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Combining ability (GCA & SCA), heterosis and inbreeding depression analysis for quantitative traits in yellow sarson (*Brassica rapa* var. yellow sarson)

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Abstract

The analysis of variance indicated significant differences among the treatments for all the characters. Parents vs. F₁s, parents vs. F₂s and F₁s vs. F₂s also revealed highly significant differences for all the characters except number of primary branches per plant. The estimate of σ^2_g were lower than σ^2_s for all the characters. The analysis of variance for combining ability were found significant differences for all the characters except number of primary and secondary branches per plant in both F₁ and F₂ generations. The parents namely; YSKM-10-1, T-42, YSC-40, NRCYS-05-02 and Pitambari were found common good general combiners in both F₁ and F₂ generations based on gca effect and *per se* performance for dwarf plant height. The cross combinations namely; YSC-63 x NRCYS-05-02, B-09 x Pitambari, YSKM-11-02 x YSH-401, YSKM-10-02 x Pitambari and YSC-80 x YSH-401 were found common good specific combiners in both F₁ and F₂ generations on the basis of sca effects and *per se* performance for dwarf plant height. The cross combinations namely; YSC-63 x NRCYS-05-02, YSKM-11-02 x YSH-401, YSC-80 x YSH-401, T-42 x NRCYS-05-02 and YSC-84 x YSH-401 were shown desirable and significant heterotic response over better and economic parent and high inbreeding depression for dwarf plant height.

Keywords: combining ability, heterosis, yellow sarson, inbreeding depression

1. Introduction

The *Brassicaceae*, contains about 3500 species and 350 genera, is one of the ten most economically important plant family, it is distinguished on the basis of the presence of counduplicate cotyledons (i.e. the cotyledons are longitudinally folded around the radical) and two segment fruits (siliquae), which contain seeds in one or both segments, and only simple hairs, if present. Crop brassicas encompass many diverse types of plants, which are grown as vegetables, fodder or sources of oils and condiments. Mustard oil contains vitamins, minerals, proteins and carbohydrate. It has been reported that 100g of mustard oil produce a sizeable amount of erucic acid (52.2%) and linolenic acid (12.4%). The protein content in mustard ranges between 24-30% on the whole seed basis and between 34-40% on meal basis. When compared to other edible oils, the rapeseed/mustard oil has the lowest amount of harmful saturated fatty acids. It also contains adequate amounts of the two essential fatty acids, linoleic and linolenic, which are not present in many of the other edible oils. The per capita consumption of oil in India is still very low in comparison to many other countries of the world. The consumption of vegetable oil in our country is roughly 12.4 kg/head/year.

2. Materials & Methods

The experimental materials were comprised 25 lines namely, YSC-63, YSC-41, B-09, YSK-71, YSKM-11-02, YSC-76, YSKM-10-1, YSKM-11-1, YSC-75, YSKM-10-02, YSK-9-01, YSC-80, K-88, YSC-15, Type-42, YSC-18, YSK-03, YSC-21, YSC-92, YSC-45, YSC-30, YSC-95, YSC-40, YSC-46 and YSC-46 used as female and 4 testers namely, NRCYS-05-02, YSH-401, YST-151 and Pitambari (check) used as male of yellow sarson. The materials comprising of 29 parents + 100 F₁s + 100 F₂s were sown in Randomized Block Design with three replications during *Rabi* 2014-2015 at Oilseed Research Farm, Kalyanpur of C.S. Azad University of Agriculture & Technology, Kanpur-208002. All the Twenty five females were crossed with each of four males in line x tester mating deigns to produce sufficient amount of F₀ seeds of 100 crosses during the *Rabi* season 2011-12 to raise the F₁s. The F₁s were selfed in order to obtain F₂s seeds during the *Rabi* season 2012-13.

The parents were also maintained through selfing in a Randomized Block Design (RBD) with three replications at the Oilseed Research Farm, Kalyanpur of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Each treatment was planted in one row, of 3 m length and 45 cm apart, Plant to plant distance was maintained at 15 cm by thinning. All the recommended agronomic practices were adopted for raising a good crop. The observations were recorded on seven characters namely; days to 50% flowering, days to maturity, plant height (cm), length of main raceme (cm), leaf area index (cm/m²), number of primary branches per plant and number of secondary branches per plant. The analysis of variance for combining ability was carried out according to the method outlined by Kempthorne (1957).

3. Results & Discussion

The results of analysis of variance are presented in Table-1. The analysis of variance indicated significant differences among the treatments for all the characters. Highly significant differences were observed among replications, treatments, parents, lines, testers, line x testers, F₁S, F₂S, parents vs F₁S, parents vs F₂S, parents vs F₁S + F₂S, F₁S vs F₂S for all the characters. Similar findings were also observed by Sharma *et al.* (2003), Raj *et al.* (2005) and Arifullah *et al.* (2012) [5, 11, 2]. The analysis of variance for combining ability are presented in Table-2. The estimate of $\hat{\sigma}^2_g$ were lower than $\hat{\sigma}^2_s$ for all the characters in both the generations. The ratio of $\hat{\sigma}^2_g / \hat{\sigma}^2_s$ was less than 1.0 in all the attributes. The ratio of $\hat{\sigma}^2_g / \hat{\sigma}^2_s$ was greater than unity in F₁ generations. The average degree of dominance [$\hat{\sigma}^2_s / \hat{\sigma}^2_g$]^{0.5} was more than unity for all the characters in both F₁ and F₂ generations showing over dominance in these attributes. Similar results were also reported by Sharma *et al.* (2004) [15], Singh *et al.* (2004) [23], Singh *et al.* (2006) [18], Gupta *et al.* (2010) [6] and Singh *et al.* (2010) [25].

The general combining ability (gca) effects are presented in table-3. For days to 50% flowering the parents namely; YSC-63, YSKM-11-01, YSC-75, YSKM-10-02, YSK-9-01, K-88, YSC-45, YSC-30 and Pitambari; for days to maturity the parents namely; YSC-41, YSC-71, YSKM-10-01, YSC-75, YSKM-10-02, YSC-18, YSC-21 and YSC-30; for dwarf plant height the parents namely; YSKM-10-01, T-42, YSC-40 and Pitambari; for length of main raceme the parents namely; YSKM-11-01, YSC-75, YSK-9-01, K-88 and Pitambari; for leaf area index the parents namely; YSKM-11-02, YSKM-10-02, YSC-80, T-42 and YST-151; for number of primary branches per plant the parents namely; B-09, YSC-75, YSC-18, YSK-03 and YSC-84 and for number of secondary branches per plant the parents namely; YSC-18, YSC-95, NRCYS-05-02 and Pitambari were found common good general combiners in both F₁ and F₂ generations on the basis of gca effects and *per se* performance. These results were also similar to Sweta *et al.* (2005) [12], Tripathi *et al.* (2005) [27], Singh *et al.* (2006) [18] and Singh *et al.* (2008a.) [24].

The specific combining ability effects (sca) are presented in table-4. Out of 100 crosses top five best cross combinations namely; YSC-71 x Pitambari, YSC-76 x NRCYS-05-02, YSKM-10-01 x YST-151, YSKM-11-01 x YST-151 and YSC-75 x NRCYS-05-02 were found common good specific combiners in both F₁ and F₂ generations on the basis of *per se* performance for days to 50% flowering. The cross combinations namely; YSC-63 x YST-151, YSC-41 x

NRCYS-05-02, B-09 x Pitambari, YSKM-11-02 x YSH-401 and YSC-76 x YSH-401 were found common good specific combiners in both F₁ and F₂ generations on the basis of *per se* performance for days to maturity. These results were also similar to Singh *et al.* (2009) [13] and Verma *et al.* (2010) [5].

The cross combinations namely; YSC-63 x NRCYS-05-02, B-09 x Pitambari, YSKM-11-02 x YSH-401, YSKM-10-02 x Pitambari and YSC-80 x YSH-401 were found common good specific combiners on the basis of *per se* performance and sca effects in F₁ generations for dwarf plant height. The cross combinations namely; YSC-41 x YSH-401, YSC-71 x Pitambari, YSK-11-02 x YST-151, YSC-76 x YSH-401 and YSC-75 x YST-151 were found good specific combiners in both F₁ and F₂ generations on the basis of sca effects and *per se* performance for length of main raceme. The cross combinations namely; YSC-63 x YST-151, YSC-41 x YSH-401, YSC-41 x Pitambari, B-09 x NRCYS-05-02 and B-09 x Pitambari were found good specific combiners on the basis of sca effects and *per se* performance in both F₁ and F₂ generations for leaf area index. Similar results were also similar to Singh *et al.* (2005) [12].

The cross combinations namely; B-09 x NRCYS-05-02, YSKM-11-02 x YST-151, YSKM-11-01 x YST-151, YSK-9-01 x NRCYS-05-02 and YSC-46 x YST-151 were found common good specific combiners in both F₁ and F₂ generations on the basis of both sca effects and *per se* performance for number of primary branches per plant and the cross combination namely; YSKM-10-01 x NRCYS-05-02, K-88 x YSH-401, T-42 x NRCYS-05-02, YSC-92 x YST-151 and YSC-95 x NRCYS-05-02 were found common good specific combiners in both F₁ and F₂ generations on the basis of sca effects and *per se* performance for number of secondary branches per plant. Similar results were also similar to Singh *et al.* (2007) [16].

Heterosis was calculated in per cent over better as well as economic parents for all the seven characters. Estimate of inbreeding depression in F₂S over their respective F₁S were calculated in terms of percentage. The results of heterosis and inbreeding depression are shown in table-5. The top five best cross combinations namely; YSC-63 x YST-151, YSC-41 x Pitambari, B-09 x Pitambari, YSKM-10-01 x YST-151 and YSKM-11-02 were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for early flowering. Similar results were also reported by Singh *et al.* (2008b) [21] and Singh *et al.* (2009b) [22].

The cross combinations namely; YSKM-11-02 x YST-151, YSC-76 x NRCYS-05-02, YSKM-11-01 x YST-151, YSC-18 x NRCYS-05-02 and YSC-21 x Pitambari were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for early maturity. The cross combinations namely; YSC-63 x NRCYS-05-02, YSKM-11-02 x YSH-401, YSC-80 x YSH-401, T-42 x NRCYS-05-02 and YSC-84 x YSH-401 were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for dwarf plant height. The cross combinations namely; YSC-41 x Pitambari, YSKM-11-02 x YSH-401, YSC-75 x NRCYS-05-02, YSC-15 x NRCYS-05-02 and YSC-15 x NRCYS-401 were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for length of main raceme. The cross combinations namely; YSC-63 x YSH-401, B-09 x Pitambari, YSC-75 x YSH-401, K-88 x NRCYS-05-02 and T-42 x YST-151 were shown positive and significant heterosis over both better and economic parent

and high inbreeding depression for leaf are index. Similar results were also reported by Chauhan *et al.* (2011) [3] and Prajapati *et al.* (2013) [8].

The cross combinations namely; B-09 x NRCYS-05-02, YSKM-11-02 x YST-151, YSKM-11-01 x YST-151, YSK-9-01 x NRCYS-05-02 and YSC-46 x YST-151 were shown positive and significant heterosis over both better and economic parent for number of primary branches per plant

and the cross combinations namely; YSKM-10-01 x NRCYS-05-02, K-88 x YSH-401, T-42 x NRCYS-05-02, YSC-92 x YST-151 and YSC-95 x NRCYS-05-02 were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for number of secondary branches per plant. These results were also similar to Lal *et al.* (2013) [7] and Dutta *et al.* (2014) [4].

Table 1: ANOVA for seven characters in line x tester analysis of yellow sarson (*Brassica rapa* var. yellow sarson): mean sum of squares (Parents + F₁s + F₂s)

Sources of variance	D.F	Days to 50% flowering	Days to maturity	Plant height (cm)	Length of main raceme (cm)	Leaf area index (cm/m ²)	Number of primary branches per plant	Number of secondary branches per plant
Replications	2	4.25	7.37**	67.22**	4.53	1.22**	1.80	19.57**
Treatments	228	12.87**	13.79**	16.58**	9.94**	1.75**	1.16	3.81**
Parents	28	22.10**	5.81**	9.37**	6.53**	1.70**	0.87	2.59**
Lines	24	5.94**	2.64**	6.24**	5.83**	1.73**	0.91	1.43
Testers	3	36.55**	21.55**	26.67**	11.41**	2.00**	0.75	0.75
Lines x Testers	1	36.64**	34.51**	32.49**	8.69**	0.00	0.02	35.6**
F ₁ s	99	7.18**	5.03**	3.75**	10.91**	1.98**	0.70	2.13**
F ₂ s	99	3.44**	2.82**	5.23**	4.24**	1.54**	0.94	1.34
Parents Vs F ₁ s	1	1196.00**	822.10**	2219.37**	64.36**	3.14**	55.41**	100.48**
Parents Vs F ₂ s	1	468.08**	1.56	562.66	66.96**	2.98**	7.33*	384.35**
Parents Vs F ₁ s+F ₂ s	1	890.19**	211.83**	1413.08**	0.01**	3.45**	29.03**	247.25**
F ₁ s Vs F ₂ s	1	372.88**	1991.08**	1216.78**	584.11	0.00	49.88	204.17**
Error	456	1.75	1.48	1.22	1.91	0.02	1.82	1.40

*, ** significant at 5 and 1 per cent level, respectively.

Table 2: ANOVA (MSS) for combining ability effects for seven characters in line x tester cross analysis of yellow sarson (*Brassica rapa* var. yellow sarson)

Source of variation	D.F	G	Days to 50% flowering	Days to maturity	Plant height (cm)	Length of main raceme (cm)	Leaf area index (cm/m ²)	Number of primary branches per plant	Number of secondary branches per plant
Replicates	2	F ₁	1.34	6.97**	1.33	0.16	0.02	4.24	1.96
		F ₂	1.12	0.81	1.65	0.56	0.20**	3.10	0.90
Lines	24	F ₁	6.87	4.34	3.35	5.34	2.15	0.47	1.68
		F ₂	2.62	3.07	4.38	4.54	2.16	0.77	0.58
Testers	3	F ₁	6.27	8.51	6.79	13.23	0.04	0.53	6.10
		F ₂	0.15	1.35	0.69	1.37	0.29	0.41	2.72
Line x Tester	72	F ₁	7.32**	5.11**	3.75**	12.67**	1.99**	0.77	2.12*
		F ₂	3.85**	2.80**	5.70**	4.26**	1.38**	1.02	1.53
Crosses	99	F ₁	7.18**	5.03**	3.74**	10.91**	1.97**	0.69	2.13
		F ₂	3.44*	2.82**	5.23**	4.24**	1.54**	0.94	1.33
Error	198	F ₁	1.25	1.35	1.51	1.80	0.01	1.72	1.39
		F ₂	2.35	1.59	1.43	2.15	0.03	2.03	1.50
Total	299	F ₁	3.21	2.61	2.25	4.80	0.66	1.39	1.64
		F ₂	2.70	1.99	2.69	2.83	0.53	1.67	1.44

*, ** significant at 5 and 1 per cent level, respectively.

Table 3: Estimate of general combining ability (gca) effects for seven characters in F₁ and F₂ generations of yellow sarson (*Brassica rapa* var. yellow sarson)

Parents	Days to 50% flowering		Days to maturity		Plant height (cm)		Length of main raceme (cm)	
	F ₁	F ₂	F ₁	F ₂	F ₁	F ₂	F ₁	F ₂
Lines								
YSC-63	0.17	-0.22	0.00	-1.14**	0.18	-0.37	0.14	-0.04
YSC-41	1.01**	0.35	0.33	-0.89*	-0.63	1.08**	-0.52	-0.21
B-09	-0.40	0.85*	-0.58	-0.89*	0.80*	-0.45	0.73	0.45
YSC-71	0.59	0.76	0.83*	0.02	-0.26	0.20	0.56	0.20
YSKM-11-02	-1.40**	0.43	0.41	0.44	-0.42	-0.47	-0.77*	-0.96*
YSC-76	0.42	-0.06	0.50	0.60	-0.02	1.08**	-0.52	1.12**
YSKM-10-1	0.84*	-0.06	-0.33	0.69	0.83*	-0.45	0.73	0.62
YSKM-11-1	-0.57	-0.06	0.08	0.10	-0.63	-0.35	0.56	-0.21
YSC-75	0.09	-0.40	-0.50	-0.14	-0.26	0.20	-1.10**	0.87*
YSKM-10-02	-0.90**	0.10	-0.66	-0.47	0.80*	-0.45	0.14	0.62
YSK-9-01	0.76*	-0.65	0.08	0.35	-0.26	-0.37	-0.52	-0.54
YSC-80	-0.90**	-0.23	-0.08	0.27	-0.42	1.08**	0.73	-0.04
K-88	-1.24**	-0.31	0.33	0.27	-0.02	0.09	0.56	-0.54
YSC-15	0.09	-0.65	-0.75*	0.35	0.22	-0.45	-0.77*	-0.04
T-42	-0.15	-0.23	0.58	-0.39	0.18	-0.35	-0.52	-0.63
YSC-18	0.92**	-0.56	-0.58	-0.22	-0.63	-0.37	0.73	-0.88*
YSK-03	-0.74*	0.10	1.33**	-0.14	0.80*	1.08**	0.56	-0.04
YSC-21	-0.59	0.60	0.16	0.77*	-0.26	-0.45	-1.10**	-0.13
YSC-92	-0.49	1.01*	0.16	-0.06	-0.42	0.20	0.14	-1.13**

YSC-45	-0.90**	0.18	-0.25	0.44	-0.02	-0.47	-0.52	0.53
YSC-30	-0.15	-0.31	0.58	-0.06	0.83*	1.08**	0.73	1.12**
YSC-95	-0.15	0.35	-1.50**	-0.56	-0.63	-0.45	0.56	0.20
YSC-40	0.92**	-0.31	0.33	0.35	-0.26	-0.35	-0.77*	-0.54
YSC-46	0.51	-0.15	0.08	0.27	0.80*	0.20	-0.52	0.28
YSC-84	1.09**	-0.48	-0.58	0.02	-0.26	-0.45	0.73	-0.04
Testers								
NRCYS-05-02	0.27*	0.02	-0.27	0.02	-0.15	-0.08	0.33*	0.12
YSH-401	0.07	0.01	-0.31*	0.11	-0.34*	-0.05	-0.37*	-0.10
YST-151	0.07	0.02	0.25	0.06	0.26	0.13	0.39*	-0.13
Pitambari (Check)	-0.41**	-0.06	0.33*	-0.19	0.23	0.00	-0.35*	0.11
SE(gi) ±	0.44	0.72	0.47	0.52	0.52	0.49	0.59	0.68

Table 3: Continue.....

Parents Lines	Leaf area index (cm/m ²)		No. of primary branches per plant		No. of secondary branches per plant	
	F ₁	F ₂	F ₁	F ₂	F ₁	F ₂
YSC-63	0.79**	0.20**	-0.03	0.30	0.38	-0.29
YSC-41	-0.47**	-0.07	0.14	-0.12	-0.29	0.46
B-09	-0.17**	-0.46**	0.14	0.55	0.05	-0.29
YSC-71	0.38**	0.68**	0.05	-0.29	0.21	-0.04
YSKM-11-02	-0.40**	-0.17**	0.22	0.38	-0.62	-0.04
YSC-76	-0.21**	0.26**	-0.03	0.13	0.38	-0.20
YSKM-10-1	0.13**	-0.45**	0.05	0.21	0.13	0.38
YSKM-11-1	0.11**	0.57**	-0.03	-0.37	0.05	-0.04
YSC-75	0.64**	-0.57**	-0.20	0.21	0.05	-0.04
YSKM-10-02	-0.21**	0.20**	0.05	-0.20	-0.62	0.05
YSK-9-01	-0.47**	-0.07	-0.28	0.05	0.38	-0.29
YSC-80	0.13**	-0.46**	0.14	0.21	-0.20	0.38
K-88	0.02	0.68**	0.22	-0.37	0.05	-0.04
YSC-15	-0.38**	-0.17**	-0.11	-0.29	0.38	-0.12
T-42	0.64**	0.26**	-0.03	0.05	-0.62	-0.04
YSC-18	-0.21**	-0.45**	-0.03	-0.04	0.38	-0.20
YSK-03	-0.47**	0.57**	-0.03	-0.37	-0.04	0.38
YSC-21	-0.12**	-0.57**	-0.36	-0.04	0.05	-0.29
YSC-92	0.47**	0.20**	0.05	0.21	0.38	-0.04
YSC-45	0.79**	-0.07	0.14	0.21	-0.62	0.05
YSC-30	-0.47**	-0.46**	0.22	-0.04	0.38	0.13
YSC-95	-0.40**	0.68**	-0.03	-0.12	-0.12	0.21
YSC-40	-0.19**	-0.17**	-0.53	-0.29	0.05	-0.04
YSC-46	0.38**	0.26**	0.39	0.13	0.46	-0.12
YSC-84	-0.38**	-0.45**	-0.11	-0.12	-0.62	0.05
Testers						
NRCYS-05-02	-0.01	0.08**	0.01	0.05	-0.30*	0.14
YSH-401	0.03*	0.02	-0.09	-0.06	0.24	-0.14
YST-151	-0.02	-0.04*	0.11	0.08	-0.18	0.18
Pitambari (Check)	0.01	-0.06**	-0.03	-0.07	0.24	-0.19
SE(gi) ±	0.00	0.01	0.54	0.62	0.48	0.51

*, ** significant at 5 and 1 per cent level, respectively.

Table 4: Estimate of specific combining ability (sca) effects and *per se* performance of F₁ and F₂ generations for seven characters in yellow sarson (*Brassica rapa* var. yellow sarson)

Characters	Cross Combinations	Generations			
		F ₁		F ₂	
		SCA	Mean	SCA	Mean
Days to 50% flowering	YSC-71 x Pitambari	-2.34**	51.00	-0.57**	56.00
	YSC-76 x NRCYS-05-02	-1.85**	52.00	-0.31**	55.00
	YSKM-10-01 x YST-151	-2.07**	52.00	-0.69**	54.00
	YSKM-11-01 x YST-151	-1.65**	51.00	-1.36**	53.00
	YSC-75 x NRCYS-05-02	-1.52**	52.00	-0.03**	54.00
Days to maturity	YSC-63 x YST-151	-2.67**	117.00	-0.36**	122.33
	YSC-41 x NRCYS-05-02	-1.48**	118.00	-0.15**	122.33
	B-09 x Pitambari	-0.50**	119.66	-0.03**	122.00
	YSKM-11-02 x YSH-401	-1.52**	118.00	-0.28**	123.33
	YSC-76 x YSH-401	-1.94**	117.66	0.22**	124.00
Plant height (cm)	YSC-63 x NRCYS-05-02	-2.74**	142.44	-2.03**	149.56
	B-09 x Pitambari	-1.72**	144.66	-0.10**	147.42
	YSKM-11-02 x YSH-401	-1.93**	142.43	-1.33**	148.78
	YSKM-10-02 x Pitambari	-1.93**	146.38	-0.93**	146.58

	YSC-80 x YSH-401	-1.93**	142.43	-1.34**	150.35
Length of main raceme (cm)	YSC-41 x YSH-401	-3.12**	57.00	-0.52**	53.00
	YSC-71 x Pitambari	-2.02**	57.00	-0.89**	54.00
	YSK-11-02 x YST-151	-2.61**	57.00	-0.63**	52.33
	YSC-76 x YSH-401	-3.24**	57.00	-0.19**	54.00
	YSC-75 x YST-151	-2.94**	57.00	-2.54**	51.00
Leaf area index (cm/m ²)	YSC-63 x YST-151	-0.28**	3.81	-0.47**	3.36
	YSC-41 x YSH-401	-0.21**	2.54	-0.16**	2.87
	YSC-41 x Pitambari	-0.22**	2.50	-0.18**	2.54
	B-09 x NRCYS-05-02	-0.18**	2.82	-0.42**	2.81
	B-09 x Pitambari	-0.92**	3.58	-0.17**	2.42
Number of primary branches per plant	YSC-63 x NRCYS-05-02	-0.09**	5.33	0.12**	5.33
	YSC-63 x Pitambari	0.28**	5.66	0.90**	6.00
	YSC-41 x Pitambari	0.45**	6.00	0.32**	5.00
	B-09 x NRCYS-05-02	0.74**	6.33	0.53**	6.00
	YSC-71 x NRCYS-05-02	0.49**	6.00	0.37**	5.00
Number of secondary branches per plant	B-09 x YST-151	1.10**	13.00	0.90**	14.00
	YSC-71 x YST-151	0.90**	13.00	0.56**	14.00
	YSC-76 x NRCYS-05-02	0.89**	13.00	0.86**	14.00
	YSKM-10-01 x NRCYS-05-02	1.80**	13.66	0.27**	14.00
	YSKM-11-01 x YST-151	1.10**	13.00	0.65**	14.00

*, ** significant at 5 and 1 per cent level, respectively

Table 5: Estimate of heterosis over superior and economic parent and inbreeding depression in per cent for seven characters in line x tester cross analysis of yellow sarson (*Brassica rapa* var. yellow sarson)

Characters	Cross Combinations	BP (%)	EP (%)	ID (%)	SCA effects	
					F ₁	F ₂
Days to 50% flowering	YSC-63 x YST-151	-17.44**	-6.40**	-0.62**	0.26**	-0.53**
	YSC-41 x Pitambari	-4.07**	-4.07**	0.60**	0.66**	0.48**
	B-09 x Pitambari	-7.56**	-7.56**	-5.66**	2.07**	0.69**
	YSKM-10-01 x YST-151	-20.00**	-9.30**	-3.84**	-0.51**	0.40**
	YSKM-11-01 x Pitambari	-9.88**	-9.88**	-6.45**	1.24**	-0.35**
Days to maturity	YSKM-11-02 x YST-151	-2.96**	-2.27**	-3.05**	-2.67**	0.36**
	YSC-76 x NRCYS-05-02	-2.44**	-2.27**	-3.33**	-1.48**	0.15**
	YSKM-11-01 x YST-151	-2.70**	-2.27**	-3.33**	0.50**	0.03**
	YSC-18 x NRCYS-05-02	-4.03**	-1.42**	-3.36**	-1.52**	-0.28**
	YSC-21 x Pitambari	-3.23**	-2.27**	-3.33**	-1.94**	0.22**
Plant height (cm)	YSC-63 x NRCYS-05-02	-4.78**	-3.04**	-5.00**	-2.74**	2.03**
	YSKM-11-02 x YSH-401	-7.29**	-3.04**	-4.45**	-1.72**	-0.10**
	YSC-80 x YSH-401	-7.29**	-3.04**	-5.56**	-1.93**	1.33**
	T-42 x NRCYS-05-02	-4.81**	-3.04**	-5.00**	-1.72**	-0.88**
	YSC-84 x YSH-401	-5.94**	-1.64**	-2.96**	-1.93**	1.34**
Length of main raceme (cm)	YSC-41 x Pitambari	-10.53**	-10.53**	-1.91**	3.12**	0.52**
	YSKM-11-02 x YSH-401	-5.56**	-10.53**	-0.65**	2.02**	0.89**
	YSC-75 x NRCYS-05-02	-7.27**	-10.53**	-3.92**	-1.00**	0.88**
	YSC-15 x NRCYS-05-02	-4.22**	-7.02**	3.77**	-1.34**	-1.87**
	YSC-15 x YSH-401	-7.83**	-10.53**	-3.26**	-2.63**	0.02**
Leaf area index (cm/m ²)	YSC-63 x YSH-401	66.51**	35.26**	32.40**	-0.01**	-0.56**
	B-09 x Pitambari	35.26**	35.26**	32.40**	0.92**	0.17**
	YSC-75 x YSH-401	77.36**	44.08**	54.98**	0.37**	-0.50**
	K-88 x NRCYS-05-02	156.98**	69.27**	24.40**	1.70**	-0.14**
	T-42 x YST-151	23.08**	69.27**	35.78**	1.09**	-0.11**
Number of primary branches per plant	B-09 x NRCYS-05-02	10.75**	26.67**	5.26**	0.18**	0.42**
	YSKM-11-02 x YST-151	50.00**	20.00**	16.66**	0.48**	0.26**
	YSKM-11-01 x YST-151	41.67**	13.36**	17.67**	-1.01**	0.48**
	YSK-9-01 x NRCYS-05-02	30.77**	13.33**	17.67**	-0.51**	0.97**
	YSC-46 x YST-151	50.00**	20.00**	16.66**	-1.35**	-0.11**
Number of secondary branches per plant	YSKM-10-01 x NRCYS-05-02	-13.89**	-5.13**	-2.43**	1.80**	0.27**
	K-88 x YSH-401	-7.89**	-10.26**	-8.57**	-0.66**	-0.36**
	T-42 x NRCYS-05-02	-8.33**	-15.38**	-22.27**	-0.11**	0.69**
	YSC-92 x YST-151	-13.89**	-5.13**	-2.43**	1.43**	0.65**
	YSC-95 x NRCYS-05-02	-5.56**	-2.56**	-10.52**	1.05**	0.44**

*, ** significant at 5 and 1 per cent level, respectively.

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