	2.35	-4.61
Sonora×Protiva	27.60***	18.52***	4.51***	1.00	11.61	-6.60	-10.09	-0.10
Sonora×Pavon	28.28***	20.37***	4.51***	3.34***	-21.01*	-33.40***	-0.08	-6.47
Sonora×Anza	13.80***	19.75***	5.54***	0.66	11.64	-35.27***	6,18	-0.27
Protiva×pavon	-5.40**	-4.60**	0.32	-0.64	-5.21	-28.69***	-5.76	3.89
Protiva×Anza	-6.16**	-5.97***	2.28*	-1.59*	11.64	-6.00*	-10.18	1.03
Pavon×Anza	3.43	20.91***	3.60**	-4.16***	-15.80	-17.64***	12.84*	12.95*

Table 3. Cont'd.

Cross	Spikelets/spike		Grains/spike		100-grain weight		Grain yield/plant		Harvest index	
	E-1	E-2	E-1	E-2	E-1	E-2	E-1	E-2	E-1	E-2
Gaurab×Kanchan	-12.94***	-10.66**	-21.99***	-10.66	-8.66***	8.63***	-2.73	-0.86	-17.37*	-14.62
Gaurab×Balaka	-10.17**	-14.63***	-5.96	-14.63	-15.16***	10.71***	3.04	30.06***	-2.05	7.65
Gaurab×Sonora	-8.04*	0.00	2.09	0.00	-17.13***	6.55***	9.35	28.26***	-0.11	1.98
Gaurab×Protiva	-9.82**	-23.87*	-24.77***	-8.68	-7.68***	7.44***	15.40***	13.91*	-6.43	-6.59
Gaurab×Pavon	-4.31	-6.67	-13.47**	-2.20	-17.52***	2.08	15.65*	8.70***	-12.19	-7.42
Gaurab×Anza	-7.82*	-4.19	12.81	-4.19	-29.72***	-13.39***	-1.17	29.17***	-19.97*	3.09
Kanchan×Balaka	-1.83	-2.17	4.02	-2.17	-13.32***	-0.98	5.69	39.91***	-12.27	-7.30
Kanchan×Sonora	-11.11***	-6.38	-6.00	-6.38	1.75	16.38***	-9.95	35.62	-3.34	-4.58
Kanchan×Protiva	-5.56	12.76***	-9.92	12.76	-8.40***	6.08**	8.68	9.87	-3.29	2.01
Kanchan×Pavon	0.00	2.10	-6.75	2.11	4.37**	-4.33***	9.57	-6.87	2.14	-9.94
Kanchan×Anza	-14.83***	-14.56***	-16.98**	-14.56	6.12***	-4.47*	-14.12*	-0.83	-5.80	4.32
Balaka×Sonora	-4.02	14.29***	-4.98	14.29	-2.91*	-1.95	-21.75**	31.98***	512.31	7.31
Balaka×Protiva	-1.94	10.89**	-16.83**	10.89	-14.04***	-11.40***	-9.76	0.90	-17.87*	-15.97
Balaka×Pavon	4.10	-4.47	-9.63	-4.47	-9.44***	1.30	-8.25	16.67**	-48.81*	0.82
Balaka×Anza	-13.71***	-22.94***	-3.57	-22.94	-8.23***	7.82***	1.50	2.08	.21.81**	6.02
Sonora×Protiva	-1.94	-4.31	-1.01	-4.31	-7.86***	2.44	0.65	-33.95***	-0.66	15.70
Sonora×Pavon	7.98*	4.47	13.44**	4.47	-17.94***	-9.60***	-11.84	1.41	25.91**	-5.40
Sonora×Anza	-9.82**	-6.25	-3.99	-6.25	-8.09***	-44.29***	48.25*4*	-12.08*	-2.06	-13.04
Protiva×pavon	0.00	0.00	-14.42**	0.00	-11.38***	7.584**	-25.16***	13.95*	-16.71	-0.38
Protiva×Anza	-5.88	-6.25	-17.82***	-6.25	-23.0***	-4.56	-30.37***	-10.83	-17.62	-9.48
Pavon×Anza	-7.82*	-10.44**	-18.29***	-10.44	10.59***	27.65***	-8.31	9.17	-4.66	22.20

*p<0.05**p<0.01; ***p<0.001

Cross Gaurab × Sonora (41.75%) in environment-1 and Gaurab × Pavon (23.09%) in environment-2 exhibited significant and highest heterobeltiosis for spikes/plant. Khan and Khan (1996) reported 31.91% heterosis over better parent in spring wheat for this character. The best crosses showed significant and superior heterobeltiosis for other yield and yield contributing characters in F_2 progeny were Balaka × Pavon in environment-I and Balaka × Sonora in environment-2 for plant height; Gaurab × Sonora in environment-I and Sonora x Pavon in environment-2 for spike length; Sonora × Pavon in environment-1 and Balaka × Sonora in environment-2 for spikelets/spike Sonora × Pavon in environment-I and Balaka × Sonora in environment-2 for grains/spike, Pavon × Anza in both cultural environments for 100-grain weight; Sonora × Anza in environment-I and Kanchan × Balaka in environment-2 for grain yield/plant Kanchan × Protiva in environment-1 and Protiva × Pavon in environment-2 for grain yield/plot; and Kanchan × Pavon in environment-1 and Pavon × Anza in environment-2 for harvest index. 26.91% heterobeltiosis for grain yield/plant in hybrid Uqab 2000 × MH.97 and Fsd. 85 × Inqalab 91 was reported by Kashif and Khaliq (2004). Highest heterosis for 100-grain weight, grain yield plant, grain yield/plot, harvest index and negative heterosis for days to 50% heading, days to maturity can be released as hybrid variety for commercial utilization. So, Pavon × Anza can be used as hybrid variety development for early maturity and 100-grain weight in both cultural environments in F_2 generation. The maximum variation was found in F_2 population for all the characters in case of heterosis, although F_1 generation gives the highest hybrid vigour, the heterosis is fixed in F_2 generation and it is possible to obtain the genuine population.

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