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ESTIMATION OF VARIABILITY, CORRELATION AND PATH COEFFICIENT IN INDIAN MUSTARD (*BRASSICA JUNCEA* L. CZERN AND COSS) GENOTYPES FOR SEED YIELD AND ITS ATTRIBUTING CHARACTERS

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ABSTRACT

Variability, heritability, genetic advance, correlation and path coefficient were studied in a set of twenty-two genotypes of mustard [*Brassica juncea* (L.) Czern and Coss] grown in a randomized block design with three replications at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *rabi,* 2021-22. The highest GCV were observed for 1000 seed weight and seed yield per plant. Close PCV values to GCV values for most of the traits suggests that improvement by phenotypic selection is possible. High heritability was found for 1000 seed weight, number of branch per plant, oil content and days to maturity. The phenotypic selection would be effective for number of branch per plant and 1000 seed weight, as they expressed the high genetic advance coupled with high heritability. Seed yield per plant exhibited highly significant and positive correlations with number of branch per plant, number of siliqua on main shoot, 1000 seed weight, number of seeds per siliquae, length of siliquae at both genotypic and phenotypic levels, while highly significant and negative correlations with days to maturity at both genotypic and phenotypic levels. Path coefficient analysis revealed that highest positive direct effect on seed yield was noticed by number of seeds per siliquae followed by plant height, number of siliqua on main shoot, oil content, number of branch per plant and days to maturity, length of siliquae and 1000 seed weight. Negative direct effect on seed yield was found with days to flowering. Based on these studies, it can be advised that for improving seed yield in mustard, more emphasis should be given to 1000 seed weight, number of branches per plant, number of siliqua on main shoot, length of siliquae and number of seeds per siliquae.

Key words : Variability, Correlation, Path analysis, Indian Mustard, Seed Yield.

Introduction

Mustard is an important oilseed crop. It contributes more than 13 per cent to global production of edible oil. Seed contain 38 to 40 per cent oil and is mainly utilized for human consumption throughout Northern India for cooking as well as frying purpose. The crop commodity provides vegetable oils, which not only form an essential part of human diet but also serves as an important raw material for industrial products like soap, paints, lubricants *etc*. It is an excellent green fodder for livestock. Its oil cake is rich in protein but it has high glucosinolate per cent which is hazardous to animal health. (Nagraj, 1995). The genus *Brassica* is an important member of *Brassicaceae* family and include many crop species. *Brassica juncea* (L.) and *Brassica campestris* var. *toria*are the most commonly cultivated species of *Brassica*. Indian mustard popularly known as rai, raya or laha is one of the most important oil seed crops of the country and it occupies considerably large acreage among the *Brassica* group of oilseed crops. Indian mustard is natural amphidiploids of *Brassica campestris* (2n=20) and *Brassica nigra* (2n=16). It is predominantly self-pollinated crop. However, certain amount of cross pollination of 2 to 15 per cent may take place as a result of honey bees carrying pollen and wind. Mustard crop was introduced in India from China and it spreads to Afghanistan and other countries.

Study of variability present in the crop species is a precondition for effective selection of genotypes. Yield is a complex character which relies on many yield contributing characters which inherited quantitatively and affected by environment extremely. Genotypic and phenotypic variance, genetic gain, heritability and genetic advance are useful to decide nature of variability. Genetic advance indicates whether the traits are governed by non-additive genes or additive genes. Correlation studies provide estimates of the level of association of yield with its components and between the components. Path coefficient analysis is used when a correlation study includes number of variables. Independent variables have direct and indirect effects on the dependent variables. Correlation due to direct effect reflects true relationship and selection is practiced for such a trait for improving the yield. If the indirect effect through another component character is noticed, then select the latter character through which indirect effect is applied.

Material and Methods

Research details

The research carried out at Agronomy Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (Gujarat) during *rabi* 2021-22. The experimental materials comprised of twenty-two genotypes (22 A lines and 22 B lines) of diverse geographic and genetic origin of Indian mustard [*Brassica juncea* (L.) Czern and Coss]. These were obtained from the germplasm maintained at Center for Oilseeds Research, S. D. Agricultural University, Sardarkrushinagar. The source of these genotypes are presented in Table 1. The experiment was laid out in Randomized Block Design with three replications. Each plot consisted of single row of 4.0meter length. The inter and intra row spacing was 45 cm and 15 cm, respectively. The sowing was carried out by hand drilling. The crossing programme was carried out during *rabi* 2020-21 at Center for Oilseeds Research, S. D. Agricultural University, Sardarkrushinagar. Female sterile lines (A lines) were crossed with its maintainer lines (B line) to get seeds of female parents for evaluation in the next season and the maintainer 'B' lines were selfed to get pure seeds.

Study of traits

Five competitive plants were selected randomly from

Table 1: Details of the mustard genotypes and their origins/sources

Sr.No.	"A" LINES	CONVERTED FROM	Sr.No.	"B" LINES	CONVERTED FROM
1.	GMMo2102A	GM 1	1.	GMMo2102B	GM 1
2.	GMMo2103A	GM 2	2.	GMMo2103B	GM 2
3.	GMMo2105A	GM 3	3.	GMMo2105B	GM 3
4.	GMMo2106A	SKM 109	4.	GMMo2106B	SKM 109
5.	GMMo2108A	SKM 125	5.	GMMo2108B	SKM 125
6.	GMMo2109A	SKM 139	6.	GMMo2109B	SKM 139
7.	GMMo2111A	SKM 149	7.	GMMo2111B	SKM 149
8.	GMMo2113A	SKM 201	8.	GMMo2113B	SKM 201
9.	GMMo2114A	SKM 219	9.	GMMo2114B	SKM 219
10.	GMMo2116A	SKM 301	10.	GMMo2116B	SKM 301
11.	GMMo2118A	SKM 303	11.	GMMo2118B	SKM 303
12.	GMMo2119A	SKM 319	12.	GMMo2119B	SKM 319
13.	GMMo2121A	SKM 9928	13.	GMMo2121B	SKM 9928
14.	GMMo2122A	RSK 88	14.	GMMo2122B	RSK 88
15.	GMMo2123A	RSK 89	15.	GMMo2123B	RSK 89
16.	GMMo2124A	RSK 90	16.	GMMo2124B	RSK 90
17.	GMMo2125A	RSK 91	17.	GMMo2125B	RSK 91
18.	GMMo2127A	RSK 92	18.	GMMo2127B	RSK 92
19.	GMMo2128A	RSK 93	19.	GMMo2128B	RSK 93
20.	GMMo2129A	RSK 94	20.	GMMo2129B	RSK 94
21.	GMMo2130A	RSK 95	21.	GMMo2130B	RSK 95
22.	GMMo2131A	RSK 96	22.	GMMo2131B	RSK 96
***Source:** Center for Oilseeds Research, S. D. Agricultural University, Sardarkrushinagar – 385 506 (GUJARAT)					

Table 2: Analysis of variance for different quantitative characters in mustard

Source of variation	d.f.	DF	DM	PH	NBPP	NSMS	NSS	LS	1000SW	OC	SYP
Replications	2	1.46	0.37	21.05	0.37	11.06	1.92	0.003	0.03	0.60	0.95
Genotypes	21	7.83**	89.19**	883.48**	11.42**	30.17**	3.11**	0.21**	2.07**	2.94**	34.09**
Error	42	4.20	8.82	192.47	1.11	7.95	0.71	0.04	0.01	0.29	8.39

*, ** Significant at 5 and 1 per cent level of significance, respectively; DF: Days to flowering; DM: Days to maturity; PH: Plant height; NBPP: Number of branch per plant; NSMS: Number of siliqua on main shoot; NSS: Number of Seeds per siliquae; LS: Length of siliquae; 100SW: 1000 seed weight; OC: Oil content; SYP: Seed yield per plant

each replication. The observation was recorded for 10 characters *viz*., days to flowering, days to maturity, plant height (cm), number of branch per plant, number of siliqua on main shoot, length of siliquae (cm), number of seeds per siliquae, 1000 seed weight (g), oil content (%) and seed yield per plant (g).

Statistical analysis

Data were analysed at the Department of Agricultural Statistics. Statistical methods used for the statistical analysis were: Analysis of variance - linear additive model (Panse and Sukhatme, 1978), coefficient of genotypic variation (GCV) and phenotypic variation (PCV) [Burton, 1952], broad sense heritability (H^2b) [Allard, 1960], genetic advance (GA) and genetic advances expressed as percentage of mean [Johnson *et al*., 1955], phenotypic, genotypic and environmental correlation coefficients (Al-Jibouri*et al*., 1958), path coefficient (Dewey and Lu, 1959). Range, mean, genotypic variance, phenotypic variance and error variance were also calculated.

Results and Discussion

Analysis of variance (ANOVA)

The ANOVA revealed highly significant differences among the genotypes for all the traits (Table 2). It had proved the existence of high amount of genetic variability in the studied traits with an ample chance to identify desirable genotypes to improve various traits. Significant variation in one or more characters studied in the present investigation have also been reported by several workers *viz*., Gupta *et al*., (2019), Patel *et al*., (2021) and Kaur *et al*., (2022).

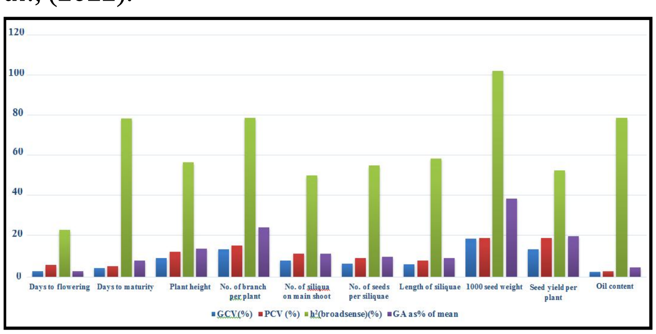

Fig. 1: Graphical representation of GCV, PCV, heritability (b.s) and genetic advance as percent of mean for ten characters in Indian mustard.

Variability

The computed data of phenotypic variance (σ^2p), genotypic variance (σ^2g), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (H^2b) and genetic advance as per cent of mean are presented in Table 3. Graph showing comparison of GCV, PCV, heritability (H^2b) and genetic advance as percentage of mean is given in Fig. 1.

The phenotypic and genotypic components of variances were calculated for all the ten characters under study are presented in Table 3. The results revealed that magnitude of phenotypic component of variance was higher than genotypic component of variance for all the characters. The highest value of σ^2g and σ^2p were found for Plant height *i.e.* (230.34 and 422.81), respectively. The lowest value of σ^2g and σ^2g were recorded for length of siliqua *i.e.* (0.06 and 0.10), which were followed by 1000 seed weight *i.e.* (0.68 and 0.70) and oil content *i.e.* (0.88 and 1.17), respectively. Thus, the result suggested that these three characters were less affected by environment as compared to other characters.

Genotypic variance was higher than environmental variance for days to maturity, plant height, number of branches per plant, siliquae length, 1000 seed weight, oil content and seed yield per plant, which indicates the reliability on phenotypic variability to measure genotypic

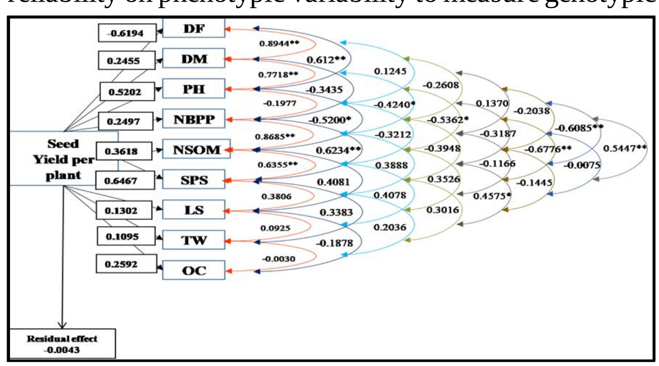

Fig. 2: Genotypic path diagram in Indian mustard. [DF=Days to flowering, DM=Days to maturity, PH=Plant height, NBPP=Number of branch per plant, NSOM=Number of siliqua on main shoot, SPS= Number of seeds per siliquae, LS =Length of siliquae, TW =1000 seed weight, OC =Oil content].

Table 3: Range, Mean, Genotypic, Phenotypic and Environmental variances, GCV, PCV, H2 (broad sense), GA and GA as percent of Mean for different quantitative characters in mustard.

Characters	Mean	Range	GV (σ^2g)	PV (σ^2p)	EV (σ^2e)	GCV (%)	PCV (%)	H2b (%)	GA	GA as % of Mean
Days to flowering	41.57	38-43.33	1.21	5.41	4.20	2.65	5.60	22.35	1.07	2.58
Days to maturity	118.90	103.33-124.73	26.79	35.61	8.83	4.35	5.02	75.22	9.25	7.78
Plant height (cm)	170.80	132.33-196.67	230.34	422.81	192.47	8.89	12.04	54.48	23.07	13.51
Number of branch per plant	14.16	9.60-17.13	3.44	4.55	1.11	13.09	15.06	75.55	3.32	23.44
Number of siliqua on main shoot	35.14	27.40-40.20	7.41	15.35	7.95	7.74	11.15	48.23	3.89	11.08
Number of seeds per siliquae	13.87	11.53-15.33	0.80	1.51	0.71	6.45	8.86	53.00	1.34	9.68
Length of siliquae (cm)	4.02	3.42-4.45	0.06	0.10	0.04	5.91	7.89	56.12	0.36	9.12
1000 seed weight (g)	4.52	3.11-5.86	0.68	0.70	0.01	18.29	18.48	97.90	1.68	37.28
Oil content (%)	37.79	35.88-39.85	0.88	1.17	0.29	2.49	2.86	75.50	1.68	4.45
Seed yield per plant(g)	22.19	15.60-28.40	8.57	16.95	8.39	13.19	18.55	50.54	4.29	19.31

GV: Genotypic variance; **PV:** Phenotypic variance; **EV:** Environmental variance

variability and for selection of these traits.

The results were in accordance for days to flowering (Akabari and Niranjana, 2015; Patel *et al.*, 2019 and Saiyad *et al.*, 2020[a]), for days to maturity (Saiyad *et al.*, 2020[a]), for plant height, number of branches per plant and seed yield per plant (Akabari and Niranjana, 2015; Patel *et al.*, 2019; Gupta *et al.*, 2019; Pandey *et al.*, 2020 and Saiyad *et al.*, 2020[a]), for siliquae length, oil content and 1000 seed weight (Akabari and Niranjana, 2015; Saiyad *et al.*, 2020[a] and Patel *et al.*, 2019).

GCV is used for measuring the range of variability available in a trait and to compares it among traits. Close PCV values to GCV values for majority traits showed possibility of improvement by phenotypic selection. Value of GCV was higher for 1000 seed weight (18.29%) and seed yield per plant (13.19%) and selection for such characters will be effective.

Moderate estimates of genotypic coefficient of variation and phenotypic coefficient of variation were observed for the characters *viz.*, number of branch per plant, seed yield per plant (g) and 1000 seed weight (g) there by effective for selection. Low estimates of GCV and PCV were observed for days to flowering, days to maturity, plant height, number of siliqua on main shoot, number of seeds per siliquae, length of siliquae, 1000 seed weight and oil content. The characters under study had the high magnitude of heritability *viz.*, days to maturity, number of branch per plant, 1000 seed weight (g) and oil content (%). While, seed yield per plant (g), plant height (cm), number of siliquae on main shoot, number of seeds per siliqua and length of siliquae had moderate heritability.

Heritability and genetic advance

Heritability point towards effectiveness with which selection of genotypes could be based on phenotypic performance. Traits showed high heritability were number of branches per plant (75.55%), 1000 seed weight (97.90%), siliquae length (56.12%), days to maturity (75.22%), seed yield per plant (50.54%) and days to flowering (22.35%). The characters are reliable for selection of genotype.

The results were in accordance with Sikarwar *et al.*, 2017; Saiyad *et al.*, 2020[a]; Gupta *et al.*, 2019; Pandey *et al.*, 2020; Bind *et al.*, 2014; Chaurasiya *et al.*, 2019; Rathod *et al.*, 2017; Malik *et al.*, 2018; Singh *et al.*, 2018a; Raliya *et al.*, 2018; Yadav and Pandey 2018; Tripathi *et al.*, 2019.

Correlation coefficient analysis

High genetic correlation indicates that the two characters could be substantially same and will produce little difference regards to environment in which selection is carried out (Falconer, 1989). On the basis of present investigation of interrelationship, it is presumed that, for improving grain yield in mustard for undertaken experimental material an ideal plant type would be a greater number of siliqua on main shoot, number of branch per plant with a medium to long siliquae and high 1000 seed weight. Hence, these characters should be used as selection criteria for improving seed yield. Hence, the correlation coefficients at genotypic and phenotypic levels were estimated between seed yield and its component traits and among the component traits (Table 4).

Days to flowering was highly significantly and positively correlated with days to maturity (r_g= 0.8944, r_p= 0.2669) and plant height (r_g= 0.6120, r_p= 0.2920) at genotypic and phenotypic level. It had highly significantly and positively correlated with oil content at genotypic level (r_g=0.5447) and non-significant and positively correlated (r_p=0.1294) at phenotypic level. Highly significant and positive association of days to flowering with plant height and days to maturity was also reported

Table 4: Genotypic and phenotypic correlation coefficients among ten quantitative characters in mustard.

Characters	(r)	DM	PH	NBPP	NSMS	NSPS	LS	100SW	OC	SYPP
Days to	**rg**	0.8944**	0.6120**	0.1245	-0.2608	0.1370	-0.2038	-0.6085**	0.5447**	-0.0081
flowering	**rp**	0.2669**	0.2920*	0.0532	-0.0655	0.1305	-0.2362	-0.2733*	0.1294	0.0325
Days to	**rg**		0.7718**	-0.3435	-0.4240*	-0.5362*	-0.3187	-0.6776**	-0.0075	-0.6105**
maturity	**rp**		0.4856**	-0.2428*	-0.2155	-0.4019**	-0.2013	-0.5989**	-0.0486	-0.4454**
Plant	**rg**			-0.1977	-0.5200*	-0.3212	-0.3948	-0.1166	-0.1445	-0.2162
height(cm)	**rp**			-0.1910	-0.1242	-0.2648*	-0.2596*	-0.0918	-0.0995	-0.1766
Number of	**rg**				0.8685**	0.6234**	0.3888	0.3526	0.4575*	0.9106**
branch per plant	**rp**				0.4913**	0.4643**	0.1454	0.2865*	0.3986**	0.5440**
Number of siliqua	**rg**					0.6355**	0.4081	0.4078	0.3016	0.9525**
on main shoot	**rp**					0.2973*	0.2064	0.2912*	0.0988	0.3851**
Number of Seeds	**rg**						0.3806	0.3383	0.2036	0.7881**
per siliquae	**rp**						0.2029	0.2771*	0.1351	0.4148**
Length of	**rg**							0.0925	-0.1878	0.4252*
siliquae (cm)	**rp**							0.0854	-0.1103	0.2639*
1000 seed	**rg**								-0.0030	0.7249**
weight(g)	**rp**								-0.0076	0.5265**
Oil	**rg**									0.1750
Content (%)	**rp**									0.1503

*, ** Significant at 5 and 1 per cent level of significance, respectively; DM: Days to maturity; PH: Plant height (cm); NBPP: Number of branch per plant; NSMS: Number of siliqua on main shoot; NSPS: Number of seeds per siliquae; LS: Length of siliquae (cm); 100SW: 1000 seed weight(g); OC: Oil content (%); SYPP: Seed yield per plant (g)

by Prasad and Patil (2018[b]), Pal *et al.,* (2019), Pandey *et al.,* (2020) and Saiyad *et al.,* (2020[b]), while the highly significant and negative association with 1000 seed weight and was also reported by Prasad and Patil (2018[b]) and Saiyad *et al.,* (2020[b]). A significant and positive correlation of number of branch per plant with number of siliqua on main shoot and seed yield per plant were also obtained by Patel *et al.,* (2019) at the genotypic level only and Saiyad *et al.,* (2020[b]) reported at both genotypic and phenotypic levels. A highly significant and positive correlation of number of siliqua on main shoot with seed yield per plant was observed by Bind *et al.,* (2014), Prasad and Patil (2018[b]) and Saiyad *et al.,* (2020[b]) reported a significant and positive correlation of seeds per siliquae with length of siliquae and seed yield per plant at both the levels as observed in the present study. Singh *et al.,* (2016) reported a significant and positive correlation of length of siliquae with seed yield per plant. Seed yield per plant was highly significantly and positively correlated with number of branch per plant (r_g= 0.9106, r_p= 0.544), number of siliqua on main shoot (r_g= 0.9525, r_p= 0.3851), number of seeds per siliquae (r_g= 0.7881, r_p= 0.4148) and 1000 seed weight (r_g=0.7249, r_p= 0.5262) at both the levels. On the other hand, it was significantly and positively correlated with length of siliquae (r_g= 0.4252, r_p= 0.2639) at both the levels. It had also a highly significant and negative association with days to maturity (r_g= 0.6105, r_p= -0.4454) at both the levels. It exhibited a non-significant and positive association for oil content (r_g= 0.175, r_p= 0.1503) at both the levels. It had non significant and negative as well as a positive correlation with days to flowering (r_g= 0.0081, r_p= 0.0325) at genotypic and phenotypic levels, respectively. It was non significant and negative correlation with plant height (r_g= -0.2162, r_p= -0.1766) at both levels. A significant and positive association of seed yield per plant with number of branch per plant, number of siliqua on main shoot and number of seeds per siliquae was observed by Saiyad *et al.,* (2020[b]). Doddabhimppa *et al.,* (2009), Akabari and Niranjana (2015) and Pandey *et al.,* (2020) reported a significant and positive association of seed yield per plant with number of siliqua per plant. Doddabhimppa *et al.,* (2009), Lodhi *et al.,* (2014) and Prasad and Patil (2018[b]) observed positive association of seed yield per plant with seeds per siliquae.

Path Coefficient Analysis

In the selection programme, correlation study alone can serve the purpose, when a smaller number of variables are considered. However, situation becomes complex, when variables increases. For solving this complexity path analysis (Wright, 1921 and Dewey and Lu, 1959) is used to divide the correlation into indirect and direct effects, so that in selection programme, relative merits of each character are established and their number is reduced. Seed yield per plant is the result of indirect and direct effects of various yield contributing traits. Path

Table 5: Direct and indirect effects of different quantitative characters on seed yield in mustard.

Characters	DF	DM	PH	NBPP	NSMS	NSS	LS	1000SW	OC	GCSYP
Days to flowering	**-0.6194**	0.2196	0.3184	0.0311	-0.0944	0.0886	-0.0265	-0.0666	0.1412	**-0.0081**
Days to maturity	-0.5540	**0.2455**	0.4015	-0.0858	-0.1534	-0.3468	-0.0415	-0.0742	-0.0019	**-0.6105****
Plantheight(cm)	-0.3791	0.1895	**0.5202**	-0.0494	-0.1882	-0.2077	-0.0514	-0.0128	-0.0375	**-0.2162**
No. of branch per plant	-0.0771	-0.0843	-0.1028	**0.2497**	0.3142	0.4032	0.0506	0.0386	0.1186	**0.9106 ****
No. of siliqua on main shoot	0.1615	-0.1041	-0.2705	0.2169	**0.3618**	0.4110	0.0531	0.0446	0.0782	**0.9525 ****
No. of seedsper siliquae	-0.0849	-0.1316	-0.1671	0.1557	0.2299	**0.6467**	0.0495	0.0370	0.0528	**0.7881 ****
Length of siliquae (cm)	0.1263	-0.0782	-0.2054	0.0971	0.1477	0.2461	**0.1302**	0.0101	-0.0487	**0.4252 ***
1000 seedweight(g)	0.3769	-0.1664	-0.0607	0.0880	0.1475	0.2188	0.0121	**0.1095**	-0.0008	**0.7249 ****
Oil Content (%)	-0.3374	-0.0018	-0.0752	0.1142	0.1091	0.1317	-0.0245	-0.0003	**0.2592**	**0.1750**

DF: Days to flowering; DM: Days to maturity; PH: Plant height (cm); NBPP: Number of branch per plant; NSMS: Number of siliqua on main hoot; NSS: Number of seeds per siliquae; LS: Length of siliquae (cm); 1000SW: 1000seed weight (g); OC: Oil content (%); GCSYP: Genotypic Correlation with seed yield perplant(g)

coefficient analysis was carried out by considering seed yield per plant as dependent character (effect), while nine characters as independent characters (causes). Genotypic correlation coefficient of different traits with seed yield were partitioned into direct and indirect effects, to know the contribution of different traits towards seed yield. The estimates of indirect and direct effects of several quantitative characters on seed yield are given in Table 5 and Fig. 3. Direct effect of component trait on seed yield provides an idea about the reliability on indirect selection to be made through that character for yield increment. In the present study, highest positive direct effect on seed yield was noticed by number of seeds per siliquae followed by plant height, number of siliqua on main shoot, oil content, number of branch per plant, days to maturity, length of siliquae and 1000 seed weight. A positive direct effect of days to maturity on seed yield per plant was also observed by Rout *et al.*, (2018[a]). The non-significant and negative association was found between days to flowering and seed yield per plant (r_g= -0.0081). Pal *et al.*, (2019) recorded negative and negligible direct effects of this trait on seed yield per plant. The non-significant and negative association was observed between plant height and seed yield per plant (r_g= -0.2162). The direct effect of plant height was positive and high (0.5202). The indirect effect of this trait on seed yield per plant was positive. The indirect effect negative and low in magnitude for number of siliqua on main shoot (0.1882) and negative and moderate in magnitude for number of seeds per siliquae (0.2077), Rout *et al.*, (2018[a]) found a positive and negligible direct effect of plant height on seed yield per plant as observed in the present study. Rout *et al.*, (2018[a]) found a positive and moderate direct effect of number of branch per plant on seed yield per plant as observed in the present study. A positive and high direct effect of number of siliqua on main shoot on seed yield per plant was also reported by Bind *et al.*, (2014). Bind *et al.*, (2014), Ompal *et al.*, (2018) and Pal *et al.*, (2019) reported similar positive and low direct effect of 1000 seed weight on seed yield per plant. Direct effect of any component characters on seed yield per plant gave an idea about reliability of indirect selection to be made through that character to bring the improvement in yield. If both the correlation coefficient and the direct effect were high and positive, then correlation explained its true relationship and a selection for that character would be effective. If the correlation coefficient was positive but the direct effect was negative or negligible, in such relations the indirect causal factors are to be considered simultaneously for selection. When correlation coefficient was negative but the direct effect was positive and high in such cases direct selection for such traits would be practiced to reduce the undesirable direct effect.

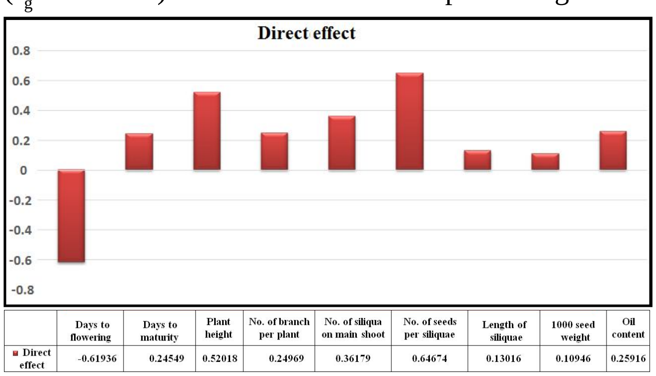

Fig. 3: Direct effect of 10 characters on grain yield per plant in 22 genotypes of Indian mustard.

Conclusion

The analysis of variance revealed that mean sum of squares due to genotypes was found significant for all the traits revealed that the genotypes under study were genetically diverse. A high degree of variability in the experimental material existed for characters like days to maturity, number of branch per plant, seed yield per plant (g), 1000 seed weight (g) and oil content (%) indicating the presence of wide variation for these characters. Based on mean performance, genotypes GMMo2116A (28.40 g), GMMo2105A (27.00 g) and GMMo2130A (27.00 g) showed their superiority for seed yield, respectively. The genotypes GMMo2114A (5.86 g), GMMo2105A (5.83 g), GMMo2116A (5.79 g), GMMo2122A (5.79 g) and GMMo2103A (5.43 g) were found bold seeded. The genotypes GMMo2118A and GMMo2108A were registered the highest oil content over the mean.

The high heritability coupled with high genetic advance was found for number of branch per plant and 1000 seed weight (g). This was due to less environmental influence and the major effect of additive genes and therefore a selection of these traits will be more effective in improvement of self pollinated crops like mustard.

Correlation studies revealed that seed yield per plant had a positive and highly significant and positive association with number of branch per plant, number of siliqua on main shoot, number of seeds per siliquae, 1000 seed weight and length of siliquae (cm) at both levels. Hence, number of branch per plant, number of siliqua on main shoot, number of seeds per siliquae, 1000 seed weight and length of siliquae (cm) should be given due consideration while selecting for increasing seed yield.

Path analysis revealed that importance of number of siliqua on main shoot, plant height and number of seeds per siliquae had high and positive direct effects towards seed yield per plant. These characters number of siliqua on main shoot and number of seeds per siliquae also exhibited highly significant and positive association at the both level with seed yield per plant.

Combined result of path analysis and correlation coefficient revealed that characters with positive correlation coefficient and positive direct effect should be selected, so that correlation explains its true relationship and a selection for these characters (number of branch per plant, number of siliqua on main shoot, number of seeds per siliquae, length of siliquae, 1000 seed weight and oil content) will become effective. While days to maturity and plant height showed negative correlation coefficient, but the direct effect is positive so direct selection should be practiced for these traits to reduce the undesirable indirect effect.

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