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HETEROSIS FOR YIELD AND YIELD CONTRIBUTING CHARACTERS OF *Brassica napus* L.

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ABSTRACT

Oilseed rape (*Brassica napus* L.) is the most important oil crop. Due to a continually increasing demand for rapeseed oil for food and non-food uses, the production of hybrid cultivars with higher seed and oil yield has become increasingly important in recent years. However, the systematic use of heterosis for hybrid breeding in oil seed rape is limited by relatively narrow genetic base of adapted germplasm, which can impede the generation of distinct heterotic pools. In the present study, experimental hybrids were developed from the crosses between tweenty pollen lines and two CMS testers. Different types of heterosis were estimated to evaluate forty *Brassica* hybrids. Mid parent heterosis (Hm), heterosis over pollen parent (Hp) and heterosis over standard check (Hc) were estimated for eleven yield and yield related characters; where BARI Sarisha-8 was used as check variety. The average heterosis for seed yield of 40 hybrids over mid parent was 60.26% and that of over pollen parent and standard check variety was 230.87% and 170.92% respectively. All hybrids showed higher plant height than the standard check variety.

Key words: Heterosis, hybrid, CMS and *Brassica napus*

INTRODUCTION

Rapeseed (*Brassica napus* L.) is an important oil seed crop belonging to the family cruciferae. It is a cross pollinated crop. Rapeseed along with mustard (*Brassica napus* L) is currently ranked as the world third most important oil crops after soybean and cotton (Piazza and Foglia, 2001 and Walker and Booth, 2001). The oil yielding crop *Brassicas* hold the forth and second position in the world in respect of area and production and about 16% of the world's production is obtained from this crops (Anonymous, 2003). The total oil seed crops cover 7.47 lach acres of land. However, rapessed and mustard cover 5.36 lac acres of land and produce about 5.95 lac Mt of oil seeds. This crop covers about 74.5% area of the total edible oil crops cultivated in Bangladesh (Anonymous, 2006). The present seed yield per hectare of mustard in Bangladesh is far below the level attained in the developed countries of the world. In F_1 varietal hybrids of *B. napus* levels of heterosis were reported to be about 20 percent above the better parent (Sernyk and Stefansson, 1983, Grant and Beversdorf, 1985, Lefort-Buson and Dattee, 1982). Superiority of F_1 hybrid over the better parent is a common phenomenon in both self and cross pollinated crops. Commercial F_1 hybrid cultivars become increasingly important for oilseed crops. Hybrids generally show vigorous growth, uniformity in its growth behavior, earliness and other desirable traits.

Heterosis is an important genetic phenomenon; synonymous with hybrid vigor refers to the manifested superiority of the F_1 hybrid resulting from the cross of genetically dissimilar homozygous parents. Identifying parental combinations with strong heterosis for yield is the most important step in the development of new hybrids cultivars (Diers *et al.* 1996 and Becker *et a*l. 1999), and heterosis effects are generally more pronounced in crosses between genetically distinct materials.

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Oilseed rape F_1 hybrids generated from crosses between resynthesised rape seed and elite breeding lines can exhibit high levels of yield heterosis (Seyis *et al.*, 2006). Therefore the knowledge about the heterosis isimportant in selecting suitable parents for hybridization, proper understanding of inheritance of quantitative traits and also in identifying the promising crosses for further use in breeding programme. The present investigation was carried out to estimate the magnitude and direction of heterosis.

MATERIALS AND METHODS

Twenty pollen lines of *Brassica napus* L. were crossed with two CMS testers in a line × tester mating design for estimation of heterosis (Table 1). The crosses among pollen lines and CMS testers were made during November 2006 to March 2007 at the experimental farm of Bangabandhu Sheikh Majibur Rahman Agricultural University, Gazipur, Bangladesh. All the parents and their hybrids were grown at the same site during November 2007 to March 2008 and assigned randomly to experimental plots. Each plot consists of 4 rows of 4 m each with 30 cm space between rows and 15 cm between plants.

Table 1. List of the seed parents, pollen parents and standard check and their F_1 hybrids for heterosis estimation

Seed parent	Pollen parents	Standard Check	F_1 Hybrids	F_1 Hybrids
CMS-Z_1	Nap108		CMS-Z_1 × Nap108	CMS-Z_2 × Nap108
CMS-Z_2	Nap0130	BS*-8	× Nap0130	× Nap0130
	Nap205		× Nap205	× Nap205
	Nap206		× Nap206	× Nap206
	Nap2001		× Nap2001	× Nap2001
	Nap2012		× Nap2012	× Nap2012
	Nap2013		× Nap2013	× Nap2013
	Nap2022		× Nap2022	× Nap2022
	Nap2037		× Nap2037	× Nap2037
	Nap2057		× Nap2057	× Nap2057
	Nap2066		× Nap2066	× Nap2066
	Nap9901		× Nap9901	× Nap9901
	Nap9904		× Nap9904	× Nap9904
	Nap9905		× Nap9905	× Nap9905
	Nap9906		× Nap9906	× Nap9906
	Nap9908		× Nap9908	× Nap9908
	Nap94006		× Nap94006	× Nap94006
	BS-7*		× BS-7*	× BS-7*
	BS-8*		× BS-8*	× BS-8*
	BS-13*		× BS-13*	× BS13*

* BS 7 = BARI Sarisha -7. *BS 8 = BARI Sarisha -8 * BS 13 = BARI Sarisha -13.

The experiment was laid out in Randomized Complete Block Design (RCBD) with two replications. Fertilizers were applied at the rate of 270: 170: 100: 150: 5 kg ha^{-1} of Urea, TSP, MP, Gypsum and Zinc sulphate respectively. Cowdung was applied at the rate of 10 M ton/ha. Whole amount of cowdung TSP, MP, Gypsum, Zinc sulphate and half of Urea were applied at the time of final land preparation. The remaining Urea was top dressed at 30 days after seedling emergence. Necessary intercultural operation was taken during cropping period for proper growth and development of the plants. Data were recorded on days to 50% flowering, days to 80% maturity, number of primary branches per plant, number of secondary branches per plant, length of inflorescence, number of siliqua per plant, length of siliqua, number of seeds per siliqua, 1000-seed weight and seed yield per plant (g). Collected data were subjected to statistical analysis using MSTAT-C computer soft ware. The overall mean value for each parent or hybrid in all replications for each character was taken to estimate heterosis. Heterosis was calculated as percent deviation of F_1 hybrid from the line value in question. The magnitude of heterosis was expressed as heterosis over mid parent (HM), heterosis over pollen parents (HP) and heterosis over check or economic heterosis (HC) for eleven characters. BARI sarisa -8 was taken as standard check variety to estimate economic heterosis.

RESULTS AND DISCUSSION

Highly significant differences were observed for all the characters among the hybrids and parents (Table 2). Heterosis for 10 characters over the mid parent (Hm), over pollen parents (Hp) and over standard check variety (Hc) are presented in Table 3 to Table 5.

Ten hybrids exhibited significant negative values for heterosis over mid parent (Hm). Such types of heterosis are desirable due to indication of earliness (Table 3). Mid parent heterosis ranged from -11.52% to 14.46% with a mean of 2.52% and for standard check the range was 1.39% to 31.94% with a mean of 13.75% (Table 5). The hybrid CMS-Z_2 × Nap 9908 had highest negative heterosis over pollen parent (-10.00%) (Table 4). Results with negative heterosis indicated that the hybrids were early compared to their parents

Eight hybrids showed significant positive heterosis. The range of mid parent heterosis was -1.18% to 4.99% with a mean of 1.10% for days to 80% maturity while ranged of pollen parent heterosis was 0.95% to 8.0% with a mean of 3.85% (Table 3 and Table 4). The hybrid CMS-Z_1 × Nap 9901 showed highest negative heterosis (-1.18%) for mid parent which was desirable for short duration. Twenty one hybrids showed significant positive heterosis over standard check variety (Table 5).

Fifteen hybrids exhibited significant positive mid parent heterosis for number of primary branches per plant. Maximum estimate was obtained from CMS-Z_2 × Nap 9901 (84.15%) and the range was -9.47% to 84.15%. Six hybrids had negative value but non-significant. In case of pollen parent heterosis, fifteen hybrids showed positive significant values with a range of -20.37% to 83.33%. Maximum estimate was obtained by CMS-Z_1 × Bari sharisa-7. The range of standard heterosis was -2.78% to 109.72% with a mean of 42.99% where as mean of mid parent heterosis and pollen parent heterosis were 32.98% and 36.89%, respectively (Table 3-5). Saurabh *et al.* (2005) observed both positive and negative heterosis for the trait in Indian mustard (*Brassica juncea* L.).

Twenty hybrids showed positive mid parent heterosis for number of secondary branches per plant and the rest showed non significant estimates. The hybridCMS-Z_2 × Nap 9904 exhibited highest significant positive (242.60%) mid parent heterosis for this trait. In case of pollen parent, CMS-Z_2 × Nap 9904 showed the highest (402.63%) significant positive heterosis. Saurabh *et al.* (2005) also observed both positive and negative heterosis for number of secondary branches per plant in Indian mustard (*Brassica juncea* L.).

Thirty two hybrids exhibited significant heterosis over mid (Hm) parent (Table 3). The range of the heterosis was -13.61% to 22.8% with a mean of 9.85%. It indicated that all hybrids were about 0.27% to 22.8% longer (plant height) than their mid parental value. For this character the estimated values of heterosis over pollen parent were significant for all hybrids. The hybrids CMS-Z_1 x Nap 2057 (49.89%) had the highest significant estimate over pollen (Hp) parent (Table 4). The hybrid CMS-Z_1 × Nap 2013 showed significant negative estimate. The hybrid CMS-Z_2 x Nap 205 possessed the highest estimate (44.35%) and the hybrid CMS-Z_1 × Nap 2013 had the lowest (12.4%). It indicated the hybrid CMS-Z_2 x NAp 205 was the longest among the hybrids and the hybrid CMS-Z_1 × Nap

2013 was the shortest one and it was a dwarf hybrid in respect of standard check variety. Saurabh *et al.* (2005) observed positive heterosis for plant height over parents in *Brassica juncea*.

Twenty three hybrids manifested significant positive mid parent and all hybrids exibited significant positive standard heterosis (Table 3 & 5)). The hybrid CMS-Z_2 × Nap 94006 expressed the highest (39.18%) mid parent heterosis. In case of pollen parent heterosis thirty three hybrids showed significant positive heterosis and other seven non-significant positive heterosis.

Table 2. Analysis of variance for different characters in *Brassica napus* L. hybrids and parents

Source of variation	df	Days to 50% flowering	Days to 80% maturity	No. of primary branches	No. of secondary branches	Plant height (cm)	Inflorescence length (cm)	No. of siliqua/ plant	Siliqua length (cm)	No. of seeds/ siliqua	1000-seeds weight (g)	Seed yield/ plant (g)
Replication	1	14.23	52.91	0.79	0.97	17.42	3.24	193.53	0.00	0.08	0.14	1.06
Entries	61	14.78**	12.12**	2.02**	102.69**	432.56**	215.73**	30950.55**	0.58**	14.81**	0.25**	87.89**
Error	61	1.34	2.08	0.76	8.37	16.67	27.06	1542.07	0.18	3.66	0.05	0.37
CV%		2.88	1.36	18.60	17.66	3.28	6.20	14.12	6.07	9.71	7.13	4.92

* Significant at 5% level; ** Significant at 1% level

The hybrid CMS-Z_2 × Nap 94006 expressed the highest (62.07%) pollen parent heterosis for this trait and the range of pollen parent heterosis for the trait was 1.16% to 62.07%. The range of standard heterosis for inflorescence length was 18.8% to 64.61% and the cross CMS-Z_1 × Nap 205 obtained the hightes estimate (64.61%). The mean heterosis over mid and pollen parent were 16.03% and 25.90%, respectively while mean standard heterosis was 39.37% for the trait.

Thirty nine hybrids showed significant heterosis over mid (Hm) parent for no. of siliqua per plant (Table 3). Hybrid CMS-Z_1 × Nap 9905 had positive but non significant value. The hybrid CMS-Z_2 × Nap 2037 had the highest value of heterosis over mid parent (172.84%). The hybrid CMS-Z2 × Bari sharisha-13 had the highest value over the pollen parent (Table 4).

On the other hand when compared the heterosis with standard check all hybrids exhibited significant positive heterosis (Table 5). Shen *et al.* (2005) and Saurabh *et al.* (2005) also observed possitive heterosis for number of siliqua per plant. Sixteen hybrids showed significant mid parent heterosis for seeds per siliqua (Table 3). In case of pollen parent heterosis the hybrid CMS-Z_2 × Nap 2022 also showed maximum heterosis (34.05%). The range of pollen parent heterosis was -37.24% to 34.05% with a mean of -9.13%. The hybrid CMS-Z_2 × Nap 9906 exibited the highest (17.11%) standard heterosis. The range of standard heterosis was -36.98% to 17.11% with a mean -5.34%.

Table 3. Estimation of heterosis over mid parent for different characters in *Brassica napus* hybrids

Hybrids	DFF	DEM	NPBP	SBP	PH	IL	NSP	SS	TSW	SYP
Z_1 × Nap 108	-9.09	0.93	-5.26	28.67	3.36	5.37	-8.93**	-23.37**	28.26**	10.13
Z_1 × Nap 0130	-3.07	1.18	41.72*	102.49**	9.04**	22.65**	46.53**	-16.77*	24.80**	138.28**
Z_1 × Nap 205	-0.59**	0.70	-4.44	24.38	8.90**	26.81**	7.20**	-11.18	2.65	88.61**
Z_1 × Nap 206	-6.90*	-1.17	-9.47	1.56	0.27	2.29	-16.39**	-18.74**	-4.70	-29.56**
Z_1 × Nap 2001	-5.39	1.65	-5.41	-14.44	4.60	3.86	-21.53**	-14.10	-4.80	-34.07**
Z_1 × Nap 2012	2.41**	0.70	34.15	58.90**	10.70**	8.48	6.32**	-4.13	22.62**	89.37**
Z_1 × Nap 2013	-7.69	0.47	22.89	40.12*	-13.61**	2.34	17.14**	2.97	36.90**	66.73**
Z_1 × Nap 2022	-2.44	-0.95	1.27	84.56**	20.10**	24.90**	49.06**	0.66	35.13**	71.91**
Z_1 × Nap 2037	-0.59**	0.95	46.51*	98.07**	10.68**	21.86**	52.32**	-30.09**	15.28*	70.95**
Z_1 × Nap 2057	-8.98	3.04*	55.26**	42.43	18.52**	10.68	6.90**	-13.62	30.05**	26.13**
Z_1 × Nap 2066	-4.14	0.71	71.43**	50.88*	2.85	10.23	9.14**	-26.48**	12.43*	44.93**
Z_1 × Nap 9901	-2.96**	-1.18	15.29	6.92	5.23	9.31	6.06**	-8.80	22.50**	78.94**
Z_1 × Nap 9904	-6.98	-0.71	16.88	83.37**	5.38	15.86**	18.14**	-22.29**	3.86	-10.23
Z_1 × Nap 9905	-2.33**	0.70	34.21	72.52**	9.80**	8.63	0.11	-7.10	12.48	67.94**
Z_1 × Nap 9906	-7.51**	0.47	55.54*	62.12**	6.09*	20.10**	46.57**	-9.17	15.92*	40.88**
Z_1 × Nap 9908	-11.48	-0.93	31.71	119.48**	20.22**	28.77**	88.72**	-11.63	6.44	34.03**
Z_1 × Nap 94006	-4.76	0.93	15.85	92.17**	10.28**	24.01**	32.07**	-23.77**	15.15*	47.57**
Z_1 × BS -7	-2.35**	0.70	54.93*	84.68**	8.55**	11.10	48.17**	-8.17	-2.43	22.86**
Z_1 × BS-8	-11.52**	-1.17	35.06	31.94	11.03**	28.05**	4.57**	-5.91	22.56**	13.71**
Z_1 × BS - 13	-9.52**	0.94	4.11	35.85	12.63**	27.93**	-22.61**	-36.60**	15.54	-23.53**
Z_2 × Nap 108	-6.36	3.27**	-2.74	30.24	10.48**	18.10**	22.96**	-32.42**	25.59**	9.39
Z_2 × Nap 0130	0.00**	2.61*	57.24	29.20	10.34**	9.74	71.37**	1.93	-2.58	193.08**
Z_2 × Nap 205	8.43**	1.18	-1.15	61.76**	15.94**	16.04**	85.01**	-7.64	-2.52	5.54
Z_2 × Nap 206	-7.60	1.18	4.35	6.22	6.28*	11.96*	12.24**	-29.64**	13.10	-29.34**
Z_2 × Nap 2001	-7.32**	0.72	35.21	79.91**	10.65**	7.14	116.34**	-20.83**	3.86	25.86**
Z_2 × Nap 2012	-1.84**	0.70	34.18	4.31	8.03**	13.85*	27.36**	-11.14	17.93*	90.97**
Z_2 × Nap 2013	8.43**	0.95	17.50	16.38	9.63**	3.86	102.72**	-5.58	3.53	63.47**
Z_2 × Nap 2022	-6.83	3.83**	26.32**	79.34**	13.06**	20.74**	137.30**	14.72	22.08**	24.19**
Z_2 × Nap 2037	3.61	3.85**	32.53	144.07**	18.94**	27.88**	172.84**	-31.92**	14.50*	76.28**
Z_2 × Nap 2057	2.44	-0.71	69.86**	91.47**	13.25**	8.21	52.46**	-7.19	14.55*	148.27**
Z_2 × Nap 2066	-1.20**	2.14	40.54	51.52*	5.57	18.03**	60.23**	-26.46**	17.97**	76.25**
Z_2 × Nap 9901	14.46	4.99**	84.15**	158.99**	4.42**	-0.68	167.01**	-9.92	17.95*	192.53**
Z_2 × Nap 9904	-1.78	1.19	54.05*	242.60**	10.39**	28.35**	108.28**	-30.92**	2.69	91.03**
Z_2 × Nap 9905	1.78	0.24	61.64**	49.30*	14.38**	18.92**	73.38**	-3.11	8.15	92.73**
Z_2 × Nap 9906	3.53**	3.76**	50.72*	94.59**	7.93**	7.61	146.50**	8.21	17.71*	129.87**
Z_2× Nap 9908	-10.00	-0.47	29.11	4.39	5.40	10.84	50.78**	-9.62	4.30	48.89**
Z_2 × Nap 94006	4.24	0.47	77.22**	96.55**	22.80**	39.18**	158.64**	-20.10**	10.56	152.02**
Z2 × BS -7	2.99*	4.00**	50.00*	67.16**	13.31**	15.52*	69.40**	1.20	0.33	85.62**
Z2 x BS- 8	-6.17	1.18	43.24*	74.14**	18.86**	29.69**	130.95**	-5.73	10.89	34.51**
Z_2 × BS -13	4.24**	0.95	42.86	126.05**	9.87**	23.19**	154.91**	-18.25*	17.19*	83.59**
Mean	-2.52	1.10	32.98	65.37	9.85	16.03	58.76	-13.32	13.21	60.26
Maximum	14.46	4.99	84.15	242.6	22.8	39.18	176.34	14.72	36.9	193.08
Minimum	-11.52	-1.18	-9.47	-14.46	-13.61	-0.68	-22.61	-36.6	-4.8	-34.07

*: Significant at 5% level, **: Significant at 1% level

H (m): Heterosis over mid parent, H (p): Heterosis over pollen parent and H(c): Heterosis over standard check variety
DFF = Days to 50% flowering, DEM = Days to 80% maturity, PBP= Primary branches/pl., SBP = Secondary branches/pl.
PH = Plant height, IL = Inflorescence length, SP = Siliqua /pl., SS= Seeds/siliqua, TSW= 1000 seeds wt., SYP = Seed yield/pl.

Table 4. Estimation of heterosis over pollen parent for different characters in *Brassica napus* hybrids

Hybrids	DFF	DEM	NPBP	SBP	PH	IL	NSP	SS	TSW	SYP
Z_1 × Nap 108	-3.61**	2.83*	2.86	153.45**	21.44**	13.01	97.06**	-24.70**	32.78**	154.84**
Z_1 × Nap 0130	12.86**	4.88**	55.07*	246.10**	27.98**	31.35**	163.85**	-15.67	15.44*	383.41**
Z_1 × Nap 205	10.53	3.86**	-12.24	23.84	20.12**	28.00**	49.24**	-6.85	-4.33	192.55**
Z_1 × Nap 206	0.00*	1.93	-20.37	8.31	11.08**	7.42	34.75**	-27.12**	-5.75	-13.73*
Z_1 × Nap 2001	6.76**	5.91	6.06	31.71	20.54**	11.63	56.25**	-10.41	-8.73	85.98**
Z_1 × Nap 2012	16.46	2.84*	34.15	138.82**	29.79**	15.60*	91.78**	4.24	20.57**	312.53**
Z_1 × Nap 2013	2.63**	3.88**	21.43	110.59**	-7.05*	1.16	144.59**	3.94	28.85**	369.77**
Z_1 × Nap 2022	12.68**	3.47*	5.26	157.89**	47.97**	44.77**	225.94**	18.45	45.98**	378.11**
Z_1 × Nap 2037	10.53	6.00**	40.00*	188.76**	33.59**	36.31**	206.05**	-30.06**	8.19	191.97**
Z_1 × Nap 2057	2.70*	6.28**	68.57**	160.94**	49.89**	26.95**	140.76**	-5.82	25.65**	355.86**
Z_1 × Nap 2066	6.58*	4.39**	83.33**	128.57**	18.58**	14.21*	108.62**	-18.70	2.57	255.32**
Z_1 × Nap 9901	7.89	2.44	11.36	55.31	18.57**	18.53*	97.19**	-1.92	46.97**	255.12**
Z_1 × Nap 9904	1.27*	2.93*	25.00	197.37**	20.62**	28.57**	144.13**	-25.92**	2.89	106.43**
Z_1 × Nap 9905	6.33	3.86**	45.71	209.09**	28.59**	14.23*	120.64**	3.00	11.15	191.55**
Z_1 × Nap 9906	0.00**	2.86*	80.65**	165.33**	19.16**	30.82**	223.90**	-4.64	14.75	219.76**
Z_1 × Nap 9908	-10.00*	1.43	31.71	240.74**	44.08**	45.10**	254.81**	-11.47	4.32	94.68**
Z_1 × Nap 94006	6.67*	3.33*	15.85	188.82**	36.03**	46.92**	154.06**	-25.32**	8.77	160.68**
Z_1 × BS -7	7.79	3.35*	83.33**	214.08**	26.23**	20.47**	190.00**	0.52	-8.23	157.14**
Z_1 × BS-8	1.39	1.44	44.44	62.93*	32.84**	47.91**	104.78**	0.73	16.54*	111.42**
Z_1 × BS - 13	1.33	4.37**	18.75	138.24**	35.78**	47.38**	82.97**	-25.59*	17.29	133.00**
Z_2 × Nap 108	-2.41**	4.25**	1.43	130.17*	26.73**	24.66**	86.82**	-34.00**	28.15**	124.46**
Z_2 × Nap 0130	14.29**	5.37**	65.22	99.29*	26.44**	15.68*	122.24**	2.64	-11.03	429.81**
Z_2 × Nap 205	18.42	3.38*	-12.24	50.00**	25.00**	15.37*	93.61**	-3.76	-10.31	47.66**
Z_2 × Nap 206	-2.47	3.38*	-11.11	4.98	15.06**	15.76*	32.57**	-37.24**	10.32	-20.86**
Z_2 × Nap 2001	2.70**	3.94**	45.45	151.22**	24.54**	13.33	290.59**	-17.96	-1.75	212.81**
Z_2 × Nap 2012	8.59**	1.90	29.27	42.35	23.66**	19.41**	65.39**	-4.03	14.38	269.68*
Z_2 × Nap 2013	18.42	3.40*	11.90	58.82	15.34**	1.16	198.56**	-5.29	-3.82	305.81**
Z_2 × Nap 2022	5.63**	7.43**	26.32**	128.42**	35.87**	37.60**	263.83**	34.05**	29.92**	204.43**
Z_2 × Nap 2037	13.16**	8.00**	22.22	223.60**	40.08**	40.70**	288.69**	-34.31**	6.07	170.30**
Z_2 × Nap 2057	13.51*	1.45	77.14**	215.63**	39.65**	22.05**	139.88**	0.52	9.19	685.55**
Z_2 × Nap 2066	7.89**	4.88**	44.44	108.33**	18.86**	20.43**	118.66**	-19.23	6.28	282.37**
Z_2 × Nap 9901	25.00	7.80**	71.59**	242.18**	14.96**	5.98	255.83**	-3.77	39.23**	417.78**
Z_2 × Nap 9904	5.06**	3.90**	58.33*	402.63**	23.42**	40.12**	203.39**	-34.53**	0.34	289.62**
Z_2 × Nap 9905	8.86**	2.42	68.57**	140.91**	30.78**	23.11**	167.67**	6.69	5.41	200.16**
Z_2 × Nap 9906	10.00**	5.24**	67.74*	188.00**	18.47**	15.34*	281.45**	12.86	14.92	362.93**
Z_2 × Nap 9908	-10.00**	0.95	24.39	46.91	23.28**	22.85**	102.86**	-10.02	0.83	95.76**
Z_2 × Nap 94006	14.67**	1.90	70.73**	168.24**	47.75**	62.07**	254.89**	-22.19**	3.08	299.05**
Z2 × BS -7	11.69	5.74**	70.00*	156.62**	28.66**	23.27**	135.92**	10.04	-6.86	242.75**
Z2 x BS- 8	5.56**	2.87*	47.22	97.41**	38.79**	47.29**	221.78**	0.25	4.06	123.67**
Z_2 × BS -13	14.67**	3.40*	56.25*	257.35**	29.25**	39.51**	318.58**	-4.74	17.29*	391.84**
Mean	7.13	3.85	36.89	143.35	27.06	25.90	158.36	-9.13	10.78	230.87
Maximum	25	8	83.33	402.63	49.89	62.07	318.58	34.05	46.97	685.55
Minimum	-10	0.95	-20.37	4.98	-7.05	1.16	32.57	-37.24	-11.03	-20.86

*: Significant at 5% level, **: Significant at 1% level

H (m): Heterosis over mid parent, H (p): Heterosis over pollen parent and H(c): Heterosis over standard check variety
DFF = Days to 50% flowering, DEM = Days to 80% maturity, PBP= Primary branches/pl., SBP = Secondary branches/pl, PH = Plant height, IL = Inflorescence length, SP = Siliqua /pl., SS= Seeds/siliqua, TSW= 1000 seeds wt., SYP = Seed yield/pl.

Table 5. Estimation of heterosis over standard check for different characters in *Brassica napus* hybrids

Hybrids	DFF	DEM	NPBP	SBP	PH	IL	NSP	SS	TSW	SYP
Z_1 × Nap 108	11.11**	4.31**	0.00	26.72	25.30**	29.30**	72.70**	-10.99	11.86	90.96**
Z_1 × Nap 0130	9.72**	2.87*	48.61*	110.34**	32.29**	50.70**	195.81**	-6.27	22.46**	329.83**
Z_1 × Nap 205	16.67**	2.87*	19.44	83.62**	38.72**	64.61**	143.95**	-3.16	-0.16	278.35**
Z_1 × Nap 206	12.50**	0.96	19.44	40.52	27.28**	27.91**	76.75**	4.77	-13.10	61.81**
Z_1 × Nap 2001	9.72**	2.87*	-2.78	-6.90	28.67**	27.21**	52.80**	-5.87	-10.30	8.93**
Z_1 × Nap 2012	18.06*	3.83**	52.78*	75.00**	34.42**	33.88**	114.50**	1.25	12.48	234.10**
Z_1 × Nap 2013	8.33**	2.39	41.67	54.31*	12.40**	35.66**	124.61**	16.41	31.67**	175.53**
Z_1 × Nap 2022	11.11**	0.00	11.11	111.21**	40.77**	43.88**	181.81**	-0.15	13.42	184.91**
Z_1 × Nap 2037	16.67	1.44	75.00**	121.55**	31.60**	44.34**	195.70**	-20.27*	11.23	228.56**
Z_1 × Nap 2057	5.56**	5.26**	63.89*	43.97	36.51**	28.53**	100.37**	-8.98	21.53**	98.98**
Z_1 × Nap 2066	12.50**	2.39	83.33**	65.52*	26.49**	39.53**	115.53**	-23.43*	12.17	147.49**
Z_1 × Nap 9901	13.89**	0.48	36.11	19.83	31.75**	32.87**	111.55**	-2.76	-5.30	225.15**
Z_1 × Nap 9904	11.11**	0.96	25.00	94.83**	30.31**	38.14**	127.96**	-6.77	-5.46	55.92**
Z_1 × Nap 9905	16.67**	2.87*	41.67	75.86**	33.43**	35.66**	88.82**	-3.46	2.65	220.63**
Z_1 × Nap 9906	11.11**	3.35*	55.56*	71.55**	33.13**	45.43**	176.23**	-1.05	5.62	145.61**
Z_1 × Nap 9908	12.50**	1.91	50.00*	137.93**	43.65**	51.63**	274.91**	0.65	-2.03	177.83**
Z_1 × Nap 94006	11.11**	3.83**	31.94	111.64**	29.15**	40.54**	160.23**	-11.19	10.30	179.79**
Z_1 × BS -7	15.28	3.35*	52.78*	92.24**	32.61**	35.04**	190.21**	-3.56	-6.08	119.44**
Z_1 × BS-8	1.39	1.44	44.44	62.93*	32.84**	47.91**	104.78**	0.73	16.54*	111.42**
Z_1 × BS - 13	5.56**	2.87*	5.56	39.66	34.03**	48.06**	43.12**	-36.98**	2.65	24.35**
Z_2 × Nap 108	12.50**	5.74**	-1.39	15.09	30.75**	42.64**	63.72**	-21.98*	7.96	68.20**
Z_2 × Nap 0130	11.11**	3.35*	58.33	21.12	30.70**	32.71**	149.15**	14.07	-5.62	371.09**
Z_2 × Nap 205	25.00**	2.39	19.44	122.41**	44.35**	48.37**	216.15**	0.05	-6.40	90.96**
Z_2 × Nap 206	9.72	2.39	33.33	36.21	31.85**	37.83**	73.88**	-9.78	1.72	48.42**
Z_2 × Nap 2001	5.56**	0.96	33.33	77.59**	32.94**	29.15**	281.97**	-13.80	-3.43	83.21**
Z_2 × Nap 2012	11.11**	2.87*	47.22	4.31	28.08**	38.29**	84.99**	-6.77	6.71	199.40**
Z_2 × Nap 2013	25.00	1.91	30.56*	16.38	39.48**	35.66**	174.17**	6.07	-1.72	138.02**
Z_2 × Nap 2022	4.17**	3.83**	33.33**	87.07**	29.27**	36.74**	214.57**	13.00	0.94	81.42**
Z_2 × Nap 2037	19.44**	3.35*	52.78	148.28**	38.00**	48.99**	275.53**	-22.83*	9.05	204.18**
Z_2 × Nap 2057	16.67**	0.48	72.22**	74.14**	27.18**	23.57**	99.63**	-2.86	5.62	242.88**
Z_2 × Nap 2066	13.89**	2.87*	44.44	50.86*	26.79**	47.13**	125.90**	-23.93*	16.22*	166.33**
Z_2 × Nap 9901	31.94**	5.74**	109.72**	164.01**	27.73**	18.80*	281.75**	-4.59	-10.30	374.08**
Z_2 × Nap 9904	15.28**	1.91	58.33*	229.31**	33.33**	50.54**	183.30**	-17.61	-7.80	194.29**
Z_2 × Nap 9905	19.44**	1.44	63.89*	37.07	35.71**	46.20**	129.07**	0.00	-2.65	230.09**
Z_2 × Nap 9906	22.22**	5.74**	44.44	86.21**	32.34**	28.22**	225.31**	17.11	5.77	255.58**
Z_2× Nap 9908	12.50**	1.44	41.67	2.59	22.92**	28.37**	114.35**	2.31	-5.30	179.37**
Z_2 × Nap 94006	19.44**	2.39	94.44**	96.55**	40.28**	55.04**	263.50**	-7.48	4.52	328.30**
Z2 × BS -7	19.44	5.74**	41.67	57.07*	35.17**	38.18**	136.09**	5.57	-4.68	195.06**
Z2 x BS- 8	5.56**	2.87*	47.22	97.41**	38.79**	47.29**	221.78**	0.25	4.06	123.67**
Z_2 × BS -13	19.44**	1.91	38.89	109.48**	27.58**	40.16**	227.41**	-19.32*	2.65	162.48**
Mean	13.75	2.74	42.99	74.14	32.21	39.37	154.87	-5.34	3.74	170.92
Maximum	31.94	5.74	109.72	229.31	44.35	64.61	281.97	17.11	31.67	374.08
Minimum	1.39	0	-2.78	-6.9	12.4	18.8	43.12	-36.98	-13.1	8.93

*: Significant at 5% level, **: Significant at 1% level

H (m): Heterosis over mid parent, H (p): Heterosis over pollen parent and H(c): Heterosis over standard check variety
DFF = Days to 50% flowering, DEM = Days to 80% maturity, PBP= Primary branches/pl., SBP = Secondary branches/pl, PH = Plant height, IL = Inflorescence length, SP = Siliqua /pl., SS= Seeds/siliqua, TSW= 1000 seeds wt., SYP = Seed yield/pl.

Saurabh *et al.* (2005) found heterosis for seeds per siliqua. Twenty hybrids showed significant positive mid parent, twelve showed positive pollen parent and five positive standard heterosis for 1000-seed weight. Mid parent heterosis ranged from -4.8% to 36.9% with a mean of 13.21% (Table 3). Pollen parent heterosis ranged from -11.03% to 46.97% with a mean of 10.78% and standard heterosis ranged from -13.10% to 31.67% with a mean of 3.74% for the trait(Table 4-5). Many researchers observed heterosis in 1000-seed weight. Such as Shen *et al.* (2005), Wojciechowski *et al.* (2002) and Saurabh *et al.* (2005) observed similar result in their research findings and supported this result.

Thirty two hybrids exhibited significant positive mid parent heterosis for seed yield per plant. The range of mid parent heterosis was -34.07% to 193.08% with a mean of 60.26%. In case of pollen parent heterosis, all hybrids exhibited significant with a range of -20.86% to 685.55%, where mean heterosis was 230.87%. One the other hand, in case of standard heterosis all hybrids had significant positive estimates. The hybrid CMS-Z_2 × Nap 9901 showed the highest (374.08%) significant positive standard heterosis for the trait is presented in Table 5. Saurabh *et al.* (2005) observed similar heterosis in Indian mustard hybrids for this trait. They observed 63.19% - 104.40% beter parent heterosis. In India Chander and Verma (2004) found hetersis over both better parent and mid parent for seed yield/ plant in cabbage. Kishor *et al.*(2006) and Shen *et al.*(2005) found heterosis for seed yield per plant. In the present study most of the hybrids showed positive heterosis for seed yield/plant. It might be due to selection of good specific cross combinations for yield and yield related characters as promising hybrids.

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