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Studies on heterosis for grain yield and yield component traits in basmati rice (*Oryza sativa* L)

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Abstract
Present investigation was undertaken to study heterosis through diallel design of experimental hybrids for yield and its component in basmati rice at Norman E. Borlaug Crop Research Centre. Pantnagar, Uttarakhand, India. Nine lines were crossed in the half diallel fashion and the resulting 36 hybrids along with their parents were evaluated for heterosis (heterobeltiosis and standard heterosis) in a replicated trial using randomized block design for grain yield per plant and various yield contributing characters namely days to 50% flowering, days to maturity, leaf area, plant height, number of panicles per plant, panicle length, number of grains per panicle, 1000 grain weight, biological yield and harvest index. Standard heterosis was estimated by using Improved Pusa Basmati 1 as a check parent. For grain yield per plant, 15 crosses over better partent (5.74 to 56.23%) and 13 over standard variety (7.20 to 40.18%) manifested significant desirable heterosis. Of these twelve crosses viz., PS 4×PS 5, PS 4×PS 6, PS 4×PSD 17, PS 4×PB 1, PS 4×Pu Bas 1, PS 5×PS 6, PS 5×PB 1, PS 5×PB 2, PS 5×Pu Bas 1, PS 6×PB 2, PB 1×PB 2 and PB 2×Pu Bas 1 displayed heterosis over both better parent as well as standard variety for grain yield per plant and also showed desirable BPH and SVH for various yield component traits.

Keywords: diallel design, heterobeltiosis, standard heterosis, check parent

Introduction

Rice is the premier cereal crop as it is the staple food for more than half of the world population. Most rice growing countries, distinctly Asian countries where 90 % of world rice is produced and consumed have done notably well in meeting their rice needs using the green revolution technologies; however, The world population is expected to reach 8 billion by 2030 and rice production must be increased by 50% in order to meet the growing demand (Khush and Brar, 2002) [6]. This production increase must be achieved per unit area and per unit time, and it must be sustainable. Scientists have amply demonstrated that commercial exploitation of heterosis may enable shifting (increase rice varietal yield) the yield frontier in rice (Yuan *et al*., 1994) [18]. In the present investigation two types of heterosis were estimated viz. heterobeltosis i.e. superiority of F1 over better parent and standard heterosis i.e. superiority of F1 over best commercial variety. Virmani *et al.* (1981) suggested that the yield advantage of 20% to 30% over standard variety should be sufficient to encourage farmers for adapting the hybrid rice cultivation.

Material and methods

The present study was conducted under irrigated and timely transplanted condition of *Tarai* region of Uttarakhand. Better parent and economic heterosis for yield and its contributing traits were estimated in diallel mating design involving nine genetically diverse rice genotypic lines viz., Pusa Sugandh 4, Pusa Sugandh 5, Pusa Sugandh 6, Pant Sugandh Dhan 15, Pant Sugandh Dhan 17, Pant Basmati 1, Pant Basmati 2, Pusa Basmati 1, Taraori Basmati. All nine parental genotypes and their 36 F1's grown in nursery and than 25 days seedlings were transplanted in a randomized complete block design with three replication during *Kharif* 2018 at N E Borlaug Crop Research Centre, G B Pant University of Agriculture and Technology, Pantnagar under irrigated and timely transplanted condition. Each plot comprises of a single three meters long row, the rows were spaced 30 cm. Apart and plant to plant distance at 15 cm. The experiment was conducted under irrigated timely transplanted condition. Observations were recorded on five randomly competitive plants from each row. The better parent and economic heterosis for all yield and its related traits were estimated as suggested by Mather (1949) [10], Mather and Jink (1982). The t-test was calculated to determine whether F1 hybrid mean were statistically significant or not from better parent and standard parental values compared to t tab values at 0.05 and 0.01 levels as discussed by Fisher (1963) [4]. Deviation of F1 from its better parent values or either of the parental values was interpreted by Mather (1971) [12] depicting type of gene action operating from controlling the trait.

Standard Heterosis = {F_1 ij - SP ij)/SP ij)} x 100

Heterobeltiosis = {F_1 ij - BP ij)/BP ij)} x 100t cal for standard heterosis

"t" = (F_1 ij - SP ij)/V3/8EMS

t cal for heterobeltiosis

"t" = (F_1 ij-BPij)_/V1/2EMS

F1 ij= the mean of the ijth F1 crosses, SP ij = the standard parent value for the ijth, BPij= value of better parent out of the i and jth parent, i= the female parent and j= the male parent.

Result and Discussion

The genotypic mean squares indicating highly significant differences among parental genotypes and their hybrids for all the characters studied [Table-1]. Results of heterosis over BP as well as SV revealed that no hybrid combination showed significant desirable heterosis for all yield, results for heterosis are given in Table 2. 10 crosses showed both heterobeltiosis and economic heterosis for days to 50% flowering, of these 10 crosses, 8 crosses PS 5×PSD 17, PSD 15×PSD 17, PSD 15×Pu Bas 1, PS 4×PB 1, PS 4×Pu Bas 1, PS 4×PB 2, PSD 15×PB 2 and PB 2×Pu Bas 1 manifested significant desirable heterosis over better parent and standard variety for days to maturity also. Quality Basmati rice of India are characterized by photo-thermosensivity and late maturity therefore, are difficult to fit into multiple cropping system. Hence, early maturity is a also observed by Kumar *et al.* 2012, Bano and Singh 2018 and Sureshkumar *et al.* 2018, Lingaiah *et al.* (2019) [7, 2, 15, 9]

In total 5 cross combination PS 4×PS 5, PS 5×Pu Bas 1, PS 4×PS 6, PS 5×PS 6 and PS 4×Pu Bas 1 showed significant desirable heterobeltiosis and economic heterosis for plant height. Dwarf and semi dwarf plant height determine lodging resistance, favourable grain/straw ratio and high grain yield at the expense of straw biomass (Itoh *et al*. 2002) [5]. Breeders are working towards developing semi dwarf varieties in the background of scented rice, mostly direct crosses are attempted subsequently handled by pedigree selection, backcross and convergent improvement methods. Negative heterosis for plant height was also observed by Ashfaq *et al.* 2013 and Roy *et al.* 2009 [1, 13]

For leaf area magnitude of better parent heterosis varied from -24.18 (PS 4×TB) to 31.18 (PS 5×Pu Bas 1) per cent and range of economic heterosis among crosses lied from -19.7 (Pu Bas 1×TB) to 36.57 (PS 6×PSD 15) per cent. In total 12 crosses PS 4×PS 6, PS 4×PSD 17, PS 4×PB 2, PS 5×PB 1, PS 5×Pu Bas 1, PS 6×PSD 15, PS 6×PB 2, PSD 15×PB 1, PSD 15×PB 2, PSD 17×PB 2, PB 1×PB 2 and PB 2×Pu Bas 1 showed significant desirable heterosis over oth better parent and standard variety. Positive heterosis for leaf area was also reported by Sarker *et al.* 2015 [14]

For number of panicles per plant which is an important yield component trait, heterosis over better parent ranged from -24.66 (PS 6×TB) to 38.35 (PS 6×PB 2) per cent. The heterosis over check variety ranged from -35.89 (PS 4×TB) to 34.61 (PS 5×PS 6) per cent.12 crosses PS 4×PS 5, PS 4×PS 6, PS 4×PSD 17, PS 4×PB 1, PS 4×Pu Bas 1, PS 5×PS 6, PS 5×PB 1, PS 5×PB 2, PS 5×Pu Bas 1, PS 6×PB 2, PB 1×PB 2 and PB 2×Pu Bas 1 manifested both significant better parent heterosis and economic heterosis in desired direction.

For panicle length magnitude for heterobeltiosis varied from -22.61 (PSD 15×TB) to 27.48** (PS 5×PS 6) per cent. Out of 36 crosses 10 showed significant heterobeltiosis in positive direction. Heterosis over check parent ranged from -12.99 (PSD 15×TB and PB 2×TB) to 26.55 (PS 5×Pu Bas 1) with 17 crosses showing significant positive economic heterosis. 8 crosses PS 4×PB 1, PS 5×PS 6, PS 5×PB 1, PS 5×PB 2, PS 5×Pu Bas 1, PS 6×PB 2, PB 1×PB 2 and PB 2×Pu Bas 1 showed both significant heterobeltiosis and economic heterosis.

In case of number of grains per panicle 20 crosses showed significant heterobeltiosis, which ranged from -16.84 (PS 6×TB) to 25.15 (PS 5×Pu Bas 1) percent. Among these 10 cross combinations showed significant positive heterobeltiosis. Significant economic heterosis was shown by 25 cross combinations which ranged from -10.50 (PSD 17×TB) to 22.90 (PS 5×PS 6) percent, out of which 21 crosses showed significant positive heterosis over check parent. Cross combinations PS 4×PS 5, PS 4×PSD 17, PS 4×Pu Bas 1, PS 5×PS 6, PS 5×PSD 17, PS 5×PB 2, PS 5×Pu Bas 1, PSD 17×Pu Bas 1, PB 1×PB 2 and PB 2×Pu Bas 1 showed both significant heterobeltiosis and economic heterosis.

Assessment of heterosis for thousand grain weight showed that 32 crosses showed significant better parent heterosis ranging from -17.83 (Pu Bas 1×TB) to 32.23 (PS 6×PSD 15) per cent of which 24 crosses exhibited significant positive heterosis over better parent. variety heterosis ranged from -21.28 (PS 4×TB) to 30.34 (PS 6×Pu Bas 1) per cent and seventeen crosses manifested significant positive economic heterosis. 14 crosses PS 4×PS 6, PS 4×PSD 17, PS 4×PB 2, PS 4×Pu Bas 1, PS 5×PS 6, PS 5×PSD 17, PS 5×PB 1, PS 6×PSD 17, PS 6×Pu Bas 1, PSD 15×Pu Bas 1, PSD 17×Pu Bas 1, PB 1×Pu Bas 1 and PB 2×Pu Bas 1 exhibited significant heterobeltiosis and standard heterosis in desired direction.

For biological yield Significant better parent heterosis was exhibited by 20 crosses which ranged from -23.65 (Pu Bas 1×TB) to 37.89 (PS 4×Pu Bas 1) per cent, out of which only 6 crosses showed significant positive heterobeltiosis. The range for economic heterosis among crosses lied from -32.06(PS 4×TB) to 20.77(PB 1×PB 2) with only 5 cross combination showing significant economic heterosis in desired direction. cross combinations PS 4×PS 5, PS 5×PB 2 and PB 1×PB 2 showed both significant desirable heterobeltiosis and economic heterosis.

Significant heterobeltiosis for harvest index was exhibited by 34 crosses which ranged from -27.55 (PSD 17×TB) to 37.89 (PS 4×Pu Bas 1) per cent, out of which 20 cross combinations exhibited significant heterobeltiosis in desired direction. PS 4×Pu Bas 1(37.89**), PS 5×PS 6(34.28**), PS 5×Pu Bas 1(34.28**), PB 2×Pu Bas 1 (33.33**) and PS 6×PB 2(29.29**) were identified as the five best heterotic crosses over better parent. 22 out of 36 crosses showed significant positive economic heterosis. Top Six cross combinations based on relative magnitude of heterosis over check parent were PS 5×PS 6(42.42**), PS 5×Pu Bas 1(42.42**), PS 5×PB 1(34.34**), PB 2×Pu Bas 1(33.33**), PS 5×PB 2(32.32**) and PS 4×Pu Bas 1(32.32). Estimates of economic heterosis among crosses ranged from -28.28 (PSD 17×TB) to 42.42 (PS 5×PS 6 and PS 5×Pu Bas 1). In total 20 crosses exhibited both signficant better parent heterosis and economic heterosis in desired direction.

Significant and desirable better parent heterosis and standard heterosis for various yield component traits were also reported by Kumar *et al.* (2012) [7], Ashfaq *et al.* (2013) [1], Aditya *et al.* (2017), Kumar *at al.* (2017) [8] and Ahmed *et al.* (2018), For grain yield per plant, 15 crosses over better parent (5.74 to 56.23%) and 13 over standard variety (7.20 to 40.18%) manifested significant desirable heterosis. Of these twelve crosses displayed heterosis over both better parent as well as standard variety for grain yield per plant and also showed desirable BPH and SVH for yield component traits and various quality traits. For cross PS 4×PS 5(BP=24.28%**, SVH=20.02%**) significant heterosis for grain yield was associated with significant BPH and SVH for plant height (BPH=-12.28%**, SVH=-13.23%**), number of panicles per plant (BPH=16.88%**, SVH=15.38%**), number of grains per panicle (BPH=17.63%**, SVH=12.16%**), biological yield (BPH=10.28%**,SVH=10.85%**) and harvest index (BPH=12.38%**, SVH=19.19%). Heterosis for grain yield per plant in cross PS 4×PS 6 (BPH=23.72%**, SVH=9.95%**) was associated with significant desirable BPH and SVH for plant height (BPH=-8.58%**, SVH=-13.23%**), leaf area (BPH=13.35%**, SVH=29.95%**), number of panicles per plant (BPH=21.19%**, SVH=14.10%**), 1000 grain weight (BPH=13.09%**, SVH=3.24%**) and harvest index (BPH=27.36%**, SVH=22.22%**). Similarly significant heterosis for grain yield in cross PS 4×PSD 17 (BPH=45.32%**, SVH=7.20%**) was found associated with number of panicles per plant (BPH=32.31%**, SVH=10.25%**), number of grains per panicle (BPH=11.58%**, SVH=9.18%**), 1000 grain weight (BPH=28.03%**, SVH=22.59%**) and harvest index (BPH=19.38%**, SVH=18.18%**). Cross PS 4×PB 1 (BPH=34.87%**, SVH=9.95%**) showing significant BPH and SVH for grain yield also exhibited desirable BPH and SVH for number of panicles per plant (BPH=25.71%**, SVH=12.82%**), panicle length (BPH=4.85%**, SVH=22.03%**) and harvest index (BPH=22.81%**, SVH=25.25%**). In additional to showing significant heterosis for grain yield per plant cross PS 4×Pu Bas 1(BPH=21.15%**, SVH=15.44%**) also showed significant desirable BPH and SVH for days to 50% flowering (BPH= -13.02%**, SVH= -14.01%**), days to maturity (BPH= -8.52%**, SVH= -8.52%**), plant height (BPH= -4.51%**, SVH= -6.48%**), number of panicles per plant (BPH=23.28%**, SVH=15.38%**), number of grains per panicle (BPH=16.98%**, SVH=10.97%**), 1000 grain weight (BPH=17.03%**, SVH=21.30%**) and harvest index (BPH=37.89%**, SVH=32.32%**). Similarly cross PS 5×PS 6 (BPH=45.16%**, SVH=40.18%**) showed desirable BPH and SVH for plant height (BPH=-7.84%**, SVH=-8.84%**), number of panicles per plant (BPH=36.36%**, SVH=34.61%**), panicle length (BPH=27.48%**, SVH=23.16%**), number of grains per panicle (BPH=8.42%** SVH=22.90%**), 1000 grain weight (BPH=5.72%**, SVH=17.43%**) and harvest index (BPH=34.82%**, SVH=42.42%**). Along with grain yield per plant cross PS 5×PB 1(BPH=32.82%**, SVH=28.27%**) showed desirable BPH and SVH for leaf area (BPH=12.21%**, SVH=16.71%**), number of panicles per plant (BPH=31.16%**, SVH=29.48%**), panicle length (BPH=23.97%**, SVH=19.77%**), 1000 grain weight (BPH=3.40%**, SVH=14.85%**) and harvest index (BPH=26.66%**, SVH=34.34%**). Heterosis for grain yield per plant in PS 5×PB 2 (BPH=35.67%**, SVH=31.02%**) was associated with number of panicles per plant (BPH=28.57%**, SVH=26.92%**), panicle length (BPH=11.95%**, SVH=16.38%**), number of grains per panicle (BPH=8.06%**, SVH=19.92%**), biological yield (BPH= 8.26%*, SVH=8.82%) and harvest index (BPH=24.76%**, SVH=32.32%**). Along with grain yield per plant PS 5×Pu Bas 1 (BPH=38.52, SVH=33.77%**) showed desirable BPH and SVH for days to 50% flowering (BPH= -4.72%**, SVH= -15.91%**), plant height (BPH= -8.99%**, SVH= -11.21%**), leaf area (BPH=31.18%**, SVH=27.47%**), number of panicles per plant (BPH=29.87%**, SVH=28.2%**), panicle length (BPH=25.14%**, SVH=26.55%**), number of grains per panicle (BPH=25.15%**, SVH=18.73%**) and harvest index (BPH=34.28%**, SVH=42.42%**). Similarly cross PS 6×PB 2 (BPH=41.25%**, SVH=25.52%**) showed significant desirable BPH and SVH for leaf area (BPH=13.63%**, SVH=25.81%**), number of panicles per plant (BPH=38.35%**, SVH=29.48%**) and panicle length (BPH=17.39%**, SVH=22.03%**). In addition to having significant heterosis for grain yield per plant cross PB 1×PB 2(BPH=56.23%**, SVH=27.36%**) also showed significant BPH and SVH for leaf area(BPH=11.9%**, SVH=16.71%**), number of panicles per plant(BPH=30%**, SVH=16.66%**), panicle length(BPH=9.78%**, SVH=14.12%**), number of grains per panicle (BPH=5.91%*, SVH=17.53%**), biological yield (BPH=37.27%**, SVH=20.77%**) and harvest index (BPH=13.89%**, SVH=16.16%**). Significant heterosis for grain yield per plant in cross PB 2×Pu Bas 1 was associated with significant BPH and SVH for days to 50% flowering (BPH=-10.89%**, SVH=-13.25%**), days to maturity (BPH=-7.08%**, SVH=-8.02%**), leaf area (BPH=10.99%**, SVH=15.76%**), number of panicles per plant (BPH=30.13%**, SVH=21.79%**), panicle length (BPH=9.78%**, SVH=14.12%**), number of grains per panicle (BPH=7.52%**, SVH=19.32%**), 1000 grain weight (BPH=7.07%**, SVH=10.98%**) and harvest index (BPH=33.33%**, SVH=33.33%**). High heterosis for grain yield per plant along with yield component traits and was also reported by Venkatesan *et al.* 2008, Roy *et al.* 2009 [13], Venkanna *et al.* 2014 [16], Bano and Singh 2018 [2], Devi *et al.* 2018 [3]. The high yield as well as high frequency of heterotic F1 hybrids may be attributed to their parents which were specifically selected on the basis of their higher per se performance, diverse origin and resistance to disease and insects.

Table 1: Analysis of variance for yield related characters in parents and their F_1 hybrids in rice

S.V.	d.f.	Mean square										
		DF	DM	PH	LA	NPP	PL	NGP	TGW	GY	BY	HI
Replication	2	121.308	136.697	54.315	27.302	69.8	52.124	7.029	5.868	50.612	84.026	18.94
Treatment	43	270.895**	285.759**	596.29**	116.519**	82.369**	29.304**	79.169**	35.187**	225.736**	472.713**	100.985**
Error	88	4.167	4.499	4.629	4.729	11.769	5.577	8.817	2.140	8.321	19.277	4.009

Table 2: Heterosis for different characters in Rice

Crosses	DFF			DM			Plant height			LA		
	Mean	BPH	SVH	Mean	BPH	SVH	Mean	BPH	SVH	Mean	BPH	SVH
PS 4×PS 5	84	8.15**	-4.54**	130	5.12**	-2.25	85.66	-12.28**	-13.23**	42.75	-7.4**	6.15**
PS 4×PS6	101.33	3.75*	15.15**	147.33	2.07	10.77**	92.33	-8.58**	-6.47**	52.33	13.35**	29.95**
PS 4×PSD 15	92	-2.12	4.54**	138.66	-0.24	4.26*	110	8.91**	11.41**	51.66	10.61**	28.3**
PS 4×PSD 17	89	-3.26	1.13	135	-2.17	1.50	103	1.98	4.32*	43.33	-6.13**	7.60**
PS 4×PB 1	91.66	-5.49**	4.16*	137.66	-3.73*	3.51*	104	2.97	5.33**	46.33	0.36	15.05**
PS 4×PB 2	76.33	-10.89**	-13.25**	122.33	-7.08**	-8.02**	113.66	12.54**	15.12**	48.66	5.41**	20.85**
PS 4×Pu Bas 1	75.66	-13.02**	-14.01**	121.66	-8.52**	-8.52**	92.33	-4.15*	-6.48**	42.33	-8.3**	5.12**
PS 4×TB	102	4.43**	15.91**	148.66	3	11.77**	131.66	30.36**	33.36**	35	-24.18**	-13.08**
PS 5×PS6	92.33	18.88**	4.92**	138.33	11.88**	4.01*	90	-7.84**	-8.84**	44	-1.31	9.26**
PS 5×PSD 15	75	-3.43*	-14.77**	121	-2.15	-9.02**	109	11.61**	10.4**	45	-0.03	11.74**
PS 5×PSD 17	92.33	-6.01**	-17.04**	119	-3.77*	-10.52**	104.66	7.17**	6.01**	40.66	1.28	0.98
PS 5×PB 1	73	16.73**	3.03	136.66	10.51**	2.75	105.66	8.19**	7.02**	47	12.21**	16.71**
PS 5×PB 2	91.66	-3	-14.39**	121.33	-1.88	-8.77**	114	16.73**	15.46**	39.66	-5.55**	-1.49
PS 5×Pu Bas 1	75.33	-4.72**	-15.91**	120	-2.96	-9.77**	87.66	-8.99**	-11.21**	51.33	31.18**	27.47**
PS 5×TB	74	16.31**	2.65	136.33	10.24**	2.50	126.66	29.70**	28.29**	33.33	-9.09**	-17.22**
PS 6×PSD 15	90.33	1.79	7.57**	140.66	1.19	5.76**	114.66	9.56**	15.14**	55	17.75**	36.57**
PS 6×PSD 17	94.66	2.17	6.81**	140	1.44	5.26**	109.33	4.46*	10.73**	42	-5.8**	4.29*
PS 6×PB 1	94.66	-1.37	8.71**	141.66	-0.93	6.51**	111.66	6.69**	13.10**	41	-8.04**	1.81
PS 6×PB 2	94	3.89*	1.13	135	2.53	1.50	112.33	7.33**	13.77**	50.66	13.63**	25.81**
PS 6×Pu Bas 1	95.66	1.91	0.75	134.66	1.25	1.25	102.33	6.23**	3.64*	40	-10.28**	-0.67
PS 6×TB	89	-3.19	14.77**	147.66	-3.06	11.02**	135	28.98**	36.73**	36.33	-18.51**	-9.77**
PSD 15×PSD 17	89	-14.85**	-10.98**	124.33	-9.9**	-6.51**	109	-1.80	10.40**	48.33	3.48	20.02**
PSD 15×PB 1	88.66	-1.43	4.16*	137.66	-0.95	3.51*	114	-1.43	15.46**	49	4.91**	21.67**
PSD 15×PB 2	101	-10.89**	-13.25**	122.33	-7.09**	-8.02**	117.66	-1.39	19.18**	51.66	10.61**	28.3**
PSD 15×Pu Bas 1	93	-13.02**	-14.01**	121.66	-8.52**	-8.52**	109.33	13.49**	10.74**	45.33	-2.94	12.57**
PSD 15×TB	78.33	8.24**	14.39**	146.66	5.51**	10.27**	137.33	15.08**	39.09**	38.33	-17.92**	-4.81**
PSD 17×PB 1	91.66	-0.36	4.16*	137.66	-0.24	3.51*	107.33	-3.3	8.71**	41.66	-0.52	3.46
PSD 17×PB 2	78.66	-8.17**	-10.60**	124.66	-5.31**	-6.26**	115.33	3.9*	16.81**	44	4.76**	9.26**
PSD 17×Pu Bas 1	86.33	-0.76	-1.89	132.33	-0.5	-0.5	108.66	12.8**	10.06**	40	-0.37	-0.67
PSD 17×TB	97.66	6.15**	10.98**	144.66	4.83**	8.77**	130.33	17.41**	32.01**	33.33	-16.97**	-17.22**
PB 1×PB 2	97	6.61**	3.78*	137.33	4.3*	3.25	117	1.15	18.50**	47	11.9**	16.71**
PB 1×Pu Bas 1	91.33	1.14	0	134	0.75	0.75	110	14.19**	11.41**	39.33	-6.09**	-2.32
PB 1×TB	88	2.40	12.87**	145.33	1.63	9.27**	130	12.39**	31.67**	33.66	-19.62**	-16.39**
PB 2×Pu Bas 1	99.33	-10.89**	-13.25**	122.33	-7.08**	-8.02**	106	10.38**	7.36**	46.61	10.99**	15.76**
PB 2×TB	85.66	15.17**	12.12**	144.66	9.87**	8.77**	135	10.35**	36.73**	34.33	-18.25**	-14.74**
Pu Bas 1×TB	76.33	10.73**	9.46**	142.33	7.01**	7.01**	120	24.57**	21.54**	32.33	-17.36**	-19.7**
CD at 1%		4.433	4.433		4.60	4.60		4.67	4.67		4.72	4.72
CD at 5%		3.33	3.33		3.46	3.46		3.51	3.51		3.55	3.55

Crosses	NPP			PL			NGP			TGW		
	Mean	BPH	SVH	Mean	BPH	SVH	Mean	BPH	SVH	Mean	BPH	SVH
PS 4×PS 5	30	16.88**	15.38**	33.33	-2.91	12.99**	62.66	17.63**	12.16**	24.66	-14.02**	-4.50**
PS 4×PS6	29.66	21.19**	14.10**	32.33	-5.82**	9.60**	61	-3.68	9.18**	26.66	13.09**	3.24**
PS 4×PSD 15	19.66	-9.23**	-24.35**	33	-3.88*	11.18**	54	-7.95**	-3.33	21.33	-9.52**	-17.41**
PS 4×PSD 17	28.66	32.31**	10.25**	31.33	-8.73**	6.21**	61	11.58**	9.18**	31.66	28.03**	22.59**
PS 4×PB 1	29.33	25.71**	12.82**	36	4.85*	22.03**	63	2.16	12.76**	25.66	8.84**	-0.63
PS 4×PB 2	23.66	4.41	-8.97**	32.66	-4.85*	10.73**	59.33	-4.30	6.19*	30.66	30.05**	18.72**
PS 4×Pu Bas 1	30	23.28**	15.38**	33	-3.88*	11.86**	62	16.98**	10.97**	31.33	17.03**	21.30**
PS 4×TB	16.66	-23.07**	-35.89**	28.66	-16.50**	-2.82	54	-1.22	-3.34	20.33	-13.76**	-21.28**
PS 5×PS6	35	36.36**	34.61**	36.33	27.48**	23.16**	68.66	8.42**	22.90**	30.33	5.72**	17.43**
PS 5×PSD 15	23	-10.39**	-11.53**	29.66	-10.55**	0.56	56	-4.54	0.23	28.66	-0.08	10.98**
PS 5×PSD 17	24.66	-3.86	-5.13	29	-12.12**	-1.69	59.33	9.87**	6.19*	30	4.56**	16.14**
PS 5×PB 1	33.66	31.16**	29.48**	35.33	23.97**	19.77**	64.33	4.32	15.14**	29.66	3.40**	14.85**
PS 5×PB 2	33	28.57**	26.92**	34.33	11.95**	16.38**	67	8.06**	19.92**	28	-2.40*	8.40**
PS 5×Pu Bas 1	33.33	29.87**	28.2**	37.33	25.14**	26.55**	66.33	25.15**	18.73**	28.91	0.79	11.95**
PS 5×TB	20	-22.07**	-23.07**	26	-8.77**	-11.86**	50.66	-1.29	-9.31**	23.66	-17.51**	-8.37**
PS 6×PSD 15	21.33	-12.32**	-17.94**	30.33	-8.54**	2.82	55	-13.15**	-1.55	29	32.23**	12.27**
PS 6×PSD 17	24.33	0	-6.41*	28.66	-13.13**	-2.82	60.33	-4.73	7.98**	29	17.26**	12.27**
PS 6×PB 1	25.33	4.11	-2.56	29	4.19*	-1.69	62	-2.10	10.97**	26.33	21.07**	1.94
PS 6×PB 2	33.66	38.35**	29.48**	36	17.39**	22.03**	65.66	3.68	17.53**	25	14.94**	-3.21**
PS 6×Pu Bas 1	26.66	9.58**	2.56	30.66	2.79	-3.95*	62.66	-1.05	12.16**	33.66	25.74**	30.34**
PS 6×TB	18.33	-24.66**	-29.48**	26.66	-2.44	-9.60**	52.66	-16.84**	-5.73*	23.66	8.81**	-8.37**
PSD 15×PSD 17	19	-6.55*	-26.92**	30.66	-7.53**	3.95*	53.66	-8.52**	-3.94	25.66	3.77**	-0.63
PSD 15×PB 1	20.33	-12.85**	-21.79**	28.33	-14.57**	-3.95*	53.66	-12.97**	-3.94	25.66	17.03**	-0.63
PSD 15×PB 2	20.33	-10.29**	-21.79**	32	-3.52	8.47**	54.66	-11.82**	-2.15	24	9.43**	-7.08**

PSD 15×Pu Bas 1	21.66	-10.96**	-16.66**	31	-6.53**	5.08*	54.66	-6.81**	-2.15	29	8.31**	12.27**
PSD 15×TB	17	-10.52**	-34.61**	25.66	-22.61**	-12.99**	57.33	-2.27	2.62	25.33	15.52**	-1.92
PSD 17×PB 1	23.66	1.42	-8.97**	29.33	-11.11**	-0.56	59.33	-3.78	6.19*	24.66	-0.27	-4.50**
PSD 17×PB 2	23.66	4.41	-8.97**	27.66	-16.16**	-6.21**	59.33	-4.30	6.19*	24	-2.96*	-7.08**
PSD 17×Pu Bas 1	24.33	0	-6.41*	29	-12.12**	-1.69	62	14.81**	10.97**	29.66	10.80**	14.85**
PSD 17×TB	18	-11.47**	-30.76**	27.33	-17.17**	-7.34**	50	-7.40**	-10.50**	24.66	-0.27	-4.50**
PB 1×PB 2	30.33	30**	16.66**	33.66	9.78**	14.12**	65.66	5.91*	17.53**	23.33	10.76**	-9.66**
PB 1×Pu Bas 1	25.66	5.47	-1.28	30.33	5.81**	2.82	60.66	-1.62	8.58**	28.33	5.82**	9.69**
PB 1×TB	18.66	-20**	-28.2**	27	-2.99	-8.47**	53.66	-12.97**	-3.94	22	4.43**	-14.82**
PB 2×Pu Bas 1	33.66	30.13**	21.79**	33.66	9.78**	14.12**	66.66	7.52**	19.32**	28.66	7.07**	10.98**
PB 2×TB	18.33	-19.12**	-29.48**	25.66	-16.30**	-12.99**	53.33	-13.97**	-4.54	23	10.4**	-10.95**
Pu Bas 1×TB	18.66	-23.28**	-28.2**	28.66	-3.91*	-2.82	52.33	-1.25	-6.33*	22	-17.83**	-14.82**
CD at 1%		7.45	7.45`		5.13	5.13		6.45	6.45		3.18	3.18
CD at 5%		5.60	5.60		3.85	3.85		4.85	4.85		2.39	2.39

Crosses	GY			BY			HI		
	Mean	BPH	SVH	Mean	BPH	SVH	Mean	BPH	SVH
PS 4×PS 5	43.66	24.28**	20.02**	110.85	10.28**	10.85**	39.33	12.38**	19.19**
PS 4×PS6	40	23.72**	9.95**	103.17	1.30	3.17	40.33	27.36**	22.22**
PS 4×PSD 15	26.66	-0.63	-26.7**	75.83	-12.27**	-24.16**	36	0	9.09**
PS 4×PSD 17	39	45.32**	7.20**	99.91	15.57**	-0.09	39	19.38**	18.18**
PS 4×PB 1	40	34.87**	9.95**	96.74	9.96**	-3.25	41.33	22.81**	25.25**
PS 4×PB 2	30.66	5.74*	-15.70**	99.74	13.56**	-0.26	30.66	-7.07**	-7.07**
PS 4×Pu Bas 1	42	21.15**	15.44**	96.04	-12.17**	-3.95	43.66	37.89**	32.32**
PS 4×TB	20	-25.47**	-45.02**	67.93	-21.41**	-32.06**	29.33	-5.27**	-11.11**
PS 5×PS6	51	45.16**	40.18**	108.42	6.45	8.42*	47	34.28**	42.42**
PS 5×PSD 15	31.33	-10.81**	-13.87**	76.39	-24**	-23.61**	41	13.88**	24.24**
PS 5×PSD 17	32.66	-7.02**	-10.20**	102.02	1.49	2.02	32	-8.57**	-3.03
PS 5×PB 1	46.66	32.82**	28.27**	105.2	4.65	5.2	44.33	26.66**	34.34**
PS 5×PB 2	47.66	35.67**	31.02**	108.82	8.26*	8.82*	43.66	24.76**	32.32**
PS 5×Pu Bas 1	48.66	38.52**	33.77**	103.60	-5.25	3.60	47	34.28**	42.42**
PS 5×TB	26.66	-24.09**	-26.7**	88.85	-11.60**	-11.14**	30	-14.28**	-9.09**
PS 6×PSD 15	30	-7.21**	-17.53**	89.90	-11.72**	-10.09**	33.33	-7.40**	-1.01
PS 6×PSD 17	33	2.07	-9.29**	95.10	-6.61	-4.89	34.66	6.12**	5.05**
PS 6×PB 1	32.66	1.04	-10.21**	78.80	-22.62**	-2.12	41.33	22.81**	25.25**
PS 6×PB 2	45.66	41.25**	25.52**	107.09	5.15	7.09	42.66	29.29**	29.29**
PS 6×Pu Bas 1	36.33	4.08	-0.12	90.04	-17.65**	-9.95**	40.33	27.36**	22.22**
PS 6×TB	23.66	-26.79**	34.94**	84.22	-17.29**	-15.77**	28	-11.58**	-15.15**
PSD 15×PSD 17	25.66	-3.38	-29.45**	80.84	-0.23	-19.15**	31.66	-12.04**	4.04*
PSD 15×PB 1	28	-5.58*	-23.03**	90.17	2.49	-9.82**	31	-13.88**	-6.06**
PSD 15×PB 2	28	-3.48	-23.03**	87.39	-0.49	-12.61**	32	-11.11**	-3.03
PSD 15×Pu Bas 1	28.66	-17.31**	-21.20**	90.4	-17.33**	-9.6**	31.66	-12.04**	-4.04*
PSD 15×TB	21	-15.77**	-42.27**	74.13	5.23	-25.86**	28.33	-21.29**	-14.14**
PSD 17×PB 1	33	11.27**	-9.29**	89.99	2.28	-10.01**	36.66	8.94**	11.11**
PSD 17×PB 2	32.66	12.64**	-10.21**	89.13	1.49	-10.86**	36.66	11.11**	11.11**
PSD 17×Pu Bas 1	33.33	-3.84	-8.37**	96.01	-12.19**	-3.98	34.66	6.12**	5.05**
PSD 17×TB	19.66	-25.97**	-45.94**	83.04	2.48	-16.95**	23.66	-27.55**	-28.28**
PB 1×PB 2	46.33	56.23**	27.36**	120.77	37.27**	20.77**	38.33	13.89**	16.16**
PB 1×Pu Bas 1	33	-4.80*	-9.29**	86.71	-20.70**	-13.28**	38	12.90**	15.15**
PB 1×TB	22.33	-24.69**	-38.61**	90.29	2.62	-9.71**	24.66	-26.71**	-25.25**
PB 2×Pu Bas 1	49.33	42.30**	35.60**	112.06	2.48	12.06**	44	33.33**	33.33**
PB 2×TB	23.33	-19.54**	-35.86**	77.79	-11.42**	-22.21**	30	-9.09**	-9.09**
Pu Bas 1×TB	25.33	-26.92**	-30.36**	83.	-23.65**	-16.51**	31	-2.10	-6.06**
CD at 1%		6.26	6.26		9.53	9.53		4.35	4.35
CD at 5%		4.71	4.71		7.17	7.17		3.27	3.27

BPH = Better parent heterosis, SVH = Standard variety heterosis

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