Int.J.Curr.Microbiol.App.Sci (2017) *6*(7): 2163-2180

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 7 (2017) pp. 2163-2180**
Journal homepage: http://www.ijcmas.com

Original Research Article

https://doi.org/10.20546/ijcmas.2017.607.315

Heterosis and Heterobeltiosis for Seed Yield and its Components in Indian Mustard (*Brassica juncea* L. Czern & Coss) under Normal (E1) and Moisture Stress (E2) Environments

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Keywords

Indian mustard, Heterosis, Heterobeltiosis and *Brassica juncea*.

Article Info

Accepted:
23 June 2017
Available Online:
10 July 2017

ABSTRACT

A set of 10 x 10 diallel crosses excluding reciprocals of Indian mustard along with their parents were evaluated in randomized block design with three replications in two set of environments *i.e.* normal (E_1) and moisture stress (E_2) in RBD design with three replications during *Rabi* 2015-16. Observation were recorded on various quantitative characters *viz.*, Observations were recorded on days to flowering, days to maturity, plant height (cm), primary branches per plant, length of main raceme (cm), number of siliqua on main raceme, number of seeds per siliqua, 1000-seed weight (g), seed yield per plant (g) and oil content (%). Heterosis and heterobeltiosis of higher magnitude was expressed for seed yield per plant, number of siliqua on main raceme and number of seeds per siliqua. The crosses Vardan x RH-30 and Bio-902 x NRCDR-2 were identified as the superior crosses under both the environments which can be utilized for high yield and moisture stress genotypes.

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss] is an important oilseed crop belongs to family *Brassicacae* (*Crucifereae*) and genus *Brassica*. It is a natural amphidiploid having 36 chromosomes (2n). It is largely self-pollinated but certain amount of cross pollination (2-15%) may take place due to honeybees (Vaghela *et al.*, 2011). Mustard was originated in China and from there; it was introduced to India (Vaughan, 1977).

Rapeseed and Mustard are the major *Rabi* oilseed crops of India. Oil content in mustard seed varies from 37 to 49 per cent. The oil obtained is the main cooking medium in Northern India and cannot be easily replaced by any other edible oil. The seed and oil of mustard have a peculiar pungency due to presence of glucosinolate and its hydrolysis products such as allyl-isothio-cynate making it suitable to be used as condiment in the preparation of pickles and for flavoring curries and vegetables. The oil is utilized for human consumption throughout Northern India in cooking and frying purposes.

Moisture stress is major limiting factor in productivity of rapeseed-mustard. Majority of the cultivation is still dependent on rainfall and conserved moisture. *Brassica* species are mostly grown on light texture soil using conserved moisture from monsoon rains. Crop inevitably suffers from drought stress during the reproductive period of growth after depletion of stored water (Kumar, 2001). Hence development of drought tolerant/ resistant varieties of Indian mustard is essential to increase the production.

In the present scenario of changing agro climatic conditions where there is depleting underground water and increased terminal temperature, the plant breeders have two challenges in the oilseed production, first the yield potential should further be increased in traditional area of mustard cultivation and second, short duration and drought tolerant oilseed varieties should be developed to maintain the production in the state and serve as an alternative to wheat in nontraditional areas.

Grafius (1959) suggested that there might not be any specific genes for yield per se. Since, heterosis has an important role in all plant breeding programmes; it would be very helpful to know the relationship between heterosis for seed yield and its components (Azizinia, 2011). Selection of desirable heterotic crosses at an early stage is very important in developing high-yielding genotypes. Effective utilization of heterosis to develop high-yielding hybrids, therefore, has been the major objective of Brassica oilseed breeding in recent years (Wang, 2005). The main objective of the present study, therefore, was to isolate superior cross combination(s) by estimating heterosis (mid parent heterosis) and heterobeltiosis in F_1 crosses under normal (E_1) and moisture stress (E_2) environments in Indian mustard [*Brassica juncea* (L.) Czern & Coss].

Materials and Methods

The experimental material comprised ten genetically diverse parents of Indian mustard *viz*; CS-52, GM-3, PBR-357, Vardan, RH-30, Bio-902, Kranti, NRCDR-2, RGN-229 and RN-393. The parents were crossed in diallel fashion (excluding reciprocal) to develop the hybrid seeds of 45 crosses. All the crosses were grown in randomized block design with three replications under two environments namely, normal (E_1) and moisture stress (E_2) at Agronomy farm S.K.N. College of Agriculture, Jobner, Jaipur. In both the environments pre-sowing irrigation was given to facilitate germination of seeds. In normal environment (E_1) and moisture stress environment (E_2), one irrigation was given at 45 days after sowing i.e. at about initiation of flowering. Moisture stress environment was created by stopping further irrigation in E_2 i.e. no irrigation was given after 45 days in E_2. In normal environment, the second and last irrigation was given at 70 days after sowing. Observations were recorded on days to flowering, days to maturity, plant height (cm), primary branches per plant, length of main raceme (cm), number of siliqua on main raceme, number of seeds per siliqua, 1000-seed weight (g), seed yield per plant (g) and oil content (%). The data obtained were subjected to analysis of variance as per standard procedures.

Results and Discussion

Analysis of variance in individual environment (Table 1) revealed highly significant differences among genotypes for all the characters in both the environments consequently established the circumstances that the characters manifested the presence of ample genetic diversity among the genotypes. This is in conformity with the findings obtained by Arrifullah *et al.,* (2013), Kumar *et al.,* (2014), Synrem *et al.,* (2014) and Akabari *et al.,* (2016).

Mean squares due to Parents vs. generations were found significant for all the characters in all the environments except for days to 50 % flowering in E_2 and plant height in E_1 indicated the presence of heterosis. Similar findings were obtained by Sheoran *et al.,* (2000) and Tuncturk and Ciftci (2007) also reported significant differences between genotypes for seed yield and its attributes.

Mean squares due to F_1 vs. F_2 were found significant for all the characters in both the environments except for days to maturity in E_1, number of primary branches per plant in E_2, number of seeds per siliqua in E_1 and E_2 and1000-seed weight in E_2.Similar findings were obtained by Vaghela *et al.,* (2011) and Arifullah *et al.,* (2013).

Short and medium plant stature less vulnerable to lodging due to heavy winds is also preferred in Brassica. Early maturity is useful in most plant species especially Brassica where delayed maturity cause losses in yield and quality of oil due to high temperature (Turi *et al.,* 2006). Similarly, initiation of branches near the base of plant is also desirable for profuse branching with vigorous stature. Negative heterosis, therefore, is useful regarding days to flowering, days to maturity and plant height. Early maturing genotypes suffer lower losses due to shattering, tolerate or seeding the next crop. Similarly, shorter plants with greater numbers of branches are desirable due to their ability to withstand winds. In the present study, negative heterotic values for these traits were noted for many of the crosses (Table 2). Crosses showing significant negative values suggested that these crosses could be used to develop new early maturing varieties. Pourdad and Sachan (2003) also reported significant negative heterosis for days to 50% flowering and maturity and high negative heterosis for plant height in *Brassica napus*. Similarly, Nassimi *et al.,* (2006) also obtained significant negative better-parent heterosis for maturity and plant height. Engqvist and Becker (1991) found that rapeseed hybrids with earlier flowering and higher yields were slightly late maturing. The crosses CS-52 x Bio-902 and GM-3 x Vardan significant positive heterosis and heterobeltiosis under both the environments. In *Brassica*, positive heterosis for number of primary branches is desirable, because plants with vigorous stature containing more branches provide opportunity for higher yields. For length of main raceme; the crosses RH-30 x NRCDR-2 and NRCDR-2 x RN-393, for siliqua on main raceme; the crosses PBR-357 x RH-30 and CS-52 x RN-393, for number of seeds per siliqua; the crosses RH-30 x Bio-902, for seed yield per plant; the crosses PBR-357 x Kranti, Vardan x RH-30 and Vardan x RN-393 significant positive heterosis and heterobeltiosis under both the environments. Results of high heterosis and heterobeltiosis for seed yield per plant and contributing traits were also reported by Ghosh *et al.,* (2002). The level of heterosis observed in these crosses justifies the development of commercial hybrids in Indian mustard. Commercial exploitation of hybrid in *Brassica juncea* has been reported by many mustard workers like Meena *et al.,* (2014, 15) and Akbar *et al.,* (2007) also reported that these crosses with positive heterosis and heterobeltiosis may be utilized for hybrid seed production by CMS and restorer lines. Heterotic crosses showing substaintial and significant SCA effects for seed yield over mid-parent and better parent are indicated (Table 3).

Table.1 ANOVA for various characters in normal (E1) and moisture stress environment (E2) in mustard

Particulars			Mean Squares				
Source of Variation (Characters →)	Env.	df	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary branches per plant	Length of main raceme (cm)
Replications	E_1	2	43.77**	9.16*	705.87**	2.80**	33.41
	E_2	2	4.34	75.14**	1407.73**	0.14	232.41**
Genotypes (G)	E1	99	9.25**	26.38**	301.92**	0.26**	164.03**
	E_2	99	5.89**	35.77**	112.68**	0.35**	94.16**
Parents (P)	E_1	9	10.16**	17.68**	177.40**	0.17**	166.27**
	E_2	9	3.54	21.34**	83.73*	0.36**	4.66
Generation	E_1	89	8.36**	24.88**	317.78**	0.24**	160.44**
	E_2	89	6.17**	36.68**	106.44**	0.34**	93.41**
F1	E_1	44	10.32**	16.60**	180.36**	0.29**	121.94**
	E_2	44	4.90*	29.65**	123.77**	0.28**	53.98**
F2	E_1	44	4.25**	33.47**	268.83**	0.18**	78.63**
	E_2	44	7.11**	32.38**	79.938**	0.42**	92.71**
F1 vs F2	E_1	1	103.29**	10.80	8517.5**	0.31*	5453.82**
	E_2	1	20.28*	534.81**	510.19**	0.03	1859.20**
Parents vs Generation	E_1	1	80.08**	238.22**	11.82	3.47**	463.33**
	E_2	1	2.61	85.33**	928.30**	0.49**	966.24**
Error	E_1	198	2.36	2.85	29.68	0.06	19.71
	E_2	198	3.23	2.28	37.082	0.06	22.93

*****, ****** Significant at 5 per cent & 1 per cent levels of significance, respectively

Table 1: Continued

Source of Variation	Characters → Env.	df	Number of siliqua on main raceme	Number of seeds per siliqua	1000 seed weight (g)	Seed yield per plant (g)	Oil content (%)
Replications	E_1	2	51.10	0.29	0.68**	1.97	28.70**
	E_2	2	436.51**	2.44	2.51**	5.94**	6.70**
Genotypes (G)	E_1	99	63.69**	2.67**	0.20**	18.78**	1.26**
	E_2	99	70.96**	2.34**	0.15*	16.92**	1.95**
Parents (P)	E_1	9	24.53	1.83	0.26**	0.64	1.72*
	E_2	9	12.20	1.85	0.17	0.94	2.07*
Generation	E_1	89	54.36**	2.53**	0.18**	19.52**	1.11**
	E_2	89	72.35**	2.20**	0.15*	17.64**	1.91**
F1	E_1	44	38.91**	2.17**	0.12*	10.93**	0.52
	E_2	44	42.74**	1.65*	0.14	8.49**	1.35*
F2	E_1	44	50.91**	2.94**	0.19**	5.78**	0.91
	E_2	44	30.97**	2.76**	0.16*	7.85**	1.27*
F1 vs F2	E_1	1	886.57**	0.32	2.53**	1002.02**	36.24**
	E_2	1	3195.48**	1.86	0.18	851.30**	54.10**
Parents vs Generation	E_1	1	1246.40**	22.75**	0.83**	115.71**	10.46**
	E_2	1	475.93**	18.79**	0.44*	96.63**	5.06*
Error	E_1	198	17.40	1.20	0.08	1.12	0.69
	E_2	198	12.65	1.05	0.10	1.04	0.86

*****, ****** Significant at 5 per cent & 1 per cent levels of significance, respectively

Table.2 Estimates of heterosis and heterobeltiosis for days to 50 % flowering under normal (E1) and moisture stress (E2) environments

S. No.	Crosses	Heterosis (%)		Heterobeltiosis (%)	
		E_1	E_2	E_1	E_2
1.	CS-52 X GM-3	-2.05	1.32	-3.05	0.66
2.	CS-52 X PBR-357	-0.25	2.58	-0.51	0.63
3.	CS-52 X Vardan	-2.77	-0.32	-3.50	-2.52
4.	CS-52 X RH-30	-1.56	-1.65	-4.06	-1.97
5.	CS-52 X Bio-902	3.11	1.96	1.02	1.30
6.	CS-52 X Kranti	-1.82	1.94	-4.06	0.00
7.	CS-52 X NRCDR-2	-3.65*	1.95	-6.09**	0.64
8.	CS-52 X RGN-229	0.52	-3.25	2.54	-4.49
9.	CS-52 X RN-393	-4.99**	3.87	-8.12**	1.90
10.	GM-3 X PBR-357	-1.29	-3.25	-2.04	-5.70*
11.	GM-3 X Vardan	-3.82*	-0.97	-5.50**	-3.77
12.	GM-3 X RH-30	-3.68*	2.99	-5.18*	2.65
13.	GM-3 X Bio-902	-2.09	-2.63	-3.11	-3.90
14.	GM-3 X Kranti	0.26	-1.30	-1.04	-3.80
15.	GM-3 X NRCDR-2	-3.16	3.27	-4.66*	1.28
16.	GM-3 X RGN-229	-2.12	-1.31	-4.15	-3.21
17.	GM-3 X RN-393	2.39	-3.90	0.00	-6.33*
18.	PBR-357 X Vardan	-4.55*	-3.47	-5.50**	-3.77
19.	PBR-357 X RH-30	2.35	-0.32	0.00	-2.53
20.	PBR-357 X Bio-902	0.25	-1.28	-1.53	-2.53
21.	PBR-357 X Kranti	-3.65*	-7.59**	-5.61**	-7.59**
22.	PBR-357 X NRCDR-2	-2.35	-0.64	-4.59*	-1.27
23.	PBR-357 X RGN-229	1.84	-4.46	-1.02	-5.06
24.	PBR-357 X RN-393	1.58	-4.43	-1.53	-4.43
25.	Vardan X RH-30	-1.29	-3.87	-4.50*	-6.29*
26.	Vardan X Bio-902	-5.40**	-1.6	-8.00**	-3.14
27.	Vardan X Kranti	-2.58	-6.62**	-5.50**	-6.92*
28.	Vardan X NRCDR-2	1.81	-0.32	-1.50	-1.26
29.	Vardan X RGN-229	0.78	-3.49	-3.00	-4.40
30.	Vardan X RN-393	-4.17*	-0.32	-8.00**	-0.63
31.	RH-30 X Bio-902	-2.13	4.26	-2.65	3.25
32.	RH-30 X Kranti	-1.33	-1.62	-1.60	-3.80
33.	RH-30 X NRCDR-2	0.53	-0.33	0.53	-1.92
34.	RH-30 X RGN-229	-1.61	1.63	-2.14	0.00
35.	RH-30 X RN-393	-0.81	2.27	-1.60	0.00
36.	Bio-902 X Kranti	-1.33	-1.92	-1.59	-3.16
37.	Bio-902 X NRCDR-2	-2.66	-3.87	-3.17	-4.49
38.	Bio-902 X RGN-229	-3.74*	0.00	-4.76*	-0.64
39.	Bio-902 X RN-393	-1.88	-1.92	-3.17	-3.16
40.	Kranti X NRCDR-2	-4.00*	1.91	-4.26	1.27
41.	Kranti X RGN-229	-4.56*	0.00	-5.32*	-0.63
42.	Kranti X RN-393	-1.61	-0.63	-2.66	-0.63
43.	NRCDR-2 X RGN-229	-3.23	-5.13*	-3.74	-5.13
44.	NRCDR-2 X RN-393	-6.20**	-2.55	-0.95**	-3.16
45.	RGN-229 X RN-393	-1.36	-5.10*	-1.62	-5.70*
	SED	1.156	1.236	1.334	1.428
	CD (5%)	2.329	2.492	2.690	2.878
	CD (1%)	3.031	3.243	3.500	3.744

Table.2 Estimates of heterosis and heterobeltiosis for days to maturity under normal (E1) and moisture stress (E2) environments

S. No.	Crosses	Heterosis (%)		Heterobeltiosis (%)	
		E_1	E_2	E_1	E_2
1.	**CS-52 X GM-3**	**1.04**	**4.79***	**0.00**	**1.69**
2.	CS-52 X PBR-357	1.29	-2.05*	1.03	-4.29**
3.	CS-52 X Vardan	1.01	3.40**	-0.50	2.04
4.	CS-52 X RH-30	-2.20*	0.29	-3.08**	-2.00
5.	CS-52 X Bio-902	-3.80**	6.39**	-5.24**	5.60**
6.	CS-52 X Kranti	-1.28	8.08**	-1.78	8.08**
7.	CS-52 X NRCDR-2	0.00	1.49	-1.01	1.19
8.	CS-52 X RGN-229	-2.58**	0.30	-3.08**	-0.59
9.	CS-52 X RN-393	-2.69**	5.97**	-3.06**	3.12**
10.	GM-3 X PBR-357	-0.26	2.70**	-1.03	1.97
11.	GM-3 X Vardan	-1.28	1.72	-3.74**	0.00
12.	GM-3 X RH-30	-0.66	-2.70**	-0.79	-3.38**
13.	GM-3 X Bio-902	-2.30*	1.44	-4.74**	-0.85
14.	GM-3 X Kranti	0.26	6.53**	-1.27	3.38**
15.	GM-3 X NRCDR-2	1.03	4.78**	-1.01	1.97
16.	GM-3 X RGN-229	0.52	3.60**	0.00	1.41
17.	GM-3 X RN-393	-0.13	4.24**	-1.53	3.94**
18.	PBR-357 X Vardan	-1.02	1.30	-2.74*	0.29
19.	PBR-357 X RH-30	-2.20*	2.29*	-2.84*	2.29*
20.	PBR-357 X Bio-902	-3.05**	4.50**	-4.74**	2.86*
21.	PBR-357 X Kranti	0.00	3.80**	-0.76	1.43
22.	PBR-357 X NRCDR-2	-2.04*	0.00	-3.27**	-2.00
23.	PBR-357 X RGN-229	0.52	2.03*	0.26	0.57
24.	PBR-357 X RN-393	-1.67	-2.13*	-2.30	-2.55*
25.	Vardan X RH-30	-4.73**	2.16*	-6.95**	1.14
26.	Vardan X Bio-902	-5.24**	3.52**	-5.24**	2.92*
27.	Vardan X Kranti	-5.79**	0.44	-6.73**	-0.87
28.	Vardan X NRCDR-2	-5.76**	-1.91	-6.23**	-2.92*
29.	Vardan X RGN-229	-3.05**	-1.32	-4.99**	-1.75
30.	Vardan X RN-393	-4.67**	-1.72	-5.74**	-3.12**
31.	RH-30 X Bio-902	-3.4**	0.44	-5.74**	-1.14
32.	RH-30 X Kranti	2.45*	4.97**	1.02	2.57*
33.	RH-30 X NRCDR-2	-1.93*	5.54**	-3.78**	3.43**
34.	RH-30 X RGN-229	-4.04**	2.90**	-4.42**	1.43
35.	RH-30 X RN-393	-2.84**	-2.42**	-4.08**	-2.83*
36.	Bio-902 X Kranti	-5.54**	7.58**	-6.48**	6.78**
37.	Bio-902 X NRCDR-2	-6.02	7.26**	-6.48**	6.78**
38.	Bio-902 X RGN-229	-2.29*	4.57**	-4.24**	4.41**
39.	Bio-902 X RN-393	-2.65**	3.47**	-3.74**	1.42
40.	Kranti X NRCDR-2	-5.57**	2.99**	-6.05**	2.68*
41.	Kranti X RGN-229	-0.26	4.15**	-1.27	3.24**
42.	Kranti X RN-393	-1.91*	3.64**	-2.04	0.85
43.	NRCDR-2 X RGN-229	-2.81**	8.58**	-4.28**	7.94**
44.	NRCDR-2 X RN-393	-2.15*	4.79**	-2.77**	2.27*
45.	RGN-229 X RN-393	-5.28**	3.61**	-6.12**	1.70
	SED	1.212	1.126	1.400	1.301
	CD (5%)	2.444	2.271	2.822	2.622
	CD (1%)	3.179	2.954	3.671	3.411

Table.2 Estimates of heterosis and heterobeltiosis for plant height under normal (E1) and moisture stress (E2) environments

S. No.	Crosses	Heterosis (%)		Heterobeltiosis (%)	
		E_1	E_2	E_1	E_2
1.	CS-52 X GM-3	-3.12	-2.98	-9.28**	-4.67
2.	CS-52 X PBR-357	2.01	4.56	-4.66	1.71
3.	CS-52 X Vardan	5.25*	4.8	-0.27	2.92
4.	CS-52 X RH-30	11.27**	8.23**	3.87	7.09*
5.	CS-52 X Bio-902	5.57*	3.83	0.81	1.15
6.	CS-52 X Kranti	13.36**	941**	9.95**	8.81*
7.	CS-52 X NRCDR-2	14.94**	8.34**	11.40**	5.49
8.	CS-52 X RGN-229	1.61	-4.06	-4.69	-9.33**
9.	CS-52 X RN-393	4.60	9.31**	-0.68	9.13**
10.	GM-3 X PBR-357	-1.76	0.13	-1.96	-0.88
11.	GM-3 X Vardan	9.71**	11.40**	8.35**	11.35**
12.	GM-3 X RH-30	2.98	4.57	2.63	3.82
13.	GM-3 X Bio-902	3.55	-4.45	1.44	-5.28
14.	GM-3 X Kranti	3.87	6.81*	0.16	4.37
15.	GM-3 X NRCDR-2	0.17	-3.07	-3.32	-3.95
16.	GM-3 X RGN-229	-6.92**	-3.69	-7.08**	-7.42*
17.	GM-3 X RN-393	-3.47	1.37	-4.87	-0.24
18.	PBR-357 X Vardan	-1.57	5.85*	-2.99	4.82
19.	PBR-357 X RH-30	1.55	9.62**	1.42	7.75*
20.	PBR-357 X Bio-902	4.56*	1.59	2.22	1.44
21.	PBR-357 X Kranti	2.55	-0.23	-1.31	-3.47
22.	PBR-357 X NRCDR-2	3.54	2.38	-0.27	2.28
23.	PBR-357 X RGN-229	3.79	7.49**	3.39	4.34
24.	PBR-357 X RN-393	2.28	6.65*	0.59	3.91
25.	Vardan X RH-30	-0.06	10.43**	-1.63	9.60**
26.	Vardan X Bio-902	1.37	4.32	0.54	3.46
27.	Vardan X Kranti	4.74*	7.96**	2.24	5.46
28.	Vardan X NRCDR-2	6.02	7.21*	3.57	6.28
29.	Vardan X RGN-229	0.68	6.35*	-0.40	2.27
30.	Vardan X RN-393	1.96	8.98**	1.73	7.20*
31.	RH-30 X Bio-902	5.54*	0.60	3.06	-0.98
32.	RH-30 X Kranti	9.01**	14.16**	4.79	12.35**
33.	RH-30 X NRCDR-2	8.67**	2.04	4.55	0.39
34.	RH-30 X RGN-229	6.69**	-0.21	6.15*	-4.74
35.	RH-30 X RN-393	6.74**	5.23	4.84	4.30
36.	Bio-902 X Kranti	10.78**	11.35**	9.01**	7.89*
37.	Bio-902 X NRCDR-2	7.83**	-1.89	6.20*	-1.94
38.	Bio-902 X RGN-229	4.34	4.75	2.39	1.54
39.	Bio-902 X RN-393	3.49	14.84**	2.87	12.06**
40.	Kranti X NRCDR-2	12.72**	11.78**	12.62**	8.26*
41.	Kranti X RGN-229	-3.43	5.70	-6.7.**	-0.62
42.	Kranti X RN-393	-0.10	13.53**	-2.28	12.72**
43.	NRCDR-2 X RGN-229	6.74**	2.90	3.19	-0.21
44.	NRCDR-2 X RN-393	2.92	7.59*	0.77	4.93
45.	RGN-229 X RN-393	-9.90**	7.50**	-11.06**	1.76
	SED	3.931	4.074	4.543	4.704
	CD (5%)	7.929	8.211	9.156	9.481
	CD (1%)	10.316	10.683	11.912	12.336

Table.2 Estimates of heterosis and heterobeltiosis for Number of primary branches per plant under normal (E1) and moisture stress (E2) environments

S. No.	Crosses	Heterosis (%)		Heterobeltiosis (%)	
		E_1	E_2	E_1	E_2
1.	CS-52 X GM-3	13.62**	7.02	11.45*	-1.61
2.	CS-52 X PBR-357	4.25	5.65	3.05	5.65
3.	CS-52 X Vardan	3.79	2.2	3.01	-6.45
4.	CS-52 X RH-30	-2.14	-0.39	-8.02*	-3.76
5.	CS-52 X Bio-902	27.84**	20.16**	24.43**	17.74**
6.	CS-52 X Kranti	16.60**	6.03	15.27**	-0.81
7.	CS-52 X NRCDR-2	11.79**	6.22	11.36*	3.23
8.	CS-52 X RGN-229	1.90	-6.14	1.52	-13.71**
9.	CS-52 X RN-393	15.56**	7.32	12.23**	6.45
10.	GM-3 X PBR-357	9.45*	14.04**	8.59	4.84
11.	GM-3 X Vardan	11.97**	22.71**	9.02*	22.12**
12.	GM-3 X RH-30	6.18	-8.86	-2.01	-18.80**
13.	GM-3 X Bio-902	12.80**	1.35	11.90*	-5.04
14.	GM-3 X Kranti	5.51	9.43	4.69	7.41
15.	GM-3 X NRCDR-2	20.93**	14.93**	18.18**	8.55
16.	GM-3 X RGN-229	20.93**	25.00**	18.18**	25.00**
17.	GM-3 X RN-393	7.17	1.77	2.16	-5.74
18.	PBR-357 X Vardan	-2.68	3.96	-4.51	-4.84
19.	PBR-357 X RH-30	-2.53	-2.72	-9.40*	-6.02
20.	PBR-357 X Bio-902	12.70**	-7.82	10.94*	-9.68
21.	PBR-357 X Kranti	15.63**	0.86	15.63**	-5.65
22.	PBR-357 X NRCDR-2	3.85	-4.56	2.27	-7.26
23.	PBR-357 X RGN-229	30.00**	3.51	28.03**	-4.84
24.	PBR-357 X RN-393	-0.37	-7.32	-4.32	-8.06
25.	Vardan X RH-30	7.80*	-1.69	2.01	-12.78**
26.	Vardan X Bio-902	9.73*	20.72**	6.02	12.61*
27.	Vardan X Kranti	13.41**	18.48**	11.28*	15.74**
28.	Vardan X NRCDR-2	7.17	5.45	6.77	-0.85
29.	Vardan X RGN-229	-0.38	24.64**	-0.75	24.04**
30.	Vardan X RN-393	-0.515	3.11	-7.19	-4.92
31.	RH-30 X Bio-902	14.29**	1.59	4.70	-3.76
32.	RH-30 X Kranti	4.69	-0.41	-2.68	-9.77*
33.	RH-30 X NRCDR-2	-0.36	-4.80	-6.04	-10.53*
34.	RH-30 X RGN-229	-3.91	-6.33	-9.40*	-16.54**
35.	RH-30 X RN-393	0.69	-10.59*	-2.68	-14.29**
36.	Bio-902 X Kranti	11.11**	0.44	9.37*	-4.20
37.	Bio-902 X NRCDR-2	7.81	-13.56**	4.55	-14.29**
38.	Bio-902 X RGN-229	14.06**	21.97**	10.61*	14.29**
39.	Bio-902 X RN-393	3.42	-0.41	-2.16	-1.64
40.	Kranti X NRCDR-2	9.23*	12.00	7.58	7.69
41.	Kranti X RGN-229	8.46*	19.81**	6.82	17.59**
42.	Kranti X RN-393	11.61**	-5.22	7.19	-10.66*
43.	NRCDR-2 X RGN-229	21.21**	-7.69	21.21**	-12.82*
44.	NRCDR-2 X RN-393	17.34**	-7.95	14.39**	-9.84
45.	RGN-229 X RN-393	9.96**	2.65	7.19	-4.92
	SED	0.166	0.181	0.191	0.209
	CD (5%)	0.334	0.365	0.386	0.422
	CD (1%)	0.435	0.475	0.503	0.549

Table.2 Estimates of heterosis and heterobeltiosis for length of main raceme under normal (E1) and moisture stress (E2) environments

S. No.	Crosses	Heterosis (%)		Heterobeltiosis (%)	
		E_1	E_2	E_1	E_2
1.	CS-52 X GM-3	55.07**	22.95*	44.38**	19.79
2.	CS-52 X PBR-357	43.31**	51.69**	36.12**	49.62**
3.	CS-52 X Vardan	23.05**	11.52	13.47*	8
4.	CS-52 X RH-30	23.27**	44.96**	11.52	44.86**
5.	CS-52 X Bio-902	31.26**	39.03**	22.20**	32.42**
6.	CS-52 X Kranti	24.60**	37.83**	1.01	32.44**
7.	CS-52 X NRCDR-2	27.35**	29.96**	12.54*	26.13**
8.	CS-52 X RGN-229	27.95**	24.93**	18.32**	20.99*
9.	CS-52 X RN-393	52.92**	36.62**	32.63**	30.70**
10.	GM-3 X PBR-357	23.85**	31.32**	21.27**	29.69**
11.	GM-3 X Vardan	33.52**	19.77*	32.13**	19.03
12.	GM-3 X RH-30	14.57**	26.78**	11.06	23.44*
13.	GM-3 X Bio-902	35.30**	19.48*	35.29**	16.73
14.	GM-3 X Kranti	-6.87	32.36**	-19.87**	30.49**
15.	GM-3 X NRCDR-2	7.23	14.15	1.34	13.70
16.	GM-3 X RGN-229	24.76**	28.96**	23.84**	28.17**
17.	GM-3 X RN-393	10.04**	34.91**	7.46	32.41**
18.	PBR-357 X Vardan	41.38**	4.66	37.02**	2.73
19.	PBR-357 X RH-30	19.29**	31.20**	13.30*	29.33**
20.	PBR-357 X Bio-902	20.98**	5.33	18.45**	1.67
21.	PBR-357 X Kranti	5.77	16.90	-10.59*	13.85
22.	PBR-357 X NRCDR-2	11.75*	26.76**	3.53	24.70*
23.	PBR-357 X RGN-229	20.93**	35.82**	17.55**	33.33**
24.	PBR-357 X RN-393	11.23*	2.94	1.03	-0.20
25.	Vardan X RH-30	8.43	33.02**	6.19	28.74**
26.	Vardan X Bio-902	12.65*	23.10**	11.49	21.01*
27.	Vardan X Kranti	-13.78**	5.55	-25.16**	4.70
28.	Vardan X NRCDR-2	0.69	5.95	-3.89	5.71
29.	Vardan X RGN-229	4.32	18.06*	4.00	18.05
30.	Vardan X RN-393	5.89	14.51	-0.98	13.07
31.	RH-30 X Bio-902	7.93	12.51	4.63	7.10
32.	RH-30 X Kranti	-7.42	33.45**	-18.17**	28.15**
33.	RH-30 X NRCDR-2	44.58**	31.43**	40.83**	27.48**
34.	RH-30 X RGN-229	29.25**	26.68**	26.19**	21.64*
35.	RH-30 X RN-393	8.93	17.83*	3.91	12.66
36.	Bio-902 X Kranti	-0.43	34.04**	-14.33**	32.82**
37.	Bio-902 X NRCDR-2	5.87	34.18**	0.06	31.60**
38.	Bio-902 X RGN-229	11.30	17.77*	10.49	15.76
39.	Bio-902 X RN-393	4.00	36.98**	-3.69	36.36**
40.	Kranti X NRCDR-2	-1.32	13.33	-10.71*	12.16
41.	Kranti X RGN-229	8.40	-1.36	-6.15	-2.15
42.	Kranti X RN-393	-6.21	9.26	-13.44**	8.76
43.	NRCDR-2 X RGN-229	20.19**	20.64*	14.38*	20.37*
44.	NRCDR-2 X RN-393	20.11**	44.46**	17.55**	42.33**
45.	RGN-229 X RN-393	-4.61	26.79**	-11.05	25.20**
	SED	2.970	3.055	3.429	3.527
	CD (5%)	5.986	6.157	6.912	7.109
	CD (1%)	7.788	8.01	8.993	9.249

Table.2 Estimates of heterosis and heterobeltiosis for siliqua on main raceme under normal (E1) and moisture stress (E2) environments

S. No.	Crosses	Heterosis (%)		Heterobeltiosis (%)	
		E_1	E_2	E_1	E_2
1.	CS-52 X GM-3	22.96**	36.33**	17.47	32.82**
2.	CS-52 X PBR-357	32.02**	50.97**	30.74**	48.39**
3.	CS-52 X Vardan	36.50**	7.79	30.64**	3.08
4.	CS-52 X RH-30	29.72**	50.71**	29.59**	44.89**
5.	CS-52 X Bio-902	23.08**	40.95**	17.86	31.69**
6.	CS-52 X Kranti	24.79**	43.17**	17.98*	35.18**
7.	CS-52 X NRCDR-2	37.15**	34.70**	33.78**	26.79**
8.	CS-52 X RGN-229	12.85	31.73**	1.02	29.18**
9.	CS-52 X RN-393	50.69**	42.87**	48.31**	35.08**
10.	GM-3 X PBR-357	31.99**	35.12**	24.93**	33.91**
11.	GM-3 X Vardan	18.54*	22.11*	18.31*	19.80*
12.	GM-3 X RH-30	16.68*	30.73**	11.58	22.58*
13.	GM-3 X Bio-902	21.18**	18.75*	20.88*	13.75
14.	GM-3 X Kranti	25.54**	29.27**	24.18**	25.17**
15.	GM-3 X NRCDR-2	9.97	18.14*	7.64	14.04
16.	GM-3 X RGN-229	13.82	31.96**	6.29	31.09**
17.	GM-3 X RN-393	47.96**	26.34**	43.54**	22.51*
18.	PBR-357 X Vardan	29.47**	-0.54	22.76*	-3.28
19.	PBR-357 X RH-30	43.49**	38.10**	41.95**	30.59**
20.	PBR-357 X Bio-902	35.52**	5.93	28.56**	0.61
21.	PBR-357 X Kranti	30.38**	14.18	22.14*	9.60
22.	PBR-357 X NRCDR-2	19.94*	25.40**	15.88	20.00**
23.	PBR-357 X RGN-229	13.34	44.37**	0.57	44.03**
24.	PBR-357 X RN-393	35.29**	5.87	31.87**	1.77
25.	Vardan X RH-30	23.24**	39.22**	18.06*	28.23**
26.	Vardan X Bio-902	12.68	23.07**	12.62	20.10*
27.	Vardan X Kranti	18.44*	5.44	16.93	4.04
28.	Vardan X NRCDR-2	23.36**	7.76	20.98*	5.98
29.	Vardan X RGN-229	7.26	19.05*	-0.01	16.04
30.	Vardan X RN-393	11.18	9.90	8.06	8.59
31.	RH-30 X Bio-902	11.01	17.25	6.40	5.62
32.	RH-30 X Kranti	30.96**	45.61**	23.94**	32.48**
33.	RH-30 X NRCDR-2	59.58**	28.20**	55.82**	16.31
34.	RH-30 X RGN-229	15.11*	29.02**	3.13	21.73*
35.	RH-30 X RN-393	13.64	25.56**	11.96	14.39
36.	Bio-902 X Kranti	17.13*	35.93**	15.58	34.43**
37.	Bio-902 X NRCDR-2	32.52**	29.35**	30.03**	28.33**
38.	Bio-902 X RGN-229	0.26	12.88	-6.58	7.45
39.	Bio-902 X RN-393	23.99**	35.81**	20.58*	34.11**
40.	Kranti X NRCDR-2	29.45**	13.49	25.37**	13.12
41.	Kranti X RGN-229	16.28*	1.83	9.71	-2.03
42.	Kranti X RN-393	22.69**	10.04	17.78*	9.88
43.	NRCDR-2 X RGN-229	1.69	10.15	-6.90	5.65
44.	NRCDR-2 X RN-393	29.67**	38.48**	28.50**	37.83**
45.	RGN-229 X RN-393	1.83	28.48**	-7.54	23.78*
	SED	2.920	2.563	3.371	2.96
	CD (5%)	5.885	5.166	6.795	5.965
	CD (1%)	7.656	6.721	8.841	7.761

Table.2 Estimates of heterosis and heterobeltiosis for number of seeds per siliqua under normal (E1) and moisture stress (E2) environments

S. No.	Crosses	Heterosis (%)		Heterobeltiosis (%)	
		E_1	E_2	E_1	E_2
1.	CS-52 X GM-3	4.65	14.07*	-1.72	7.99
2.	CS-52 X PBR-357	3.00	8.02	2.67	7.21
3.	CS-52 X Vardan	3.18	10.36	2.54	6.68
4.	CS-52 X RH-30	9.41	17.14**	4.01	16.27*
5.	CS-52 X Bio-902	-0.88	6.67	-4.16	5.78
6.	CS-52 X Kranti	5.06	5.36	3.95	-0.23
7.	CS-52 X NRCDR-2	6.91	2.49	2.67	-2.69
8.	CS-52 X RGN-229	16.19*	14.63*	13.36	14.29
9.	CS-52 X RN-393	8.65	-2.44	7.79	-3.01
10.	GM-3 X PBR-357	7.02	12.17	0.80	6.94
11.	GM-3 X Vardan	11.24	12.43	5.07	3.08
12.	GM-3 X RH-30	1.04	-1.94	-0.26	-6.51
13.	GM-3 X Bio-902	10.95	18.12**	7.65	12.72
14.	GM-3 X Kranti	9.74	12.49	2.04	1.16
15.	GM-3 X NRCDR-2	0.17	-2.35	-9.42	-11.96
16.	GM-3 X RGN-229	22.49**	23.97**	17.77*	17.03*
17.	GM-3 X RN-393	11.70	17.26*	5.69	10.40
18.	PBR-357 X Vardan	9.59	7.42	9.26	3.08
19.	PBR-357 X RH-30	10.10	6.92	4.99	6.92
20.	PBR-357 X Bio-902	8.92	10.01	5.64	10.91
21.	PBR-357 X Kranti	-1.26	-7.17	-2.62	-12.72
22.	PBR-357 X NRCDR-2	-0.12	2.84	-4.38	-3.05
23.	PBR-357 X RGN-229	10.17	3.59	7.84	2.51
24.	PBR-357 X RN-393	7.37	9.75	6.85	8.30
25.	Vardan X RH-30	5.25	5.52	0.65	1.26
26.	Vardan X Bio-902	9.23	12.04	6.25	7.43
27.	Vardan X Kranti	-8.80	-9.19	-10.31	-11.10
28.	Vardan X NRCDR-2	0.86	2.92	-3.72	1.03
29.	Vardan X RGN-229	11.84	1.77	9.78	-1.34
30.	Vardan X RN-393	4.64	8.77	4.45	5.74
31.	RH-30 X Bio-902	25.97**	19.13**	23.78**	19.03*
32.	RH-30 X Kranti	2.75	1.95	-3.30	-4.14
33.	RH-30 X NRCDR-2	11.26	11.69	1.80	5.30
34.	RH-30 X RGN-229	2.07	-0.56	-0.62	-1.60
35.	RH-30 X RN-393	12.10	9.63	7.39	8.18
36.	Bio-902 X Kranti	11.75	3.95	6.94	-2.34
37.	Bio-902 X NRCDR-2	10.34	-3.20	2.60	-8.81
38.	Bio-902 X RGN-229	1.65	1.31	0.70	0.17
39.	Bio-902 X RN-393	-0.08	4.11	-2.64	2.64
40.	Kranti X NRCDR-2	-9.25	-11.93*	-11.95	-12.18
41.	Kranti X RGN-229	7.80	9.69	4.10	4.16
42.	Kranti X RN-393	16.12**	5.59	13.99*	0.54
43.	NRCDR-2 X RGN-229	5.93	11.23	-0.64	5.92
44.	NRCDR-2 X RN-393	-1.73	-3.46	-6.34	-7.83
45.	RGN-229 X RN-393	25.03**	11.31	22.96**	10.99
	SED	0.781	0.733	0.902	0.846
	CD (5%)	1.575	1.478	1.818	1.706
	CD (1%)	2.049	1.923	2.366	2.22

Table.2 Estimates of heterosis and heterobeltiosis for 1000- seed weight under normal (E1) and moisture stress (E2) environments

S. No.	Crosses	Heterosis (%)		Heterobeltiosis (%)	
		E_1	E_2	E_1	E_2
1.	CS-52 X GM-3	9.19	6.46	7.35	4.47
2.	CS-52 X PBR-357	-0.17	-0.29	-7.06	-6.09
3.	CS-52 X Vardan	6.87	4.1	6.15	3.03
4.	CS-52 X RH-30	4.59	9.82	1.93	9.19
5.	CS-52 X Bio-902	0.96	1.87	-7.38	-4.9
6.	CS-52 X Kranti	7.53	5.85	3.99	3.88
7.	CS-52 X NRCDR-2	8.48	13.76*	6.65	12.01
8.	CS-52 X RGN-229	5.62	7.28	1.33	3.07
9.	CS-52 X RN-393	1.27	4.80	-4.08	-1.30
10.	GM-3 X PBR-357	-0.23	2.78	-5.62	-1.44
11.	GM-3 X Vardan	13.48**	12.67*	12.32*	11.71
12.	GM-3 X RH-30	8.61	10.39	7.63	8.95
13.	GM-3 X Bio-902	5.29	3.46	-1.88	-1.68
14.	GM-3 X Kranti	3.48	2.54	1.76	2.54
15.	GM-3 X NRCDR-2	2.66	-6.17	2.66	-6.49
16.	GM-3 X RGN-229	5.39	-4.67	2.80	-6.71
17.	GM-3 X RN-393	0.77	1.14	-2.98	-3.01
18.	PBR-357 X Vardan	3.53	-8.24	-3.00	-12.73*
19.	PBR-357 X RH-30	4.62	-6.83	-0.19	-11.77
20.	PBR-357 X Bio-902	-4.12	-14.10**	-5.63	-14.91*
21.	PBR-357 X Kranti	-1.62	2.43	-5.43	-1.78
22.	PBR-357 X NRCDR-2	-3.60	-5.91	-8.81	-10.06
23.	PBR-357 X RGN-229	-2.80	-4.89	-5.81	-6.84
24.	PBR-357 X RN-393	3.65	-2.53	1.69	-2.53
25.	Vardan X RH-30	11.88*	6.78	9.77	6.30
26.	Vardan X Bio-902	4.52	-0.53	-3.51	-6.25
27.	Vardan X Kranti	11.89*	6.36	8.94	5.44
28.	Vardan X NRCDR-2	13.83**	10.72	12.68*	10.14
29.	Vardan X RGN-229	9.00	5.55	5.26	2.43
30.	Vardan X RN-393	8.43	3.13	3.37	-1.92
31.	RH-30 X Bio-902	-0.29	-3.61	-6.29	-9.54
32.	RH-30 X Kranti	13.14**	10.54	12.25*	9.10
33.	RH-30 X NRCDR-2	12.91**	12.36*	11.90*	11.26
34.	RH-30 X RGN-229	11.03*	-0.63	9.25	-4.00
35.	RH-30 X RN-393	2.70	-3.36	-0.26	-8.49
36.	Bio-902 X Kranti	5.88	4.31	0.24	-0.87
37.	Bio-902 X NRCDR-2	10.16*	6.49	2.66	0.87
38.	Bio-902 X RGN-229	6.88	4.43	2.00	1.34
39.	Bio-902 X RN-393	0.75	-3.46	-2.60	-4.37
40.	Kranti X NRCDR-2	12.98**	5.42	11.10*	5.07
41.	Kranti X RGN-229	8.83	3.06	7.92	0.86
42.	Kranti X RN-393	7.81	3.93	5.51	-0.34
43.	NRCDR-2 X RGN-229	9.97*	3.84	7.26	1.28
44.	NRCDR-2 X RN-393	6.70	1.04	2.72	-3.42
45.	RGN-229 X RN-393	0.03	-6.15	-1.30	-8.08
	SED	0.222	0.249	0.256	0.288
	CD (5%)	0.447	0.503	0.516	0.581
	CD (1%)	0.582	0.654	0.672	0.756

Table.2 Estimates of heterosis and heterobeltiosis for seed yield per plant under normal (E1) and moisture stress (E2) environments

S. No.	Crosses	Heterosis (%)		Heterobeltiosis (%)	
		E_1	E_2	E_1	E_2
1.	CS-52 X GM-3	42.61**	49.25**	35.11**	37.47**
2.	CS-52 X PBR-357	27.83**	48.72**	27.08*	47.97**
3.	CS-52 X Vardan	39.61**	45.51**	33.76**	36.81**
4.	CS-52 X RH-30	37.37**	41.04**	33.36**	41.00**
5.	CS-52 X Bio-902	28.77**	35.73**	24.68*	27.64*
6.	CS-52 X Kranti	25.99**	29.41*	21.89*	20.54
7.	CS-52 X NRCDR-2	39.63**	61.80**	32.53**	48.63**
8.	CS-52 X RGN-229	68.81**	70.30**	59.91**	55.36**
9.	CS-52 X RN-393	63.57**	65.31**	59.13**	52.17**
10.	GM-3 X PBR-357	12.77	21.21	7.44	11.13
11.	GM-3 X Vardan	48.94**	4.26	47.20**	2.00
12.	GM-3 X RH-30	14.37	-1.13	5.37	-8.91
13.	GM-3 X Bio-902	58.10**	40.69**	54.60**	37.61**
14.	GM-3 X Kranti	15.92	16.11	13.44	14.72
15.	GM-3 X NRCDR-2	7.56	22.35*	7.36	22.00
16.	GM-3 X RGN-229	45.03**	64.24**	45.01**	62.53**
17.	GM-3 X RN-393	68.47**	72.04**	63.95**	71.92**
18.	PBR-357 X Vardan	51.48**	75.97**	45.94**	64.67**
19.	PBR-357 X RH-30	36.07**	62.96**	31.36**	62.11**
20.	PBR-357 X Bio-902	17.31	37.56**	14.22	28.76*
21.	PBR-357 X Kranti	85.20**	97.50**	80.19**	83.10**
22.	PBR-357 X NRCDR-2	61.61**	68.85**	54.24**	54.41**
23.	PBR-357 X RGN-229	40.73**	41.81**	34.05**	28.79*
24.	PBR-357 X RN-393	42.65**	56.31**	39.56**	43.22**
25.	Vardan X RH-30	92.78**	72.49**	79.55**	62.22**
26.	Vardan X Bio-902	78.82**	73.94**	76.89**	73.90**
27.	Vardan X Kranti	27.57**	32.45**	26.30*	31.12*
28.	Vardan X NRCDR-2	46.59**	50.42**	45.16**	46.74**
29.	Vardan X RGN-229	42.79**	64.80**	41.10**	59.57**
30.	Vardan X RN-393	83.05**	88.49**	80.20**	84.28**
31.	RH-30 X Bio-902	41.91**	60.95**	33.52**	51.39**
32.	RH-30 X Kranti	46.67**	53.52**	37.90**	43.03**
33.	RH-30 X NRCDR-2	67.69**	50.34**	54.77**	38.14**
34.	RH-30 X RGN-229	41.93**	62.74**	30.74**	48.50**
35.	RH-30 X RN-393	31.15**	35.35**	23.97*	24.62*
36.	Bio-902 X Kranti	30.04**	27.98*	29.93**	26.67*
37.	Bio-902 X NRCDR-2	86.96**	79.20**	83.15**	74.78**
38.	Bio-902 X RGN-229	65.87**	80.31**	62.16**	74.55**
39.	Bio-902 X RN-393	72.60**	90.03**	71.75**	85.74**
40.	Kranti X NRCDR-2	65.63**	61.56**	62.38**	59.17**
41.	Kranti X RGN-229	54.73**	56.62**	51.39**	53.15**
42.	Kranti X RN-393	48.12**	27.70**	47.27**	26.09*
43.	NRCDR-2 X RGN-229	30.30**	47.36**	30.03**	46.24**
44.	NRCDR-2 X RN-393	75.06**	57.27**	70.67**	56.92**
45.	RGN-229 X RN-393	24.77**	26.73*	21.40**	25.49*
	SED	0.764	0.766	0.882	0.896
	CD (5%)	1.540	1.565	1.778	1.807
	CD (1%)	2.004	2.036	2.314	2.351

Table.2 Estimates of heterosis and heterobeltiosis for oil content under normal (E1) and moisture stress (E2) environments

S. No.	Crosses	Heterosis (%)		Heterobeltiosis (%)	
		E_1	E_2	E_1	E_2
1.	CS-52 X GM-3	0.96	-0.33	0.01	-2.61
2.	CS-52 X PBR-357	-1.57	-0.11	-3.73*	-3.28
3.	CS-52 X Vardan	1.66	3.24	0.72	2.07
4.	CS-52 X RH-30	-1.11	0.14	-4.41*	-2.01
5.	CS-52 X Bio-902	1.11	0.36	-0.16	-0.93
6.	CS-52 X Kranti	1.12	2.63	0.13	2.51
7.	CS-52 X NRCDR-2	-0.07	0.26	-2.31	-1.61
8.	CS-52 X RGN-229	-0.61	0.71	-2.71	-0.29
9.	CS-52 X RN-393	0.66	1.07	-0.80	-0.15
10.	GM-3 X PBR-357	-3.20*	-3.63*	-4.43*	-4.52*
11.	GM-3 X Vardan	2.90	-1.15	2.89	-2.32
12.	GM-3 X RH-30	-2.10	0.12	-4.49*	-0.02
13.	GM-3 X Bio-902	1.23	-1.52	0.91	-2.54
14.	GM-3 X Kranti	-0.11	2.65	-0.14	0.18
15.	GM-3 X NRCDR-2	-0.97	-2.33	-2.27	-2.76
16.	GM-3 X RGN-229	-1.30	-1.21	-2.48	-2.51
17.	GM-3 X RN-393	-0.04	0.56	-0.55	-0.55
18.	PBR-357 X Vardan	1.08	2.18	-0.22	0.05
19.	PBR-357 X RH-30	-3.41*	-1.25	-4.57**	-2.31
20.	PBR-357 X Bio-902	-0.88	-2.03	-1.83	-3.93*
21.	PBR-357 X Kranti	-0.87	3.17	-2.10	-0.22
22.	PBR-357 X NRCDR-2	-2.48	-0.74	-2.53	-2.08
23.	PBR-357 X RGN-229	-2.44	-2.47	-2.52	-4.64*
24.	PBR-357 X RN-393	-0.48	-3.69*	-1.24	-5.63**
25.	Vardan X RH-30	-3.25*	1.84	-5.62**	0.78
26.	Vardan X Bio-902	0.42	-0.68	0.08	-0.83
27.	Vardan X Kranti	0.22	-1.55	0.17	-2.78
28.	Vardan X NRCDR-2	-0.86	-0.56	-2.19	-1.30
29.	Vardan X RGN-229	-0.06	-0.42	-1.27	-0.56
30.	Vardan X RN-393	-0.43	-3.07	-0.96	-3.15
31.	RH-30 X Bio-902	-4.41**	-1.57	-6.45**	-2.44
32.	RH-30 X Kranti	-1.48	1.88	-3.86*	-0.42
33.	RH-30 X NRCDR-2	-1.36	0.79	-2.50	0.50
34.	RH-30 X RGN-229	-319*	3.64*	-4.42*	2.42
35.	RH-30 X RN-393	-2.50	0.45	-4.40*	-0.51
36.	Bio-902 X Kranti	1.82	1.34	1.52	-0.08
37.	Bio-902 X NRCDR-2	1.52	0.03	0.50	-0.56
38.	Bio-902 X RGN-229	-1.07	1.69	-1.94	1.39
39.	Bio-902 X RN-393	-0.44	-2.94	-0.63	-3.02
40.	Kranti X NRCDR-2	-1.00	0.21	-2.27	-1.78
41.	Kranti X RGN-229	-0.59	1.24	-1.75	0.11
42.	Kranti X RN-393	0.05	1.58	-0.43	0.23
43.	NRCDR-2 X RGN-229	-1.97	-0.35	-2.10	-1.24
44.	NRCDR-2 X RN-393	1.56	0.77	0.73	0.09
45.	RGN-229 X RN-393	-1.17	1.20	-1.85	0.98
	SED	0.604	0.657	0.697	0.758
	CD (5%)	1.218	1.324	1.406	1.529
	CD (1%)	1.584	1.723	1.830	1.989

Table.3 Best three heterotic and heterobeltiotic crosses (F1) for seed yield/plant along with their SCA effects and per se performance in normal (E1) and moisture stress (E2) environments

Environ-ments	Heterotic Crosses	Heterosis	SCA effect	*per se* perfor-mance (g)	Heterobeltiotic crosses	*Heterob-eltiosis*	SCA effect	*per se* perfor-mance
E_1	Vardan x RH-30	92.78**	3.86**	15.57	Bio-902 x NRCDR-2	83.15**	3.42**	16.19
	Bio-902 x NRCDR-2	86.96**	3.42**	16.19	Vardan x RN-393	80.20**	2.61**	15.62
	PBR-357 x Kranti	85.20**	4.37**	15.31	PBR-357 x Kranti	80.19**	4.37**	15.31
E_2	PBR-357 x Kranti	97.50**	3.87**	13.43	Bio-902 x RN-393	85.74**	2.81**	13.98
	Bio-902 x RN-393	90.03**	2.81**	13.98	Vardan x RN-393	84.28**	2.85**	13.87
	Vardan x RN-393	88.49**	2.85**	13.87	PBR-357 x Kranti	83.10**	3.87**	13.43

Dixit *et al.,* (2005) reported that these crosses showing heterosis and heterobeltiosis for seed yield per plant possessed significant and positive SCA effects. Similar results of significant correlation between heterosis for seed yield and mean performance of the crosses were reported by Ramech (2012) and Aher *et al.,* (2009) found that the promising hybrid also had high *per se* performance and significant desirable SCA effects for various characters. The crosses PBR-357 x Kranti showed high heterotic and heterobeltiotic crosses under both the environments.

From data of heterosis and heterobeltiosis, it was observed that crosses with high magnitude of heterosis had higher magnitude of SCA effects and better *per se* performance. Hence selection of superior crosses for development of hybrids should necessarily base not only on the magnitude of heterosis, but also high mean performance and high SCA effects.

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How to cite this article:

Mukesh Bhakal, D.K. Gothwal and Sohan Lal Kajla. 2017. Heterosis and Heterobeltiosis for Seed Yield and its Components in Indian Mustard (*Brassica juncea* L. Czern & Coss) under Normal (E1) and Moisture Stress (E2) Environments. *Int.J.Curr.Microbiol.App.Sci.* 6(7): 2163-2180. doi: https://doi.org/10.20546/ijcmas.2017.607.315