

## Correlation and Path Analysis in Indian Mustard (*Brassica juncea* L. Czern and Coss) under Late Sown Condition

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**Abstract** Forty diverse genotypes of Indian mustard [*Brassica juncea* (L.) Czern & Coss] were evaluated for seed yield and its yield components (fourteen characters) under late sown condition. Both phenotypic and genotypic coefficients of variation were higher for important traits including seed yield per plant, number of pods per plant, leaf area index, secondary branches per plant and total biomass. High heritability in conjunction with high genetic advance were observed for seed yield per plant, number of pods per plant, leaf area index and secondary branches per plant suggesting predominant role of additive gene action for expression of these traits. The correlation study revealed that seed yield per plant was found to be positively and significantly correlated with pod length, number of seeds per pod and oil content while, negative significant association of seed

yield was observed with days to first flowering and total biomass. Path analysis revealed that oil content, leaf area index showed the highest positive direct effect on seed yield per plant followed by number of seeds per pod and pod length which suggested that selection oil content, leaf area index, number of seeds per pod and pod length would be quite effective in improving seed yield in late sown Indian mustard. The present study has clearly indicated the need for giving due weight age to leaf area index, number of seeds per pod and pod length for improving seed yield in Indian mustard.

**Keywords** Correlation, Path analysis, Mustard, *Brassica juncea* L.

### Introduction

The genus *Brassica* is an important member of the Cruciferae family. It comprises of several economically important species which yield edible roots, stems, leaves, buds, flowers and seed as condiment. Most of the species are used as oilseed crop and some as forage. Indian mustard (*B. juncea* L. Czern and Coss) 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 oil seed crops. India stands first both in acreage and production of rapeseed and mustard in Asia. The crops are cultivated in an area of 5,745.52 thousand ha with a production of 6796.12

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**Table 1.** Analysis of variance for fourteen quantitative characters of forty late sown mustard genotypes.

Sl. No.	Characters	Range	General mean	Treatment mean sum of square	Standard error
1.	Days to first flowering	32.67-61.67	45.97	151.09**	1.07
2.	Days to maturity	98.67-125.00	110.62	118.84**	1.33
3.	Leaf area index	0.98-2.76	1.80	0.696**	0.07
4.	Length of primary mother axis	102.52-176.77	142.20	1076.30**	3.00
5.	Primary branches/plant	4.40-8.33	6.36	2.93**	0.22
6.	Secondary branches / plant	8.07-26.87	16.90	53.33**	0.84
7.	No. of pods/plant	166.47-684.00	374.17	33180.56**	17.00
8.	Pod length (cm)	3.02-5.23	4.29	0.59**	0.16
9.	No. of seeds/pod	11.33-16.09	13.60	3.43**	0.51
10.	1000-seed weight (g)	2.43-4.16	3.34	0.32**	0.08
11.	Total biomass	12.05-31.95	22.00	72.28**	1.66
12.	Seed yield / plant	2.46-7.47	4.7	4.47**	0.27
13.	Harvest index	10.96-35.02	21.94	67.92**	1.88
14.	Oil contents	37.18-41.95	40.42	3.09**	0.02

thousand tonnes and with an average yield of 1183 kg/ha (Ministry of Agriculture, Govt. of India, 2015-2016). In India, mustard and rape seed are being grown largely in states like, Uttar Pradesh, Rajasthan, Bihar, Haryana, Assam, Gujarat, Punjab, West Bengal and Madhya Pradesh. In oiliferous (*Brassica*) dramatic transformation was attributed mainly to Indian mustard, which resulted in Rs 383 crores foreign exchange earnings in the year 1996-1997 leading to a phenomenon the yellow revolution. But still was, in terms of oilseed production, have yet to achieve self sufficiency to fulfill demands of growing population and demand supply gap. For which still we have to achieve the projected target of 8 million tons by 2000 AD and up to 14 million tons by 2020 AD from the present level of 6.10 million tons (Vision 2020-Rapeseed-Mustard). Bihar predominantly grows mustard and has tremendous potentialities to meet the future requirements. Besides normal sown-irrigated and rainfed cultivation, mustard under late sown offers great opportunity to horizontal expansion in area, which could be successfully utilized to meet states as well as our national demands. This technology has ample scope in very vast eastern and north-eastern hill region (Zone-V), comprising Odisha, WB, Bihar and North-Eastern hill states of our country where, the harvest of lowland rice in late November to December first week, approx 15 million ha of land remains available. Late sown mustard offers tremendous scope for hori-

zontal increase in area in these states and they may be able us to fulfill our demand-supply gap in the following millennium. Mustard under late sown is comparatively a new technology with Varuna, Vardan as nationally recommended varieties. But due to their low productivity, still there is need to identify new variety and sources for improvement in late sown mustard. Before embarking upon improvement and further development of any suitable genotype in this area, character association studies under rainfed situation which is in majority faced by local farmers before replacing sunflower for mustard as an alternative oilseed crop is vital with the view that it serves the purpose of understanding the yield and the relationship of its contributing traits. Further, this type of study remains worthwhile since they also provide the means of finding out the component traits of economic product and provide vital help to the breeder in various breeding programs.

#### Materials and Methods

The experiment consisting of 46 germplasm of late sown condition including two checks Varuna and Vardan of Indian mustard (*Brassica juncea* L. Czern & Coss) were grown at the research area of the Oilseeds Section, Department of Plant Breeding and Genetics, Tirhut College of Agriculture, Rajendra Agricultural University, Pusa, Samastipur (Bihar) in ran-

**Table 2.** Genotypic and phenotypic correlation coefficient between yield and its component characters in forty late sown mustard genotypes. \* Significant at  $p = 0.05$  (0.3125), \*\* Significant at  $p = 0.01$  (0.4032).

Sl. No.	Characters	Days to maturity	Leaf area index	Length of primary mother axis	Pri-ary branches/plant	Sec-ondary branches/plant	No. of pods/plant	Pod length (cm)
1.	Days to first flowering	0.8440 0.7373*	0.0285 0.0448	0.3621 0.3177*	0.0805 0.0860	0.0627 0.0746	0.0154 0.0288	-0.1071 -0.0794
2.	Days to maturity		0.1809 0.1292	0.3300 0.2354	0.1344 0.0789	0.1767 0.1302	0.0585 0.0487	0.0457 0.0427
3.	Leaf area index			0.1572 0.1627	-0.0022 0.0147	0.0239 0.0376	0.1025 0.0995	0.1079 0.0798
4.	Length of primary mother axis				-0.2323 -0.2333	-0.3931 -0.3372*	-0.2726 -0.2365	0.2832 0.2027
5.	Primary branches/plant					0.7422 0.7022**	0.6669 0.6346**	-0.0660 -0.0672
6.	Secondary branches/plant						0.7626 0.7435**	-0.1985 -0.1676
7.	No. of pods/plant							-0.2064 -0.1840
8.	Pod length (cm)							
9.	No. of seeds/pod							
10.	1000-seed weight (g)							
11.	Total biomass							
12.	Harvest index							
13.	Oil contents							

**Table 2.** Continued.

Sl. No.	Characters	No. of seeds/pod	1000-seed weight (g)	Total biomass	Har-vest index	Oil con-tents	Seed yield/plant
1.	Days to first flowering	-0.3931	0.1153	0.1115	-0.2502	-0.0962	-0.5106
		-0.2679	0.1011	0.1130	-0.2494	-0.0875	-0.3130*
2.	Days to maturity	-0.3728	0.1708	0.2731	-0.1495	0.0686	-0.2145
		-0.2336	0.1145	0.2347	0.1407	0.0750	-0.1417
3.	Leaf area index	-0.1715	0.0974	0.6080	0.0692	0.6372	0.5649
		-0.1273	0.0874	0.4500**	0.0651	0.5413**	0.1157
4.	Length of primary mother axis	-0.2989	-0.1837	0.1469	0.1736	-0.0699	-0.4471
		-0.2042	-0.1708	0.1049	0.1594	-0.0663	-0.2147
5.	Primary branches/plant	0.0834	0.4308	0.0418	-0.3165	0.0822	0.2032
		0.0436	0.3766*	0.0247	-0.2861	0.0612	0.0784
6.	Secondary branches/plant	0.1387	0.1928	0.0759	-0.1826	0.0867	0.2161
		0.1185	0.1721	0.0677	-0.1744	0.0915	0.0783
7.	No. of pods/plant	0.0839	0.1798	0.0780	0.1003	0.0897	0.2073
		0.0826	0.1603	0.0855	0.0865	0.0842	0.0530
8.	Pod length (cm)	0.2575	0.1859	0.0962	0.1964	0.2526	0.3992
		0.3370*	0.1343	0.0422	0.1611	0.1874	0.3671*
9.	No. of seeds/pod		-0.0884	-0.4193	0.0923	-0.1702	0.3888
			-0.0607	-0.2723	0.0861	-0.0971	0.3143*
10.	1000-seed weight (g)			0.3875	0.0193	0.3435	0.1874
				0.3272*	0.0163	0.3134*	0.0638

**Table 2.** Continued.

Sl. No.	Characters	No. of seeds/pod	1000-seed weight (g)	Total biomass	Harvest index	Oil contents	Seed yield/plant
11.	Total biomass				0.1631 0.1149	0.6281 0.5456**	-0.0328 -0.4269**
12.	Harvest index					0.1285 0.1152	0.0238 -0.0035
13.	Oil contents						0.7252 0.4991**

domized block design with three replications. The entries were sown in two rows each of 5.0 m length with spacing of 45 cm between rows and 15 cm between the plants. Observations were recorded on five randomly selected plants in each genotype and replication for different fourteen characters. Heritability and genetic advance as percent of mean were estimated according to the formula. The genotypic and phenotypic correlation coefficients were estimated according to the formula given earlier. The partition-

ing of genotypic correlation coefficient of traits into direct and indirect effects was carried out using the standard procedure.

### Results and Discussion

The analysis of variance revealed significant differences among the genotypes for all the fourteen characters under study (Table 1), suggested that the genotypes were genetically divergent. This indicates that

**Table 3.** Direct and indirect effect of different characters on seed yield in mustard under late sown condition. \* Significant at  $p = 0.05$  (0.3125), \*\* Significant at  $p = 0.01$  (0.4032). Residual effect (Genotypic) = 0.2369.

Sl. No.	Characters	Days to 1 <sup>st</sup> flowering	Days to maturity	Leaf area index	Length of primary mother axis	Primary branches/plant	Secondary branches/plant	No. of pods/plant
1.	Days to first flowering	<b>-0.1665</b> <b>-0.0360</b>	0.0442 0.0255	0.0148 0.0002	-0.1269 0.0165	0.0028 0.0003	0.0090 0.0041	-0.0000 0.0004
2.	Days to maturity		<b>0.0524</b> <b>0.0346</b>	0.0938 0.0005	-0.1157 -0.0100	0.0046 0.0002	0.0254 0.0072	-0.0001 0.0007
3.	Leaf area index			<b>0.5185</b> <b>0.0038</b>	-0.0551 -0.0069	-0.0001 0.0000	0.0034 0.0021	-0.0002 0.0015
4.	Length of primary mother axis				<b>-0.3505</b> <b>-0.0426</b>	-0.0080 -0.0007	-0.0566 -0.0186	0.0006 -0.0035
5.	Primary branches/plant					<b>0.0346</b> <b>0.0030</b>	0.1069 0.0388	-0.0015 0.0095
6.	Secondary branches/plant						<b>0.1440</b> <b>0.0552</b>	-0.0017 0.0111
7.	No. of pods/plant							<b>-0.0022</b> <b>0.0150</b>
8.	Pod length (cm)							
9.	No. of seeds/pod							
10.	1000-seed weight (g)							
11.	Total biomass							
12.	Harvest index							
13.	Oil contents							

Table 3. Continued.

Sl. No.	Characters	Pod length (cm)	No. of seeds/pod	1000-seed weight (g)	Total bio-mass	Harvest index	Oil contents	Seed yield/plant
1.	Days to first flowering	-0.0358	0.1040	0.0020	-0.2481	-0.0014	-0.1087	-0.5106
		-0.0029	0.0133	-0.0042	-0.2114	-0.0009	-0.0894	-0.3130*
2.	Days to maturity	0.0153	0.0987	0.0030	-0.3204	-0.0085	0.0775	-0.2145
		0.0016	0.0116	-0.0048	-0.2329	-0.0005	0.0766	-0.1399
3.	Leaf area index	0.0360	0.0454	0.0017	-0.7133	0.0039	0.7199	0.5649
		0.0029	0.0063	-0.0037	-0.4466	0.0002	0.5532	0.1157
4.	Length of primary mother axis	0.0946	0.0789	-0.0032	-0.1723	0.0099	-0.0790	-0.4471
		0.0074	0.0101	0.0072	-0.1041	0.0006	-0.0678	-0.2092
5.	Primary branches/plant	-0.0220	-0.2210	0.0075	-0.0490	-0.0180	0.0929	0.2032
		-0.0025	-0.0022	-0.0158	-0.0245	-0.0010	0.0625	0.0784
6.	Secondary branches/plant	-0.0663	-0.0367	0.0034	-0.0890	-0.0104	0.0980	0.2161
		-0.0061	-0.0059	-0.0072	-0.0672	-0.0006	0.0935	0.0782
7.	No. of pods/plant	-0.0689	-0.0222	0.0031	-0.9150	0.0057	0.1013	0.2073
		-0.0067	-0.0041	-0.0067	-0.0849	0.0003	0.0860	0.0530
8.	Pod length (cm)	<b>0.3340</b>	-0.0681	0.0032	-0.1129	0.0112	0.2854	0.3992
		<b>0.2367</b>	-0.0167	-0.0056	-0.0419	0.0006	0.1915	0.3671*
9.	No. of seeds/pod		<b>0.2646</b>	-0.0015	0.4919	0.0052	-0.1923	0.3838
			<b>0.0496</b>	0.0025	0.3703	0.0003	-0.0992	0.3143*
10.	1000-seed weight (g)			<b>0.0174</b>	-0.4546	0.0011	0.3881	0.1874
				<b>-0.0419</b>	-0.3247	0.0001	0.2934	0.0638
11.	Total biomass				<b>-1.1732</b>	0.0093	0.7096	-0.0328
					<b>-0.9925</b>	0.0004	0.5575	-0.4269**
12.	Harvest index					<b>0.0568</b>	0.1452	0.0238
						<b>0.0036</b>	0.1177	-0.0035
13.	Oil contents						<b>1.1298</b>	0.7252
							<b>1.0219</b>	0.4991**

there is ample scope for selection of promising lines from the present gene pool for yields and its components. The correlation study revealed that seed yield per plant was found to be positively and significantly correlated (Table 2) with pod length, number of seeds per pod and oil content, while negative significant association of seed yield was observed with days to first flowering and total biomass. The possible reason is that in late sown mustard increased period of flowering may simultaneously reduce the reproductive phase, ultimately resulting in lower yields. Such positive association of seed yield per plant with number of seeds per siliqua was also observed earlier [3—6] for pod length. Positive association of pod length and number of pod also reflected towards higher yields. Days to first flowering showed positive highly significant association with days to maturity and significant association with length of primary mother axis, while significant negative association with seed yield

per plant, indicating that an increase in vegetative phase results in later maturity duration adversely affecting the seed yield of such genotypes. Similar results were observed earlier [6]. Primary branches per plant was positive highly significant associated with secondary branches per plant [5, 6] and 1,000 seed weight whereas, both primary and secondary branches/plant were positively and highly significantly correlated with number of pods per plant. It is evident that an increase in total number of branches (primary +secondary) a corresponding increase in number of pods per plant is expected. Length of primary mother axis and secondary branches per plant showed negative and significant correlation while, positive and significant correlation was recorded between total biomass and 1,000 seed weight, which also exhibited positive highly significant association with leaf area index and expressed high oil content. The undesirable association of seed yield per plant

**Table 4.** Direct and indirect effect of different characters on oil content in late sown mustard. \* Significant at  $p = 0.05$  (0.3125), \*\* Significant at  $p = 0.01$  (0.4032). Residual effect (Genotypic) = 0.0400.

Sl. No.	Characters	Days to 1 <sup>st</sup> flowering	Days to maturity	Leaf area index	Length of primary mother axis	Primary branches/plant	Secondary branches/plant	No. of pods/plant
1.	Days to first flowering	<b>0.0654</b> <b>0.0210</b>	-0.0547 -0.0231	-0.0000 0.0014	0.0088 0.0092	0.0017 -0.0011	-0.0006 -0.0005	-0.0010 -0.0011
2.	Days to maturity		<b>-0.0648</b> <b>-0.0314</b>	-0.0003 0.0041	0.0080 0.0068	0.0028 -0.0010	-0.0018 -0.0008	-0.0037 -0.0018
3.	Leaf area index			<b>-0.0014</b> <b>0.0316</b>	0.0038 0.0047	-0.0000 -0.0002	-0.0002 -0.0002	-0.0065 -0.0038
4.	Length of primary mother axis				<b>0.0244</b> <b>0.0288</b>	-0.0048 0.0029	0.0040 0.0021	0.0174 0.0089
5.	Primary branches/plant					<b>0.0208</b> <b>-0.0126</b>	-0.0076 -0.0044	-0.0425 -0.0239
6.	Secondary branches/plant						<b>-0.0102</b> <b>-0.0062</b>	-0.0486 -0.0280
7.	No. of pods/plant							<b>-0.0637</b> <b>-0.0377</b>
8.	Pod length (cm)							
9.	No. of seeds/pod							
10.	1000-seed weight (g)							
11.	Total biomass							
12.	Seed yield/plant							
13.	Harvest index							

**Table 4.** Continued.

Sl. No.	Characters	Pod length (cm)	No. of seeds/pod	1000-seed weight (g)	Total biomass	Seed yield/plant	Harvest index	Oil contents
1.	Days to first flowering	0.0011 0.0013	-0.0097 0.0091	0.0028 0.0049	0.0986 0.1030	-0.2017 -0.1920	-0.0068 -0.0013	-0.0962 -0.0875
2.	Days to maturity	-0.0005 -0.0007	-0.0092 -0.0080	0.0041 0.0055	0.2416 0.2139	-0.1588 -0.1264	-0.0041 -0.0007	0.0686 0.0750
3.	Leaf area index	-0.0011 -0.0013	-0.0042 -0.0043	0.0023 0.0042	0.5379 0.4102	0.1147 0.1032	0.0019 0.0003	0.6372 0.5413**
4.	Length of primary mother axis	-0.0029 -0.0033	-0.0074 -0.0070	-0.0044 -0.0082	0.1300 0.0956	-0.2329 -0.1915	0.0047 0.0008	-0.0699 -0.0663
5.	Primary branches/plant	0.0007 0.0011	0.0021 0.0015	0.0103 0.0181	0.0370 0.0225	0.0792 0.0673	-0.0086 -0.0015	0.0822 0.0612
6.	Secondary branches/plant	0.0020 0.0027	0.0034 0.0040	0.0046 0.0083	0.0671 0.0671	0.0748 0.0698	-0.0050 -0.0009	0.0867 0.0915
7.	No. of pods/plant	0.0021 0.0030	0.0021 0.0028	0.0043 0.0077	0.0690 0.0779	0.0767 0.0473	0.0027 0.0004	0.0897 0.0842
8.	Pod length (cm)	<b>-0.0103</b> <b>-0.0163</b>	0.0063 0.0115	0.0044 0.0064	0.0851 0.0385	0.1511 0.1323	0.0053 0.0008	0.2526 0.1874
9.	No. of seeds/pod		<b>0.0247</b> <b>0.0340</b>	-0.0021 -0.0029	-0.3710 -0.2482	0.1920 0.1376	0.0025 0.0004	-0.1702 -0.0971
10.	1000-seed weight (g)			<b>0.0239</b> <b>0.0480</b>	0.3428 0.2983	-0.0070 -0.0305	0.0005 0.0001	0.3435 0.3134*

Table 4. Continued.

Sl. No.	Characters	Pod length (cm)	No. of seeds/pod	1000-seed weight (g)	Total bio-mass	Seed yield/plant	Harvest index	Oil contents
11.	Total biomass				-0.8847 <b>0.9115</b>	-0.2464 -0.3806	0.0044 0.0006	-0.06281 -0.5456**
12.	Seed yield/plant					<b>0.8274</b> <b>0.8914</b>	-0.0010 -0.0000	0.7252 0.4971**
13.	Harvest index						<b>0.0272</b> <b>0.0051</b>	0.1285 0.1152

with days to first flowering and total biomass, showed higher values for genotypic correlation coefficient than phenotypic ones. It was expressed that such type of genotypic correlation might be due to the effect of pleiotropy. In case of negative correlation caused by pleiotropy, a new combination of traits would be attained through mutagenesis. On the other hand, if the genotypic correlation is due to linkage, it may be possible to break the linkage by breeding methods as biparental mating or disruptive selection. The estimates of correlation coefficient, although, indicate inter-relationship of different traits, but it does not furnish information on cause and effect.

Under such situation path analysis helps the breeder to identify the index of selection. Oil content, leaf area index showed the highest positive direct effect on seed yield per plant (Tables 3, 4) followed by number of seeds per pod and pod length; these traits also showed positive and significant correlation with seed yield per plant. Therefore, considering these traits as selection criteria will be advantageous in bringing improvement in Indian mustard. These results are in conformity with the findings of [4—7]. However total biomass, length of primary mother axis and days to first flowering showed negative and very high direct effects with seed yield in late sown Indian mustard. The component traits having high direct effect on oil content were total biomass and seed yield. Leaf area index, which has high direct effect on seed yield, via total biomass and seed yield contributed towards high oil content. Earlier it was reported high positive direct effect of number of seeds per siliqua, 1,000 seed weight and primary branches. The high direct effect of pod length and number of seeds per pod was evi-

dent due to the maintenance of a more efficient transport of assimilates from pods to the developing seeds which reflects in high yield in late sown mustard. Since oil content was negatively correlated and had negative direct effect on seed yield per plant it implies that consideration of this trait for increasing oil content is also valuable. Thus, the material studied is of diverse nature and information emanated would help in designing the selection methodology which can further be used in the breeding program for improvement of seed yield. Days to 1<sup>st</sup> flowering exhibited negative direct effect and negative indirect effect via length of primary mother axis, via total biomass and via oil content on seed yield. In late sown mustard, delay in sowing meant that an increasingly greater part of the reproductive development phase was exposed to drought stress. Pre-anthers development also affected dry matter accumulation as a result of biomass yield. As reproductive phase is very important for yielding ability in late sown mustard, late flowering reduces seed yield, as it is evident from its negative significant correlation and high direct effect on seed yield under late sown. For improvement in yield, the emphasis must therefore be laid on early to medium flowering genotypes of Indian mustard. As total biomass reflects rate of dry matter accumulation in a growth period duration, the post-anthesis period is more important for late sown mustard, where rapid growth occurs after-anthesis considered with the drought stress ultimately reflecting high negative direct effect of biomass on seed yield. Biomass content inversely affected seed yield by reducing the oil content, pod length and days to first flowering via total biomass but seed number per pod increased via total biomass and showed positive sig-

nificant correlation with seed yield per plant. It is therefore suggested that for improvement of yield selection for earlier first flowering types in early generations will be more effective as this trait is governed by high heritability and moderate genetic advance. Selection for high biomass types will therefore result in a corresponding increase towards leaf area index, 1,000-seed weight and directly on oil content, but simultaneously reducing the yield of late sown mustard. This character requires careful consideration in crop improvement program as this character is governed by moderate heritability and moderate genetic advance. Thus indicating importance of both fixable and non-fixable genetic components. Pod length and number of seeds per pod were direct yield attributing components via biomass resulted in on reduced and increased yield, respectively.

The study further suggested that there is need for giving due weight age to leaf area index, number of seeds per pod and pod length for improving seed yield in Indian mustard. The selection for early flowering is highly effective i.e. short pre-anthesis period with normal reproductive development phase, as it has direct negative effect on yield along with nega-

tive in direct effect via pod length and number of seeds per pod on it. Leaf area index has high direct effect on seed yield and on high oil content via total biomass and seed yield. This character has additive genetic control and this fixable genetic portion may be exploited in early generation for yield as well as oil content.

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