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Study of Heterosis for Grain Yield and its Contributing Traits in Bread Wheat (*Triticum aestivum* L.) under Normal and Late Sown conditions

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ABSTRACT: The study was executed during *rabi* 2019-20 at Agricultural Research Farm of RARI Durgapura, Jaipur (Rajasthan) to study of the heterosis, heterobeltiosis, inbreeding depression. The ten parents along with their 45 F_1's and 45 F_2's, were evaluated in a randomized block design with three replications in two environments created by two dates of sowing *i.e.* normal sown (10th November) and late sown (25th December). In this study, the significant and high heterosis and heterobeltiosis range has been evaluated for all the characters in both the environments.The crosses that revealed high heterosis for grain yield DPW 621-50 × UP 2425 (67.82%), DPW 621-50 x Raj 4037 (57.27%) and DPW 621-50 x Raj 3765 (55.96%) under E_1 whereas, crosses *viz.,* DPW 621-50 x Raj 4037 (77.23%), DBW 90 x Raj 4037 (64.24%) and DPW 621-50 x PBW 550 (61.16%) under E_2. Though, heterobeltiosis for grain yield per plant DPW 621-50 x UP 2425 (43.65%), Raj 3765 x Raj 4079 (39.01%) and Raj 4037 x Raj 4079 (38.98%) under E_1 whereas, Raj 4037 x Raj 4079 (41.34%), Raj 4037 x Raj 3765 (40.79%) and Raj 3765 x Raj 4079 (37.17%) under E_2. The cross DPW 621-50 x Raj 4037 in both environments exhibited desirable heterosis for yield and its attributing traits, respectively. The crosses Raj 4037 x Raj 4079 in E_1 while, Raj 4037 x Raj 4079 and Raj 4037 x Raj 3765 in E_2 showed desirable heterobeltiosis for yield and its associated traits. Consequent changes in climatic conditions and irregular increasing temperature adversely affects the plant growth and development that causes terrible loss of wheat productivity. The deleterious effects of climate change on wheat production are challenging the food security of the world population. Therefore, to moderate unfavourable effect on wheat of heat stress it is required to develop such varieties that can more succeed in changing climatic conditions of India and specially to Rajasthan. The knowledge of genetic architecture and mode of inheritance of different traits helps breeder to select suitable breeding programme for the development of heat stress tolerant varieties.

Keywords: Heterosis, Yield, Traits, Normal sown, late sown.

INTRODUCTION

Wheat is popularly known as 'Stuff of life or king of cereals' because of the acreage occupied, high productivity and the prominent position in the international cereal trade. It also occupies second position in India after rice. In India, it is grownup in about an area of 31.45 million ha with the production of 107.59 million tonnes and average productivity 3420 kg per hectare (Anonymous, 2019-2020). Wheat (*Triticum* sp.) is self-pollinated cereal crop, belongs to family of *Poaceae*. It is an allohexaploid (2n = 6x = 42 = AABBDD). It believes that bread wheat evolved through two steps of allopolyploidization first the formation of tetraploid wild emmer wheat that is *Triticum turgidum* (AABB), from hybridization between two diploid species: the male donor of the A sub-genome, a species very similar to *Triticumurartu* and female donor of B sub-genome, a species related to *Aegilops speltoides* (Marcussen*et al.,* 2014). The second allopolyploidizationoccurrence produced hexaploid wheat (*Triticum aestivum)* evolved through hybridization between tetraploid (*Triticum turgidum*) and diploid (*Triticum tauschii*).

The heterosis is direct relevant for developed hybrids in cross-pollinated crops, but also has importance in self-pollinated crops. In this crop, F_1's had higher frequency of productive derivatives in F_2 and advance generations. Therefore, estimation of the heterosis along with combining ability should be obliging for selection of parents with good general combining ability and in the assortment of crosses through desirable transgressive segregants. Wheat and any other self-pollinated crops variation in F_2 should have been taken into consideration.

Heat stress has a wide range effect on plants in terms of physiology, biochemical and gene regulation pathways. It is a thermo-sensitive crop mostly grown in temperate environment. In general, optimum temperature essential by wheat crop is 18 to 24°C (Bahar *et al.,* 2011) but during anthesis and grain filling cardinal temperature is 12-22°C (Farooq *et al.,* 2011). Heat stress abridges grain-filling duration or post anthesis period (Wiegand

and Cuellar 1981). Increase in each degree temperature results three days' decline in the duration of grain filling (Asana and Williams 1965).

Selection criteria for detecting better wheat genetic recourses to heat stress tolerance generally are based on characteristics allied with higher grain yield under the adverse conditions.

MATERIAL AND METHOD

The material for the present study contains of ten diverse bread wheat varieties (DPW 621-50, DBW 90, PBW 502, Raj 1482, Raj 4037, UP 2425, Raj 3765, PBW 550, HI 1563 and Raj 4079) selected on the basis of broad range of genetic diversity for different yield components, from the elite germplasm which are maintained in All India Coordinated Wheat and Barley Improvement Project [AICW&BIP] at RARI, Durgapura, Jaipur under Sri Karan Narendra Agriculture University, Jobner, Jaipur (Rajasthan). The selected wheat varieties were crossed in half-diallel fashion, during *rabi* 2018-19 at RARI, Durgapura. In *kharif* 2019, half of the F_1's seed was raised up at IARI Regional Station Wellington (Tamil Nadu) to get F_2's seed for investigation. In *rabi* 2019-20 ten parents with their 45 F_1's and 45 F_2's progenies were grown in a randomized block design with 3 replications in 2 environments created by using two different dates of sowing *viz.,* normal sown and late sown [10 Nov. and 25 Dec.] respectively. The experimental material was planted in 3 replications for each environment at Agricultural Research Farm of RARI, Durgapura. Each row was 3 m in length with maintaining row to row spacing of 30 cm and plant to plant spacing of 10 cm was maintained in all the plots.

Observations were recorded for days to heading, days to maturity, plant height, tillers per plant, flag leaf area, spike length, grains per ear, 1000-grain weight, biomass per plant, grain yield per plant, harvest index, canopy temperature and protein content in both environments. The data so obtained were exposed to analysis of variance (Panse and Sukhatme 1985) heterosis, heterobeltiosis, and inbreeding depression (Fonseca and Patterson 1968) estimation.

RESULT AND DISCUSSION

The pooled analysis of variance (Table 1) exhibited significant and diversified differences between both the environment created through dates of sowing for all the investigated characters showing the influence on the expression of these characters of the environments. Sprague and Federer (1951) suggested that the biasness affected by G × E interaction in the assessments of genetic parameters is of unknown direction and magnitude, it may not be same for each parameter. Taking into consideration, G x E interaction was significant for all the studied characters. Lodhi *et al*. (2015) reported significant differences between G x E for grain yield and its contributing traits. Likewise, the differences among parents*vs* generations were significant for all the examined characters under both the environments revealed the presence of heterosis in both the environments.

Table 1: Analysis of variance showing mean squares pooled over two environments for parents, F_1's and F_2's for yield and its contributing traits.

Particulars						Mean Square								
Source of variation	Df	Days to heading	Days to maturity	Plant height	Tillers per plant	Flag leaf area	Spike length	Grains per ear	1000-grains weight	Biomass per plant	Grain yield per plant	Harvest Index	Canopy temperature	Protein content
Env.	1	33810.03**	44496.48**	48123.99**	2768.77**	13330.03**	740.01**	10150.88**	4541.41**	4400.88**	5508.3**	5299.77**	1000.01**	570.55**
Reps./Env.	4	6	7.15	17.75	0.06	8.14	0.73	4.61	1.85	12.45	3.52	7.91	1.25	0.15
Genotypes	99	278.15**	304.48**	400.47**	8.19**	154.3**	15.13**	244.82**	184.1**	139.06**	167.4**	375.14**	25.11**	5.08**
Parents	9	76.22**	47.74**	77.56**	6.51**	27.72**	6.99**	55.73**	35.74**	38.95**	95.09**	243.4**	7.33**	1.54**
Generations	89	277.65**	290.12**	343.03**	7.82**	143.8**	15.11**	239.36**	196.99**	129.69**	155.39**	372.63**	25.25**	4.9**
Parents vs Generations	1	2140.74**	3893**	8418.69**	56.08**	2228.2**	90.54**	2432.51**	372.15**	1874.62**	1887.44**	1784.48**	172.48**	53.76**
G x E	99	29.91**	31.72**	44.39**	1.03**	32.45**	1.6**	25.052**	10.32**	36.22**	17.65**	24.28**	1.29*	1.45**
Error	396	7.64	11.44	17.75	0.27	7.18	0.77	8.17	5.59	8.72	4.43	8.29	0.94	0.23

*, ** Significant at 5 and 1 per cent levels, respectively.

The performance of the hybrids is expressed in terms of the percentage increase and decrease in their performance over the mid-parent (heterosis) and better parent (heterobeltiosis) (Hochholdinger and Hoecker 2007). The magnitude of the heterosis that deliver information on the extent of genetic diversity of the parents which elaborate in a cross and helps in choosing the parents for developing superior F_1's. The commercial utilization of heterosis in the plant breeding is regarded as superb execution of genetics. In self-pollinated crop like wheat, commercial hybrid seed production is not practicable due to lack of the appropriate mechanism to produce hybrid seed. Some theories explain the genetic basis of the heterosis in crops but most effective in self-pollinated crops which explain the phenomenon, that is dominant linked gene hypothesis (Jones, 1917). Additive and non-additive gene effects both explain heterosis.

In the present study, the maximum heterosis range has been evaluated for all the characters. An overall appraisal of the table 2 revealed that maximum range of heterosis was observed for yield per plant that was -4.84 per cent to 67.82 per cent in E_1 and -27.94 per cent to 77.23 per cent in E_2 followed by flag leaf area that was -1.59 to 53.65 per cent in E_1 and -23.72 per cent to 63.82 per cent in E_2, tillers per plant that was -

20.22 per cent to 36.7 per cent in E_1 and -31.88 per cent to 55.63 per cent in E_2 and grains per ear that was -9.34 per cent to 40.82 per cent in E_1 and -13.08 per cent to 46.48 per cent in E_2. Whereas, other yield component traits also expressed the wide range of heterosis. The results of experiment for different characters under both environments were inconformity with the findings of several researchers such as Rasul *et al.* (2002); Akinci (2009); Kumar and Maloo (2011); Gaur *et al.* (2014); Khaibani *et al.* (2015); Dedaniya *et al.* (2018); Nagar *et al.* (2019); Upadhyay *et al.* (2020). Under E_2 environment sharp decline was observed in number of heterotic crosses that was observed for grain yield per plant, protein content, spike length, biomass per plant, flag leaf area, harvest index, grains per ear and days to heading. Whereas, for canopy temperature, 1000-grain weight, tillers per plant, plant height and days to maturity number of heterotic crosses increased under E_2 environment. The expression of heterosis was affected by the high temperature for most of the characters were reported by Prakash (2007); Modarresi *et al.* (2010); Shashi *et al.* (2014); Kumar *et al.* (2017); Kumar *et al.* (2021).

Table 2: The lowest to highest values (Range) of the heterosis in grain yield and some contributing traits.

Characters	Env.	Crosses	Range
Grain yield per plant	E_1	(Raj 3765 x HI 1563) to (DPW 621-50 x UP 2425)	-4.84 to 67.82
	E_2	(PBW 502 x Raj 1482) to (DPW 621-50 x Raj 4037)	-27.94 to 77.23
Flag leaf area	E_1	(UP 2425 x PBW 550) to (PBW 502 x Raj 3765)	-1.59 to 53.65
	E_2	(PBW 502 x Raj 3765) to (DPW 621-50 x Raj 4037)	-23.72 to 63.82
Tillers per plant	E_1	(Raj 4037 x PBW 550) to (DBW 90 x UP 2425)	-20.22 to 36.70
	E_2	(Raj 4037 x PBW 550) to (DPW 621-50 x Raj 4079)	-31.88 to 55.63
Grains per ear	E_1	(Raj 4037 x UP 2425) to (DPW 621-50 x Raj 3765)	-9.34 to 40.82
	E_2	(DBW 90 x PBW 550) to (Raj 1482 x Raj 3765)	-13.08 to 46.48
Biomass/ plant	E_1	(PBW 502 x Raj 4079) to (DPW 621-50 x UP 2425)	-4.04 to 40.94
	E_2	(DPW 621-50 x DBW 90) to (DPW 621-50 x UP 2425)	-8.99 to 24.32

The Table 3 exhibited the three best heterotic and heterobeltiotic crosses for the grain yield per plant. In this table the crosses that revealed high heterosis for grain yield DPW 621-50 x UP 2425 (67.82%), DPW 621-50 x Raj 4037 (57.27%) and DPW 621-50 x Raj 3765 (55.96%) under E_1 whereas, crosses *viz.,* DPW 621-50 x Raj 4037 (77.23%), DBW 90 x Raj 4037 (64.24%) and DPW 621-50 x PBW 550 (61.16%) under E_2. Though, heterobeltiosis for grain yield per plant DPW 621-50 x UP 2425 (43.65%), Raj 3765 x Raj 4079 (39.01%) and Raj 4037 x Raj 4079 (38.98%) under E_1 whereas, Raj 4037 x Raj 4079 (41.34%), Raj 4037 x Raj 3765 (40.79%) and Raj 3765 x Raj 4079 (37.17%) under E_2.

High heterotic crosses which revealed significant and negative inbreeding depression for grain yield were PBW 502 x Raj 4037, PBW 502 x Raj 3765, PBW 502 x Raj 4079, Raj 4037 x Raj 3765, Raj 4037 x Raj 4079, Raj 3765 x PBW 550 under E_1 while, crosses DPW 621-50 x Raj 4037, DPW 621-50 x Raj 3765, DBW 90 x Raj 4037, DBW 90 x Raj 3765, DBW 90 x Raj 4079, Raj 1482 x Raj 3765, Raj 4037 x Raj 3765 and Raj 4037 x Raj 4079 under E_2that depicted F_2 plants accomplished higher grain yield per plant as compared to F_1 hybrids.

Table 3: Top three crosses for their heterosis, heterobeltiosis and inbreeding depression estimate under normal (E_1) and late sown (E_2) conditions for grain yield and its contributing traits.

Characters	Env.	Heterosis	Heterobeltiosis	Inbreeding depression
Days to heading	E_1	DPW 621-50 x Raj 4079	Raj 4037 x Raj 3765	Raj 3765 x Raj 4079
		DPW 621-50 x Raj 4037	Raj 4037 x Raj 4079	Raj 4037 x Raj 4079
		Raj 1482 x Raj 4079	Raj 3765 x Raj 4079	Raj 4037 x Raj 3765
	E_2	Raj 4037 x Raj 4079	Raj 4037 x Raj 4079	Raj 3765 x Raj 4079
		Raj 3765 x Raj 4079	Raj 3765 x Raj 4079	Raj 4037 x Raj 3765
		Raj 4037 x Raj 3765	Raj 4037 x Raj 3765	Raj 1482 x Raj 3765
Days to maturity	E_1	Raj 3765 x Raj 4079	Raj 3765 x Raj 4079	Raj 4037 x Raj 4079
		Raj 4037 x Raj 3765	Raj 4037 x Raj 3765	Raj 3765 x Raj 4079
		Raj 4037 x Raj 4079	Raj 4037 x Raj 4079	UP 2425 x PBW 550
	E_2	UP 2425 x HI 1563	UP 2425 x HI 1563	Raj 1482 x HI 1563
		Raj 4037 x Raj 4079	Raj 4037 x Raj 4079	PBW 502 x HI 1563
		Raj 4037 x Raj 3765	Raj 4037 x Raj 3765	PBW 550 x HI 1563
Plant height	E_1	Raj 4037 x Raj 3765	DBW 90 x Raj 4079	Raj 3765 x PBW 550
		DBW 90 x Raj 4079	Raj 4037 x Raj 3765	Raj 4037 x Raj 4079
		Raj 3765 x Raj 4079	Raj 3765 x Raj 4079	Raj 4037 x Raj 3765
	E_2	Raj 4037 x Raj 3765	DBW 90 x Raj 4079	PBW 502 x Raj 3765
		Raj 4037 x Raj 4079	Raj 4037 x Raj 3765	Raj 3765 x PBW 550
		DBW 90 x Raj 4079	Raj 4037 x Raj 4079	UP 2425 x HI 1563
Tillers per plant	E_1	DBW 90 x UP 2425	DPW 621-50 x UP 2425	DBW 90 x PBW 502
		DPW 621-50 x UP 2425	DPW 621-50 x PBW 550	DBW 90 x Raj 3765
		DPW 621-50 x Raj 3765	Raj 1482 x PBW 550	Raj 4037 x UP 2425
	E_2	DPW 621-50 x Raj 4079	PBW 502 x Raj 1482	DBW 90 x Raj 4037
		DPW 621-50 x Raj 3765	Raj 1482 x HI 1563	Raj 4037 x Raj 4079

		DPW 621-50 x DBW 90	PBW 502 x HI 1563	DPW 621-50 x PBW 502
Flag leaf area	E_1	PBW 502 x Raj 3765	Raj 4037 x Raj 3765	DBW 90 x Raj 3765
		Raj 4037 x Raj 3765	Raj 3765 x Raj 4079	DBW 90 x Raj 4037
		PBW 502 x PBW 550	Raj 4037 x Raj 4079	Raj 4037 x Raj 3765
	E_2	DPW 621-50 x Raj 4037	Raj 3765 x Raj 4079	Raj 4037 x Raj 3765
		Raj 4037 x Raj 4079	Raj 4037 x Raj 4079	-
		DPW 621-50 x Raj 3765	Raj 4037 x Raj 3765	-
Spike length	E_1	Raj 4037 x Raj 4079	DPW 621-50 x HI 1563	DBW 90 x Raj 1482
		Raj 4037 x Raj 3765	DBW 90 x Raj 4037	Raj 1482 x UP 2425
		DPW 621-50 x PBW 550	DPW 621-50 x Raj 4037	DPW 621-50 x Raj 4079
	E_2	Raj 4037 x Raj 4079	Raj 4037 x Raj 4079	Raj 1482 x PBW 550
		Raj 4037 x Raj 3765	Raj 4037 x Raj 3765	DBW 90 x Raj 4037
		PBW 502 x Raj 3765	PBW 502 x Raj 4079	DPW 621-50 x Raj 4079
Grains per ear	E_1	DPW 621-50 x Raj 3765	DPW 621-50 x Raj 3765	Raj 4037 x PBW 550
		Raj 3765 x PBW 550	Raj 3765 x Raj 4079	DPW 621-50 x Raj 4079
		DPW 621-50 x Raj 4079	Raj 4037 x Raj 4079	PBW 550 x HI 1563
	E_2	Raj 1482 x Raj 3765	Raj 4037 x Raj 4079	PBW 502 x Raj 1482
		DPW 621-50 x Raj 3765	Raj 4037 x Raj 3765	DPW 621-50 x HI 1563
		Raj 4037 x Raj 4079	PBW 550 x Raj 4079	DBW 90 x PBW 550
1000-grain weight	E_1	PBW 502 x Raj 3765	Raj 4037 x Raj 3765	PBW 502 x Raj 4079
		PBW 502 x Raj 4037	Raj 3765 x Raj 4079	UP 2425 x HI 1563
		DPW 621-50 x Raj 4079	DPW 621-50 x Raj 4037	Raj 4037 x Raj 4079
	E_2	DPW 621-50 x Raj 4079	DPW 621-50 x Raj 4079	UP 2425 x PBW 550
		UP 2425 x Raj 4079	UP 2425 x Raj 4079	PBW 502 x Raj 3765
		PBW 502 x Raj 4037	Raj 3765 x Raj 4079	DPW 621-50 x UP 2425
Biomass per plant	E_1	DPW 621-50 x UP 2425	DPW 621-50 x UP 2425	Raj 1482 x Raj 4079
		UP 2425 x Raj 3765	DPW 621-50 x PBW 502	DPW 621-50 x Raj 1482
		PBW 502 x Raj 3765	UP 2425 x Raj 4079	PBW 502 x HI 1563
	E_2	DPW 621-50 x UP 2425	PBW 502 x Raj 3765	Raj 1482 x Raj 4079
		DBW 90 x Raj 1482	DBW 90 x Raj 1482	DPW 621-50 x DBW 90
		PBW 502 x Raj 3765	DPW 621-50 x UP 2425	Raj 3765 x Raj 4079
Grain yield per plant	E_1	DPW 621-50 x UP 2425	DPW 621-50 x UP 2425	UP 2425 x HI 1563
		DPW 621-50 x Raj 4037	Raj 3765 x Raj 4079	PBW 502 x HI 1563
		DPW 621-50 x Raj 3765	Raj 4037 x Raj 4079	PBW 502 x Raj 3765
	E_2	DPW 621-50 x Raj 4037	Raj 4037 x Raj 4079	DPW 621-50 x DBW 90
		DBW 90 x Raj 4037	Raj 4037 x Raj 3765	PBW 502 x Raj 1482
		DPW 621-50 x PBW 550	Raj 3765 x Raj 4079	UP 2425 x HI 1563

Contd…….

Harvest index	E_1	PBW 502 x Raj 4079	PBW 502 x Raj 4079	DBW 90 x PBW 502
		DBW 90 x Raj 4079	Raj 4037 x Raj 4079	HI 1563 x Raj 4079
		DPW 621-50 x Raj 4037	DPW 621-50 x DBW 90	DPW 621-50 x UP 2425
	E_2	DPW 621-50 x Raj 4037	Raj 4037 x Raj 4079	PBW 550 x Raj 4079
		DPW 621-50 x Raj 3765	Raj 4037 x Raj 3765	PBW 502 x Raj 1482
		DBW 90 x Raj 4037	DBW 90 x Raj 4037	UP 2425 x Raj 3765
Canopy temperature	E_1	DPW 621-50 x Raj 4079	DPW 621-50 x Raj 3765	DBW 90 x Raj 4079
		DPW 621-50 x Raj 3765	DPW 621-50 x Raj 4079	DPW 621-50 x Raj 4037
		Raj 3765 x Raj 4079	DPW 621-50 x Raj 4037	-
	E_2	DBW 90 x Raj 4079	DPW 621-50 x Raj 4079	-
		Raj 3765 x Raj 4079	DBW 90 x Raj 4079	-
		DPW 621-50 x Raj 4079	DPW 621-50 x Raj 4037	-
Protein content	E_1	DBW 90 x Raj 4037	PBW 502 x HI 1563	PBW 502 x Raj 3765
		DPW 621-50 x Raj 3765	DBW 90 x Raj 4037	Raj 1482 x UP 2425
		PBW 502 x HI 1563	Raj 1482 x PBW 550	UP 2425 x HI 1563
	E_2	Raj 1482 x Raj 4079	Raj 1482 x Raj 4079	DPW 621-50 x Raj 3765
		Raj 4037 x Raj 4079	Raj 4037 x Raj 4079	PBW 502 x Raj 4079
		Raj 1482 x PBW 550	Raj 1482 x PBW 550	PBW 502 x Raj 3765

The crosses DPW 621-50 x Raj 4037 under both environments exhibited desirable heterosis for all yield attributing traits, respectively in Table 4. The crosses Raj 4037 x Raj 4079 under E_1 and Raj 4037 x Raj 4079 and Raj 4037 x Raj 3765 under E_2 showed desirable heterobeltiosis for all yield contributing traits. The table 4 reveals a significant relation of heterosis and heterobeltiosis for grain yield and its contributing characters *i.e.* crosses have desirable heterosis and heterobeltiosis for grain yield per plant also exhibited desirable heterosis and heterobeltiosis for most of yield attributes except DPW 621-50 x UP 2425 and DPW 621-50 x PBW 550.The expression of heterosis and heterobeltiosis were influenced by the environments for most of the traits due to significant G x E interactions. The results of this research were in accordance with earlier reports of Singh *et al.* (2013); Sharma *et al.* (2018); Nagar *et al.* (2019); Saad *et al.* (2010); Soomro *et al.* (2019) also reported maximum heterosis for grain yield.

Table 4: Best crosses exhibiting high heterosis and heterobeltiosis for grain yield per plant along with desirable (+) heterotic expression for other characters under normal (E_1) and late sown (E_2) conditions.

Particulars	Heterosis						Heterobeltiosis					
Environment	E_1			E_2			E_1			E_2		
Crosses Possessing high heterosis and heterobeltiosis for grain yield per plant	DPW 621-50 x UP 2425	DPW 621-50 x Raj 4037	DPW 621-50 x Raj 3765	DPW 621-50 x Raj 4037	DBW 90 x Raj 4037	DPW 621-50 x PBW 550	DPW 621-50 x UP 2425	Raj 3765 x Raj 4079	Raj 4037 x Raj 4079	Raj 4037 x Raj 4079	Raj 4037 x Raj 3765	Raj 3765 x Raj 4079
Days to heading	-	+	+	+	+	+	-	+	+	+	+	+
Days to maturity	-	+	+	+	+	-	-	+	+	+	+	+
Plant height	+	+	+	+	+	+	+	+	+	+	+	+
Tillers per plant	+	+	+	+	-	-	+	-	+	+	+	+
Flag leaf area	+	+	+	+	+	-	-	+	+	+	+	+
Spike length	-	+	+	+	+	-	-	+	+	+	+	+
Grains per ear	+	+	+	+	+	-	-	+	+	+	+	-
1000-grain weight	-	+	-	+	+	+	-	+	+	+	+	+
Biomass per plant	+	+	+	+	+	+	+	+	+	+	+	+
Harvest index	+	+	+	+	+	+	-	+	+	+	+	+
Canopy temperature	-	+	+	+	+	-	-	+	+	+	+	+
Protein content	-	+	+	+	+	+	-	-	+	+	+	+

(+) = Significant and (-) = Non significant

A comparative analysis of the heterotic crosses on the basis of grain yield in each environment, exhibited that the expression of significant heterosis and heterobeltiosis for grain yield per plant depended on other yield contributing traits. The heterosis is direct relevant for developing hybrids in cross-pollinated crops, but it also has importance in self-pollinated crops. In wheat crop, F_1's had higher frequency of productive derivatives in F_2 and advance generations. Therefore, assessment of the heterosis along with combining ability should be helpful for selection of parents with good general combining ability and in the choice of crosses through desirable transgressive segregants.

CONCLUSIONS

The crosses DPW 621-50 x Raj 4037 under both environments exhibited desirable heterosis for all yield attributing traits, respectively. The crosses Raj 4037 x Raj 4079 under E_1 and Raj 4037 x Raj 4079 and Raj 4037 x Raj 3765 under E_2 showed desirable heterobeltiosis for all yield contributing traits. Future scope of the study is a comparative analysis of the heterotic crosses on the basis of grain yield in each environment, exhibited that the expression of significant heterosis and heterobeltiosis for grain yield per plant depended on other yield contributing traits. The heterosis is direct relevant for developing hybrids in cross-pollinated crops, but it also has importance in self-pollinated crops. In wheat crop, F_1's had higher frequency of productive derivatives in F_2 and advance generations. Therefore, estimation of the heterosis along with combining ability should be helpful for selection of parents with good general combining ability and in the selection of crosses through desirable transgressive segregants.

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Conflict of Interest. None.

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