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Heterosis for quantitative traits in *Gobhi Sarson* (*Brassica napus* L)

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Abstract

Five genotypes of *Gobhi Sarson* (*Brassica napus* L.) were crossed in a half-diallel mating design to calculate heterosis for seed yield and yield components. Ten crosses and their parents were evaluated in the field followed by a randomized complete block design with three replications. The F1 hybrids and their parents were evaluated at Mata Gujri College, Fatehgarh Sahib, Punjab. Analysis of variance showed significant differences for all the traits in crosses and highly significant heterosis was detected among the hybrids. It indicated the existence of considerable genetic variability in breeding material. Seed yield per plant showed 70.8 to 136.5% significant difference in heterobeltiosis followed by secondary branches per plant (80.5 1o 99.0%), biological yield (30.7 to 90.7%), siliqua length (33.6 to 56.7%), primary branches (18.9 to 42.1%), number of seeds per siliqua (21.1 to 32.9%), plant height (15.0 to 27.3%), harvest index (12.6 to 23.7%) as well as biological yield showed 41.9 to 77.8% significant difference in standard heterosis followed by secondary branches per plant (42.3 to 64.9%), siliqua length (31.3 to 46.5%), seed yield per plant (9.4 to 44.6%), number of seed per siliqua (16.3 to 26.4%), primary branches (22.8 to 42.8%), days to 50% flowering (-7.0 to -21.1%) and days to first flowering (-6.0 to 10.3%). The crosses with high seed yield per plant indicate a considerable potential to embark on breeding of hybrid in *Gobhi Sarson*.

Keywords: *Genetic variability, Gobhi Sarson, heterobeltiosis, yield*

Introduction

Gobhi Sarson (*Brassica napus* L.; AACC, 2n = 38) is an amphidiploid plant that was created when *B. rapa* (AA, 2n = 20) and *B. oleracea* (CC, 2n = 18) spontaneously hybridized with each other (Allender and King, 2010). The genetic diversity of winter, semi-winter, and spring rapeseed can be increased through hybridization (Qian *et al*., 2009; Kebede *et al*., 2010). Rapeseed (*B. napus*) is one of the most important edible oilseed crops in the world as well as a major potential source of edible oil production. In the crushing industry, about 80% of the value of rapeseed is related to oil production.

The term "heterosis" is used to describe the phenomenon in which F_1 hybrids derived from two genetically dissimilar genotypes exhibit superior phenotypic performance as compared with either parent, typically manifested in rapid growth, high fertility, superior biomass production, resistance to disease and insect pests, and high grain yield (Shull, 1948; Birchler *et al*., 2010). For nearly a century, farmers have increasingly used heterosis in crop production in an effort to breed hardier, higher-yielding hybrid cultivars (Fu *et al*., 2014). The first important step in taking advantage of heterosis is to know its scope and direction. Type and size help to recognize better cross combinations and their exploitation to get better transgressive segregates. The size of heterosis gives data on the degree of hereditary differing qualities in parents of a cross and helps in choosing the parents for predominant F_1s, so as to exploit hybrid vigour. The commercial use of heterosis is considered to be an excellent application of genetic principles in the field of plant breeding. Hybrids adopted by heterosis are the needs of modern agriculture to break existing yield barriers and achieve higher levels of productivity. The magnitude of heterosis effects depends on the ecological and genetically differences and also on the diversity of origin of parents (Dhawan and Singh, 1961; Moll *et al.,* 1962). The application of hybridization has also enhanced our understanding of the genetic basis of heterosis in *B. napus* and facilitated the development of superior hybrid varieties.

Materials and Methods

Five genetically diverse lines, viz., EC 338978, RBS Bold, EC 338975, HMS 4 and BMS 4 were collected from the National Bureau of Plant Genetic Resources, New Delhi. Experiment conducted at experimental farm of Mata Gujri College, Fatehgarh Sahib during the winter seasons of 2020-21 and 2021-22. The experimental farm (30°6"N and 76°4"E) is located at 269 m above mean sea level with mean annual precipitation of about 770 mm and soil type of loamy sand at the surface and calcareous sandy loam in subsurface layers. Hyola ADV 405 variety is used as a standard check. The parental lines were chosen in a systematic random way to represent the phenotypic diversity, and a study was conducted for yield and yield-related parameters. The genotypes were crossed artificially during winter season 2020-21 in diallel mating fashion. The seeds of each cross were harvested at maturity and stored for the next season. In the next season, the seed collected from crosses along with parents was sown in field under randomized block design with three replications. Standard agronomic management practices were followed for raising the crop. The data were recorded on different parameters including days to first flowering, days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, days to maturity, number of siliquae per plant, plant height, number of seeds per siliqua, siliqua length, biological yield per plant, harvest index and seed yield per plant. The recorded data was subjected to analysis of variance to determine the genotypic differences for selected traits.

Results and Discussion

The analysis of variance for 15 entries, five parents (EC 338978, RBS Bold, EC 338975, HMS 4 and BMS 4) and their 10 crosses were made for twelve yield and yield characters in the winter seasons of 2020-21 and 2021-22. Analysis of variance showed that the mean squares by parent and hybrid were significant and that there was reasonable variation in them for all traits. Comparison of mean squares due to parents and hybrids was found to be significant for traits under study. The similar findings were recorded by Kaur *et al*. (2022). Heterosis breeding has played an important role in crop improvement programme for obtaining higher seed production. The pre-requisite is to know the magnitude and direction of heterosis so, that it can be effectively exploited in crop improvement. The hybrid vigour has so far not been extensively exploited in self-pollinated crops in comparison to cross pollinated ones. However, heterosis as a means of increasing productivity has been an object of considerable study in mustard. In the present investigation, the magnitude of heterosis (heterobeltiosis and economic heterosis) has been calculated. The magnitude of heterosis has been expressed as a percent increase or decrease of F_1 over better parent (heterobeltiosis) and standard check (standard heterosis).

Days to first flowering are important characters for early maturity. The mean performance for days to first flowering were varies in cross combinations from 48.8 (EC 338978 × RBS Bold) to 52.9 (HMS 4 × BMS 4) days (Table 1). One cross combination namely EC 338978 × HMS 4 (4.8%) showed significant positive heterosis over better parent, while none of the cross combinations was found to be significant negative heterosis. Seven cross combinations showed significant negative heterosis over standard check ranging from -6.0% (EC 338975 × BMS 4) to -10.3% (EC 338978 × RBS Bold). This similar value in cross combination was observed by Bhinda *et al*. (2020). The mean performance for days to 50% flowering varies in the cross combinations from 55.7 (EC 338978 × EC 338975) to 72.9 (HMS 4 × BMS 4) days (Table 1). None of the cross combinations showed significant negative heterosis over better parent while six cross combinations showed significant positive heterosis ranging from 6.3% (EC 338978 × RBS Bold) to 16.0% (EC 338975 × BMS 4). Seven F1 hybrids showed significant negative useful heterosis over standard check ranging from -5.7% (EC 338975 × BMS 4) to -13.8% (EC 338978 × RBS Bold). Similar findings were observed by Shalini *et al*., (2000). Positive heterosis for the number of primary branches per plant is desirable because plants with vigorous stature having more branches provide the opportunity for higher yield. The mean performance for this trait varies in cross combinations from 7.3 (EC 338978 × HMS 4) to 8.5 (RBS Bold × HMS 4). Ten cross combinations ranging from 18.8% (EC 338975 × BMS 4) to 42.1% (EC 338978 × EC 338975) showed significant positive heterosis over better parent, while all ten cross combinations exhibited a significant positive heterosis for number of primary branches over standard check ranging from 22.8% (EC 338978 × HMS 4) to 42.8% (RBS Bold × HMS 4) (Table 1). A similar result was observed by Kaur *et al*. (2023).

The mean performance for the number of secondary branches per plant varies in cross combinations from 19.3 (EC 338978 × RBS Bold) to 22.4 (EC 338978 × BMS 4). All cross combinations exhibited a significant positive heterosis over better parent ranging from 80.5% (EC 338978 × RBS Bold) to 99.0% (RBS Bold × HMS 4), while all ten cross combinations showed a significant positive standard heterosis ranging from 42.3% (EC 338978 × RBS Bold) to 64.9% (EC 338978 × BMS 4) (Table 2). Similar research findings were recorded by Shekhawat *et al.* (2021). The mean performance for days to maturity varies in cross combinations ranging from 146.7 (HMS 4 × BMS 4) to 149.7 (EC 338978 × EC 338975). None of the cross combinations showed significant heterosis over the better parent and standard check (Table 2).

The performance of mean (Table 2) for plant height (cm) varies in cross combinations ranging from 179.2 (RBS Bold × BMS 4) to 193.1 (EC 338978 × EC 338975) cm. All ten hybrids ranging from 15.0% (RBS Bold × BMS4) to 27.3% (EC 338978 × EC 338975) showed a significant positive heterosis over better parent while seven cross combinations showed a significant positive

Table 1: Estimation of percent heterosis based on days to first flowering, days to 50% flowering and primary branches per plant in *B. napus*

Cross Combination	Days to first flowering			Days to 50% flowering			Primary branches per plants		
	Mean	Better parent	Standard check	Mean	Better parent	Standard check	Mean	Better parent	Standard check
EC 338978 × RBS Bold	48.8	0.7	-10.3**	60.9	6.3**	-13.8**	8.2	24.9 **	38.1**
EC 338978 × EC 338975	49.4	1.9	-9.3**	55.7	-2.7	-21.1**	7.8	42.1 **	30.5**
EC 338978 × HMS 4	50.8	4.8**	-6.7**	65.7	14.7**	-7.0**	7.3	24.7 **	22.8**
EC 338978 × BMS 4	49.5	2.1	-9.1**	64.3	12.3**	-9.0	**7.9	24.1 **	32.7**
RBS Bold × EC 338975	50.8	-1.6	-6.8**	61.1	6.4**	-13.5**	8.0	22.0 **	34.9**
RBS Bold × HMS4	52.5	1.8	-3.5	69.6	3.2	-1.5	8.5	29.1 **	42.8**
RBS Bold × BMS4	50.8	-1.5	-6.7**	70.0	3.9	-0.9	8.4	27.0 **	40.4**
EC 338975 × HMS4	52.8	-0.1	-3.1	65.4	13.9**	-7.4**	7.7	31.0 **	29.0**
EC 338975 × BMS4	51.2	-2.7	-6.0**	66.6	16.0**	-5.7**	7.61	8.8 **	27.1**
HMS 4 × BMS4	52.9	0.5	-2.9	72.9	-2.2	3.1	8.0	26.3 **	35.1**
SEm±	-	0.9	0.9	-	3.4	3.4	-	0.4	0.4
CD at 5%	-	2.1	2.1	-	7.6	7.6	-	0.9	0.9

*Where; **: Significant at 1% level of significance*

Table 2: Estimation of percent heterosis based on secondary branches per plant, days to maturity and plant height in *B. napus*

Cross Combination	Secondary branches per plant			Days to maturity			Plant height (cm)		
	Mean	Better parent	Standard check	Mean	Better parent	Standard check	Mean	Better parent	Standard check
EC 338978 × RBS Bold	19.3	80.5**	42.3**	149.0	0.3	0.2	184.7	17.9**	3.8*
EC 338978 × EC 338975	20.7	81.6**	52.2**	149.7	-0.6	0.6	193.1	27.3**	8.6**
EC 338978 × HMS 4	21.3	90.1**	56.6**	148.5	0.6	-0.2	189-6	22.5**	6.6**
EC 338978 × BMS 4	22.4	98.8**	64.9**	148.5	0.6	-0.2	189.0	21.3**	6.3**
RBS Bold × EC 338975	21.4	88.2**	57.8**	148.2	-0.2	-0.4	181.1	19.5**	1.8
RBS Bold × HMS4	22.3	99.0**	64.0**	147.2	-0.3	-1.0	182.2	17.7**	2.4
RBS Bold × BMS4	22.0	95.1**	61.8**	147.0	-0.4	-1.2	179.2	15.0**	0.8
EC 338975 × HMS4	20.6	80.7**	51.5**	148.0	0.2	-0.5	187.3	23.5**	5.3**
EC 338975 × BMS4	20.8	82.2**	52.8**	148.0	0.3	-0.5	187.4	23.6**	5.4**
HMS 4 × BMS4	20.9	85.4**	53.8**	146.7	-0.6	-1.4	183.9	18.8**	3.4*
SEm±	-	1.3	1.3	-	1.0	1.0	-	3.86	3.9
CD at 5%	-	2.8	2.8	-	2.2	2.2	-	8.5	8.5

*Where; *: significant at 5% level of significance, **: Significant at 1% level of significance*

Table 3: Estimation of percent heterosis based on number of siliquae per plant, number of seed per siliqua and siliqua length in *B. napus*

Cross Combination	Number of siliquae per plant			Number of seeds per siliqua			Siliqua length (cm)		
	Mean	Better parent	Standard check	Mean	Better parent	Standard check	Mean	Better parent	Standard check
EC 338978 × RBS Bold	269.3	1.5	-4.9	24.5	21.0 **	19.0**	8.1	41.0 **	31.3**
EC 338978 × EC 338975	249.4	-3.3	-12.0**	24.9	22.8 **	20.7**	8.5	48.0 **	37.8**
EC 338978 × HMS4	252.0	-2.3	-11.0**	25.5	25.8 **	23.7**	8.6	47.3 **	38.5**
EC 338978 × BMS4	258.3	0.2	-8.8**	26.1	28.6 **	26.4**	8.8	40.1 **	41.1**
RBS Bold × EC 338975	229.5	-13.5*	-19.0**	24.7	29.9 **	19.8**	8.6	56.7 **	38.3**
RBS Bold × HMS4	224.0	-15.6*	-20.9**	24.6	29.8 **	19.1**	8.4	43.8 **	35.3**
RBS Bold × BMS4	260.5	-1.9-	8.1**	24.0	32.8 **	16.3**	8.3	33.6 **	34.6**
EC 338975 × HMS4	206.5	10.6	-27.1**	24.0	26.2 **	16.4**	8.6	47.8 **	39.0**
EC 338975 × BMS4	186.0	-3.1	-34.3**	25.3	32.9 **	22.6**	9.1	45.5 **	46.5**
HMS 4 × BMS4	195.4	1.8	-31.0**	24.9	31.4 **	20.7**	8.9	43.0 **	44.0**
SEm±	-	17.3	17.3	-	0.6	0.6	-	0.5	0.5
CD at 5%	-	38.4	38.4	-	1.3	1.3	-	1.1	1.1

*Where; *: significant at 5% level of significance, **: Significant at 1% level of significance*

Table 4: Estimation of percent heterosis based on biological yield per plant, harvest index and seed yield per plant in *B. napus*

Cross Combination	Biological yield per plant (g)			Harvest index (%)			Seed yield per plant (g)		
	Mean	Better parent	Standard check	Mean	Better parent	Standard check	Mean	Better parent	Standard check
EC 338978 × RBS Bold	217.0	71.4**	54.3**	28.9	12.6*	-10.6**	62.6	125.1**	37.6*
EC 338978 × EC 338975	238.0	36.6**	69.2**	21.6	-15.9*	-33.3**	51.3	84.5**	12.8**
EC 338978 × HMS 4	199.6	84.2**	41.9**	27.8	8.1	-14.2**	55.3	99.0**	21.7**
EC 338978 × BMS 4	207.2	90.7**	47.3**	31.8	23.7**	-1.8	65.8	136.5**	44.6**
RBS Bold × EC 338975	248.5	42.5**	76.6**	20.0	-6.4	-38.0**	49.8	83.7**	9.4**
RBS Bold × HMS4	229.3	81.1**	63.0**	21.5	-8.4	-33.6**	49.2	81.7**	8.2**
RBS Bold × BMS4	217.8	72.1**	54.9**	25.5	19.1*	-21.2**	55.5	104.9**	22.0**
EC 338975 × HMS4	250.1	43.4**	77.8**	17.4	-25.9**	-46.3**	43.0	70.8**	-5.4
EC 338975 × BMS4	228.0	30.7**	62.1**	18.9	-10.3	-41.7**	43.1	70.8**	-5.3
HMS 4 × BMS4	200.2	84.3**	42.3**	23.6	0.9	-26-9**	47.2	106.9**	3.8
SEm±	-	6.2	6.2	-	1.6	1.6	-	2.3	2.3
CD at 5%	-	13.8	13.8	-	3.5	3.5	-	5.1	5.1

*Where; *: significant at 5% level of significance, **: Significant at 1% level of significance*

Table 5: Number of crosses showing significant heterosis, ranges of heterosis and best crosses for seed yield in *B. napus*

Heterosis	Traits	No of crosses showing significant heterosis		Range of heterosis in desirable direction	The best cresses in desirable direction	Heterosis
		Positive	Negative			
Heterobeltiosis	Days to first flowering	1	-	-	-	-
	Days to 50% flowering	6	-	-	-	-
	Primary branches per plant	10	-	18.8 to 42.1%	EC 338978 × EC 338975	42.1%
	Secondary branches per plant	10	-	80.5 to 99.0%	RBS Bold × HMS 4	99.0%
	Days to maturity	-	-	-	-	-
	Plant height (cm)	10	-	15.0 to 27.3%	EC 338978 × EC 338975	27.3%
	Number of siliquae per plant	-	2	-	-	-
	Number of seeds per siliqua	10	-	21.0 to 32.9%	EC 338975 × BMS4	32.0%
	Siliqua length (cm)	10	-	33.6 to 56.7%	RBS Bold × EC 338975	56.7%
	Biological yield per plant (g)	10	-	30.7 to 90.7%	EC 338978 × BMS4	90.7%
	Harvest index (%)	3	2	12.6 to 23.7%	EC 338978 × BMS4	23.7%
	Seed yield per plant (g)	10	-	70.8 to 136.5%	EC 338978 × BMS4	136.5%
Standard	Days to first flowering	-	7	-6.0 to -10.3%	EC 338978 × RBS Bold	-10.3%
Heterosis	Days to 50% flowering	-	7	-7.0 to -21.1%	EC 338978 × EC 338975	-21.1%
	Primary branches per plant	10	-	22.8 to 42.8%	RBS Bold × HMS4	42.8%
	Secondary branches per plant	10	-	42.3 to 64.9%	EC 338978 × BMS4	64.9%
	Days to maturity	-	-	-	-	-
	Plant height (cm)	7	-	3.4 to 8.6%	EC 338978 × EC 338975	8.6%
	Number of siliquae per plant	-	9	-	-	-
	Number of seeds per siliqua	10	-	16.3 to 26.4%	EC 338978 × BMS4	26.4%
	Siliqua length (cm)	10	-	31.3 to 46.5%	EC 338975 × BMS4	46.5%
	Biological yield per plant (g)	10	-	41.9 to77.8%	EC 338975 × HMS4	77.8%
	Harvest index (%)	-	9	-	-	-
	Seed yield per plant (g)	7	-	9.4 to 44.6%	EC 338978 × BMS4	44.6%

heterosis over standard check ranging from 3.4% (HMS4 × BMS4) to 8.6% (EC 338978 × EC 338975). This similar value in cross combinations was observed by Bhinda *et al*. (2020).

The mean performance for a number of siliquae per plant varies in cross combinations from 186.0 (EC 338975 × BMS 4) to 269.3 (EC 338978 × RBS Bold). Two F1 hybrids namely RBS Bold × EC 338975 (-13.5%) and RBS Bold × HMS 4 (-15.6%) showed significant negative heterosis over better parent, while nine cross combinations showed significant negative heterosis over the standard check ranging from -8.1% (RBS Bold × BMS 4 to -34.3% (EC 338975 × BMS 4) (Table 3). Similar results were recorded by Akabari *et al*. (2017) and Bharti *et al.* (2018). The mean performance (Table 3) for the number of seeds per siliqua varies in hybrid combinations from 24.0 (RBS Bold × BMS 4) to 26.1 (EC 338978 × BMS 4). All ten cross combinations exhibited a significant positive heterosis ranging from 21.0% (EC 338978 × RBS Bold) to 32.9% (EC 338975 × BMS 4) over the better parent while ten cross combinations exhibited a significant positive standard heterosis ranging from 16.3% (RBS Bold × BMS 4) to 26.4% (EC 338978 × BMS 4). Similar findings were recorded by Kaur *et al.* (2023). The mean performance for siliqua length (cm) varies in cross combinations from 8.1 (EC 338978 × RBS Bold) to 9.1 (EC 338975 × BMS4) cm (Table 3). All cross combinations exhibit a significant positive heterosis over better parent ranging from 33.6% (RBS Bold × BMS 4) to 56.7% (RBS Bold × EC 338975) as well as all cross combinations exhibited a significant positive heterosis over standard check ranging from 31.3% (EC 338978 × RBS Bold) to 46.5% (EC 338975 × BMS4). Similar research findings were recorded by Snehi *et al*. (2019).

The mean performance for biological yield varies in cross combinations from 199.6 (EC 338978 × HMS4) to 250.1 (EC 338975 × HMS4). Ten cross combinations showed a significant positive heterosis over better parent ranging from 30.7% (EC 338975 × BMS 4) to 90.7% (EC 338978 × BMS 4). All ten F1s exhibited a significant positive heterosis over the standard check ranging from 41.9% (EC 338978 × HMS 4) to 77.8% (EC 338975 × HMS 4) (Table 4). Similar results were recorded by Gupta *et al*. (2010). The mean performance for harvest index (%) varies in cross combinations from 17.3 (EC 338975 × HMS4) to 31.7% (EC 338978 × BMS4). Three of the cross combinations ranging from 12.6% (EC 338978 × RBS Bold) to 23.7% (EC 338978 × BMS 4) showed a significant positive heterosis over better parent, while two cross combinations namely EC 338978 × EC 338975 (-15.9%) and EC 338975 × HMS 4 (-25.9%) showed a significant negative heterosis for this trait. Nine cross combinations showed significant negative heterosis over standard check ranging from -10.6% (EC 338978 × RBS Bold) to -46.3% (EC 338975 × HMS 4). Similar research findings were observed by Patel *et al.* (2015). The mean performance (Table 4) for seed yield per plant varies in cross combinations from 43.0g (EC 338975 × HMS4) to 65.8g (EC 338978 × BMS4). All ten hybrid combinations ranging from 70.8% (EC 338975 × HMS 4) to 136.5% (EC 338978 × BMS 4) showed a significant positive heterosis over the better parent. Seven hybrid combinations ranging from 8.2% (RBS Bold × HMS4) to 44.6% (EC 338978 × BMS4) exhibited significant positive heterosis over standard check. Surin *et al.* (2018) find 109.1% heterosis over better parents and 161.5% over check. Similar results were recorded by Qian *et al*. (2007), Sabaghnia *et al*. (2010), Dar *et al*. (2011) and Choudhary *et al.* (2020). Overall significant crosses showing desirable performance for seed yield and yield components were mentioned in Table 5. The results revealed that based on standard heterosis, cross EC 338978 × RBS Bold for days to first flowering, EC 338978 × EC 338975 for days to 50% flowering and plant height, RBS Bold × HMS4 for primary branches per plant, EC 338975 × BMS4 for siliqua length, EC 338975 × HMS4 for biological per plant and EC 338978 × BMS4 for secondary branches per plant, number of seeds per siliqua and seed per plant showed desirable heterosis over standard check whereas none of the crosses exhibited standard heterosis for rest of yield components (Table 5). In addition, cross EC 338978 × BMS4 was also showed desirable better parent heterosis for siliqua length, biological yield per plant, harvest index and seed yield per plant (Table 5). This association was very study is comparable to the previous study in Indian mustard (Choudhary *et al.,* 2020) but was less than Riaz *et al.* (2001) in *Brassica napus*.

Conclusion

These results show that the experimental material contains genetic variability that could be applied to future breeding programme. Crosses EC 338978 × BMS4, RBS Bold × HMS4, EC 338975 × BMS4 should be used in breeding program for hybrid development. Lines EC 338978, BMS4 and RBS Bold may be used as potential parents for the hybridization program.

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