ANSF APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science 10 (1): 70 -76 (2018)

Stability factor and heterosis for yield and yield determinants over environments in Indian rapeseed, *Brassica rapa* var. yellow *sarson*

A.K. Singh[1], A. K. Mall[2*] and P. K. Singh[1]

[1]Department of Genetics and Plant Breeding, NDUA&T, Kumarganj, Faizabad-224229 (UP), INDIA
[2]ICAR-Indian Institute of Sugarcane Research, Lucknow-226002 (UP), INDIA
*Corresponding author. E-mail: Ashutosh.Mall@icar.gov.in

Received: May 16, 2017; Revised received: August 2, 2017; Accepted: January 12, 2018

Abstract: Forty-four yellow sarson hybrids developed by line x testers mating design (3 pistillate lines x 9 male parents) were studied along with parents and a standard check for heterosis of yield determinant characters in two environments [Genetics and Plant Breeding Farm (E_1), Kumarganj and CRS, Masodha (E_2)]. Significant desired heterobeltiosis ranged from 4.52 to 44.86 per cent in E_1 and 13.42 to 62.07 per cent in E_2 while, standard heterosis ranged from -6.64 to 23.01 per cent in E_1 and -6.30 to 21.85 per cent for seed yield plant^{-1}. Other characters also showed considerable heterosis over better parent and standard check. The crosses L2 x T1 and L3 x T1 were identified as potential for commercial exploitation of heterosis both for seed yield plant^{-1} and oil content. High heterotic hybrids in both the environments *viz.*, L8 x T1 and L9 x T1 showed stability in performance for nine characters including seed yield plant^{-1} where as among parent NDYS-141 showed near unity ratio of stability factor for five characters. L9 x T1 followed by L8 x T1 could be identified as most promising crosses on the basis of stability, *per se* performance, standard heterosis, high GCA and significant SCA effects.

Keywords: *Brassica rapa*, GCA, Heterosis, Line x Tester design, SCA, Stability factor

INTRODUCTION

Yellow sarson (*Brassica rapa* var. yellow sarson) is an important rabi oilseed crop of north east India (Mookherjee *et al*., 2014). Rapeseed-mustard crops in India account for about 21.6 per cent and 23.2 per cent of the total oilseed harvested area and production, respectively (Anonymous, 2008). The rapeseed-mustard group of crops offers the best opportunity to meet the increasing oil requirement and chance for diversification in cereal producing states (Singh and Singh 2004). Being a self-compatible and self-pollinated crop, pure line selection in genetically variable populations has been the main stay of breeding programme. Under experimental condition, high heterosis for seed yield has been reported in rapeseed-mustard, which clearly demonstrated the presence of commercially exploitable magnitude of heterosis (Chand and Singh, 2012). In yellow sarson, some available genetic male sterility lines provided the pollination control. This will help in the development of sarson hybrids, which can bring in quantum jump in productivity of sarson. Hence, the present investigation was under taken to study the magnitude of heterobeltiosis and standard heterosis for seed yield and its attributes in rapeseed.

MATERIALS AND METHODS

In the present study, nine genotypes viz., NDYS-120 (L1), NDYS-122 (L2), NDYS-123 (L3), NDYS-128 (L4), NDYS-139 (L5), NDYS-141 (L6), NDYS-2018 (L7), NDYS-9802 (L8) and NDYS-9 (L9) were crossed with three testers viz., NDYS-2 (T1), NDYS-921 (T2), YST-251 (T3) using a line x tester mating design during dry season. The resulting 27 hybrids along with their parents were sown in a completely randomized block design in three replications at Genetics and Plant Breeding Farm (E_1) of Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad and Crop Research Station (E_2), Masodha, Faizabad (U.P.) during 2013-14. The geographical situation of Faizabad district lies between a latitude of 26^0.47' north and longitude of 82^0.12' east, on altitude of 113 meters above sea level in the gangetic alluvium of eastern Uttar Pradesh, India. In both experiments each entry was grown in single row of three meter length. The spacing between rows to row was 30 cm and plant to plant distance of 15 cm was maintained by thinning after 15 days of sowing. All entries were given equal dose of fertilizers i.e. 60 kg N, 30 kg P_2O_5 and 30 kg K_2O per hectare with three irrigations. Observations were recorded on 10 plants selected randomly from each row for nine characters viz., plant height (PH), length of main raceme (LMR), number of primary branches per plant (PB/P), number of siliquae on main raceme (SMR),

ISSN : 0974-9411 (Print), 2231-5209 (Online) | journals.ansfoundation.org

number of siliquae per plant (S/P), number of seeds per siliqua (S/S), 1000-seed weight (TW), seed yield per plant (SY/P) and oil content (OC). Data were recorded for days to 50 per cent flowering (DFF) and days to maturity (DM) on plot basis in the field. Heterosis was assessed over the BP (Heterobeltiosis) and SV (Standard heterosis) (Hayes *et al*., 1955). Twenty-seven hybrids and twelve parents were also evaluated to study the stability factor for all the characters. The stability factor analysis was carried out as per the method suggested by Lewis (1954).

RESULTS AND DISCUSSION

In self-pollinated crop like yellow sarson, the scope for exploitation of hybrids vigour largely depends on direction and magnitude of heterosis and the case with which hybrid seed can be produced. Discovery of male sterile line (Chand and Singh, 2012) indicated the possibility exploiting heterosis in this crop as well. In the present investigation superiority of single cross hybrids was assessed over standard variety NDYS-2. A reference to the estimates of heterosis showed that the mean heterosis over BP as well as SV was negative for DFF and DM in both environments whereas, it was positive for SY/P and S/P in both the environments (Table 1). The mean heterosis estimates for other characters showed inconsistencies not only in magnitude but also in direction.

Out of 27 crosses, all the crosses in E_1 and 22 crosses in E_2 showed the heterosis over BP as well as over SV in negative direction. All the crosses showed significant and negative heterosis over SV in both the environments. Earliness in flowering and maturity is highly desirable trait for the crop like yellow sarson. Hence, the crosses exhibiting heterosis in negative direction are of immense value. The crosses L3 x T1 (-12.13, -8.09), L2 x T2 (-12.67, -6.05) and L5 x T2 (-5.55, –9.55) were identified as promising crosses for earliness of flowering based on consistency in the heterosis estimated in both the environments. On the analogy the

Table 1. Heterosis (%) over better parent (BP) and standard variety (SV) for various characters in rapeseed [GPB Farm, Kumarganj (E_1) and CRS, Mashodha (E_2)].

S. No.	Days to 50 per cent flowering		Days to maturity		Plant height (cm)		Length of main raceme (cm)	
	BP	SV	BP	SV	BP	SV	BP	SV
E_1								
1	L2 x T2 (-12.67**)	L2 x T2 (-13.49**)	L1 x T3 (-3.11****)	L3 x T1 (-5.63**)	L7 x T3 (43.36**)	L7 x T3 (20.92**)	L5 x T1 (25.86**)	-
2	L3 x T2 (-12.16**)	L3 x T2 (-12.78**)	L6 x T2 (-2.90*)	L6 x T2 (-5.60**)	L1 x T2 (34.51**)	L2 x T1 (12.06*)	L8 x T2 (19.55**)	-
3	L3 x T1 (-12.13**)	L4 x T3 (-10.81**)	L2 x T2 (-2.88*)	L2 x T2 (-5.35**)	L9 x T3 (27.40**)	L5 x T1 (11.63*)	L6 x T2 (19.30**)	-
4	L1 x T2 (-9.88**)	L3 x T1 (-12.68**)	L5 x T2 (-2.82*)	L5 x T2 (-5.35**)	L4 x T3 (24.96**)	L1 x T2 (10.98*)	L5 x T3 (14.34**)	-
5	L8 x T2 (-9.33**)	L1 x T2 (-10.52**)	L4 x T3 (-2.59*)	L4 x T3 (-5.35**)	L5 x T3 (24.39**)	-	L3 x T1 (9.90*)	-
E_2								
1	L4 x T1 (-11.80**)	L6 x T2 (-14.11**)	L7 x T1 (-4.95**)	L6 x T1 (-4.95**)	L9 x T2 (47.63**)	-	L8 x T1 (20.10**)	L8 x T1 (7.70**)
2	L5 x T2 (-9.55**)	L3 x T1 (-13.70**)	L8 x T1 (-4.67**)	L7 x T1 (-4.95**)	L8 x T2 (47.56**)	-	L8 x T2 (15.49**)	L4 x T3 (6.22*)
3	L6 x T2 (-9.31**)	L5 x T2 (-12.62**)	L6 x T1 (-4.42**)	L8 x T1 (4.67**)	L9 x T3 (39.01**)	-	L2 x T1 (15.14**)	-
4	L8 x T1 (-8.75**)	L2 x T2 (-12.60**)	L6 x T2 (-4.38**)	L5 x T1 (-4.40**)	L7 x T3 (35.13**)	-	L9 x T1 (14.25**)	-
5	L3 x T1 (-8.09**)	L4 x T1 (-11.80**)	L9 x T1 (-4.12**)	L8 x T2 (-4.40**)	L1 x T3 (31.21**)	-	L3 x T2 (13.57**)	-

Contents	Environments	Days to 50 per cent flowering		Days to maturity		Plant height (cm)		Length of main raceme (cm)	
		BP	SV	BP	SV	BP	SV	BP	SV
Mean heterosis (%)	E_1	-8.14	-9.43	-0.85	-3.89	16.27	1.00	1.03	-12.57
	E_2	-4.73	-9.32	-2.91	-3.64	19.84	-13.91	3.56	-4.13
Number of crosses with significant positive heterosis	E_1	0	0	2	0	15	4	4	0
	E_2	1	0	0	0	24	0	8	2
Number of crosses with significant negative heterosis	E_1	27	27	5	27	2	3	5	26
	E_2	22	27	22	27	1	27	4	12
Range of heterosis	E_1	-12.67	-13. 49	-3.11	-5.63	-12.66	-22.72	-26.03	-34.79
		-5.21	-7.43	6.19	-3.10	43.36	20.92	25.86	0.46
	E_2	-11.80	-14.11	-4.95	-4.95	-10.16	-27.83	-20.82	-15.35
		3.59	-4.21	0.85	-2.00	47.63	-0.68	20.10	7.70

Conti….

S. No.	Number of primary branches/plant		Siliqua on main raceme		Siliquae/ plant		Seeds/siliqua	
	BP	SV	BP	SV	BP	SV	BP	SV
E_1								
1	L6 x T3 (51.91**)	-	L5 x T3 (68.18**)	L4 x T3 (36.56**)	L5 x T3 (13.38**)	L5 x T3 (20.19**)	-	L6 x T3 (20.18**)
2	L3 x T2 (45.82**)	-	L2 x T3 (57.32**)	L7 x T3 (25.37**)	L4 x T3 (12.89*)	L4 x T3 (13.39*)	-	L2 x T2 (19.40**)
3	L3 x T3 (25.91**)	-	L2 x T1 (42.24**)	L5 x T3 (15.75**)	L8 x T2 (11.75*)	L3 x T3 (13.17*)	-	L6 x T1 (19.36**)
4	L8 x T1 (21.04**)	-	L9 x T3 (36.06**)	L9 x T3 (10.67**)	-	L2 x T3 (12.50*)	-	L3 x T2 (19.15**)
5	L9 x T3 (13.77*)	-	L8 x T3 (35.80**)	-		L1 x T3 (11.49*)	-	L7 x T2 (18.74**)
E_2								
1	L2 x T1 (127.72**)	L7 x T3 (114.86**)	L5 x T3 (60.61**)	L5 x T3 (32.39**)	L5 x T2 (18.90**)	L5 x T2 (19.00**)	L6 x T1 (13.05**)	L9 x T2 (10.24**)
2	L4 x T3 (97.30**)	L4 x T3 (97.30**)	L2 x T1 (51.48**)	L2 x T1 (27.48**)	L7 x T2 (18.47**)	L7 x T2 (16.27**)	L4 x T1 (8.26*)	L5 x T1 (9.99**)
3	L2 x T3 (94.03**)	L1 x T2 (97.30**)	L2 x T3 (41.72**)	L3 x T1 (24.20**)	L1 x T3 (16.14**)	L1 x T3 (13.84**)	L4 x T2 (6.90*)	L5 x T2 (9.02**)
4	L5 x T3 (62.12**)	L4 x T2 (90.54**)	L3 x T3 (38.19**)	L7 x T3 (22.74**)	L2 x T2 (13.65**)	L2 x T2 (13.75**)	L9 x T2 (6.68*)	L4 x T1 (8.26*)
5	L1 x T2 (60.44**)	L2 x T3 (75.68**)	L6 x T3 (36.02**)	L3 x T3 (20.93**)	L9 x T2 (12.73**)	L6 x T2 (12.33**)	L5 x T1 (6.43*)	L8 x T2 (8.24*)

Contents	Environments	Number of primary branches/plant		Siliqua on main raceme		Siliquae/ plant		Seeds/siliqua	
		BP	SV	BP	SV	BP	SV	BP	SV
Mean heterosis (%)	E_1	E_1	-14.51	15.88	-3.15	1.18	4.66	-8.74	4.75
	E_2	E_2	53.32	17.32	7.85	2.13	4.73	-6.25	-3.63
Number of crosses with significant positive heterosis	E_1	5	0	14	4	3	5	0	24
	E_2	16	20	17	11	22	21	5	9
Number of crosses with significant negative heterosis	E_1	14	16	3	9	1	0	9	3
	E_2	0	0	1	2	2	0	7	6
Range of heterosis	E_1	-40.54	-45.11	-17.57	-34.46	-11.04	-6.38	-40.69	-32.10
	E_2	-51.91	3.53	68.18	36.56	13.38	20.19	5.88	20.19
	E_1	-19.16	-8.78	-13.46	-17.31	-11.79	-1.82	46.86	-44.43
	E_2	127.72	114.86	60.61	32.39	18.90	19.00	13.05	10.24

S. N.	1000-seed weight (g)		Seed yield (g)		Oil content (%)	
	BP	SV	BP	SV	BP	SV
E_1						
1	L3 x T1 (50.64**)	L3 x T1 (79.88**)	L5 x T2 (44.86**)	L9 x T1 (23.00**)	L7 x T2 (5.10**)	-
2	L7 x T1 (33.08**)	L7 x T1 (65.27**)	L6 x T2 (40.01**)	L4 x T1 (23.01**)	L3 x T1 (3.55**)	-
3	L3 x T2 (27.66**)	L3 x T2 (63.11**)	L3 x T2 (37.33**)	L8 x T1 (22.35**)	L5 x T1 (3.03**)	-
4	L5 x T2 (25.68**)	L5 x T2 (60.59**)	L5 x T1 (34.96**)	L4 x T2 (21.24**)	L4 x T1 (2.96**)	-
5	L7 x T2 (20.81)	L3 x T3 (50.89**)	L4 x T1 (32.38**)	L5 x T2 (19.03**)	L8 x T3 (2.96**)	-
E_2						
1	L9 x T1 (39.60**)	L1 x T2 (13.52*)	L5 x T1 (62.07**)	L9 x T1 (21.85**)	L7 x T2 (5.10**)	-
2	L8 x T1 (25.19**)	L6 x T2 (13.23*)	L8 x T1 (59.22**)	L4 x T1 (21.80**)	L8 x T3 (4.86**)	-
3	L2 x T1 (22.40**)	-	L2 x T1 (56.20**)	L8 x T1 (21.22**)	L3 x T1 (3.55**)	-
4	L6 x T1 (15.27*)	-	L5 x T2 (49.95**)	L5 x T1 (21.01**)	L9 x T3 (3.10**)	-
5	L3 x T1 (14.72*)	-	L2 x T2 (44.66**)	L2 x T2 (44.66**)	L4 x T1 (2.97**)	-

Contents	Environments	1000-seed weight (g)		Seed yield (g)		Oil content (%)	
		BP	SV	BP	SV	BP	SV
Mean heterosis (%)	E_1	-1.30	32.73	21.63	10.33	1.00	-2.74
	E_2	1.02	-5.56	23.33	11.79	-0.45	1.93
Number of crosses with significant positive heterosis	E_1	18	23	27	18	10	0
	E_2	5	2	27	18	11	0
Number of crosses with significant negative heterosis	E_1	10	0	0	2	4	20
	E_2	7	9	0	2	5	27
Range of heterosis	E_1	-47.61	-8.26	-4.50	-6.64	-3.16	-4.24
	E_2	33.08	79.88	49.86	23.01	5.10	-0.07
	E_1	-25.32	-27.53	13.42	-6.30	-2.77	-5.53
	E_2	39.60	13.52	59.22	21.85	5.10	-0.04

Table 2. High heterotic crosses (over BP) for different characters over locations in yellow sarson.

S. No.	Characters	Cross with heterosis	SCA	
			E_1	E_2
1	Days to 50 per cent flowering	L3 x T1 (-12.13, -8.09)	H	L
		L2 x T2 (-12.67, 6.05)	L	L
		L5 x T2 (-5.22, 9.55)	L	L
2.	Days to maturity	L3 x T1 (-2.90, -3.81)	L	L
		L4 x T1 (-2.59, -3.59)	L	L
		L6 x T1 (-2.88, 4.42)	L	L
3.	Plant height (cm)	L6 x T1 (-11.99, -1.67)	L	L
		L5 x T2 (-12.66, -3.56)	L	L
4.	Length of main raceme (cm)	L5 x T1 (25.86, 6.17)	H	L
		L8 x T2 (19.55, 15.49)	L	H
5.	Number of primary branches / plant	L3 x T3 (25.91. 43.11)	H	L
		L3 x T3 (51.91, 45.87)	H	L
6.	Siliquae on main raceme	L2 x T1 (42.24, 51.48)	H	H
		L3 x T1 (17.21, 19.59)	L	H
		L5 x T1 (36.50, 12.0)	H	H
7.	Siliquae per plant	L8 x T2 (11.75, 11.31)	L	L
		L4 x T3 (12.89, 11.70)	L	L
8.	Seeds per Siliquae	L2 x T1 (4.58, 1.93)	L	L
		L3 x T1 (5.88, 2.03)	L	L
		L4 x T1 (1.41, 8.26)	L	L
9.	1000- Seed weight (g)	L3 x T1 (13.13, 22.40)	L	L
		L2 x T1 (50.65, 14.12)	H	L
		L8 x T1 (11.09, 25.19)	L	L
10	Seed yield (g)	L1 x T1 (24.09, 38.10)	L	L
		L2 x T1 (19.57, 56.20)	L	H
		L3 x T1 (17.57, 34.10)	L	H
11	OC (%)	L3 x T1 (3.55, 3.55)	H	H
		L2 x T1(2.96, 2.97)	L	L
		L5 x T1 (3.03, 2.28)	L	L

Figures within the parenthesis are heterosis estimates over BP

Table 3. Prospective cross combinations based on *per se* performance and desirable effects for seed yield and oil content and suggested breeding strategy over both the environments [GPB Farm, Kumarganj (E_1) and CRS, Mashodha (E_2)].

Cross combinations	*per se* performance	SCA effects	Heterosis		GCA effect combining parent		Heterosis for other significant characters	Heterosis for oil content	Suggested breeding methodology
			BP	SV					
For seed yield per plant (g) E_1									
L8 x T1	9.22	0.92**	27.42**	22.35**	L	H	DF, PB, SMR, TW & SY	-2.77**	Heterosis breeding, mass selection with concutent random mating
L3 x T2	9.27	1.95**	28.11**	23.01	L	H	DF, DM, PB & SY	-3.16*	Heterosis breeding, mass selection with concutent random mating
L3 x T2	8.58	0.86**	37.33**	13.94**	H	H	DF, PB, TW & SY	2.92**	Heterosis breeding, conventional breeding method with selection pressure on DF, PB, TW & OC
L6 x T2	8.67	0.93**	40.01**	15.02**	L	H	DF, DM, LMR, TW & SY	-0.67	Heterosis breeding, mass selection with concutent random mating
L9 x T1	8.58	0.98**	31.51**	13.94**	L	H	DF, DM, LMR, TW & SY	2.79**	Heterosis breeding, mass selection with concutent random mating
For seed yield per plant (g) E_2									
L8 x T1	9.62	0.92**	59.**	21.22**	L	H	DF, DM, PH, LMR, TW & SY	-2.27**	Heterosis breeding/ mass selection with concutent random mating
L9 x T1	9.67	1.94**	43.64**	21.85**	L	H	DF, DM, LMR, SMR, SIP, TW, SY & OC	1.01**	Heterosis breeding/ mass selection with concutent random mating
L3 x T2	8.98	0.86**	33.48**	13.24**	H	H	DF, DM, SP & SY	2.92**	Heterosis breeding/ mass selection with concutent random mating
L6 x T2	9.07	0.93**	30.61**	18.66**	L	H	DF, DM, SP, SY & OC	0.07**	Heterosis breeding/ mass selection with concutent random mating
L9 x T2	8.98	0.98**	33.48**	13.24**	L	H	DF. DM, LMR, PB, SMR, SP, SS & SY	2.80	Heterosis breeding/ mass selection with concutent random mating

Table 4. Stability factor for different characters in parent and crosses in rapeseed.

Parent and Crosses	DF	DM	PH	LMR	PB	SMR	SP	SS	TW	SY	OC
L1	1.12	0.99	0.90	0.88	0.49	1.03	1.02	1.01	0.96	0.78	1.00
L2	1.14	1.04	0.88	0.86	0.61	1.17	1.08	0.97	0.99	0.86	0.99
L3	1.09	1.07	0.96	0.95	0.78	1.09	1.05	1.02	1.39	0.83	0.99
L4	1.08	1.05	1.03	0.98	0.85	1.08	1.21	0.98	1.02	0.97	0.97
L5	1.14	1.06	0.91	0.94	0.53	0.93	1.04	0.97	1.33	0.99	1.00
L6	1.10	1.04	0.87	1.01	0.66	1.12	1.16	0.99	1.24	1.00	0.99
L7	1.09	1.06	0.92	0.89	0.27	1.05	1.03	1.06	1.23	0.89	0.99
L8	1.18	1.04	1.02	1.18	0.37	1.28	1.03	0.93	1.08	0.99	0.81
L9	1.14	1.06	0.97	0.92	0.53	1.20	1.07	0.99	1.01	0.86	0.99
T1	1.15	1.03	1.13	0.90	0.43	0.91	1.14	1.11	1.69	0.98	1.00
T2	1.14	1.07	0.99	1.17	0.34	1.06	1.02	1.05	1.11	0.96	0.99
T3	1.09	1.06	0.79	0.94	0.93	0.98	1.12	1.03	1.60	1.26	0.99
L1 X T1	1.14	1.03	0.96	0.96	0.64	1.00	1.07	1.22	1.18	1.04	0.99
L2 X T1	1.15	1.02	0.93	1.01	0.99	0.95	1.00	1.28	1.49	1.04	0.99
L3 X T1	1.16	1.02	0.92	0.98	0.69	1.04	1.03	0.67	0.83	1.05	0.99
L4 X T1	1.18	1.04	0.88	1.00	0.98	0.83	1.04	0.97	1.16	1.04	0.99
L5 X T1	1.19	1.04	0.89	0.92	1.14	1.04	0.93	0.83	1.00	1.03	0.99
L6 X T1	1.14	1.04	0.96	0.94	0.75	1.01	1.09	0.91	1.10	1.06	0.99
L7 X T1	1.21	0.97	0.90	0.90	0.95	0.89	1.08	1.14	1.26	1.04	0.99
L8 X T1	1.21	1.04	1.01	0.90	1.20	1.05	0.99	1.22	1.17	1.05	0.99
L9 X T1	1.21	1.02	1.05	1.02	0.63	0.96	1.00	0.88	1.04	1.04	0.99
L1 X T2	1.15	1.02	0.89	0.97	1.07	1.04	1.07	1.17	1.31	1.04	0.99
L2 X T2	1.16	1.05	0.97	0.99	0.76	1.15	1.14	0.99	1.26	1.05	0.99
L3 X T2	1.21	1.03	1.02	1.05	0.70	1.06	0.97	0.99	1.47	1.05	0.99
L4 X T2	1.17	1.04	0.90	1.00	0.99	1.07	1.00	1.00	1.04	1.05	0.99
L5 X T2	1.09	1.05	1.13	0.94	0.81	1.05	1.04	1.07	1.44	1.05	0.99
L6 X T2	1.09	1.04	0.91	0.81	0.72	0.94	1.07	1.04	1.10	1.04	1.00
L7 X T2	1.15	1.02	0.91	0.91	0.74	1.02	1.08	1.01	1.48	1.04	1.00
L8 X T2	1.19	1.02	1.08	1.13	0.88	1.11	0.99	1.02	1.10	1.05	0.99
L9 X T2	1.14	1.03	1.04	1.04	0.95	1.07	1.06	1.06	1.38	1.04	0.99
L1 X T3	1.13	1.02	1.04	0.98	0.57	1.03	1.05	1.15	1.23	1.05	0.99
L2 X T3	1.12	1.05	0.92	1.01	1.05	1.12	0.90	1.03	1.33	1.05	0.99
L3 X T3	1.14	1.05	0.96	0.90	0.58	1.00	0.95	1.02	0.93	1.05	0.99
L4 X T3	1.12	1.03	0.84	1.21	0.72	1.08	0.98	1.04	1.23	1.05	0.99
L5 X T3	1.16	1.02	0.92	0.99	0.73	1.06	0.96	1.10	1.37	1.05	0.99
L6 X T3	1.11	1.03	1.13	1.27	0.73	1.00	1.00	1.01	1.29	1.05	0.99
L7X T3	1.15	1.01	0.97	1.03	0.73	1.01	1.03	0.99	1.12	1.05	0.99
L8 X T3	1.12	1.01	1.05	1.06	1.06	1.02	0.97	1.03	1.14	1.05	0.99
L9 X T3	1.18	1.02	1.01	0.98	0.98	0.92	0.92	1.00	1.47	1.05	0.99

crosses L3 x T1, L4 x T1 and L6 X T1 were judged up as potential crosses for earliness of maturity. Of these crosses L3 x T1 appeared as most promising cross combination simultaneously for DFF and DM.

In case of LMR, the superior crosses identified were L8 x T1 and L4 x T3 in E_2 only over the NDYS 2. Relatively low to high level of standard heterosis with high mean heterosis was observed for PB/P in E_2 only. The maximum heterosis over SV was recorded in the cross L7 x T3 followed by L4 x T3 and L4 x T2. For SMR maximum positive heterobeltiosis was observed in the cross L5 x T3, L2 x T3 and L2 x T1 while, L7 x T3 and L5 x T3 were superior crosses under both the environments.

The S/P is important yield component and out of 27 cross combinations three crosses showed positive significant heterosis over BP were L5 x T3, L4 x T3 and L8 x T2 in E_1 and in E_2 22 crosses exhibited positive significant heterosis, three promising crosses for number of S/P were L5 x T2, L7 x T2 and L1 x T3. In respect of standard heterosis 5 and 27 cross combinations exhibited positive significant values in E_1 and in E_2, respectively. Three best combinations considering E_1 and E_2 both were L5 x T3, L5 x T2 and L7 x T2. Seeds siliqua^{-1} is also important yield attributing character and 24 crosses showed positive significant heterosis over SV in E_1 and nine cross combinations in E_2. These results agree with Singh and Mishra (2001) and Prajapati *et al.* (2007). Standard heterosis for TW was significant for 23 hybrids in E_1 and two hybrids in E_2. Three best combinations were L3 x T1, L7 x T1, and L3 x T2 and L5 x T2 x L7 x T2 over SV as well as BP in E_1 while in E_2 significant positive heterosis was shown by only two crosses viz, L1 x T2 and L6 x T1.

The most important attribute of a plant is yielding ability. In yellow sarson besides yield, oil content is also an economic attribute. It is significant to note that all the 27 crosses manifested positive heterosis for seed yield over BP and 18 over SV in both the environment. Though all hybrids expressed SY/P heterosis over BP but none showed heterosis for all the three major yield components S/P, S/S and TW. Nevertheless, all heterotic crosses for SY/P were found to exhibit heterosis for one or two of these key components. These findings agree with the reports of Katiyar *et al*. (2004) and Prajapati *et al*. (2007).

Heterosis estimates for OC showed that none of the cross showed positive heterosis over SV a high OC parent. However, heterosis estimates over BP were significant positive for ten hybrids in E_1 and 11 in E_2. The low heterosis for OC as observed in this study is consonance with earlier reporter (Prajapati *et al*., 2007). The crosses L2 x T1 and L3 x T1 were identified as potential for commercial exploitation of heterosis both for SY/P and OC (Table 2). Such finding was also reported by Vaghela *et al*. (2012). Simultaneously, these crosses also exhibited heterobeltiosis for TW, S/S and SMR, while, L3 x T1 showed earliness in flowering and maturity which essential characteristics is for short duration yellow sarson crop.

A high order positive correlation was noticed between heterosis and SCA of single crosses for all the characters in both the environments except LMR in E_1. Examination of top heterotic hybrids for various characters with GCA status of parents involved showed that majority of crosses involved parent of high x low, high x average, average x average, average x low and, low x low GCA status. The present study further, suggested heterosis for SY/P has many manifested through different combination of component traits in different crosses.

A simultaneous consideration of genetic information generated on various aspects included in the parent investigation led to identify five prospective cross combinations for further, use in the genetic improvement of yellow sarson (Table 3). High BP heterosis for SY/P was recorded for L6 x T2 (40.01%) in E_1 and L8 x T1 (59.32%) in E_2. The commercial worth of the genotype will, however, depend on the magnitude of improvement in SY/P over SV. Hence, combinations that registered high standard heterosis may be considered ideal for SY/P improvement programme. Based on this consideration L9 x T1 (23.01%, 21.85%) followed by L8 x T1 (22.35, 22.22%) could be identified as most promising crosses. A cursory view of GCA effects of parents involved in these high heterotic crosses showed differing GCA status of parents in respect of all the promising crosses except L3 x T2 in E_1 which combined both the parents with high general combining ability. Involvement of one parent with desirable and high GCA effect and other with low GCA effect in high performing crosses showed that in these crosses the additive genetic system of good general combiner and epistatic effect of poor combiners acted in a complementary manner to maximize the desirable expression of attributes. The estimates of SCA effects were significant and positive for all the top-ranking crosses in both the environment. Similar results were reported by Vaghela *et al*. (2012) and Monpara and Dobariya (2007).

Stability factor of parents and hybrids: Genotype and environment interaction is of immense value in plant breeding programme. It plays an important role in the performance of genotype. This arises from lack of correspondence between genetic and non-genetic factors (Verma and Gill 1975). Stability factor suggested by Lewis (1954) is a simplest criterion for identifying a genotype with less fluctuation in yield.

In the present study, it was observed that most of the parents and hybrids recorded on the near unity ratio of stability factor for SY/P, OC, DFF and DM. Among major yield components, only 20 hybrids showed desirable stability factor for S/P (Table 4). Contrary to this all hybrid showed favourable stability factor (near to one) for TW except two hybrids. Relatively greater value of stability factor ratio (>1.00) was recorded for PH, LMR and PB/P for most of the parents and hybrids. Cursory view of stability factors for SY/P vis-à-vis that of component traits showed that stability of SY/P in respect of promising hybrids was imparted by stability on six to nine component traits. For instance, high, heterotic hybrids in both the environments viz., L8 x T1 and L9 x T1 showed stability in performance for nine characters including SY/P. Among parent NDYS-141 showed near unity ratio of stability factor for five characters where as NDYS-921 showed stability for maximum number of nine characters. The study further showed that for several characters such as SMR, PB/P, S/S and TW the hybrids involved at least one parent unstable. This superior performance of such hybrids for stability could be possibly attributed to the pre-dominance of non - fixable effects. Foregoing discussion led to infer that it may be worthwhile to attempt population improvement using recurrent selection scheme, biparental mating or diallele selective mating to capitalize on additive genetic variance.

Conclusion

In breeding for wide adaptation, the aim is to obtain a variety which performs well in nearly all environments; in breeding for specific adaptation, the aim is to obtain a variety which performs well in a definite subset of environments within a target region. Recombination breeding through multiple crosses involving high GCA and high SCA hybrid will also be rewarding approach for amelioration up seed yield in yellow *sarson*.

REFERENCES

Anonymous (2008). Agricultural statistics at a glance. Agricultural Statistics Division Directorate of Economics and Statistics, Department of Agriculture and Cooperation Ministry of agriculture, Government of India, New Delhi.

Chand, P. and Singh, S. P. (2012). Breeding for better brassicas: A review. Progressive Agriculture. Progressive Agriculture, 4 (2):101-107.

Hayes, H. K., Immer, F. A. and Smith, D. C. (1955). Methods of Plant Breeding, Mc Graw Hill Book Co., Inc., New York.

Katiyar, R. K., Chamola, R., Singh, H. B. and Tickoo, S. (2004). Heterosis and combining ability analysis for seed yield in yellow sarson (*Brassica campestris* Prain). *Brassica*, 6 (1&2):23-28.

Lewis, D. (1954). Gene-environment interaction. A relationship between dominance, heterosis, phenotypic stability and variability. *Heredity* 8:333-356.

Monpara, B. A. and Dobariya, K. L. (2007). Heterosis and combining ability in Indian mustard, Brassica juncea (L.) Czern & Coss. *J Oilseeds Res.*, 24 (2):306-308.

Mookherjee, S., Malik, G. C., Bandyopadhyay and Mitra, B. (2014). The productivity of *Brassica rapa* var. Yellow Sarson as influenced by integrated nutrient management practices and seed priming in Eastern Indian Sub-Himalayan plains. *SAARC J. Agri.*, 12 (1):106-116.

Prajapati, C. H., Patel, K. M., Patel, M. P. and Pathak HC (2007). Heterosis for seed yield and its components in Indian rapeseed, *Brassica campestris* var. Yellow Sarson. *J Oilseeds Res.* 24(2):309-310.

Ram Bhajan, Chauhan Y. S. and Kumar, K. (1993). Studies on genic male sterility and its use in exploitation of heterosis in *Brassica campestris* L. *Acta Agronomica Hungarica*, 42:99-102.

Singh, A. and Singh, L. (2004). Effect of improved varieties on productivity of rapeseed-mustard under frontline demonstrations. *J. Oilseeds Res*., 21 (2):357-358.

Singh, D. and Mishra, V. K. (2001). Heterosis and inbreeding depression in inter specific hybrids of yellow sarson. *Research in Crops*, 2 (3):419-422.

Vaghela, P. O., Sutariya, D. A., Parmar, S. K. and Prajapati, D. V. (2012). Exploitation of heterosis breeding through diallel matting in Indian mustard [Brassica juncea (L.) Czern and Coss]. International Journal of Agricultural Sciences, 8 (1):158-160.

Verma, M.M. and Gill, K.S. (1975). Genotype-Environment Interaction-Its Measurement and Significance in Plant Breeding. Teaching Aid Bull No. 1. Punjab Agricultural University, Ludhiana.