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Short Communication

Heterosis in bread wheat [*Triticum aestivum* (L.) Em. Thell.]

S. S. Punia, M. A. Shah and G. K. Mittal

Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, MPUA&T, Udaipur 313 001

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Twelve diverse lines of bread wheat [*Triticum aestivum* (L.) Em. Thell.] including checks *viz.*, Raj 3777, Raj 3077, Raj 3765, HI 977 (late sown), WH 542, HD 2329, K 9708, C 306, Raj 1482, Kalyansona, GW 190 and DWR 195 were mated with four diverse testers *viz.*, HD 2189, Ajantha, PBN 51 and Kailash (timely sown) in line × tester fashion to obtain 48 single cross hybrids to estimate the heterosis of the yield and heat tolerance traits. These single cross hybrids along with their parents were sown in three different dates *viz.*, 21 November (Normal sown), 11 December (late sown) and 1 January (very late sown). All these 64 genotypes were grown in single row of 4 m length with spacing 22.5 × 10 cm in a randomized block design with two replications. Observations were recorded on five randomly selected plants in each replication in all the three environments for the grain yield per plant (g). Observation for heat tolerance parameters *viz.*, Pollen viability (%) and proline content (µg/100 mg fresh wt) were taken in normal and late sown environments. Pollen viability estimated by using potassium iodide, whereas proline content at the time of anthesis from flag leaf was determined as per Bates *et al.* [1]. The other heat tolerance parameters *viz.*, per cent heat injury was measured as per Sullivan's [2] stomatal frequency was computed with evaluation of number of stomata per square centimeter using xylene thermocol print method, whereas estimation of chlorophyll content (mg/g) was carried out by dimethylformamide method [3] and all these estimations were carried out at the time of grain filling in normal environment. The extent of heterosis over mid parent, better parent and standard parent (best performing parent) in individual environments for all the traits except pollen viability where on pooled basis and its significance was tested by 't' test.

Standard heterosis for grain yield was significant for 4 hybrids in normal sown, 5 in late sown and 6 hybrids in very late sown with varying range from 21.16

Table 1. Mean performance of parents for grain yield and heat tolerance traits in bread wheat

Characters parents	Grain yield/per plant (g)			Proline content (µg/100 mg fresh wt)		Pollen viability (%)	Heat injury (%)	Stomatal frequency (upper)	Chlorophyll content
	Normal sown	Late sown	Very late sown	Normal sown	Late sown	Pool	Normal sown	Normal sown	Normal sown
Raj 3777	16.89	21.19	10.57	8.31	9.51	91.45	35.51	41.88	1.18
WH 542	16.72	20.94	8.05	8.75	9.69	91.20	60.11	38.88	1.18
HD 2329	18.24	12.03	9.39	6.13	6.82	90.10	45.06	42.50	1.27
Raj 3077	22.87	16.88	6.99	4.70	5.76	84.53	66.35	37.50	0.96
K 9708	19.61	22.57	6.82	8.44	9.19	91.69	66.68	41.00	1.50
C 306	18.76	14.88	9.49	7.26	7.44	94.31	38.62	73.75	0.81
Raj 1482	21.77	16.02	10.22	9.26	9.50	89.97	23.75	40.50	1.04
Kalysona	19.61	10.28	9.86	10.94	9.88	90.27	47.71	43.62	1.37
GW 190	13.85	21.12	8.59	7.32	7.62	92.86	52.27	51.50	1.31
Raj 3765	22.28	18.56	8.35	9.06	8.38	88.78	70.60	44.38	1.24
DWR 195	17.41	21.08	9.50	8.06	7.75	92.49	36.17	44.00	1.19
HI 977	23.30	16.40	7.36	7.50	7.76	93.80	57.89	44.88	1.49
HD 2189	14.13	15.73	7.05	10.06	11.00	91.73	64.02	50.88	1.10
Ajantha	22.50	20.33	7.35	8.81	7.13	85.68	62.92	41.75	1.20
PBN 51	17.31	12.14	7.23	10.81	11.88	95.61	65.29	39.25	1.03
Kailash	19.56	19.68	9.77	7.38	7.82	88.89	48.25	45.12	1.27

to 38.25 per cent in normal, 10.57 to 27.27 per cent in late sown and from 16.51 to 53.64 per cent in very late sown. The highly significant standard heterosis for grain yield under normal sown was exhibited by Raj 3077 × Kailash (38.2 %) followed by DWR 195 × Kailash (38.0%), C 306 × PEN 51 (22.6%) and

Table 2. Standard heterosis (EH) for grain yield, proline content, pollen viability, heat injury, stomatal frequency and chlorophyll content in bread wheat

Cross/characters	Grain yield/plant (g)			Proline content (µg/100 mg fresh wt)		Pollen viability (%)	Heat injury (%)	Stomatal frequency (upper)	Chlorophyll content (mg/g)
	Normal sown	Late sown	Very late sown	Normal sown	Late sown	Pool	Normal sown	Normal sown	Normal sown
	SH	SH	SH	SH	Hb	Hb	SH	SG	Hb
Raj 3777 × HD 2189	9.25	-	-	-	-	2.74	-	-	-
× Ajantha	-	-	-	-	0.96	-	-	-	-
× PBN 51	-	-	8.33	-	-	-	-	-	-
× Kailash	-	-	-	-	20.36**	-	-	−10.40	-
WH 542 × HD 2189	-	-	16.51*	-	-	-	-	−3.69	7.14
× Ajantha	-	27.27**	-	-	-	-	-	-	-
× PBN 51	5.09	-	-	-	-	-	-	-	-
× Kailash	-	-	-	-	8.36*	-	-		4.74
HD 2329 × HD 2189	3.18	-	-	-	-	-	-	-	
× Ajantha	-	-	-	-	-	0.43	-	-	-
× PBN 51	-	22.66**	-	-	-	-	-	-	-
× Kailash	-	-	2.41	-	17.59**	4.91	-	-	-
Raj 3077 × HD 2189	-	-	-	-		-	-	-	-
× Ajantha	-	-	-	-	11.36*	6.65*	-	−7.38	-
× PBN 51	-	9.11	-	-	-	-	-	-	34.24*
× Kailash	38.25**	-	18.78*	-	14.40**	2.06	-	-	10.46
K 9708 × HD 2189	-	2.02	-	-	-	1.66	-	-	-
× Ajantha	-	-	-	-	3.37	-	-	-	-
× PBN 51	-	-	-	-	-	-	-	-	-
× Kailash	-	-	-	-	-	0.54	-	-	-
C 306 × HD 2189	-	-	53.64**	-	-	-	-	-	-
× Ajantha	-	-	-	-	5.04	-	-	-	-
× PBN 51	22.67**	10.57*	1.80	-	-	-	-	−7.38	-
× Kailash	-	-	2.65	-	-	-	-	-	-
Raj 1482 × HD 2189	-	-	-	-	-	2.37	-	-	-
× Ajantha	-	-	-	-	-	-	-	-	-
× PBN 51	-	-	-	-	-	-	-	-	7.08
× Kailash	-	-	-	-	-	2.10	-	-	2.84
K'sona × HD 2189	10.82	-	-	-	-	-	-	−1.34	-
× Ajantha	21.16**	-	-	-	-	-	-	-	-
× PBN 51	-	22.33**	-	-	-	-	-	-	-
× Kailash	-	7.11	-	-	11.39**	-	-	-	-
GW 190 × 2189	9.77	-	-	-	-	-	-	-	-
× Ajantha	-	-	-	-	11.39**	-	-	-	-
× PBN 51	-	-	-	-	-	-	-	-	-
× Kailash	-	3.31	-	28.79**	-	-	-	4.91	-
Raj 3765 × HD 2189	-	-	-	-	-	-	-	−7.05	-
× Ajantha	-	-	-	-	-	-	-	−0.34	11.63
× PBN 51	-	-	22.42**	-	-	-	-	-	16.71
× Kailash	-	-	-	-	33.61**	4.94	-	-	-
DWR 195 × HD 2189	-	-	16.93*	-	-	-	−0.65	-	3.19
× Ajantha	-	-	-	-	26.65**	-	-	-	-
× PBN 51	-	-	0.76	-	-	-	-	-	9.75
× Kailash	38.01**	-	13.91	8.00*	49.58**	-	-	-	-
HI 977 × 2189	-	13.29*	-	-	-	-	-	-	-
× Ajantha	3.50	-	-	-	-	-	-	-	-
× PBN 51	10.24	-	3.55	-	-	-	-	-	-
× Kailash	3.24	-	-	-	27.19**	0.41	-	-	-

*,**Significant at P = 0.05 and P = 0.01 level, respectively.

Kalyansona × Ajantha (21.1%), under late sown by WH 542 × Ajantha (27.2%), followed by HD 2329 × PBN 51 (22.6%), Kalyansona × PBN 51 (22.3%) and C 306 × PBN 51 (10.5%), whereas highest magnitude under very late sown was depicted by cross C 306 × HD 2189 (53.64%) followed by Raj 3765 × PBN 51 (22.42%), Raj 3077 × Kailash (18.78%) and WH 542 × HD 2189 (16.51%). Of these cross Raj 3077 × Kailash showed standard heterosis in both normal as well as very late sown environments, whereas C 306 × PBN 51 in normal and late sown environments (Table 2).

The expression of heterosis for heat tolerance traits was highly variable. It was more pronounced for heat injury and proline content (in both environments), while it was less for other heat tolerant traits. The significant standard heterosis for proline content was recorded in only cross DWR 195 × Kailash in normal sown (8.0%) environment along with highest mean total proline content in normal (11.81 µg/g) and in late sown (11.69 (µg/g) environment. Hence, this cross may lead to segregates containing high proline content, which ultimately may reflect high heat tolerance.

As regards to pollen viability none of these crosses showed standard heterosis, only cross Raj 3077 × Ajantha (7.37%) exhibited significant and positive heterosis over better parent on pool basis. Whereas for another important heat tolerant trait heat injury only cross DWR 195 × HD 2189 had negative standard heterosis (–0.65) along with lowest mean heat injury (23.60%) (Table 2). As low heat injury is desirable, negative heterosis is a positive feature for this trait. For stomatal frequency the cross combination WH 542 × HD 2189 exhibited maximum standard heterosis (–10.40%) followed by Raj 3077 × Ajantha and C 306 × PBN51 (–7.38%).

The highest mean total chlorophyll content 1.45 mg/g was observed in Raj 3765 × PBN 51 (Table 1), while none of these cross had standard heterosis except Raj 3077 × PBN 51 which showed significant positive heterosis over better parent (34.24%) for this trait. This indicates that the hybrid vigour in the cross Raj 3077 × PBN 51 was due to the broad leaves of the both parents. Hence, it may lead to segregates containing high chlorophyll content, which ultimately may reflect for more biological yield.

There were two crosses *viz.*, Raj 3077 × Kailash and C 306 × PBN 51 had significant standard heterosis in more than one environment for grain yield. On the other hand the cross DWR 195 × HD 2189 had significant standard heterosis (16.93) in very late sown environment along with negative standard heterosis (–0.65) for heat injury. Therefore progeny of these crosses may have resistance to high temperature along with high grain yield.

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