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Early Generation Selection Parameters for Genetic Improvement using Morpho-physiological and Seed Yield Components in *Brassica* species

Akhil Sharma [a], Vedna Kumari [a] and Amit Rana [a*]

[a] *Department of Genetics and Plant Breeding, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (H. P.)-176062 India.*

Authors' contributions

This work was carried out in collaboration among all authors. Conceptualization and designing of the research work authors AS and VK. Execution of field/lab experiments and data collection authors AS and AR Analysis of data and interpretation authors AS, VK and AR Preparation of manuscript authors AR and VK. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: To determine the best selection indices for seed yield improvement in *Brassica* crops
Place of Study: Experimental Farm of Department of Genetics & Plant Breeding, CSK HPKV, Palampur, during *rabi* 2018-19.
Methodology: The experimental material for the investigation comprised of twenty five advanced breeding lines including released varieties of four different *Brassica* species laid out in randomized complete block design with three replications which were evaluated for correlation (genotypic and phenotypic) studies, direct and indirect effects using various growth parameters and yield contributing traits.
Results: Analysis of variance revealed significant genotypic variances for all the growth parameters and seed yield components under study except for Leaf Area Index (LAI), number of primary branches per plant, number of secondary branches per plant, siliquae per plant and harvest index. Correlation coefficients at phenotypic level indicated that seed yield per plant had significant positive correlations with relative growth rate (RGR), leaf area ratio (LAR), number of secondary branches per plant, siliquae per plant, seeds per siliqua, 1000-seed weight, biological yield per plant and harvest index while it had significant negative association with specific leaf weight (SLW),

**Corresponding author: E-mail: amitrana.gpb@gmail.com;*

days to 50% flowering, days to 75% maturity and number of primary branches per plant. Path coefficient analysis revealed that biological yield per plant followed by harvest index had high positive direct as well as indirect effects on seed yield.
Conclusion: Biological yield per plant and harvest index could be considered most important characters for improvement of seed yield both directly and indirectly in different *Brassica* species. Therefore, these traits could be preferred as the best selection indices in future for genetic improvement of rapeseed-mustard.

Keywords: Rapeseed-mustard; correlation; path analysis; growth parameters.

1. INTRODUCTION

Oilseeds holds a premier position since ancient times in the agricultural economy around the world and are important next to cereal pool in terms of area and production [1]. The imperative need for nutritionally rich edible oils is constantly increasing in our daily life due to expanding human population. India ranks fourth largest oilseed producing economy worldwide [2]. Among various oilseed crops in India and the rest of the globe, rapeseed-mustard (*Brassica* spp.) is the second and third most significant edible oilseed respectively. Globally, rapeseed-mustard occupies over an area of 36.24 million hectares with production of 73.16 million tonnes while in India, it is grown over an area of 8.20 million hectares with a total production of 8.50 million tons and productivity 1.04 q/ha [1]. Apart from being a major component of the human diet, it is also used to make soaps, paints and varnishes, hair oils, lubricants, textiles, pharmaceuticals and animal feed. Indian mustard (*Brassica juncea* L. Czern & Coss) and three ecotypes/varieties of *B. rapa* L., namely brown sarson, yellow sarson and toria are the dominant species covering major areas of rapeseed-mustard cultivation in India [3]. These species are well adapted to drier conditions and mature earlier than other oilseed *Brassica* species [4]. However, both the species are susceptible to aphids, alternaria blight and white rust and have a limited genetic variation for resistance to biotic stresses [5]. On the other hand, *B. napus* L. (rape or rapeseed), known for its higher yield potential in favorable environments [6], is characterized by higher oil content, better oil quality and resistance against white rust [7] but, it suffers from late maturity, pod shattering and drought susceptibility problems and needs alternation to rectify the undesirable attributes for its wider adaptability in Indian conditions.

Ample genetic variability among the germplasm is the foundation for all plant breeding improvement programmes. The development of new varieties mainly depends on the magnitude of genetic variability in the base material for the desired character. Hence, studying inheritable variability among the rapeseed-mustard genotypes is pivotal for developing high yielding varieties. Improvement in complex trait like yield depends upon different yield contributing characters which mostly inherit quantitatively. The information on different degree of interrelationship between these characters is of foremost importance for yield and quality improvement [8,9]. These associations are however then helpful for making the best use in early selection [10]. The characters showing positive association with yield can be subsequently used in indirect selection criterion for yield improvement programmes. Simple analysis for correlation between single character may not act as a useful perception of the importance of single factor affecting yield [11-13]. When these indirect correlations becomes complicated, the best way is to find the direct and indirect effects through path coefficient analysis [14]. Path analysis divides correlation into different direct and indirect effects giving plant breeders the opportunity to study critically all concerned traits that produce a given correlation which can be used efficiently in current selection strategy for its subsequent exploitation in future breeding programme [15,16]. Therefore, estimation of direct and indirect effects and magnitude and direction of the relationship between various yield contributing traits is a pre-requisite for making effective selection. Thus, the present study aimed to determine inheritable parameters contributing to growth parameters and yield related traits in rapeseed-mustard.

2. MATERIALS AND METHODS

2.1 Experimental Material and Site

The experimental material for the investigation comprises of 25 advanced breeding lines including released varieties of four different *Brassica* species laid out in randomized complete block design with three replications during *rabi* 2018-19 at the Experimental Farm of Department of Genetics and Plant Breeding, CSK HPKV, Palampur (HP), India. Each entry was raised in two rows with the plot size of 2.5×0.6 m^2 with row to row and plant to plant spacing of 30 cm and 15 cm, respectively following recommended agronomic cultural practices under irrigated conditions (Table 1).

2.2 Field Study and Data Evaluation

Observations were recorded on five randomly selected plants in each genotype for seven growth parameters *viz.,* Crop Growth Rate (CGR), Relative Growth Rate (RGR), Net Assimilation Rate (NAR), Leaf Area Ratio (LAR), Leaf Area Index (LAI), Specific Leaf Weight (SLW) and Relative water content (RWC) calculated on the basis of average data recorded at different growth stages and agro-morphological and yield contributing characters viz., days to 50 per cent flowering (50%F), days to 75 per cent maturity (75%M), plant height (PH), number of primary branches per plant (PB), number of secondary branches per plant (SB), siliquae per plant (SQ), seeds per siliqua (SSQ), 1000-seed weight (1000-SW), biological yield per plant (BY), harvest index (HI) and seed yield per plant (SY). For statistical analysis of mean values, analysis of variance for each trait was done as per Panse and Sukhatme [17]. estimates of variability viz., phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2_{bs}) in broad sense and expected genetic advance (GA) expressed as % of mean resulting from the selection of 5 % superior individuals was calculated as per Burton and De Vane [18] and Johnson et al. [19]. The phenotypic and genotypiccoefficients of correlation were computed as per Al-Jibouri et al. [20] and path coefficients of yield and other characters with seed yield were worked out following Dewey and Lu [21].

3. RESULTS AND DISCUSSION

3.1 Mean Performance and Analysis of Variance

Analysis of variance revealed that mean squares due to genotypes were significant for all the growth parameters except LAI (Table 2). All morphological and yield contributing characters also revealed significant genotypic variation except for PB, SB, SQ and HI indicating sufficient genetic variability for all the characters studied except for PB, SB, SQ and HI in the diverse experimental material under investigation. Similar results were reported by Rameeh [22] for 50%F, 75%M, SSQ and 1000-SW. Shalini et al. [23], Patel and Patel [24] and Zare and Sharafzadeh [25] also reported highly significant differences for 50%F and 75%M, SB, PH, 1000-SW, SY and HI; Singh et al. [26]; Monalisa et al. [27] also reported similar results for 50%F, 75%M, PB, PH, SQ, SSQ, 1000-SW and SY. Abideen et al. [28] also reported non-significant differences for PB. Devi [29] and Singh et al. [30] revealed considerably exploitable variability among most of these characters in *Brassica juncea*. Therefore, the results obtained from earlier findings corroborated with the present studies showing fitting relevance of characters under study as early selection parameters in *Brassica* improvement programmes.

3.2 Estimates of Variability

The estimates of parameters of variability for all the traits studied are presented in Table 3. PCV values were higher than their corresponding GCV for all traits studied which indicated that the apparent variation was not only due to genotypes but also due to the influence of environment. Therefore, caution has to be exercised in making selection for these characters on the basis of phenotype alone as environmental variation is unpredictable in nature. Similar findings with respect to PCV and GCV have been reported by Karuppaiyan et al. [31]. Phenotypic coefficient of variation (PCV) was high (>30%) for SLW while moderate estimates of PCV (10-30 %) were recorded for the characters such as PH, LAR, LAI, NAR, SSQ, PB, RGR, SB, BY, CGR, SQ, SY, 1000-SW and HI. The highest GCV (>30%) was recorded for SLW and the estimates were moderate for PB, SB, LAR, 1000-SW, NAR, SSQ, RGR, SY, CGR, LAI, BY and HI. The results were in conformation with the findings of Singh et al. [26] and Chakraborty et al. [32]. Moderates estimates of GCV and PCV were observed for SY in the present study but, Verma et al. [33] observed high PCV and GCV for SY in *Brassica juncea*.

Heritability estimates were high for 50% F, 75% M, LAR, RGR, CGR, SLW and 1000-SW. Nasim et al. [34] also reported high heritability for 50% F, SSQ and 1000-SW. The estimates were moderate (30-60%) for the characters such as BY, SY, RWC, PH, HI, PB, LAI and SB while low heritability (<30%) was exhibited by SQ. Results were in conformation with the findings of Afrin et al. [35] and Shaukat et al. [36] in *Brassica napus*. The high expected genetic advance (>30%) expressed as percent of mean was observed for SLW, LAR, 1000-SW, NAR, RGR, SSQ, CGR and SY. The moderate estimates (10-30 %) were recorded for BY, 50% F, LAI, PB, PH, SB, HI and RWC. High genetic advance for SY, SSQ and SQ was also reported by Devi [29] in Indian mustard and Sikarwar et al. [37] in *Brassica campestris*. High heritability coupled with high genetic advance was observed for the characters such as CGR, RGR, NAR, SLW, SSQ and 1000-SW. High heritability coupled with high genetic advance for SSQ was also reported by Uzair et al. [38] in Indian mustard. This suggested the importance of additive gene action for their inheritance and improvement could be brought about by simple phenotypic selection.

3.3 Correlation Analysis

After understanding the nature of variation for seed yield and other characters, it would be desirable to know the nature and magnitude of associations among these characters in order to bring out improvement in a complex character like seed yield. In order to understand the nature and magnitude of correlations among seed yield and other characters, estimates of correlation coefficients at phenotypic and genotypic levels were computed under non-stress field conditions.

At phenotypic level, SY had significant positive association with RGR, LAR, SB, SQ, SSQ, 1000-SW, BY and HI, while it had significant negative association with SLW, 50%F, 75%M and PB (Table 4). Earlier Sirohi et al. [39] and Devi [29] also reported that SY had significant and positive association with BY and HI. Singh et al. [40] had also reported that 50%F had negative correlation with SY. Significant positive association of SY with SB has also been reported earlier by Beena and Charan [41]; Mahla et al. [42] and Singh et al. [30].

Among growth parameters, CGR had significant positive correlation with RGR, NAR, SB and 1000-SW while it had significant negative correlation with SLW only. RGR showed

Table 1. Details of the experimental material along with source used in the study

S. No.	Genotype	Species	Source
1	HPBS-1	*Brassica campestris*	Released variety of H.P.
2	HPKM-04-01	*Brassica campestris*	Local cultivar of H.P.
3	KDH-B5-06 × 03-472	*Brassica campestris*	Dept. of Genetics and Plant Breeding
4	03-473 ×03-472	*Brassica campestris*	Dept. of Genetics and Plant Breeding
5	03-472 × 02 KLM-6	*Brassica campestris*	Dept. of Genetics and Plant Breeding
6	HPBS-1 × 02-KLM-6	*Brassica campestris*	Dept. of Genetics and Plant Breeding
7	Jayanti	*Brassica carinata*	Released variety of H.P.
8	$P(4)2_a$ (80KR)	*Brassica carinata*	Mutant line
9	$P(4)2_b$ (0.3% EMS WPS)	*Brassica carinata*	Mutant line
10	$P13_a$ (100KR)	*Brassica carinata*	Mutant line
11	$P13_b$ (0.4% EMS WPS)	*Brassica carinata*	Mutant line
12	P(11)2 (0.3 EMS WPS)	*Brassica carinata*	Mutant line
13	P(3)2 (0.3% EMS WPS)	*Brassica carinata*	Mutant line
14	P22 (0.3% EMS WPS)	*Brassica carinata*	Mutant line
15	P36 (0.5% EMS WPS)	*Brassica carinata*	Mutant line
16	Sheetal (HPN-1)	*Brassica napus*	Released variety of H.P.
17	Neelam (HPN-3)	*Brassica napus*	Released variety of H.P.
18	ONK-1	*Brassica napus*	Released variety of H.P.
19	ONK-1 × CAN-130	*Brassica napus*	Dept. of Genetics and Plant Breeding
20	ONK-1 × HPN-1	*Brassica napus*	Dept. of Genetics and Plant Breeding
21	RCC-4	*Brassica juncea*	Released variety of H.P.
22	TM-172	*Brassica juncea*	BARC, Mumbai
23	TM-204	*Brassica juncea*	BARC, Mumbai
24	TM-215	*Brassica juncea*	BARC, Mumbai
25	RCC-4 × Varuna	*Brassica juncea*	Dept. of Genetics and Plant Breeding

Table 2. Mean performance and analysis of variance for different characters in different *Brassica* species

S.No.	Characters	Genotypes	Error
	df	**24**	**48**
1	CGR (g/day)	0.006*	0.000283
2	RGR (g/day)	0.000742*	0.000024
3	NAR (g/dm^2/day)	0.002646*	0.000198
4	LAR (g/dm^2/day)	0.076*	0.002
5	LAI	0.009	0.003
6	SLW	0.374*	0.021
7	RWC (%)	89.102*	17.125
8	50%F	201.791*	0.764
9	75%M	153.970*	1.132
10	PH (cm)	903.206*	220.912
11	PB	2.200	0.803
12	SB	4.874	2.022
13	SQ	882.754	621.468
14	SSQ	38.374*	3.324
15	1000-SW (g)	2.161*	0.163
16	BY (g)	256.008*	47.889
17	HI (%)	14.673	5.000
18	SY (g)	14.84*	2.851

**Significant at 5% level*

Table 3. Estimates of different parameters of variability for various characters in different *Brassica* species

S.No.	Characters	Range	Mean ± SE	PCV	GCV	h^2_{bs}	GA
	df						**(% of mean)**
1	CGR (g/day)	0.21-0.37	0.26±0.01	18.07	16.88	87.27	32.48
2	RGR (g/day)	0.05-0.11	0.08±0.00	21.15	20.00	89.44	38.97
3	NAR (g/dm^2/day)	0.09-0.2	0.13±0.01	24.08	21.46	79.40	39.39
4	LAR (g/dm^2/day)	0.38-0.98	0.62±0.03	26.49	25.42	92.10	50.25
5	LAI	0.2-0.42	0.28±0.01	25.83	15.34	35.27	18.76
6	SLW	0.35-1.6	0.72±0.07	51.35	47.35	85.04	89.96
7	RWC (%)	53.75-75.99	68.64±1.09	9.34	7.14	58.35	11.23
8	50%F	76.67-99	89.35±1.64	9.21	9.16	98.87	18.77
9	75%M	153.67-177	167.03±1.43	4.32	4.27	97.83	8.71
10	PH (cm)	113.6-179.87	155.01±3.57	13.75	9.79	50.73	14.37
11	PB	4-7.53	5.51±0.17	20.44	12.38	36.69	15.45
12	SB	5.53-10.33	7.92±0.25	21.76	12.30	31.98	14.33
13	SQ	126.47-188.47	155.15±3.43	17.16	6.02	12.29	4.34
14	SSQ	11.67-22.33	16.99±0.72	22.81	20.12	77.85	36.57
15	1000-SW (g)	1.69-5.2	3.37±0.17	27.02	24.21	80.31	44.70
16	BY (g)	47.33-83.33	58.06±1.85	18.65	14.35	59.16	22.73
17	HI (%)	12.21-22	17.75±0.44	16.12	10.10	39.21	13.02
18	SY (g)	6.47-15.87	10.33±0.44	25.34	19.36	58.37	30.47

significant positive association with NAR and LAR and showed significant negative association with SLW and 50%F. NAR recorded significant negative association with LAR, LAI and RWC. LAR recorded significant positive correlation with SSQ and significant negative correlation with SLW, 50%F and 75%M. LAI recorded significant negative correlation with PB. SLW had significant positive correlation with 50%F and 75%M while it had significant negative association with HI. RWC recorded significant positive correlation with SSQ and significant negative correlation with 50%F and 75%M while 50%F recorded significant positive correlation with 75%M, PH and PB. It had significant negative association with SB, SSQ, BY and HI. 75%M had significant positive correlation with PH, PB and significant negative association with SB, SSQ, BY and HI. PH showed significant positive correlation with SQ and significant negative correlation with SB only. PB recorded significant negative correlation with SSQ and HI. SB had significant positive correlation with SQ, SSQ and BY. SQ had significant positive correlation with BY. SSQ recorded significant positive correlation with BY and HI while 1000-SW showed significant positive association with BY. Estimates of genotypic correlation coefficients were slightly higher than their corresponding phenotypic coefficients for most of the characters. The results were in accordance with the earlier findings of Sirohi et al. [39]. SY had significant positive association with RGR, LAR, LAI, RWC, SB, SQ, SSQ, 1000-SW, BY and HI. Ray et al. [43] also reported significant positive correlation of SY with RGR and RWC. SY had significant negative correlation with SLW, 50%F, 75%M, PH and PB. Singh et al. [40] had also reported significant negative correlation of SY with 50%F and Pant and Singh [44] reported significant negative correlation of SY with PB. Hence, significant positive association of growth parameters and agro-morphological traits like RGR, LAR, SB, SQ, SSQ, 1000-SW, BY and HI whereas significant negative association with SLW, 50%F, 75%M and PB with SY indicated their importance as potential traits for improving genetic gain in breeding programmes and can be considered as important selection parameters.

3.4 Path Analysis

In order to understand the casual factors of correlations among the characters studied, the estimates of direct and indirect effects were computed through path analysis (Table 5). At phenotypic level, high positive direct effects on seed yield were contributed by BY followed by HI. The results are in conformity with the earlier findings [39] who reported that BY and HI had high and positive direct effects on SY. Nazzar et al. [45] reported that HI had high positive direct effect on SY.

Characters such as CGR, NAR, LAR, SLW, RWC, PH and PB had small negative direct effects on SY. Shalini et al. [23] reported that most of the characters had indirect effect on SY. The significant positive correlation of RGR with SY was mainly due to indirect effects *via* BY and HI though, its own direct effect was negligible. The significant positive correlation of LAR with SY was mainly due to indirect effects *via* BY and HI though, its direct effect is negative and low. The significant negative correlation of SLW with SY was mainly due to its high negative indirect effects by HI followed by BY. The significant negative correlation of 50% F and 75% M with SY was mainly due to its high negative indirect effects by HI and BY though, their direct effects were low. The significant negative correlation of PB with SY was mainly due to its high negative indirect effects by HI and BY. The significant positive correlation of SB with SY was mainly due to high positive indirect effects *via* BY and HI. Chakraborty et al. [32] also reported positive direct effect of SB on SY.

The significant positive correlation of SQ was mainly contributed by BY though, counterbalanced by HI to some extent. The significant positive correlation of SSQ was mainly due to indirect effects *via* BY and HI and is counterbalanced by 50%F to some extent. The significant positive correlation of 1000-SW was contributed by BY followed by HI. The significant positive correlation of BY was mainly due to its own high positive direct effect followed by direct effect *via* HI. The significant positive correlation of HI was mainly due to its own high positive direct effect as well as indirect effect *via* BY. The magnitude of residual effects (0.00731) recorded in the present study indicated that the characters studied accounted for much of the present variation in SY. At genotypic level, high positive direct effects were shown by BY, HI and RGR.

Acharya and Patil [46] also reported similar observations for some of the characters studied while LAR, SB, SSQ, PH, 50%F and RWC showed negative direct effects. Uddin et al. [47] reported that 50%F had negative direct effect on SY in Indian mustard. Therefore, path analysis for SY among growth parameters like RGR, LAR, SLW and agro-morphological traits like 50%F, 75%M, PH, PB, SB, SQ, SSQ, 1000-SW, BY and HI indicated significant direct and indirect effects and could be used as selection parameters.

Table 4. Estimation of Correlation coefficients at phenotypic (P) and genotypic (G) levels among different characters

		RGR	NAR	LAR	LAI	SLW	RWC	50%F	75%M	PH	PB	SB	SQ	SSQ	1000-SW	BY	HI	SY
CGR	P	0.505*	0.507*	-0.068	-0.020	-0.235*	-0.182	-0.192	-0.116	0.080	0.030	0.256*	-0.073	0.104	0.239*	0.174	-0.105	0.066
	G	0.504*	0.488*	-0.045	-0.148	-0.231*	-0.206	-0.203	-0.122	0.070	-0.032	0.362*	0.024	0.121	0.248*	0.237*	-0.221	0.063
RGR	P		0.352*	0.491*	-0.203	-0.822*	-0.073	-0.243*	-0.214	0.005	0.095	0.137	-0.044	0.152	0.079	0.198	0.169	0.274*
	G		0.323*	0.553*	-0.319*	-0.916*	-0.043	-0.255*	-0.219	0.002	0.001	0.177	0.007	0.157	0.068	0.210	0.162	0.272*
NAR	P			-0.601*	-0.322*	-0.079	-0.342*	0.115	0.202	0.106	0.163	0.177	-0.080	-0.197	0.111	-0.056	-0.115	-0.098
	G			-0.596*	-0.331*	-0.141	-0.355*	0.149	0.227*	0.121	0.271*	0.287*	0.139	-0.242*	0.082	-0.084	-0.271*	-0.177
LAR	P				0.115	-0.626*	0.204	-0.277*	-0.325*	-0.084	-0.110	-0.042	0.034	0.238*	-0.059	0.180	0.193	0.259*
	G				-0.047	-0.633*	0.255*	-0.293*	-0.339*	-0.059	-0.154	-0.078	-0.015	0.275*	-0.055	0.216	0.298*	0.318*
LAI	P					-0.203	0.162	-0.117	-0.144	-0.005	-0.307*	0.025	0.139	0.168	0.058	0.105	0.059	0.109
	G					0.045	0.064	-0.230*	-0.225*	-0.112	-0.759*	0.052	0.602*	0.204	0.143	0.191	0.282*	0.268*
SLW	P						-0.061	0.344*	0.325*	0.037	0.053	-0.105	-0.078	-0.210	-0.054	-0.177	-0.234*	-0.296*
	G						-0.058	0.372*	0.352*	0.081	0.144	-0.164	-0.049	-0.227*	-0.050	-0.233*	-0.356*	-0.378*
RWC	P							-0.245*	-0.294*	-0.153	-0.065	-0.072	-0.031	0.230*	-0.205	0.164	0.064	0.129
	G							-0.350*	-0.361*	-0.300*	-0.142	-0.193	-0.643*	0.317*	-0.283*	0.302*	0.266*	0.310*
50%F	P								0.978*	0.490*	0.337*	-0.310*	0.033	-0.653*	0.081	-0.310*	-0.428*	-0.467*
	G								0.993*	0.678*	0.521*	-0.558*	0.058	-0.756*	0.092	-0.401*	-0.677*	-0.607*
75%M	P									0.536*	0.296*	-0.326*	0.051	-0.668*	0.134	-0.306*	-0.441*	-0.471*
	G									0.744*	0.529*	-0.528*	0.153	-0.740*	0.151	-0.379*	-0.704*	-0.606*
PH	P										0.193	-0.226*	0.275*	-0.221	0.000	-0.135	-0.111	-0.151
	G										0.130	-0.779*	0.389*	-0.447*	0.003	-0.297*	-0.316*	-0.349*
PB	P											0.043	0.038	-0.250*	-0.078	-0.102	-0.289*	-0.252*
	G											-0.406*	-0.397*	-0.515*	-0.212	-0.345*	-0.819*	-0.651*
SB	P												0.350*	0.286*	0.214	0.471*	0.123	0.415*
	G												0.173	0.520*	0.348*	0.732*	0.159	0.597*
SQ	P													0.173	0.149	0.385*	-0.053	0.257*
	G													0.301*	0.590*	0.850*	0.072	0.682*
SSQ	P														0.180	0.527*	0.576*	0.728*
	G														0.220	0.550*	0.924*	0.851*
1000-SW	P															0.287*	0.045	0.250*
	G															0.420*	0.084	0.374*
BY	P																0.091	0.772*
	G																0.292*	0.876*
HI	P																	0.696*
	G																	0.710*

**Significant at P≤0.05*

Table 5. Estimates of path coefficient at phenotypic (P) and genotypic (G) levels of different characters on seed yield

		CGR	RGR	NAR	LAR	LAI	SLW	RWC	50%F	75%M	PH	PB	SB	SQ	SSQ	1000-SW	BY	HI	SY
CGR	P	-0.0057	0.02863	-0.01239	0.00169	-0.00011	0.00109	0.00353	-0.00492	-0.00176	-0.00076	-0.00032	0.0005	-0.00125	0.00017	0.00076	0.12354	-0.06688	0.066
	G	-0.0715	0.22406	-0.09416	0.01068	-0.00001	-0.04528	0.01124	0.00863	-0.0004	-0.00488	-0.00023	-0.03469	0.00103	-0.00988	0.00448	0.18383	-0.11966	0.063
RGR	P	-0.00287	0.05667	-0.00859	-0.01219	-0.00111	0.00383	0.00142	-0.00621	-0.00324	-0.00005	-0.00102	0.00027	-0.00075	0.00025	0.00025	0.14016	0.10724	0.274*
	G	-0.03602	0.44477	-0.06221	-0.12986	-0.00001	-0.17943	0.00233	0.01083	-0.00072	-0.00017	0.00001	-0.01699	0.00032	-0.01287	0.00123	0.16302	0.08757	0.272*
NAR	P	-0.00288	0.01993	-0.0244	0.01492	-0.00177	0.00037	0.00663	0.00296	0.00307	-0.001	-0.00174	0.00035	-0.00136	-0.00033	0.00035	-0.0394	-0.07331	-0.098
	G	-0.03492	0.14351	-0.1928	0.13996	-0.00001	-0.02759	0.01935	-0.00632	0.00075	-0.00847	0.00193	-0.02755	0.00606	0.01981	0.00149	-0.065	-0.14704	-0.177
LAR	P	0.00039	0.02781	0.01467	-0.0248	0.00063	0.00292	-0.00396	-0.00708	-0.00493	0.00079	0.00117	-0.00008	0.00059	0.0004	-0.00019	0.12781	0.12301	0.259*
	G	0.00325	0.24597	0.11492	-0.2348	0.0000	-0.12391	-0.01389	0.01249	-0.00112	0.00412	-0.0011	0.00752	-0.00065	-0.02249	-0.001	0.16742	0.16135	0.318*
LAI	P	0.00011	-0.01152	0.00786	-0.00286	0.00548	0.00095	-0.00314	-0.003	-0.00218	0.00005	0.00327	0.00005	0.00236	0.00028	0.00018	0.07422	0.03728	0.109
	G	0.01058	-0.14171	0.06376	0.01099	0.00004	0.00872	-0.0035	0.00977	-0.00074	0.00782	-0.0054	-0.00497	0.02626	-0.01665	0.0026	0.14761	0.15273	0.268*
SLW	P	0.00133	-0.04656	0.00194	0.01555	-0.00112	-0.0047	0.00118	0.00881	0.00493	-0.00035	-0.00056	-0.0002	-0.00133	-0.00035	-0.00017	-0.12553	-0.14864	-0.296*
	G	0.01653	-0.40758	0.02716	0.14859	0.0000	0.19581	0.00318	-0.01583	0.00116	-0.00567	0.00103	0.01576	-0.00214	0.01859	-0.00091	-0.18068	-0.19297	-0.378*
RWC	P	0.00103	-0.00414	0.00835	-0.00507	0.00089	0.00028	-0.0194	-0.00627	-0.00446	0.00144	0.0007	-0.00014	-0.00052	0.00038	-0.00065	0.11599	0.04064	0.129
	G	0.01473	-0.01898	0.06838	-0.0598	0.0000	-0.01143	-0.0546	0.01488	-0.00119	0.02102	-0.00101	0.01853	-0.02807	-0.02588	-0.00513	0.23391	0.14427	0.310*
50%F	P	0.00109	-0.01375	-0.00282	0.00688	-0.00064	-0.0016	0.00475	0.02559	0.01484	-0.00463	-0.00358	-0.00061	0.00056	-0.00109	0.00026	-0.21963	-0.27252	-0.467*
	G	0.0145	-0.11323	-0.02864	0.06892	-0.00001	0.07288	0.01908	-0.0425	0.00328	-0.04755	0.00371	0.05354	0.00252	0.06176	0.00167	-0.31058	-0.36656	-0.607*
75%M	P	0.00066	-0.0121	-0.00495	0.00807	-0.00079	-0.00151	0.0057	0.02502	0.01518	-0.00507	-0.00315	-0.00064	0.00088	-0.00112	0.00043	-0.21679	-0.28057	-0.471*
	G	0.00871	-0.09756	-0.04386	0.07969	-0.00001	0.06889	0.01968	-0.04226	0.0033	-0.05214	0.00376	0.05068	0.00669	0.06048	0.00273	-0.29349	-0.38128	-0.606*
PH	P	-0.00045	0.00029	-0.00259	0.00209	-0.00003	-0.00017	0.00296	0.01255	0.00814	-0.0095	-0.00206	-0.00044	0.00469	-0.00037	0	-0.09548	-0.07083	-0.151
	G	-0.00498	0.00106	-0.02329	0.0138	0.0000	0.01584	0.01636	-0.02886	0.00245	-0.0701	0.00092	0.07479	0.01698	0.03652	0.00006	-0.22972	-0.17109	-0.349*
PB	P	-0.00017	0.00541	-0.00399	0.00274	-0.00168	-0.00025	0.00127	0.00861	0.00449	-0.00183	-0.0107	0.00008	0.00065	-0.00042	-0.00025	-0.07202	-0.18385	-0.252*
	G	0.0023	0.00034	-0.05231	0.03613	-0.00003	0.02825	0.00776	-0.02216	0.00174	-0.00909	0.00712	0.03898	-0.01732	0.04211	-0.00384	-0.2675	-0.44396	-0.651*
SB	P	-0.00146	0.00779	-0.00433	0.00105	0.00014	0.00049	0.0014	-0.00794	-0.00495	0.00214	-0.00046	0.00195	0.00596	0.00048	0.00068	0.33387	0.07793	0.415*
	G	-0.02585	0.07877	-0.05536	0.01841	0.0000	-0.03216	0.01053	0.02374	-0.00174	0.05463	-0.00289	-0.096	0.00754	-0.04246	0.00629	0.56732	0.08641	0.597*
SQ	P	0.00042	-0.00248	0.00194	-0.00085	0.00076	0.00036	0.00059	0.00084	0.00078	-0.0026	-0.0004	0.00068	0.01704	0.00029	0.00047	0.27321	-0.03371	0.257*
	G	-0.00169	0.00322	-0.02674	0.00348	0.00002	-0.00961	0.03507	-0.00245	0.00051	-0.02725	-0.00282	-0.01658	0.04366	-0.02456	0.01067	0.65837	0.03918	0.682*
SSQ	P	-0.00059	0.00859	0.0048	-0.00591	0.00092	0.00098	-0.00445	-0.01671	-0.01014	0.00209	0.00266	0.00056	0.00296	0.00167	0.00057	0.37363	0.36628	0.728*
	G	-0.00865	0.07003	0.04673	-0.06463	0.00001	-0.04454	-0.01728	0.03215	-0.00244	0.03133	-0.00367	-0.04986	0.01312	-0.0817	0.00397	0.42626	0.50052	0.851*
1000-SW	P	-0.00136	0.0045	-0.0027	0.00146	0.00032	0.00025	0.00397	0.00208	0.00204	0.0000	0.00083	0.00042	0.00254	0.0003	0.00316	0.2033	0.02865	0.250*
	G	-0.01771	0.03031	-0.01583	0.01294	0.00001	-0.00989	0.01544	-0.00392	0.0005	-0.00022	-0.00151	-0.03336	0.02574	-0.01794	0.01811	0.32559	0.04576	0.374*
BY	P	-0.00099	0.0112	0.00136	-0.00448	0.00057	0.00082	-0.00317	-0.00792	-0.00464	0.00127	0.00108	0.00092	0.00656	0.00088	0.00091	0.70937	0.05789	0.772*
	G	-0.01696	0.09359	0.01618	-0.05074	0.00001	-0.04566	-0.01647	0.01705	-0.00125	0.02078	-0.00246	-0.07027	0.0371	-0.04496	0.00761	0.77473	0.15813	0.876*
HI	P	0.0006	0.00956	0.00282	-0.00481	0.00032	0.00109	-0.00124	-0.01097	-0.0067	0.00105	0.00308	0.00024	-0.0009	0.00096	0.00014	0.06457	0.63599	0.696*
	G	0.01579	0.07188	0.05232	-0.06992	0.00001	-0.06973	-0.01453	0.02878	-0.00232	0.02213	-0.00583	-0.0153	0.00316	-0.07549	0.00153	0.2261	0.54183	0.710*

*Significant at $P \leq 0.05$

4. CONCLUSION

The effectiveness of any breeding or selection programme depends upon the nature and association between yield and other component characters, as more directly and positively a character is associated with seed yield, the more will be the success of the selection programme [16]. Analysis of variance revealed significant variation for all the characters except PB, SB, SQ and HI which indicated presence of sufficient genetic variability in the present material. Phenotypic coefficients of variation were higher than their respective genotypic coefficients of variation. High PCV and GCV were observed for SLW and high heritability coupled with high genetic advance were observed for CGR, RGR, NAR, LAR, SLW, SSQ and 1000-SW. Based on both coefficient of correlation and path analysis, growth parameters like RGR, LAR, LAI, SLW, RWC and agro-morphological traits like 50%F, 75%M, PB, SB, SQ, SSQ, 1000-SW, BY and HI could be considered as indirect early selection parameters for yield improvement in *Brassica*. However, BY followed by HI had high positive direct effects on SY. Most of the traits exhibited high indirect effects *via* BY and HI under field conditions. Hence, BY and HI could be considered most important characters for improvement of SY both directly and indirectly in different *Brassica* species. Therefore, while exercising selection in rapeseed-mustard, these traits could be considered in future breeding programmes for improving seed yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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