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Research Note

Estimates of genetic variability parameters and interrelationships of morpho-physiological traits in yellow sarson (*Brassica rapa* L. var. yellow sarson)

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Abstract
The objective of investigation was to assess the heterosis, heritability in broad sense, inbreeding depression and inter-relationships among the quantitative traits in six intra-specific crosses developed in yellow sarson. The experimental material comprised six parental genotypes, 12 F_1 and F_2 populations, grown in complete randomized block design with three replications. Data on ten morpho-physiological traits were recorded. Results revealed significant differences for all yield and quality characters indicated the presence of sufficient genetic variability for effective selection. In all cross combinations, hybrids performed better than their respective parents and significant positive standard and better parent heterosis was observed for the trait seed yield per plant. Based on high mean performance and heterotic values, hybrids and their corresponding parental lines under this study can be exploited further for commercial hybrid production. Positive Inbreeding depression in F_{1-2} families ranged from 0.01 to 31.38 percent for length of fruiting zone in Ragni x NDYS-425 and primary branches per plant in Jagrati x YST-151 cross, respectively. High heritability (95.73 cm) coupled with high genetic advance were noticed for length of fruiting zone (Ragni x YST-151) and for seed yield per plant in Jagrati x YST-151, NDYS-427 x YST-151, Pusa Gold x Jagrati and Ragni x NDYS-425 crosses. Seed yield per plant showed highly significant and positive association with primary branches per plant and siliqua length.

Key words
Yellow sarson, Rapeseed, Brassica, Heritability, Heterosis

Rapeseed-mustard is the second most important edible oilseed after groundnut sharing 27.8% in the India's oilseed economy. The rapeseed-mustard group broadly includes Indian mustard, yellow sarson, brown sarson, raya, and toria crops (Shekhawat *et al*., 2012). Yellow sarson (*Brassica rapa* var. yellow sarson) is mainly grown in Assam, Bihar, North-eastern States, Orissa, eastern Uttar Pradesh and West Bengal. Hybrids are becoming the dominant cultivar type in rapeseed-mustard to utilize the heterosis for seed yield and other agronomical quantitative traits. It is well known that the utilization of heterosis is an effective way to increase crop yield. Heritability estimates could be used to predict gain from selection. Higher heritability estimates along with better genetic advance values are useful in predicting the gain under selection in developing genotypes (Ghimirary and Sarkar, 2000). Correlation studies are of interest to plant breeders because traits that are correlated with main breeding objectives may be useful for indirect selection and, when the selection is simultaneous for various traits, the correlation between them may restrict the response to selection (Engqvist and Becker, 1993). The current research program was conducted to assess heterosis, broad sense heritability, inbreeding depression in F_{1-2} and relationships between yield and its related attributes.

Six yellow sarson cultivars *viz*. Jagrati, YST-151, NDYS-427, NDYS-425, Pusa Gold and Ragni with different genetic background were used as parents in present study. Six crosses were produced using these parents and F_1 seeds harvested during 2009-2010 crop season. Subsequently, F_1s of respective crosses were selfed to obtain F_2 seeds. Simultaneously, fresh crosses were also attempted to produce F_1 seeds. The hybrids and their parents, second filial (F_2) were experimented in Complete Randomized Block Design with three replications during Rabi season (2011-12) under timely sown condition at Research Farm, Department of Genetics and Plant Breeding, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, India. The parents (P_1, P_2) and hybrids (F_1s) were grown in single row and F_2s in 4 rows of 5m length. The inter and intra row spacing was maintained at 30 x 10 cm. Five competitive plants of P_1, P_2, F_1 and and twenty of F_2 were randomly selected from each generation and replication. The data were recorded on randomly selected plants for plant height (cm), primary branches/plant, number of siliqua per plant, length of fruiting zone (cm), seed yield per plant, 1000-seed weight and oil content (%) on plot basis. For each cross, the plot means for each generation were averaged over the number of replications to get the generation means that used for calculating of various genetic parameters.

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Statistical analysis: In hybrids, heterosis over better parent (BP) and heterosis over standard variety (over cultivars Jagrati and YST-151) were estimated by using formulas.

$$\mathrm{BP}\ (\%) = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100, \qquad \mathrm{SV}\ (\%) = \frac{\bar{F}_1 - \overline{SV}}{\overline{SV}} \times 100$$

Where, $\bar{F}_1$ = Mean performance of hybrid, $\overline{BP}$ = Mean performance of better parent and $\overline{SV}$ = Mean performance of standard variety.

Inbreeding depression refers to decrease in fitness and vigour due to inbreeding. It was measured as follows.

$$\mathrm{ID}(\%) = \frac{\bar{F}_1 - \bar{F}_2}{\bar{F}_1} \times 100$$

$\bar{F}_1$ and $\bar{F}_2$ are the mean value of F_1 and F_2 generations. The 't' test was applied for testing significance of estimated value. Heritability in broad sense (h^2b) was calculated using the formula as suggested by Burton and de Vane (1953)-

$$(h^2b)\% = \frac{\sigma^2 g}{\sigma^2 g + \sigma^2 e} \times 100$$

Where, $\sigma^2 g$ = genotypic variance, $\sigma^2 e$ = environmental variance. The Expected genetic advance (Ga) was computed by using the formula of Johnson *et al.* (1955)-

$$Ga = K.h^2b.\ \sigma p$$

K is the selection differential intensity at 5% selection (K = 2.06), h^2b = Heritability in broad sense and σp = Phenotypic standard deviation.

The simple correlations between different characters at genotypic and phenotypic levels were worked out as suggested by Searle (1961). All statistical analyses were carried out using Windostat software (V 8.6).

The mean values of parents, hybrids, second filial generations and estimates of genetic parameters are presented in table 1 and 2, respectively. For seed yield per plants, the mean values of hybrids were higher than their respective parents and F_2 generations. It signifies the importance of developing hybrid cultivars in yellow sarson for improving the seed yield. The highest average 1000-seed weight (4.77 g) was observed in F_1 of Ragni × NDYS-425 cross. The possible reasons of getting maximum 1000-seed weight in this cross are high broad sense heritability (75.52 %) and maximum mean value of parent Ragni for this quantitative trait. Table 2 showed that all the crosses revealed the significant positive standard (over cultivars Jagrati and YST-151) and better parent heterosis for seed yield per plant. For 1000-seed weight, significant positive standard heterosis was found in Pusa Gold x Jagrati, Ragni x NDYS-425 and Ragni x YST-151crosses. On the other hand, significant negative heterosis was observed for plant height and days to 50% flowering. Our results further strengthened by the findings of Verma *et al*. (2009) who reported that NDYS-116-1 x YST-151 and NDYS-107 x YST-151 crosses in yellow sarson exhibited significant positive heterosis over better parent as well as standard variety for number of siliquae on main raceme, 1000-seed weight. Hetrosis over standard varieties and better parent was positive and highly significant ($p \leq 0.01$) for oil content in Pusa Gold x Jagrati cross. However, for this trait, heterosis over YST-151 was significantly positive in four out of six crosses. The maximum positive heterosis (53.34%) over standard cultivar Jagrati was observed for primary branches per plant in Pusa Gold x Jagrati cross and minimum (0.77) in Jagrati x YST-151 cross for oil content. However, inter-varietal crosses (yellow sarson), YST-151 x Pusa Gold (Dwarf) and MYSL-203 x EC-333596 showed highest heterosis, upto 150.33 and 43.38 per cent over best parent and commercial variety, respectively (Katiyar *et al*., 2004). Similar results in regard of heterosis in different Indian mustard crosses were reported by Aher *et al.* (2009) and Singh *et al.* (2007). Quantitative traits showing positive heterosis indicates preponderance of dominant gene effects in the inheritance of these traits. On the contrary, negative heterosis indicated predominance of additive gene effects. Seed yield per plant expressed high heterosis, it suggested that the parents used in currently studied crosses are promising breeding material for exploiting hybrid vigor and improving the seed yield. Positive inbreeding depression in $F_{1\text{-}2}$ families ranged from 0.01 to 31.38 percent for length of fruiting zone in Ragni x NDYS-425 cross and primary branches per plant in Jagrati x YST-151 cross, respectively. For seed yield per plant, inbreeding depression was positive and highly significant in all the crosses except in Ragni x NDYS-425 cross. Significant inbreeding depression was observed in none of the crosses for oil content.

Significant and positive standard heterosis, heterobeltiosis and inbreeding depression were observed for primary branches per plant in Pusa Gold x Jagrati and for seed yield per plant in all the crosses except in Ragni x NDYS-425. These results were in concordance of Ranjeet and Sweta (2007) and Verma and Kushwaha (1999). The occurrence of high inbreeding depression in highly heterotic crosses indicated predominant role of non-fixable (non-additive) gene action. It indicated the involvement of dominance and epistatic component in manifestation of heterosis accompanied by inbreeding depression for these traits. In general, high positive heterosis was accompanied by significant inbreeding depression except in Pusa Gold x Jagrati cross for oil content.

The crosses showing absence of inbreeding depression can be used for further selection programme because of predominance of additive or additive x additive gene interaction.

High heritability together with high genetic advance is vital tool for selection of the best individuals and for successful genetic improvement (Tewodros and Getachew, 2013). In current studies, broad sense heritability (h^2b) and genetic advance as percent of mean (Ga) were in the range of 1.03 to 95.73 percent and 0.34 to 37.47 percent, respectively. The minimum h^2b along with genetic advance was observed for primary branches per plant in NDYS-427 x YST-151cross. The maximum h^2b and Ga were noticed for length of fruiting zone and primary branches per plant in Ragni x YST-151 and Pusa Gold x Jagrati crosses, respectively. High heritability (*h2b*) coupled with high genetic advance were noticed for length of fruiting zone (Ragni x YST-151) and for seed yield per plant in Jagrati x YST-151, NDYS-427 x YST-151, Pusa Gold x Jagrati and Ragni x NDYS-425 crosses. Similarly, high genetic advance with heritability was observed for plant height, number of secondary branch per plant and grain filling period in Ethiopian mustard (Walle *et al*. 2014) and for seed yield per plant in *Brassica rapa* (Nasim *et al*., 2014). The high magnitude of broad sense heritability (>75%) was estimated for seed yield per plant in all the crosses, for plant height and length of fruiting zone in 83.33 % crosses, for oil content in 66.67 % crosses. High h^2b also found in Jagrati x YST-151 cross for siliqua length and for days to maturity in Pusa Gold x Jagrati cross. The high estimate of heritability for oil yield and seed yield reported in winter rapeseed (Aytac and Kinaci, 2009) and Indian mustard (Patel *et al*., 2006).

Phenotypic correlation coefficients (55 correlations) among the ten morpho-physiological traits are presented in table 3. Genotypic correlation between seed yield per plant and evaluated traits is depicted by fig. 1. In general, there was a close similarity between genotypic and phenotypic correlations. Seed yield per plant, in both type of correlations, showed highly significant ($p \leq 0.001$) and positive association with primary branches per plant and siliqua length. Contrarily, this trait had significant negative correlation with plant height, days to 50% flowering and days to maturity. These results were in concurrence of Kale *et al*. (2014) who reported that number of siliqua on main raceme and number of branches per plant showed direct positive effect along with positive association with seed yield per plant in pooled analysis over two years but height up to first fruiting branch showed negative association along with negative direct effect on seed yield per plant in yellow sarson. Significant negative phenotypic correlations were observed among the traits oil content, days to maturity and 1000-seed weight.

Based on current findings, hybrids in all the cross combinations have the potential for enhancing the seed yield per plant and in Pusa Gold x Jagrati cross for improving oil content yield. Therefore, are recommended to be used in future breeding programs for developing high yielding hybrid varieties in *Brassica rapa* var. yellow sarson. Seed yield per plant has strong positive correlation with primary branches per plant and siliqua length. Higher heritability estimates along with high genetic advance values are effective in envisaging gain under selection in developing genotypes.

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Table 1. Mean of parents, hybrids and second filial generations

Parents	**PH (cm)**	**PBPP**	**DF**	**LFZ(cm)**	**SPP**	**SL (cm)**	**DM**	**SYPP (g)**	**1000-SW (g)**	**OC (%)**
Jagrati	116.53	5.00	44.67	51.05	45.33	5.33	113.33	15.71	3.97	44.35
NDYS-427	118.67	6.00	41.67	57.47	42.67	5.29	116.00	16.81	3.87	45.14
Pusa Gold	120.43	4.67	42.67	51.67	44.33	4.98	120.00	15.52	4.23	44.29
Ragni	117.97	5.33	39.00	42.53	40.00	6.01	112.33	17.16	4.36	44.22
YST-151	115.80	6.00	47.00	54.83	40.33	4.50	118.33	16.71	3.80	43.30
NDYS-425	110.83	5.33	45.67	52.97	43.67	5.29	115.00	15.05	4.23	44.50
Hybrids (F_{1s})										
Jagrati x YST-151	101.77	6.33	39.00	52.17	46.00	5.93	112.33	21.53	4.20	43.63
NDYS-427 x YST-151	108.03	7.00	40.00	57.13	43.33	5.83	110.33	22.61	4.14	44.34
Pusa Gold x YST-151	113.63	7.00	40.67	52.67	45.00	6.15	112.00	20.77	4.53	44.22
Pusa Gold x Jagrati	116.75	7.67	40.67	51.22	47.33	5.52	105.67	21.20	4.50	45.50
Ragni x NDYS-425	106.80	6.33	41.67	47.14	46.67	5.32	111.33	22.08	4.77	44.16
Ragni x YST-151	110.70	7.00	40.33	46.27	45.00	5.40	109.33	20.54	4.64	44.19
Second filial (F_{2s})										
Jagrati x YST-151	115.00	4.33	41.67	50.33	46.33	5.57	113.67	16.75	3.60	45.20
NDYS-427 x YST-151	113.87	6.00	45.33	48.60	44.67	4.87	114.00	16.80	3.63	45.26
Pusa Gold x YST-151	115.50	5.00	46.33	48.10	43.33	5.03	115.00	16.63	3.80	44.12
Pusa Gold x Jagrati	110.53	5.33	44.00	49.73	46.33	4.41	110.33	16.09	3.90	45.33
Ragni x NDYS-425	108.07	5.33	45.67	47.13	42.33	4.95	110.67	16.86	3.80	45.29
Ragni x YST-151	112.47	5.67	43.33	50.67	46.33	4.80	116.33	15.94	3.70	44.53
Overall mean	**112.96**	**5.85**	**42.74**	**50.65**	**44.39**	**5.29**	**113.11**	**18.04**	**4.09**	**44.53**
CV (%)	6.58	15.54	6.06	7.43	4.74	9.40	3.02	14.26	8.82	1.40
Max	120.43	7.67	47.00	57.47	46.33	6.15	120.00	22.61	4.77	45.50
Min	101.77	4.33	39.00	42.53	40.00	4.41	105.67	15.05	3.60	43.30

PH (Plant height), PBPP (Primary branches per plant), DF (Days to 50% flowering), LFZ (Length of fruiting zone), SPP (Siliqua per plant), SL (Siliqua length), DM (Days to maturity), SYPP (Seed yield per plant), 1000-SW (1000-seed weight), OC (Oil content)

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Table 2. Estimates of genetic variability parameters in six crosses of yellow sarson

Genetic parameters	PH (cm)	PBPP	DF	LFZ (cm)	SPP	SL (cm)	DM	SYPP (g)	1000-SW (g)	OC (%)
Jagrati × YST-151										
H(%) over SV (Jagrati)	-12.67**	26.67	-12.69**	2.19	1.47	11.25*	-0.88	36.80**	5.88	-1.62
H (%) over SV (YST-151)	-12.12**	5.56	-17.02**	-4.86*	14.05**	31.85**	-5.07*	28.80**	10.53	0.77
H (%) over BP	-12.67**	5.50	-12.69**	-4.85*	1.48	11.26*	-0.88	28.84**	5.88	-1.62
ID (%) in F_2	-13.00**	31.38*	-6.84	3.52	-0.73	6.19	-1.19	22.20**	14.29*	-3.6**
h^2b (%)	90.38	32.98	73.17	72.49	70.07	76.31	11.21	87.78	47.5	66.66
Ga as % of mean	9.61	12.06	10.53	6.57	8.39	18.71	0.69	25.22	9.01	2.46
NDYS-427 × YST-151										
H(%) over SV (Jagrati)	-7.29**	40.00*	-10.45*	11.91**	-4.40	9.38	-2.65	4.39*	4.28	-2.18
H (%) over SV (YST-151)	-6.71**	16.67	-14.89**	4.19*	7.44	29.56*	-6.76**	35.31**	8.95	2.40**
H (%) over BP	-8.96**	16.67	-4.01	-0.59	1.56	10.21	-4.89*	34.50**	7.07	-1.77**
ID (%) in F_2	-5.40**	14.29	-13.33*	14.94**	-3.08	16.58*	-3.32	25.71**	12.24	-2.09**
h^2b (%)	89.92	1.03	55.27	94.14	25.23	13.77	31.65	91.20	22.33	91.88
Ga as % of mean	7.38	0.34	8.23	15.66	2.75	3.05	2.03	31.19	3.88	3.04
Pusa Gold × YST-151										
H(%) over SV (Jagrati)	-2.49*	40.00*	-8.95*	3.17	-0.73	15.38	-1.17	31.95*	14.10*	-0.29
H (%) over SV (YST-151)	-1.87**	16.67	-13.47**	-3.95*	11.57**	36.67	-5.35*	24.30**	19.30**	2.12**
H (%) over BP	-5.65**	16.67	-4.69	-3.94*	1.50	6.21	-5.34*	25.35**	7.09	-0.17
ID (%) in F_2	-1.64**	28.58*	-13.93**	8.68	3.70	18.20*	-2.68	19.95**	16.18**	0.22
h^2b (%)	75.14	40.98	65.09	84.08	55.33	33.51	37.45	78.05	69.23	92.30
Ga as % of mean	3.50	16.40	8.81	9.44	6.72	7.68	2.47	18.81	12.83	3.09
Pusa Gold ×Jagrati										
H(%) over SV (Jagrati)	-0.19	53.34*	-8.96*	0.33	4.41	3.38	-6.77**	34.95**	13.43	2.59**
H (%) over SV (YST-151)	-0.82	27.83*	-13.47**	-6.58**	17.36**	22..67	10.69**	26.87**	18.42*	5.08**
H (%) over BP	-3.16**	35.30**	-4.69	-0.87	5.95*	-7.53	-6.76**	36.33**	9.76	2.59**
ID (%) in F_2	5.33**	30.44**	-8.20	2.90	2.12	20.00*	-4.42	24.09**	13.40	0.37
h^2b (%)	93.51	73.79	46.60	80.92	45.91	24.07	76.35	89.65	45.00	81.39
Ga as % of mean	10.11	37.46	6.48	7.24	3.67	6.98	7.31	27.75	10.35	3.46
Ragni × NDYS-425										
H(%) over SV (Jagrati)	-8.35**	26.60*	-6.67	-7.66**	2.96	-0.19	0.00	40.55**	22.30**	-0.43
H (%) over SV (YST-151)	-7.77**	5.50	-11.34**	-14.02**	15.72**	18.22	-5.92**	32.14**	25.53**	1.99**
H (%) over BP	-3.64**	18.76	6.85	-11.01**	6.87*	-3.27	-0.89	28.67**	8.32	-0.76
ID (%) in F_2	-1.19	15.79	-5.12*	0.01	9.29**	6.96	0.60**	23.63	20.34**	-2.57**
h^2b (%)	1.43	60.95	67.07	87.34	73.98	37.86	9.69	86.39	75.52	61.27
Ga as % of mean	1.43	23.83	18.29	13.18	10.07	14.88	0.43	25.06	15.30	1.34
Ragni × YST-151										
H(%) over SV (Jagrati)	-5.00**	40.00*	-9.72*	-9.36**	-0.77	1.31	-3.53	30.74**	16.88**	-0.36
H (%) over SV (YST-151)	-4.40**	16.67	-14.19**	-4.40**	11.57**	20.00	-7.61**	22.88**	22.11**	2.06**
H (%) over BP	-6.16**	31.25	3.41	-15.61**	11.58**	-10.00	-2.67	19.69**	6.67	2.24**
ID (%) in F_2	-1.60	19.05	-7.44	-9.5**	-2.97	11.11	-6.40*	22.38**	20.26**	-0.79
h^2b (%)	87.92	60.14	62.84	95.73	76.81	40.08	41.93	76.81	69.50	82.69
Ga as % of mean	6.81	36.44	10.63	30.11	10.15	10.72	3.02	18.85	14.10	1.88

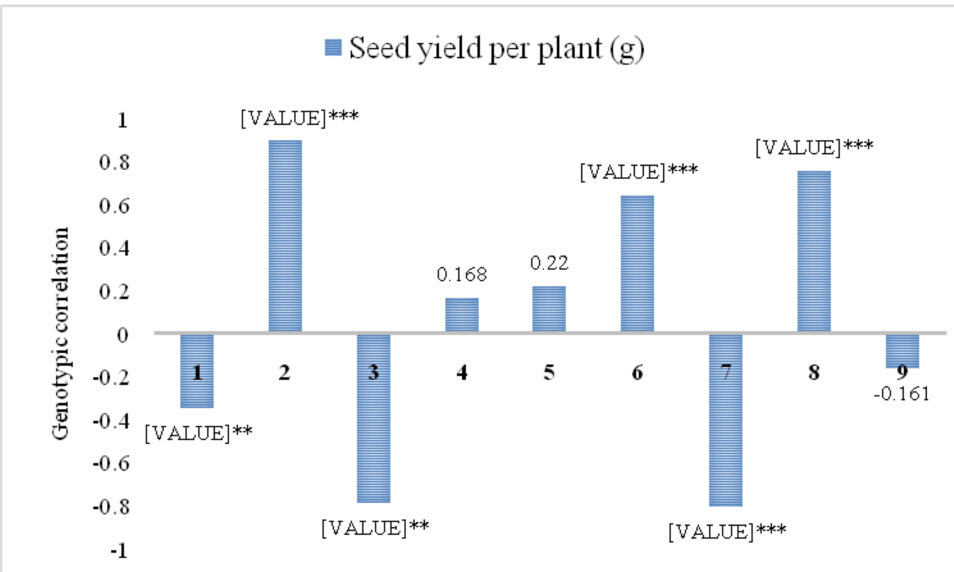
*, **, *** Significant at 5%, 1% and 0.1 % level of significance, respectively

Table 3. Phenotypic correlation among the different quantitative traits

	PH (cm)	PBPP	DF	LFZ (cm)	SPP	SL (cm)	DM	SYPP (g)	1000-SW (g)	OC (%)
PH (cm)	1.000	-0.119	0.087	0.059	0.059	0.015	0.298**	-0.280**	-0.135	0.0196
PBPP		1.000	-0.327**	0.122	0.028	0.124	-0.288**	0.566***	0.344***	-0.047
DF			1.000	-0.108	-0.057	-0.405***	0.291***	-0.537***	0.400***	0.130
LFZ (cm)				1.000	-0.008	0.031	0.119	0.140	-0.046	-0.024
SPP					1.000	0.003	-0.102	0.142	-0.032	0.229*
SL (cm)						1.000	-0.087	0.401***	0.305**	-0.132
DM							1.000	-0.354***	0.309***	-0.255*
SYPP (g)								1.000	0.520***	-0.120
1000-SW (g)									1.000	-0.255*
OC (%)										1.000

*, **, *** Significant at 5%, 1% and 0.1 % level of significance, respectively

Fig. 1. Genotypic correlation of different quantitative traits with seed yield per plant (g)



*, **, *** Significant at 5%, 1% and 0.1 % level of significance, respectively,
1. Plant height, 2. Primary branches per plant, 3. Days to 50% flowering, 4. Length of fruiting zone,
5. Siliqua per plant, 6. Siliqua length, 7. Days to maturity, 8. 1000-seed weight, 9. Oil content