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Analysis of path coefficient and correlation for indian mustard yield and its components (*Brassica juncea* L.)

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Abstract

The current research was conducted on fifty genotypes of *Brassica juncea* L. in order to evaluate the relationship of seed yield with its component characteristics according to the path coefficient and correlation analyses at genotypic and phenotypic levels. Genotypic correlations were found to be stronger compared to phenotypic correlations and indicated a significant effect of genetic factors in the relationships between traits. Correlation analysis indicated that branching characters, siliqua length and seed/siliqua were positively correlated with seed yield all the time, whereas delayed maturity and more siliquae/plant were undesirable. Path coefficient analysis established biological yield/plant and the harvest index as the main principal determinants of the seeds yield and other characters like siliqua length, seeds/siliqua and branching played indirectly through these important components. The research identifies that selection based on biological yield and harvest index, underpinned by principal reproductive traits, would be optimum for genetic enhancement of seed yield in Indian mustard.

***Keywords**: Biological yield, Brassica juncea* L., *correlation, harvest index, path coefficient, seed yield*

Introduction

One of India's most important oilseed crops, *Brassica juncea* (L.) Czern & Coss. contributes around one-third of the nation's total oilseed production. *Brassica* sps are the second-most important oilseed after soybean, making nearly 24% of the overall oilseed production. Indian mustard (2n=36) is a *rabi* oilseed crop that is cultivated in a variety of agro climatic settings from October to February-March. It is utilized as a green leafy vegetable and for its oil and oil meal. Rapeseed-mustard crops are grown on 35.95 million hectares worldwide, according to the DRMR, Bharatpur. India ranks second in acreage (19.81%) after Canada and fourth in output (10.37%), behind China, the EU, and Canada (Yadava *et al*., 2025). The top mustard-growing states are Rajasthan, Uttar Pradesh, Haryana, West Bengal, Madhya Pradesh, Gujarat, and Assam, accounting for 92% of total mustard production.

Enhancing seed yield is still a primary breeding goal for *B. juncea*, but yield is a complicated trait that depends on a number of interconnected factors, including plant height, the number of siliquae per plant, the number of seeds per siliqua, seed weight, and the harvest index. Since polygenic inheritance and substantial environmental interactions affect production, direct selection for yield alone is frequently futile. Therefore, creating successful selection techniques requires a grasp of the correlations between yield and its component qualities. Although correlation analysis does not differentiate between direct and indirect factors, it does provide information on the degree of relationship between yield and associated variables. This restriction is addressed by path coefficient analysis, which was first put out by Wright (1921) and divides correlations into direct and indirect effects. In order to determine which yield components, have the biggest causal impact on productivity, this method has been frequently used in mustard and other crops. The aim of the current study was to ascertain how different yield-contributing features relate to one another and how they affect Indian mustard (*Brassica juncea* L.) seed yield both directly and indirectly.

Materials and Methods

During the r*abi* season of 2022-23, the experiment was conducted in 50 genotypes at the Department of Agriculture's Research Farm at Mata Gujri College in Sri Fatehgarh Sahib, Punjab. Using a Randomized Block Design with three replications, fifty genotypes of *B. juncea* L. were planted in the field with a 45 cm row-to-row spacing and a 15 cm plant-to-plant distance. For each of the twelve traits, observations were made on five randomly chosen plants in each genotype and replication. Twelve characteristics, including days to first flowering, days to 50% flowering, number of primary and secondary branches, plant height (cm), number of siliquae/plants, number of seeds/siliquae, siliqua length (cm), days to maturity, biological yield (g), seed yield (g), and harvest index (%), were observed in five randomly selected plants. To determine the direct and indirect effects of the components on yield, as proposed by Wright (1921) and demonstrated by Dewey and Lu (1957), path analysis was conducted using the genotypic correlation coefficient, while the genotypic correlation coefficients were estimated using the formula provided by Al-Jibouri *et al.* (1958).

Statistical analysis : OPSTAT software was used to perform statistical analysis using the acquired phenotypic data.

Results and Discussion

For finding out the most important determinants influencing yield, twelve quantitative features were analysed using correlation and path coefficients at the genotypic and phenotypic levels.

Genotypic correlation studies

Genotypic correlation matrix given in Table 1 showed a highly significant positive association between seed yield per plant and some other characters such as number of secondary branches, length of siliquae, number of seeds per siliqua, and harvest index. A strong positive correlation was also found between days to first flowering and some characters like number of secondary branches (0.769**), length of siliquae (0.714**), and harvest index (0.833**), which suggests that early flowering plants tend to have better yield characters. On the other hand, seed yield showed a negative association with days to 50% flowering (-0.981**) as well as number of siliquae per plant (-0.997**), indicating that flowering delay and a high number of siliquae could negatively impact attaining a high yield. Again, biological yield showed a highly significant negative association with harvest index (-0.930**), which suggests that high overall biomass plants somehow do not optimize the conversion of their yield components into seed yield efficiently. Generally, the findings indicate that Indian mustard yield is controlled by a multifaceted interaction of traits. Branching traits, siliquae length, and seeds per siliquae were the most consistent selection indices, whereas delayed maturity and a greater number of siliquae were unfavourable. From the observations, it can be inferred that breeders should make efforts towards early- to medium-duration genotypes with good branching and effective partitioning capacity to obtain persistent improvement in mustard yield. These findings are supported by Kumar *et al.* (2019), Choubey *et al.* (2022), Gupta *et al.* (2022), and Gadi *et al.* (2025).

Table 1: Genotypic correlation analysis showing effect of twelve characters on yield components on Indian mustard (*Brassica juncea* L.)

Characters	Days of first flowering	Days of 50% flowering	Primary branches (no.)	Secondary branches (no.)	Plant height (cm)	Siliquae per plant (no.)	Siliquae length (cm)	Seeds per siliquae (no.)	Days of maturity	Biological yield/ plant (g)	Seed yield/ plant (g)	Harvest index (%)
Days to first flowering	1.000	-0.736**	0.635**	0.769**	0.259**	-0.779**	0.714**	0.758**	-0.514**	-0.770**	0.049	0.833**
Days of 50% flowering		1.000	-0.932**	-0.988**	-0.409**	1.007**	-0.976**	-0.997**	0.529**	0.920**	-0.103	-0.981**
Primary branches (no.)			1.000	0.942**	0.405**	-0.952**	0.930**	0.929**	-0.506**	-0.913**	0.145	0.908**
Secondary branches (no.)				1.000	0.460**	-1.004**	0.980**	0.987**	-0.502**	-0.917**	0.115	0.967**
Plant height (cm)					1.000	-0.415**	0.463**	0.418**	-0.026	-0.344**	0.073	0.290**
Siliquae per plant (no.)						1.000	-0.991**	-1.010**	0.534**	0.894**	-0.162*	-0.997**
Siliquae length (cm)							1.000	0.973**	-0.370**	-0.905**	0.018	0.953**
Seeds per siliquae (no.)								1.000	-0.529**	-0.929**	0.097	0.978**
Days of maturity									1.000	0.579**	-0.461**	-0.566**
Biological yield/ plant (g)										1.000	0.017	-0.930**
Seed yield/ plant (g)											1.000	0.187*
Harvest index (%)												1.000

*,** significant at 5% and 1% level

Phenotypic correlation studies

For the phenotypic level (Table 2), a similar trend was identified, although the magnitude of correlations was generally weaker than at the genotypic level, thus indicating the effect of environmental factors. The seed yield per plant showed strong positive correlations with the number of secondary branches (0.889**), length of siliquae (0.827**), and number of seeds per siliquae (0.903**). By contrast, days to first flowering had a negative correlation with days until 50% flowering (-0.683**) and number of siliquae per plant (-0.647**), which highlights that flowering earlier tends to be a feature of high-quality reproductive structures. Biological yield showed a negative correlation with the harvest index (-0.846**), which reflected the trends at the genotypic level. These results support the conclusion that, despite environmental influences on trait expression, relationships between components of yield generally remain similar, which suggests that selection according to these traits might greatly increase yield potential. Similar results were also indicated by Gangapur *et al*. (2009). Phenotypically, seed yield had significant correlation with main and lateral branches, plant height, seeds per siliquae, biological yield, and harvest index, which is in concurrence with Lyngdoh *et al*. (2017), Gupta *et al*. (2022) and Gadi *et al.* (2025).

Path analysis

Direct and indirect effects at genotypic level

Genotypic analysis of path coefficients (Table 3) provides a deeper insight into both indirect and direct effects of various traits on seed yield per plant. Biological yield per plant presented the highest positive direct effect (0.88169) on seed yield, thus confirming its position as the key contributor affecting productivity. In addition, the harvest index presented a strong direct effect (0.76949), emphasizing its contribution towards the conversion of biological yield into seed yield. Out of the other traits investigated, number of secondary branches presented a moderate direct effect (-0.27194) but showed high indirect effects through the harvest index (0.27549) as well as on biological yield (-0.33112), consequently nullifying the effect of its negative direct effect. Days to first flowering, on the other hand, showed a negative direct effect (-0.64982) and days to 50% flowering presented a similar trend (-0.61731), showing that delayed flowering negatively affects yield. Siliquae length, on the other hand, presented a contribution through indirect effects operating through biological yield and harvest index. The residual effect presented -0.02854, indicating that a high amount of variation for seed yield was explained by the investigated traits. Overall, biological yield and harvest

Table 2: Phenotypic correlation analysis showing effect of twelve characters on yield components on Indian mustard (*Brassica juncea* L.)

Characters	Days of first flowering	Days of 50% flowering	Primary branches (no.)	Secondary branches (no.)	Plant height (cm)	Siliquae per plant (no.)	Siliquae length (cm)	Seeds per siliquae (no.)	Days of maturity	Biological yield/ plant (g)	Seed yield/ plant (g)	Harvest index (%)
Days to first flowering	1.000	-0.683**	0.529**	0.694**	0.090	-0.647**	0.601**	0.694**	-0.375**	-0.653**	-0.015	0.688**
Days to 50% flowering		1.000	-0.773**	-0.974**	-0.280**	0.914**	-0.911**	-0.993**	0.468**	0.865**	-0.068	-0.902**
Primary Branches (no.)			1.000	0.802**	0.346**	-0.696**	0.788**	0.783**	-0.323**	-0.702**	0.022	0.698**
Secondary branches (no.)				1.000	0.353**	-0.892**	0.923**	0.974**	-0.423**	-0.851**	0.075	0.889**
Plant height (Cm)					1.000	-0.270**	0.376**	0.291**	-0.012	-0.228**	0.036	0.197*
Siliquae /plant (no.)						1.000	-0.843**	-0.910**	0.423**	0.817**	-0.052	-0.835**
Siliquae length (cm)							1.000	0.918**	-0.286**	-0.792**	-0.005	0.827**
Seeds/siliquae (no.)								1.000	-0.460**	-0.871**	0.058	0.903**
Days of maturity									1.000	0.510**	-0.483**	-0.477**
Biological yield/ plant (g)										1.000	0.054	-0.846**
Seed yield/ plant (g)											1.000	0.149
Harvest index (%)												1.000

*,** significant at 5% and 1% level

Table 3: Direct and indirect effect (genotypic level) of 12 components character on seed yield per plant in mustard (*Brassica juncea* L)

Characters	Days of first flowering	Days of 50% flowering	Primary branches (no.)	Secondary branches (no.)	Plant height (cm)	Siliquae per plant (no.)	Siliquae length (cm)	Seeds per siliquae (no.)	Days of maturity	Biological yield/ plant (g)	Seed yield/ plant (g)
Days to first flowering	-0.64982	0.48236	-0.0158	0.04432	0.01958	0.13056	-0.05987	-0.02497	0.03714	-0.17767	0.01426
Days to 50% flowering	-0.61731	0.50776	-0.00642	0.12712	0.02128	0.06758	-0.08636	-0.01874	0.00608	-0.22265	0.04272
Primary Branches (no.)	0.04412	-0.01401	0.23268	-0.12612	0.01888	-0.09159	-0.02758	0.02927	-0.00377	0.00517	0.00872
Secondary branches (no.)	0.10591	-0.23735	0.10791	-0.27194	0.0221	0.0515	0.0196	0.09508	0.03755	-0.33112	0.27549
Plant height (Cm)	-0.15398	0.1308	0.05317	-0.07274	0.08262	-0.13719	-0.00286	0.03849	0.03204	0.0705	0.11746
Siliquae /plant (no.)	0.22834	-0.09235	0.05736	0.03769	0.03051	-0.37156	0.08883	-0.00251	-0.00682	0.10779	0.03804
Siliquae length (cm)	-0.17426	0.1964	0.02874	0.02388	0.00106	0.14782	-0.22327	0.06367	-0.02695	0.06864	-0.22192
Seeds/siliquae (no.)	0.08153	-0.04781	0.03421	-0.12989	0.01597	0.00468	-0.07142	0.19906	0.05247	0.46217	-0.07187
Days of maturity	0.18093	-0.02313	0.00657	0.07655	-0.01984	-0.019	-0.0451	-0.07829	-0.13341	-0.03789	-0.17123
Biological yield/ plant (g)	0.13095	-0.12822	0.00136	0.10213	0.00661	-0.04542	-0.01738	0.10434	0.00573	0.88169	-0.3985
Seed yield/ plant (g)	-0.01204	0.02819	0.00264	-0.09736	0.01261	-0.01837	0.06439	-0.01859	0.02969	-0.45661	0.76949

Residual effect -0.02854; *,** significant at 5% and 1% level

index emerged as the best criteria for selection for yield improvement. These findings are in consistent with reports from previous path coefficient studies in *Brassica juncea*. Dawar *et al*. (2018), Shrivastava *et al.* (2023), Besharwal and Bhadoria (2025) validating the robustness of branching traits and harvest index as key selection criteria.

Direct and indirect effects at phenotypic level

For the phenotypic level (Table 4), the results agreed with the genotypic findings, although with smaller coefficients. The biological yield per plant had the largest significant positive direct effect (1.00591) for seed yield, followed by harvest index (0.82902). Furthermore, length of siliquae (0.10017) and number of seeds per siliquae (0.02387) had positive contributions, both direct and indirect, emphasizing their role in determining reproductive efficiency. Days to first and 50% flowering showed small negative direct effects (-0.04205 and -0.03218), confirming earlier flowering as desirable for yield. At phenotypic level, residual effect (0.16814) was relatively large, which means environmental influences impacted expression of traits. However, both biological yield and harvest index had stability as main determinants at both levels, which confirm them as reliable indices for selection for breeding programs. These findings concur with the recent reports where biological yield and harvest index were also considered to be significant yield-contributing traits in *Brassica juncea (*Dwivedi *et al.*, 2023; Arthik *et al.*, 2025). As evidenced by recent path coefficient analyses, other supporting traits such as siliquae length, number of seeds per siliquae, plant height, and branching pattern indirectly but significantly contribute to increased seed yield (Reddy *et al*., 2022; Singh *et al.*, 2025). Therefore, the ideal method for genetically improving mustard seed production would be direct selection for biological yield and harvest index combined with indirect augmentation by siliquae length and seeds/siliquae.

Pest management

During our research trial, we identified a pest infestation characterized by the presence of mustard aphids (*Lipaphis erysimi*). The cold and overcast weather conditions significantly facilitated the rapid proliferation of this pest. A substantial number of these green plant lice invaded the inflorescences and siliquae of mustard crop. These aphids extract large quantities of plant sap, resulting in severe stress to the affected plants. Consequently, the infected plants exhibit stunted growth, the siliquae become desiccated, and seed production is adversely impacted or may completely fail. To mitigate

Table 4: Direct and indirect effect (phenotypic level) of 12 components character on seed yield per plant in mustard (*Brassica juncea* L).

Characters	Days of first flowering	Days of 50% flowering	Primary branches (no.)	Secondary branches (no.)	Plant height (cm)	Siliquae per plant (no.)	Siliquae length (cm)	Seeds per siliquae (no.)	Days of maturity	Biological yield/ plant (g)	Seed yield/ plant (g)
Days to first flowering	-0.04205	0.02038	-0.00061	-0.00066	0.00276	0.00023	0.01162	-0.00213	0.00383	-0.14512	0.00796
Days to 50% flowering	-0.03218	0.02663	0.00005	-0.00048	0.0024	0.00017	0.01041	-0.00071	0.00068	-0.09	-0.05316
Primary Branches (no.)	0.00122	0.00006	0.0212	0.00376	0.00341	-0.00033	0.02967	0.00602	-0.00147	0.09472	-0.03327
Secondary branches (no.)	0.0034	-0.00157	0.00968	0.00822	0.00397	-0.00026	0.0156	0.00537	-0.00156	-0.00876	-0.01179
Plant height (Cm)	-0.00757	0.00416	0.00472	0.00213	0.01535	-0.00035	0.00924	0.00382	0.00043	0.14063	0.02081
Siliquae /plant (no.)	0.00915	-0.00437	0.00667	0.00201	0.00506	-0.00106	0.01334	0.00426	-0.00002	0.11622	0.00796
Silique length (cm)	-0.00488	0.00277	0.00628	0.00128	0.00142	-0.00014	0.10017	0.00682	-0.0039	0.19968	-0.23389
Seeds/siliquae (no.)	0.00374	-0.00079	0.00535	0.00185	0.00245	-0.00019	0.02864	0.02387	-0.0001	0.33666	-0.03982
Days of maturity	0.00657	-0.00074	0.00127	0.00052	-0.00027	0	0.01592	0.00009	-0.02452	0.03653	-0.12017
Biological yield/ plant (g)	0.00607	-0.00238	0.002	-0.00007	0.00215	-0.00012	0.01988	0.00799	-0.00089	1.00591	-0.44972
Seed yield/ plant (g)	-0.0004	-0.00171	-0.00085	-0.00012	0.00039	-0.00001	-0.02826	-0.00115	0.00355	-0.54568	0.82902

Residual effect 0.16814; *,** significant at 5% and 1% level

this issue, it is recommended to begin monitoring fields for aphid infestations starting in the first week of January. As a preventive measure, if aphids are detected, it is advisable to apply Metasystox 25 EC (oxydemeton methyl) at a concentration of 100 ml per 10 liters of water. Spraying should be made in the afternoon when the activity of pollinators is at its lowest, thereby reducing the risk to beneficial insects.

Conclusion

The findings of the present investigation indicated that harvest index and biological yield per plant had the strongest positive direct effects at both genotypic and phenotypic levels, primarily control seed output in Indian mustard. The characteristics such as branching pattern, siliquae length, and seeds per siliquae had an indirect impact on seed yield through their associations with harvest index and biological yield. However, delayed maturity and an excessive number of siliquae per plant contributed negatively, suggesting that they were not very effective for selection.

Implications for breeding

While indirect selection can focus on siliquae length, seeds per siliquae, and optimum branching, direct selection must prioritize biological yield and harvest index for ongoing genetic improvement of seed yield in Indian mustard. Breeding programs should focus on early- to medium-duration genotypes with high assimilate partitioning efficiency in order to provide greater and more reliable yield.

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