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Research Note

Heterosis studies in brown sarson (*Brassica rapa* L.)

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Abstract:
Heterosis was estimated over mid and better parent, respectively among 45 F1 hybrids for seed yield and related traits.. The most desirable cross combination *viz*., CR-1485 x CR-1607 for seed yield plant^{-1} also showed desirable mid and better parent heterosis for 1000-seed weight and primary branches plant^{-1}. The cross combinations CR-1485 x CR-1607 (primary branches plant^{-1}), CR-1630 x KS-101 (secondary branches plant^{-1}), CR-2638 x KOS-1 (number of siliquae on main raceme), CR-1630 x CR-2871 (number of siliquae plant^{-1}), CR-1607 x KOS-1 (days to maturity) and KOS-1 x KS-101 (oil content) showed highest mid and better parent heterosis. These cross combinations also revealed high *per se* performance.

Key words: Brown sarson, heterosis, , germplasm

Substantial efforts were made to improve, seed yield and other yield-related parameters and/or to transfer its useful traits to related *Brassica* oil crops (Rakow, 1995; Meng *et al*. 1998). A quantum jump in yield could be achieved through heterosis breeding. Development of hybrid cultivars has been successful in many *Brassica* spp. (Melchinger and Gumber, 1998; Becker and Robbelen, 1999; Miller, 1999). In brown sarson improvement, breeding methods like inter-varietal hybridization and inter-specific hybridization broaden the genetic base either through creation of variability or introgression of desirable genes from wild species. Therefore, in the present investigation an attempt was made to estimate heterosis for yield, and other related attributes.

Ten diverse genotypes of brown sarson (*Brassica rapa* L.) *viz*., CR-1485, CR-1630, CR-1607, CR-1480, CR-2871, CR-2638, CR-1617, CR-2677, KOS-1 and KS-101 were used in the present study. Forty five F_1 crosses (excluding reciprocals) were generated through a 10 x 10 diallel mating design during *rabi* 2008-09. The final experimental material comprised the ten parents and their 45 F_1's which were evaluated during *rabi* 2009-10 at the Experimental Farm of the Division of Plant breeding and Genetics, SKUAST-K. The experiment was laid out in a completely randomized block design with two replications at each location. The experimental plot comprised 3 rows each of 1 meter length. Row to row and plant to plant spacing was maintained at 30 and 10 cm. Recommended agronomic practices were followed to raise a good crop at both the locations. Observations were recorded on five randomly selected competitive plants of each parent and F_1 in every replication for following traits *viz*., days to 50 % flowering, plant height (cm), primary branches plant^{-1}, secondary branches plant^{-1}, number of siliquae on the main raceme, number of siliquae plant^{-1}, number of seeds siliqua^{-1}, days to maturity, 1000-seed weight (g), seed yield plant^{-1} (g), oil content (%) and harvest index (%). In the case of maturity traits (days to 50% flowering and maturity), the data was recorded on the whole plot basis. Heterosis was estimated in relation to mid-parent and better parent. This was calculated as increase or decrease of F_1's over mid-parent and better parent, respectively.

Brown sarson is a self-incompatible crop and hence it is highly amenable for the exploitation of heterosis. The scope for exploitation of hybrid vigour depends on the direction and magnitude of heterosis involved. Heterosis will also have a direct effect on the breeding methodology to be used for varietal improvement. The phenomenon of heterosis, though widely reported and utilised in allogamous crop species, has also been commercially exploited in some autogamous crop species. However, the economic exploitation of heterosis in crop plants is largely governed by the technical feasibility besides the manifestation of heterotic effect for different economic traits and other attributes. In the present study, two types of heterosis *viz*. heterosis over the mid parent and better parent for each trait were computed over pooled environments. The results revealed a wide range of heterotic patterns for all the traits studied. Maximum range of heterosis was observed in mid-parental heterosis for most of the traits.

The characters like early maturity, flowering, reduced plant height and length of main axis are preferred in *Brassica* group, which enable plant breeders to develop varieties tolerant to abiotic stresses like heat and lodging, Also, they possess accurate seed formation due to the large seed filling period. They provide ample time for the cultivation of the succeeding crop. Therefore, the negative heterosis is desirable for these traits. Other yield-related characters, such as the number of primary and secondary branches plant^{-1}, seed yield per 100 siliquae, seed yield plant^{-1}, biological yield plant^{-1} and harvest index, provide more opportunities for increasing yield, and hence, the positive heterosis is preferred. Since higher yields in F_1 may be due to either dominace or epistatic gene action, the total effect partition of F_1 progeny into general and specific combining ability effects deciphers the causes of heterosis.

The F_1 heterosis over the mid and better parent for days to 50 per cent flowering ranged from -3.11 to 0.45 and -4.13 to 1.14 per cent; for plant height from -9.39 to 13.06 and -13.34 to 9.78 per cent; for primary branches plant^{-1} from 3.38 to 80.21 and 4.04 to 72.89 per cent. Similarly for secondary branches plant^{-1} it ranged from 23.12 to 115.77 and 11.14 to 111.99 per cent; for number of siliquae on main raceme from 3.36 to 42.49 and 2.45 to 39.85 per cent; for number of siliquae plant^{-1} from -22.24 to 50.13 and -35.00 to 28.39 per cent; for number of seeds siliqua^{-1} from 3.08 to 29.08 and 1.17 to 17.96 per cent; for days to maturity from -3.68 to 2.61 and -6.09 to 1.12 per cent ; for 1000-seed weight from 6.24 to 41.71 per cent and 4.80 to 27.50 per cent; for seed yield plant^{-1} from 7.40 to 79.10 and 2.25 to 58.83 per cent; for oil content from -5.50 to 11.18 and -5.84 to 10.10 per cent and for harvest index from 4.12 to 15.06 and 1.62 to 8.90 per cent respectively (Table 1).

Yield is a complex character and highly influenced by environment. Grafius (1959) suggested that there might not be genes for yield *per se* but for the components. Therefore, it would be interesting to know the relationship between the heterosis of component traits. During the present investigation F_1 heterosis over the mid and better parent for seed yield plant^{-1} and its important attribute namely oil content ranged from 7.40 to 79.10 and 2.25 to 58.83 % and -5.50 to 11.18 and -5.84 to 10.10 %, respectively. Significant heterosis for yield, yield components and maturity traits in brown sarson and other oilseed *Brassicas* have been reported by several workers (Chauhan *et al.,* 2000; Tyagi *et al.,* 2000; Singh *et al.*, 2003; Turi *et al.*, 2006; Prajapati *et al.*, 2007 and Singh and Dixit, 2007) who attributed increased vigor mainly due to dominance. The results obtained in the present investigation suggest that judicious selection of parents having one or more important maturity as well as yield attributing traits is needed to exploit heterosis provided a mechanism for hybrid seed production is available in the self-incompatible background of brown sarson.

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Table 1: Heterosis (%) over mid parent for yield and yield contributing characters in brown sarson

Cross	Days to 50% flowering	Plant height (cm)	Primary branches $plant^{-1}$	Secondary branches $plant^{-1}$	No. of siliquae on main raceme	No. of siliquae $plant^{-1}$	No. seeds of $siliqua^{-1}$	Days to maturity	1000-seed weight (g)	Seed yield $plant^{-1}$ (g)	Oil content (%)	Harvest index (%)
CR-1485 x CR-1630	-2.66**	5.89**	53.65**	97.98**	18.37**	8.29*	12.60**	-2.23**	20.14**	34.82**	3.58**	4.89**
CR-1485 x CR-1607	-1.16**	8.60**	80.21**	90.73**	13.88**.	-2.66	24.86**	-1.01**	41.71**	79.10**	2.24	9.00**
CR-1485 x CR-1480	-1.39*	6.83**	43.14**	102.11**	18.71**	-5.19	11.93**	-1.66**	26.34**	35.25**	3.49**	12.30**
CR-1485 x CR-2871	0.04	1.12	56.12**	89.86**	9.27**	40.07**	5.26**	-2.17**	3.88	49.20**	-0.48	9.71**
CR-1485 x CR-2638	-2.51**	2.89**	20.60**	83.65**	20.18**	-15.49**	29.08**	-0.33	20.20**	37.57**	0.55	12.78**
CR-1485 x CR-1617	-1.58**	-0.12	45.14**	58.46**	3.36**	-6.85*	11.97**	-3.69**	21.72**	26.39**	-1.64	5.72**
CR-1485 x CR-2677	-0.87**	-0.75	26.85**	73.61**	6.37**	10.36**	10.27**	2.36**	12.19**	33.27**	-1.83	10.17**
CR-1485 x KOS-1	-0.49**	1.19	23.02**	81.82**	20.40**	-15.83**	16.43**	2.61**	18.95**	17.70**	5.72**	5.63**
CR-1485 x KS-101	-0.61**	7.24**	37.27**	68.52**	13.10**	-17.33**	17.67**	2.53**	24.33**	17.77**	7.90**	7.65**
CR-1630 x CR-1607	-1.04**	-9.49**	36.37**	88.67**	27.60**	-0.86	7.72**	1.79**	19.11**	23.05**	-1.47	4.84**
CR-1630 x CR-1480	-1.35**	-4-29**	29.54**	79.21**	18.97**	-2.75	11.47**	-0.41	21.59**	30.73**	0.28	6.21**
CR-1630 x CR-2871	2.05**	10.44**	42.42**	93.36**	11.17**	50.13**	0.05	-0.55	1.69*	42.20**	0.13	7.31**
CR-1630 x CR-2638	-0.54**	-6.25**	33.11**	65.75**	26.85**	6.53**	11.30**	-1.90**	-0.16	34.13**	5.63**	6.29**
CR-1630 x CR-1617	-1.77**	5.79**	33.48**	35.02**	18.37**	8.29*	12.60**	-2.23**	17.27**	39.81**	4.27**	7.18**
CR-1630 x CR-2677	-1.61**	2.04**	40.58**	87.50**	13.88**.	-2.66	24.86**	-1.01**	19.53**	23.14**	5.94**	6.59**
CR-1630 x KOS-1	-2.62**	4.93**	25.35**	91.44**	18.71**	-5.19	11.93**	-1.66**	4.48	26.13**	9.51**	7.05**
CR-1630 x KS-101	-2.10**	13.06**	21.65**	115.77**	9.27**	40.07**	5.26**	-2.17**	28.87**	26.31**	9.16**	9.43**
CR-1607 x CR-1480	-2.13**	5.45**	36.43**	68.63**	20.18**	-15.49**	29.08**	-0.33	11.17**	36.10**	3.21*	6.36**
CR-1607 x CR-2871	0.45*	8.09**	34.59**	54.51**	3.36**	-6.85*	11.97**	-3.69**	14/05**	35.63**	-1.10	7.81**
CR-1607 x CR-2638	-1.56**	4.45**	48.87**	63.95**	6.37**	10.36**	10.27**	2.36**	6.24*	41.66**	9.19**	7.61**
CR-1607 x CR-1617	-2.75**	-2.42**	52.06**	28.52**	20.40**	-15.83**	16.43**	2.61**	11.37**	45.16**	4.34**	3.89**
CR-1607 x CR-2677	-3.11**	4.66**	35.79**	66.21**	13.10**	-17.33**	17.67**	2.53**	18.23**	45.78**	4.48**	11.65**
CR-1607 x KOS-1	-0.36*	5.73**	16.15**	54.36**	27.60**	-0.86	7.72**	1.79**	7.28**	12.75**	7.10**	5.67**
CR-1607 x KS-101	-2.71*	7.44**	21.32**	71.70**	18.97**	-2.75	11.47**	-0.41	15.22**	16.09**	7.32**	9.99**
CR-1480 x CR-2871	-0.80**	6.90**	17.00**	61.45**	11.17**	50.13**	0.05	-0.55	-1.81	22.78**	6.84**	9.05**
CR-1480 x CR-2638	-1.78**	7.77**	15.46**	64.87**	26.85**	6.53**	11.30**	-1.90**	22.23**	21.31**	3.41*	6.33**
CR-1480 x CR-1617	-1.35**	-2.06**	13.36.**	35.22**	18.40**	-3.20	12.19**	0.51	8.14**	23.45**	-0.27	6.86**
CR-1480 x CR-2677	-1.25**	5.17**	7.49**	77.99**	4.00**	12.65**	21.17**	0.31	22.76**	35.74**	-5.50**	4.12**
CR-1480 x KOS-1	-2.22**	5.08**	5.77**	49.79**	20.44**	-3.50	5.92**	-0.80	11.45**	16.69**	8.19**	6.80**
CR-1480 x KS-101	-1.55**	10.80**	7.75**	74.05**	17.84**	0.79	5.36**	0.57	16.16**	19.94**	7.72**	10.89**

Contd..

Table 1. Contd..

Cross	Days to 50% flowering	Plant height (cm)	Primary branches plant-1	Secondary branches plant-1	No. of siliquae on main raceme	No. of siliquae plant-1	No. seeds of siliqua-1	Days to maturity	1000-seed weight (g)	Seed yield plant-1 (g)	Oil content (%)	Harvest index (%)
CR-2871 x CR-2638	0.45*	11.35**	23.84**	53.05**	18.55**	-22.24**	17.51**	0.30	32.59**	28.81**	2.61*	9.66**
CR-2871 x CR-1617	-1.19**	6.91**	24.56**	38.45**	11.34**	4.94	11.20**	-0.42	2.10	19.20**	8.70**	4.86**
CR-2871 x CR-2677	0.60**	8.22**	25.09**	60.76**	6.88**	-13.56**	13.77**	0.47	32.00**	28.59**	2.74*	8.08**
CR-2871 x KOS-1	-0.14	5.26**	28.40**	57.68**	18.17**	-1.86	12.40**	-0.87*	24.01**	41.25**	0.40	11.18**
CR-2871 x KS-101	-0.68**	11.30**	26.34**	57.50**	14.26**	3.78	12.67**	-0.27	24.78**	34.24**	8.72**	12.04**
CR-2638 x CR-1617	-1.72**	-0.06	22.68**	53.90**	14.03**	-10.92**	16.16**	-0.55	22.35**	20.12**	4.68**	8.22**
CR-2638 x CR-2677	-0.09	2.87**	27.48**	63.05**	14.45**	-12.28**	27.66**	0.86*	22.73**	33.94**	4.38**	6.17**
CR-2638 x KOS-1	-0.58**	9.71**	30.48**	64.85**	42.49**	16.90**	10.75**	-1.97**	9.74**	47.75**	3.37*	11.53**
CR-2638 x KS-101	-2.82**	6.94**	28.63**	72.33**	15.60**	34.23**	-2.82**	-1.57**	11.31**	4387**	6.06**	15.06**
CR-1617 x CR-2677	-1.13**	0.37	32.11**	44.99**	10.09**	0.31	14.91**	-0.79*	23.91**	28.48**	2.80*	7.72**
CR-1617 x KOS-1	-1.85**	11.27**	9.44**	53.80**	19.76**	-14.12**	10.42**	-1.72**	15.15**	7.40**	8.17**	6.23**
CR-1617 x KS-101	-1.55**	12.22**	35.38**	49.25**	17.14**	11.58**	12.20**	-1.78**	17.18**	42.36**	5.19**	11.15**
CR-2677 x KOS-1	-2.07**	11.07**	20.66**	23.12**	17.92**	6.43*	26.60**	-1.43**	8.22**	47.12**	4.95**	10.14**
CR-2677 x KS-101	-2.78**	7.34**	32.96**	48.73**	9.31**	6.91*	17.05**	-1.19**	22.58**	54.46**	4.09**	14.68**
KOS-1 x KS-101	-1.54**	10.86**	3.38**	44.43*	9.81**	14.53**	5.07**	-1.16**	2.76	27.41**	11.18**	7.20**

Table 2: Heterosis (%) over better parent for yield and yield contributing characters in brown sarson

Cross	Days to 50% flowering	Plant height (cm)	Primary branches plant^{-1}	Secondary branches plant^{-1}	No. of siliquae on main raceme	No. of siliquae plant^{-1}	No. seeds of siliqua^{-1}	Days to maturity	1000-seed weight (g)	Seed yield plant^{-1} (g)	Oil content (%)	Harvest index (%)
CR-1485 x CR-1630	-3.62**	2.63**	45.29**	96.54**	6.33**	4.71	6.51**	-3.84**	18.09**	28.13**	2.00	0.20
CR-1485 x CR-1607	-1.96**	7.11**	72.89**	75.85**	7.91**	-13.00**	13.98**	-1.96**	27.50**	58.83**	0.61	5.65**
CR-1485 x CR-1480	-1.72**	3.38**	24.41**	92.12**	17.51**	-12.49**	3.16**	-2.21**	6.84**	16.86**	1.20	5.83**
CR-1485 x CR-2871	-0.06	0.59	23.26**	76.05**	8.49**	23.31**	4.42**	-3.44**	-15.75**	12.86**	-3.77**	6.40**
CR-1485 x CR-2638	-3.71**	-1.38**	5.93**	75.75**	14.17**	-35.00**	14.15**	-2.56**	13.36**	10.56**	-1.18	4.51**
CR-1485 x CR-1617	-2.27**	-8.43**	31.66**	35.84**	0.51	-19.35**	6.17**	-6.09**	5.63*	1.56	-3.03*	3.02**
CR-1485 x CR-2677	-1.21**	-7.18**	8.89	69.74**	2.53*	-2.73	2.45**	-0.09	11.66**	10.77**	-3.66*	3.03**
CR-1485 x KOS-1	-0.49*	-1.06	12.43**	67.12**	12.38**	-28.41**	3.86**	0.98*	11.42**	8.28**	3.42*	4.62**
CR-1485 x KS-101	-0.73**	2.85**	30.05**	64.39**	9.27**	-24.28**	8.79**	1.12**	15.59**	8.67**	4.55**	5.59**
CR-1630 x CR-1607	-1.22**	-13.34**	24.01**	72.80**	20.58**	-13.97**	3.73**	1.07*	8.85**	4.40*	-1.53	3.28**
CR-1630 x CR-1480	-2.00**	-10.13**	-0.90	71.53**	5.92**	-12.96**	8.45**	-1.51**	4.32	8.23*	-3.40*	4.71**
CR-1630 x CR-2871	1.14**	6.50**	7.95**	80.51**	-0.77	28.39**	-4.64**	-0.90*	-16.41**	3.57**	-1.70	5.64**
CR-1630 x CR-2638	-0.79**	-12.78**	11.43**	57.53**	19.55**	-19.96**	3.62**	-2.50**	-4.28	3.75**	2.26	2.94**
CR-1630 x CR-1617	-2.05**	-5.72**	15.17**	15.05**	-4.43**	-7.14*	9.86**	-1.76**	3.29	8.12**	1.24	5.01**
CR-1630 x CR-2677	-2.25**	-7.30**	15.19**	82.03**	-6.71**	-19.33**	6.58**	-1.15*	16.95**	-1.70	2.41	4.59**
CR-1630 x KOS-1	3.59**	0.49	8.91**	74.80**	22.35**	-17.21**	9.35**	-2.60**	-0.51	10.77**	5.52**	3.26**
CR-1630 x KS-101	-3.18**	5.24**	9.32**	111.99**	3.69**	-11.04**	5.60**	-2.38**	21.76**	11.25**	4.20**	2.62**
CR-1607 x CR-1480	-2.59**	3.44**	23.03**	48.44**	8.53**	10.26**	2.00*	-2.71**	3.66	32.09**	-0.65	3.32**
CR-1607 x CR-2871	0.27	7.16**	9.71**	32.97**	11.01**	6.49*	10.74**	-0.02	1.39	10.29**	-2.84*	7.74**
CR-1607 x CR-2638	-1.99**	1.48**	35.75**	57.67**	21.66**	-10.51**	17.96**	-1.93**	1.04	26.42**	5.64**	2.72**
CR-1607 x CR-1617	-2.85**	-9.39**	43.41**	18.67**	11.39**	13.61**	7.53**	-3.33**	6.93**	29.52**	1.25	3.32**
CR-1607 x CR-2677	-3.56**	-0.83**	20.86**	56.51**	2.45*	-3.08	6.59**	-2.71**	5.93*	35.30**	0.93	7.96**
CR-1607 x KOS-1	-1.17**	4.80**	10.41**	53.54**	21.65**	-6.40*	4.53**	-3.47**	2.73	8.31**	3.14*	3.44**
CR-1607 x KS-101	-3.61**	4.44**	19.74**	54.75**	21.58**	-0.89	-1.42	-2.71**	11.21**	11.16**	2.38	4.63**
CR-1480 x CR-2871	-1.04**	3.97**	4.38**	57.27**	7.49**	7.73*	4.90**	-1.67**	-6.74**	2.25*	1.11	5.87**
CR-1480 x CR-2638	-2.68**	6.72**	14.05**	50.33**	13.64**	-33.19**	7.64**	-0.69	8.79**	11.24**	2.88	4.43**
CR-1480 x CR-1617	-1.72**	-7.38**	8.08**	11.14**	16.29**	-9.74**	8.87**	-1.46**	4.89*	13.18**	-1.09	3.24**
CR-1480 x CR-2677	-1.26**	1.52**	5.92**	47.00**	1.24	-16.94**	4.44**	-1.56**	3.42	29.62**	-5.84**	3.62**
CR-1480 x KOS-1	-2.55**	3.98**	0.04	31.47**	11.36**	-11.77**	2.19**	-1.84**	-0.16	8.93**	8.15**	1.62**
CR-1480 x KS-101	-1.99**	9.78**	-1.68	69.48**	12.75**	-0.04	5.01**	-0.26	4.80*	11.61**	6.72**	2.63**

Contd..

Table 2. Contd..

Cross	Days to 50% flowering	Plant height (cm)	Primary branches plant-1	Secondary branches plant-1	No. of siliquae on main raceme	No. of siliquae plant-1	No. seeds of siliqua-1	Days to maturity	1000-seed weight (g)	Seed yield plant-1 (g)	Oil content (%)	Harvest index (%)
CR-2871 x CR-2638	-1.59**	7.27**	9.30**	36.30**	11.87**	-33.62**	4.65**	-0.66	12.42**	15.81**	-2.42	4.62**
CR-2871 x CR-1617	-1.79**	-1.51**	6.57**	11.49**	9.03**	2.93	6.25**	-1.63**	-5.79**	7.18**	3.68**	4.35**
CR-2871 x CR-2677	0.35	1.71	13.08**	46.01**	3.74**	-13.68**	4.92**	-0.65	6.67**	11.34**	-2.44	4.44**
CR-2871 x KOS-1	-0.24	3.45**	9.10**	35.31**	9.57**	-5.72*	0.98	-1.16**	6.15**	11.38**	-4.96**	8.90**
CR-2871 x KS-101	-0.89**	7.29**	4.04**	59.00**	9.65**	-0.66	4.95**	-0.34	7.55**	5.59**	1.98	6.64**
CR-2638 x CR-1617	-2.26**	-4.60**	18.35**	37.11**	5.50**	-22.69**	7.89**	-0.81	11.96**	20.09**	4.36**	2.76**
CR-2638 x CR-2677	-0.98**	0.25	24.11	59.52**	5.01**	-25.19**	5.94**	0.69	15.24**	28.37**	4.22**	4.77**
CR-2638 x KOS-1	-1.81**	7.51**	24.87**	58.02**	39.85**	3.33	9.67**	-2.63**	8.95**	27.30**	2.88	4.32**
CR-2638 x KS-101	-4.13**	6.88**	18.70**	61.06**	13.60**	10.54**	-7.62**	-2.45**	9.62**	23.60**	4.54**	4.73**
CR-1617 x CR-2677	-1.48**	-1.76**	24.20**	26.71**	9.10**	-1.73	1.65**	-0.89*	7.11**	23.10**	2.32	3.60**
CR-1617 x KOS-1	-2.54**	4.17**	8.53**	42.45**	8.91**	-15.92**	3.49**	-2.63**	6.07*	-7.49**	7.32**	4.56**
CR-1617 x KS-101	-2.35**	7.05**	29.29**	25.33**	10.16**	4.85	9.23**	-2.91**	8.75**	22.28**	4.07**	6.30**
CR-2677 x KOS-1	-2.41**	6.13**	12.56**	15.57**	6.37**	2.12	5.89**	-2.25**	0.93	31.58**	4.61**	4.32**
CR-2677 x KS-101	-3.23**	4.45**	19.73**	41.94**	1.94	2.47	1.17*	-2.12**	13.46**	37.74**	2.75	5.66**
KOS-1 x KS-101	-1.66**	8.70**	-0.48	29.78**	5.94**	5.52*	1.04	-1.39**	1.92	26.99**	10.10**	4.11**