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Studies on correlation and path coefficient analysis for yield and yield related traits in Indian mustard (*Brassica juncea* L. Czern & Coss.) under timely and late sown conditions

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Abstract
Two sets of field experiments were conducted at Genetics and Plant Breeding Research Farm of Narendra Deva University of Agriculture and Technology Kumarganj, Faizabad (U.P.), India during *Rabi* 2014-15 with 30 diverse genotypes of Indian mustard including three checks (Kranti, Vardan and RGN-73) to assess the correlation and path coefficients for yield and yield related traits under timely (TS) and late sown (LS) conditions. The genotypes were evaluated for thirteen quantitative characters *viz.*, days to 50% flowering, days to maturity, plant height (cm), number of primary branches plant^{-1}, number of secondary branches plant^{-1}, length of main raceme (cm), silique on main raceme (cm), seeds silique^{-1}, 1000-seed weight (g), biological yield plant^{-1} (g), harvest index (%), oil content (%) and seed yield plant^{-1} (g). Seed yield plant^{-1} showed highly significant and positive association with biological yield plant^{-1} followed by harvest index, silique on main raceme, length of main raceme, 1000-seed weight and secondary branches plant^{-1} both, under timely and late sown conditions. On the other hand plant height possessed highly significant and positive association with seed yield plant^{-1} only under timely sown condition. Path analysis identified biological yield plant^{-1} followed by harvest index, as major direct contributors towards seed yield plant^{-1} (both under timely and late sown conditions), while plant height emerged as most important indirect yield component under timely sown condition. Secondary branches plant^{-1} (at genotypic level) and Plant height (at phenotypic level) showed maximum indirect effect on seed yield plant^{-1} *via.*, biological yield plant^{-1} under late sown condition. The characters mentioned above should be given due consideration at the time of selection to develop stable high yielding genotypes in Indian mustard to sustain the production and productivity.

Keywords: Indian mustard, correlation, path coefficient analysis

Introduction
Rapeseed-mustard is the third important oilseed crop in the world after soybean (*Glycine max*) and palm (*Elaeis guineensis* Jacq.) oil. It has 38 to 42% oil & 24% protein. Oil is used in Northern India for cooking and frying purposes. India ranks first in the world in area and production for groundnut, castor, sesame and niger while second in safflower, rapeseed-mustard and third in linseed. Planting time is the single most important variable affecting the seed yield of rapeseed and mustard. Sowing time of sarson and rai must be completed in the first fortnight of October. Yield is a complex trait and is dependent on many other ancillary characters which are mostly inherited quantitatively. The components which have positive correlation with yield can be used in the indirect selection for yield and may act as an alternate mode of selection for yield improvement. When indirect associations become complex path coefficient analysis is the most effective means to find out direct and indirect causes of association among the different variables. Path coefficient analysis (Wright, 1921) [20] can be used to discriminate between realistic (general) and inflated (environmental) correlations. Hence, the knowledge of direct and indirect effects of different components on yield of rapeseed-mustard is of prime importance in selection of high yielding genotypes and knowledge of association of various yield components associated with traits of economic importance would help suitable selection criterion which could be used in future breeding programs.

Materials and Methods
The present investigation was carried out at Research farm of Genetics and Plant Breeding, N.D. University of Agriculture and Technology, Kumarganj, Faizabad (U.P.), India during *Rabi* 2014-15. Geographically, this place is situated between 26.47°N latitude and 82.12°E

longitude and at an altitude of 113 m above mean sea level on Faizabad-Raebareli Road, about 42 km away from Faizabad city. The climate of district Faizabad is semi-arid with hot summer and cold winter. Thirty diverse genotypes of Indian mustard including three checks (Kranti, Vardan and RGN-73) were taken for study obtained from Oilseed Section of Department of Genetics & Plant Breeding, NDUA&T Campus, Kumarganj (Faizabad). These genotypes were grown under timely (TS) and late sown (LS) conditions in a Randomized Block Design using three replications each. Each plot consisted of single row of 3 meter length, spaced at 45 cm apart. The distance between plant to plant 15 cm was maintained by thinning. All the recommended cultural practices were adopted for raising a good crop. Data were recorded on five randomly selected plants from each plot for thirteen characters *viz.*, days to 50% flowering, days to maturity, plant height (cm), number of primary branches plant^{-1}, number of secondary branches plant^{-1}, length of main raceme (cm), silique on main raceme (cm), seeds silique^{-1}, 1000-seed weight (g), biological yield plant^{-1} (g), harvest index (%), oil content (%) and seed yield plant^{-1} (g), except days to 50% flowering and days to maturity where data were recorded on line basis. Data recorded on the above characters were subjected to correlation coefficient (Al-jiobouri *et al.*, 1958) and path coefficient analysis (Dewey and Lu, 1959) [5, 6].

Results and Discussion

The estimates of correlation coefficients were worked out at genotypic and phenotypic levels for all the 13 characters and have been presented in Tables 1 and 2. In general, genotypic correlations were higher than phenotypic ones in magnitude for all the characters in TS and LS.

Timely sown: Phenotypic correlations

Simple correlation coefficients computed among the thirteen characters under timely sown condition indicated that there are significant associations between the investigated traits. The strongest positive correlations were formed between biological yield plant-^{1} and seed yield plant^{-1} and between harvest index and seed yield plant^{-1}. The seed yield plant^{-1} exhibited highly significant and positive correlation with Biological yield plant^{-1} (0.6909), harvest index (0.4369), silique on main raceme (0.4244), length of main raceme (0.4031), 1000-seed weight (0.3506), secondary branches plant^{-1} (0.3200) and plant height (0.3135). Thus, these characters emerged as most important factors influencing seed yield in Indian mustard. Seed yield plant^{-1} showed non significant and positive correlation with days to maturity (0.595), seeds silique^{-1} (0.1978) and oil content (0.1028); besides, non-significant and negative correlation with days to 50% flowering (-0.1685) and primary branches plant^{-1} (-0.0874). The strong positive association of grain yield with one or more of the above traits has also been observed by previous workers (Tyagi *et al*., 1996; Choudhary *et al*., 2003; Sirohi *et al*., 2004 and Kumar and Pandey, 2014) [19, 4, 17, 8]. Days to 50% flowering showed highly significant and positive correlation with days to maturity (0.3951), silique on main raceme (0.3021) and oil content (0.4582) while highly significant and negative correlation with secondary branches plant^{-1} (-0.2892) and biological yield plant^{-1} (-0.3876). It also showed significant and positive correlation with primary branches plant^{-1} (0.2212). Days to maturity exhibited significant and positive correlation with silique on main raceme (0.2235) while highly significant and positive correlation with 1000-seed weight (0.2911). It also showed highly significant and negative correlation with secondary branches plant^{-1} (-0.2954). Plant height showed highly significant and positive correlation with length of main raceme (0.3711), 1000-seed weight (0.2726) and biological yield plant^{-1} (0.5221). It also showed significant and negative correlation with harvest index (-0.2185). Secondary branchrs plant^{-1} showed highly significant and positive correlation with biological yield plant^{-1} (0.3910) while significant and positive correlation with length of main raceme (0.2083). It also exhibited significant and negative correlation with oil content (-0.2205). Length of main raceme showed highly significant and positive correlation with silique on main raceme (0.3725) while significant and positive correlation with biological yield plant^{-1} (0.2363), harvest index (0.2187) and oil content (0.2113). Silique on main raceme showed highly significant and positive correlation with seeds silique^{-1} (0.3279) and biological yield plant^{-1} (0.2962). Test weight showed highly significant and positive correlation with biological yield plant^{-1} (0.3559). Biological yield plant^{-1} showed highly significant and negative correlation with harvest index (-0.3039) and oil content (-0.2780). Harvest index possessed highly significant and positive correlation with oil content (0.4130). These findings are broadly in agreement with some earlier reports (Tyagi *et al*., 1996; Patel *et al*., 2000; Srivastava and Singh, 2002; Mahak *et al*., 2003; Choudhary *et al*., 2003; Sirohi *et al*., 2004 and Kumar and Pandey, 2014) [19, 4, 18, 17, 8].

Late sown: Phenotypic correlations

Simple correlation coefficients computed among the thirteen characters under late sown condition indicated that there are significant associations between the investigated traits. The strongest positive correlations were observed between biological yield plant^{-1} and seed yield plant^{-1} and between plant height and biological yield plant^{-1}. The seed yield plant^{-1} exhibited highly significant and positive correlation with biological yield plant^{-1} (0.6887), harvest index (0.5323), silique on main raceme (0.3975), length of main raceme (0.3831), secondary branches plant^{-1} (0.3457) and 1000-seed weight (0.3232). Thus, these characters emerged as most important factors influencing seed yield in Indian mustard. Seed yield plant^{-1} reflected non significant and positive correlation with days to maturity (0.0251), plant height (0.1526), and seeds silique^{-1} (0.2026); besides non significant and negative correlation with days to 50% flowering (-0.1678), primary branches plant^{-1} (-0.0959) and oil content (-0.0690). The strong positive association of grain yield with one or more of the above traits has also been observed by previous workers (Tyagi *et al*., 1996; Sirohi *et al*., 2004 and Kumar and Pandey, 2014) [19, 17, 8]. Days to 50% flowering showed highly significant and positive correlation with days to maturity (0.4932), silique on main raceme (0.3536) and oil content (0.4104). It also showed highly significant and negative correlation with biological yield plant^{-1} (-0.3874) while significant and negative correlation with secondary branches plant^{-1} (-0.2417). Days to maturity showed highly significant and positive correlation with oil content (0.3140) while significant and negative correlation with secondary branches plant^{-1} (-0.2332) and seeds silique^{-1} (-0.2341). Plant height possessed highly significant and positive correlation with length of main raceme (0.2805) and biological yield plant^{-1} (0.4617). It also showed highly significant and negative correlation with harvest index (-0.3338) while significant and negative correlation with oil content (-0.2566). Primary branches plant^{-1} showed highly significant and negative correlation with oil content (-0.3184). Secondary

branches plant^{-1} showed highly significant and positive correlation with biological yield plant^{-1} (0.4046). It also exhibited significant and positive correlation with length of main raceme (0.2335) while highly significant and negative correlation with oil content (-0.3329). Length of main raceme showed highly significant and positive correlation with silique on main raceme (0.3684) while significant and positive correlation with biological yield plant^{-1} (0.2344). Silique on main raceme showed highly significant and positive correlation with seeds silique^{-1} (0.2964) and biological yield plant^{-1} (0.2883). It also showed significant and positive correlation with oil content (0.2165). Test weight exhibited significant and positive correlation with biological yield plant^{-1} (0.2496). Biological yield plant^{-1} showed highly significant and negative correlation with oil content (-0.3647). Harvest index was found to have highly significant and positive correlation with oil content (0.3071). The findings are closely in agreement with some earlier reports (Tyagi *et al*., 1996; Patel *et al*., 2000; Srivastava and Singh, 2002; Mahak *et al*., 2003; Choudhary *et al*., 2003; Sirohi *et al*., 2004 and Kumar and Pandey, 2014) [19, 18, 4, 17, 8].

Path coefficient

The genotypic and phenotypic correlation coefficients of seed yield plant^{-1} with remaining traits under study were further partitioned into direct and indirect effects using path coefficient analysis and are presented in Table 3 and 4. Path coefficient analysis under timely sown condition showed that biological yield plant^{-1} exhibited maximum direct effect (0.8077) on seed yield plant^{-1} followed by harvest index (0.6971), secondary branches plant^{-1} (0.2536), days to maturity (0.2205), oil content (0.2002), primary branches plant^{-1} (0.1777), seeds silique^{-1} (0.1283) and plant height (0.1100) at genotypic level; and at phenotypic level biological yield plant^{-1} possessed maximum direct effect (0.9692) on seed yield plant^{-1} followed by harvest index (0.6970), oil content (0.0884), primary branches plant^{-1} (0.0745), days to 50% flowering (0.0622), secondary branches plant^{-1} (0.0488) and seeds silique^{-1} (0.0183). Other traits *viz.*, length of main raceme, silique on main raceme and 1000-seed weight had negative direct effect on seed yield plant^{-1} at both genotypic and phenotypic levels. On the other hand, days to 50% flowering showed negative direct effect on seed yield plant^{-1} only at genotypic level whereas days to maturity and plant height had negative direct effect on seed yield plant^{-1} only at phenotypic level. Therefore, it is suggested that the traits which exhibited maximum direct effects on grain yield and oil content should be considered in selection programme for enhancing yield potential. Similar findings were also reported by Srivastava and Singh, 2002 [18]; Mahak *et al*., 2003; Sirohi *et al*., 2004 [17] and Kumar and Pandey, 2014 [8]. The maximum positive indirect effect on seed yield plant^{-1} *via.*, biological yield plant^{-1} was observed for plant height followed by secondary branches plant^{-1}, 1000-seed weight, silique on main raceme, length of main raceme, days to maturity and seeds silique^{-1} whereas negative indirect effect was observed for days to 50% flowering and primary branches plant^{-1} *via.*, biological yield plant^{-1} both at genotypic and phenotypic levels. Therefore, the characters exhibited positive direct effects on seed yield should be preferred while making selection for improvement of seed yield and more emphasis should be given to these traits with greater magnitude of positive direct effect than those with smaller magnitude.

Path coefficient analysis under late sown condition showed that biological yield plant^{-1} had maximum direct effect (0.7807) on seed yield plant^{-1} followed by harvest index (0.6372), secondary branches plant^{-1} (0.0926), primary branches plant^{-1} (0.0829), days to maturity (0.0688), length of main raceme (0.0573), 1000-seed weight (0.0515), seeds silique^{-1} (0.0394), oil content (0.0380), plant height (0.0165), days to 50% flowering (0.0155) and silique on main raceme (0.0009) at genotypic level and at phenotypic level biological yield plant^{-1} showed maximum direct effect (0.8044) on seed yield plant^{-1} followed by harvest index (0.6598), primary branches plant^{-1} (0.0562), 1000-seed weight (0.0540), length of main raceme (0.0536), secondary branches plant^{-1} (0.0396), days to 50% flowering (0.0284), days to maturity (0.0270), oil content (0.0224), seeds silique^{-1} (0.0218) and silique on main raceme (0.0162). Only one trait *viz.*, plant height exhibited negative direct effect on seed yield plant^{-1} only at phenotypic level. Therefore, it is suggested that the traits which exhibited maximum direct effects should be considered in selection programme for improving seed yield. Similar findings were also reported by Srivastava and Singh, 2002 [18]; Mahak *et al*., 2003; Sirohi *et al*., 2004 [17] and Kumar and Pandey, 2014 [8]. The maximum positive indirect effect on seed yield plant^{-1} *via.*, biological yield plant^{-1} was observed for secondary branches plant^{-1} followed by plant height, silique on main raceme, 1000-seed weight, length of main raceme and seeds silique^{-1} at genotypic level; and at phenotypic level the maximum positive indirect effect on seed yield plant^{-1} *via*., biological yield plant^{-1} was observed for plant height followed by secondary branches plant^{-1}, silique on main raceme, 1000-seed weight, length of main raceme and seeds silique^{-1}, whereas negative indirect effect was observed for days to 50% flowering, days to maturity and primary branches plant^{-1} via biological yield plant^{-1} both at genotypic and phenotypic levels. Therefore, the characters having positive direct effects on seed yield should be preferred while making selection for improvement of seed yield and more emphasis should be given to these traits with greater magnitude of positive direct effect than those with smaller magnitude.

Table 1: Genotypic (G) and phenotypic (P) correlation coefficients for different characters in Indian mustard under timely sown condition

Character		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Length of main raceme (cm)	Siliquae on main raceme	Seeds/ siliqua	1000-seed weight (g)	Biological yield/ plant (g)	Harvest index (%)	Oil content (%)	Correlation with Seed yield/plant (g)
Days to 50% flowering	G	1.0000	0.3785	-0.0284	0.2927	-0.4050	0.1905	0.3422	-0.1037	0.0013	-0.4273	0.2180	0.4930	-0.1890
	P	1.0000	0.3951**	-0.0068	0.2212*	-0.2892**	0.1923	0.3021**	-0.0688	0.0042	-0.3876**	0.1774	0.4582**	-0.1685
Days to maturity	G		1.0000	0.1231	-0.0284	-0.4306	-0.1007	0.2277	-0.3374	0.3505	0.1931	-0.1352	0.1062	0.0751
	P		1.0000	0.1237	-0.0026	-0.2954**	-0.0384	0.2235*	-0.1858	0.2911**	0.1803	-0.1308	0.0858	0.0595
Plant height (cm)	G			1.0000	0.0236	0.0624	0.3945	0.2241	0.1010	0.3185	0.5489	-0.2276	-0.1639	0.3500
	P			1.0000	0.0299	0.0793	0.3711**	0.1967	0.1045	0.2726**	0.5221**	-0.2185*	-0.1423	0.3135**
Primary branches/ plant	G				1.0000	-0.0769	0.0508	0.0226	-0.1937	0.0331	-0.1219	-0.0667	-0.2087	-0.0889
	P				1.0000	-0.0895	0.0562	0.0654	-0.0720	0.0408	-0.0827	-0.1038	-0.1515	-0.0874
Secondary branches/ plant	G					1.0000	0.1932	-0.0004	0.0719	0.0160	0.5012	-0.1546	-0.2993	0.4192
	P					1.0000	0.2083*	0.0375	0.0886	0.0034	0.3910**	-0.0964	-0.2205*	0.3200**
Length of main raceme (cm)	G						1.0000	0.4048	0.0847	-0.0621	0.2390	0.2864	0.2360	0.4484
	P						1.0000	0.3725**	0.0901	-0.0604	0.2363*	0.2187*	0.2113*	0.4031**
Siliquae on main raceme	G							1.0000	0.4164	0.0794	0.3283	0.2251	0.2251	0.4818
	P							1.0000	0.3279**	0.0391	0.2962**	0.1908	0.2057	0.4244**
Seeds/ siliqua	G								1.0000	0.2035	0.1453	0.1572	0.1018	0.2493
	P								1.0000	0.1482	0.1228	0.1024	0.0806	0.1978
1000-seed weight (g)	G									1.0000	0.3737	0.0411	0.1657	0.3812
	P									1.0000	0.3559**	0.0310	0.1549	0.3506**
Biological yield/ plant (g)	G										1.0000	-0.3125	-0.2962	0.7124
	P										1.0000	-0.3039**	-0.2780**	0.6909**
Harvest index (%)	G											1.0000	0.4687	0.4022
	P											1.0000	0.4130**	0.4369**
Oil content (%)	G												1.0000	0.1067
	P												1.0000	0.1028
Seed yield/plant (g)	G													1.0000
	P													1.0000

*, ** Significant at 5% and 1% probability levels, respectively

Table 2: Genotypic (G) and phenotypic (P) correlation coefficients for different characters in Indian mustard under late sown condition

Character		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Length of main raceme (cm)	Siliquae on main raceme	Seeds/ siliqua	1000-seed weight (g)	Biological yield/ plant (g)	Harvest index (%)	Oil content (%)	Correlation with Seed yield/plant (g)
Days to 50% flowering	G	**1.0000**	0.4813	-0.0170	0.1743	-0.3729	0.1524	0.4170	-0.0556	-0.0442	0.4476	0.1644	0.4648	-0.1942
	P	**1.0000**	0.4932**	-0.0050	0.1238	-0.2417*	0.1772	0.3536**	0.0725	-0.0173	-0.3874**	0.1255	0.4104**	-0.1678
Days to maturity	G		**1.0000**	-0.2119	-0.0220	-0.3306	-0.2394	0.1779	-0.2847	0.1048	-0.1221	0.1510	0.3684	0.0358
	P		**1.0000**	-0.1591	-0.0616	-0.2332*	-0.1513	0.1567	-0.2341*	0.0974	-0.0947	0.1033	0.3140**	0.0251
Plant height (cm)	G			1.0000	0.0370	-0.0003	0.3077	0.2032	0.0966	0.2166	0.4836	-0.3513	-0.2664	0.1811
	P			1.0000	0.0358	0.0258	0.2805**	0.1718	0.1256	0.1530	0.4617**	-0.3338**	-0.2566*	0.1526
Primary branches/ plant	G				1.0000	0.0180	0.0314	0.1223	-0.1595	-0.0674	-0.1004	-0.1594	-0.3808	-0.1159
	P				1.0000	-0.0186	0.0137	0.0883	-0.0357	-0.0715	-0.0688	-0.1326	-0.3184**	-0.0959
Secondary	G					1.0000	0.2155	-0.0264	0.1053	0.1524	0.4927	-0.0233	-0.4376	0.4431

branches/ plant	P					1.0000	0.2335*	0.0029	0.0905	0.1434	0.4046**	-0.0296	-0.3329**	0.3457**
Length of main raceme (cm)	G						1.0000	0.4124	0.0968	0.0233	0.2415	0.2542	-0.0307	0.4255
	P						1.0000	0.3684**	0.0808	0.0144	0.2344*	0.1935	-0.0259	0.3831**
Siliquae on main raceme	G							1.0000	0.4442	-0.1003	0.3212	0.2004	0.2066	0.4528
	P							1.0000	0.2964**	-0.0781	0.2883**	0.1617	0.2165*	0.3975**
Seeds/ siliqua	G								1.0000	0.0629	0.1917	0.1763	0.2352	0.2971
	P								1.0000	0.0017	0.1459	0.0913	0.1479	0.2026
1000-seed weight (g)	G									1.0000	0.2881	0.0697	-0.0135	0.3427
	P									1.0000	0.2496*	0.1034	-0.0035	0.3232**
Biological yield/ plant (g)	G										1.0000	-0.1942	-0.3874	0.7087
	P										1.0000	0.1982	-0.3647**	0.6887**
Harvest index (%)	G											1.0000	0.3579	0.5161
	P											1.0000	0.3071**	0.5323**
Oil content (%)	G												1.0000	-0.0734
	P												1.0000	-0.0690
Seed yield/plant (g)	G													1.0000
	P													1.0000

*,** Significant at 5% and 1% probability levels, respectively

Table 3: Direct and indirect effects for different characters on seed yield at genotypic and phenotypic levels in Indian mustard under timely sown condition

		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Length of main raceme (cm)	Siliquae on main raceme	Seeds/ siliqua	1000-seed weight (g)	Biological yield/ plant (g)	Harvest index (%)	Oil content (%)	Correlation coefficient with seed yield/plant (g)
Days to 50% flowering	G	-0.0808	0.0835	-0.0031	0.0520	-0.1027	-0.0096	-0.0203	-0.0133	-0.0002	-0.3451	0.1520	0.0987	-0.1890
	P	0.0622	-0.0088	0.0001	0.0165	-0.0141	-0.0017	-0.0099	-0.0013	-0.0001	-0.3756	0.1237	0.0405	-0.1685
Days to maturity	G	-0.0306	0.2205	0.0135	-0.0051	-0.1092	0.0051	-0.0135	-0.0433	-0.0453	0.1559	-0.0942	0.0213	0.0751
	P	0.0246	-0.0222	-0.0020	-0.0002	-0.0144	0.0003	-0.0073	-0.0034	-0.0070	0.1748	-0.0912	0.0076	0.0595
Plant height (cm)	G	0.0023	0.0271	0.1100	0.0042	0.0158	-0.0198	-0.0133	0.0130	-0.0411	0.4433	-0.1587	-0.0328	0.3500
	P	-0.0004	-0.0027	-0.0161	0.0022	0.0039	-0.0034	-0.0065	0.0019	-0.0066	0.5060	-0.1523	-0.0126	0.3135**
Primary branches/ plant	G	-0.0237	-0.0063	0.0026	0.1777	-0.0195	-0.0025	-0.0013	-0.0248	-0.0043	-0.0985	-0.0465	-0.0418	-0.0889
	P	0.0138	0.0001	-0.0005	0.0745	-0.0044	-0.0005	-0.0021	-0.0013	-0.0010	-0.0802	-0.0724	-0.0134	-0.0874
Secondary branches/ plant	G	0.0327	-0.0949	0.0069	-0.0137	0.2536	-0.0097	0.0000	0.0092	-0.0021	0.4048	-0.1077	-0.0599	0.4192
	P	-0.0180	0.0066	-0.0013	-0.0067	0.0488	-0.0019	-0.0012	0.0016	-0.0001	0.3789	-0.0672	-0.0195	0.3200**
Length of main raceme (cm)	G	-0.0154	-0.0222	0.0434	0.0090	0.0490	-0.0501	-0.0240	0.0109	0.0080	0.1930	0.1996	0.0473	0.4484
	P	0.0120	0.0009	-0.0060	0.0042	0.0102	-0.0091	-0.0122	0.0017	0.0015	0.2290	0.1524	0.0187	0.4031**
Siliquae on main raceme	G	-0.0277	0.0502	0.0246	0.0040	-0.0001	-0.0203	-0.0593	0.0534	-0.0103	0.2652	0.1569	0.0451	0.4818
	P	0.0188	-0.0050	-0.0032	0.0049	0.0018	-0.0034	-0.0328	0.0060	-0.0009	0.2871	0.1330	0.0182	0.4244**
Seeds/ siliqua	G	0.0084	-0.0744	0.0111	-0.0344	0.0182	-0.0042	-0.0247	0.1283	-0.0263	0.1174	0.1096	0.0204	0.2493
	P	-0.0043	0.0041	-0.0017	-0.0054	0.0043	-0.0008	-0.0108	0.0183	-0.0036	0.1190	0.0714	0.0071	0.1978
1000-seed weight (g)	G	-0.0001	0.0773	0.0350	0.0059	0.0041	0.0031	-0.0047	0.0261	-0.1291	0.3018	0.0287	0.0332	0.3812
	P	0.0003	-0.0065	-0.0044	0.0030	0.0002	0.0005	-0.0013	0.0027	-0.0242	0.3449	0.0216	0.0137	0.3506**
Biological yield/ plant (g)	G	0.0345	0.0426	0.0604	-0.0217	0.1271	-0.0120	-0.0195	0.0186	-0.0482	0.8077	-0.2179	-0.0593	0.7124
	P	-0.0241	-0.0040	-0.0084	-0.0062	0.0191	-0.0021	-0.0097	0.0022	-0.0086	0.9692	-0.2118	-0.0246	0.6909**
Harvest index (%)	G	-0.0176	-0.0298	-0.0250	-0.0119	-0.0392	-0.0144	-0.0134	0.0202	-0.0053	-0.2524	0.6971	0.0938	0.4022
	P	0.0110	0.0029	0.0035	-0.0077	-0.0047	-0.0020	-0.0063	0.0019	-0.0008	-0.2945	0.6970	0.0365	0.4369**
Oil content (%)	G	-0.0399	0.0234	-0.0180	-0.0371	-0.0759	-0.0118	-0.0134	0.0131	-0.0214	-0.2392	0.3267	0.2002	0.1067

	P	0.0285	-0.0019	0.0023	-0.0113	-0.0108	-0.0019	-0.0068	0.0015	-0.0038	-0.2694	0.2878	0.0884	0.1028

Bold figure indicates direct effect
Residual effect = 0.1741(at genotypic level), 0.2168 (at phenotypic level)
*, ** significant at 5% and 1% probability levels, respectively

Table 4: Direct and indirect effects for different characters on seed yield at genotypic and phenotypic levels in Indian mustard under late sown condition

		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Length of main raceme (cm)	Siliquae on main raceme	Seeds/ siliqua	1000-seed weight (g)	Biological yield/ plant (g)	Harvest index (%)	Oil content (%)	Correlation coefficient with seed yield/plant (g)
Days to 50% flowering	G	**0.0155**	0.0331	-0.0003	0.0145	-0.0345	0.0087	0.0004	-0.0022	-0.0023	-0.3494	0.1048	0.0176	-0.1942
	P	**0.0284**	0.0133	0.0001	0.0070	-0.0096	0.0095	0.0057	-0.0016	-0.0009	-0.3116	0.0828	0.0092	-0.1678
Days to maturity	G	0.0075	**0.0688**	-0.0035	-0.0018	-0.0306	-0.0137	0.0002	-0.0112	0.0054	-0.0953	0.0962	0.0140	0.0358
	P	0.0140	**0.0270**	0.0032	-0.0035	-0.0092	-0.0081	0.0025	-0.0051	0.0053	-0.0762	0.0681	0.0070	0.0251
Plant height (cm)	G	-0.0003	-0.0146	**0.0165**	0.0031	0.0000	0.0176	0.0002	0.0038	0.0112	0.3775	-0.2238	-0.0101	0.1811
	P	-0.0001	-0.0043	**-0.0202**	0.0020	0.0010	0.0150	0.0028	0.0027	0.0083	0.3714	-0.2203	-0.0057	0.1526
Primary branches/ plant	G	0.0027	-0.0015	0.0006	**0.0829**	0.0017	0.0018	0.0001	-0.0063	-0.0035	-0.0784	-0.1016	-0.0145	-0.1159
	P	0.0035	-0.0017	-0.0007	**0.0562**	-0.0007	0.0007	0.0014	-0.0008	-0.0039	-0.0553	-0.0875	-0.0071	-0.0959
Secondary branches/ plant	G	-0.0058	-0.0227	0.0000	0.0015	**0.0926**	0.0123	0.0000	0.0041	0.0079	0.3846	-0.0148	-0.0166	0.4431
	P	-0.0069	-0.0063	-0.0005	-0.0010	**0.0396**	0.0125	0.0000	0.0020	0.0078	0.3255	-0.0195	-0.0074	0.3457**
Length of main raceme (cm)	G	0.0024	-0.0165	0.0051	0.0026	0.0200	**0.0573**	0.0004	0.0038	0.0012	0.1885	0.1619	-0.0012	0.4255
	P	0.0050	-0.0041	-0.0057	0.0008	0.0093	**0.0536**	0.0060	0.0018	0.0008	0.1885	0.1277	-0.0006	0.3831**
Siliquae on main raceme	G	0.0065	0.0122	0.0034	0.0101	-0.0024	0.0236	**0.0009**	0.0175	-0.0052	0.2507	0.1277	0.0078	0.4528
	P	0.0100	0.0042	-0.0035	0.0050	0.0001	0.0197	**0.0162**	0.0065	-0.0042	0.2319	0.1067	0.0048	0.3975**
Seeds/ siliqua	G	-0.0009	-0.0196	0.0016	-0.0132	0.0098	0.0055	0.0004	**0.0394**	0.0032	0.1496	0.1123	0.0089	0.2971
	P	-0.0021	-0.0063	-0.0025	-0.0020	0.0036	0.0043	0.0048	**0.0218**	0.0001	0.1174	0.0603	0.0033	0.2026
1000-seed weight (g)	G	-0.0007	0.0072	0.0036	-0.0056	0.0141	0.0013	-0.0001	0.0025	**0.0515**	0.2249	0.0444	-0.0005	0.3427
	P	-0.0005	0.0026	-0.0031	-0.0040	0.0057	0.0008	-0.0013	0.0000	**0.0540**	0.2008	0.0682	-0.0001	0.3232**
Biological yield/ plant (g)	G	-0.0069	-0.0084	0.0080	-0.0083	0.0456	0.0138	0.0003	0.0075	0.0148	**0.7807**	-0.1238	-0.0147	0.7087
	P	-0.0110	-0.0026	-0.0093	-0.0039	0.0160	0.0126	0.0047	0.0032	0.0135	**0.8044**	-0.1307	-0.0082	0.6887**
Harvest index (%)	G	0.0025	0.0104	-0.0058	-0.0132	-0.0022	0.0146	0.0002	0.0069	0.0036	-0.1516	**0.6372**	0.0136	0.5161
	P	0.0036	0.0028	0.0067	-0.0075	-0.0012	0.0104	0.0026	0.0020	0.0056	-0.1594	**0.6598**	0.0069	0.5323**
Oil content (%)	G	0.0072	0.0253	-0.0044	-0.0316	-0.0405	-0.0018	0.0002	0.0093	-0.0007	-0.3024	0.2281	**0.0380**	-0.0734
	P	0.0116	0.0085	0.0052	-0.0179	-0.0132	-0.0014	0.0035	0.0032	-0.0002	-0.2934	0.2026	**0.0224**	-0.0690

Bold figure indicates direct effect
Residual effect = 0.1807 (at genotypic level), 0.2151 (at phenotypic level)
*, ** significant at 5% and 1% probability levels, respectively

Conclusion

From correlation and path analysis studies, it is concluded that the traits such as biological yield plant^{-1}, harvest index, secondary branches^{-1} silique on main raceme, length of main raceme and plant height which exhibited significant positive correlation and most of them also had either direct or indirect effects on seed yield both under timely and late sown conditions, emerged as important component contributing to seed yield plant^{-1} and the selection primarily based on these traits may result in development of high yielding genotypes.

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