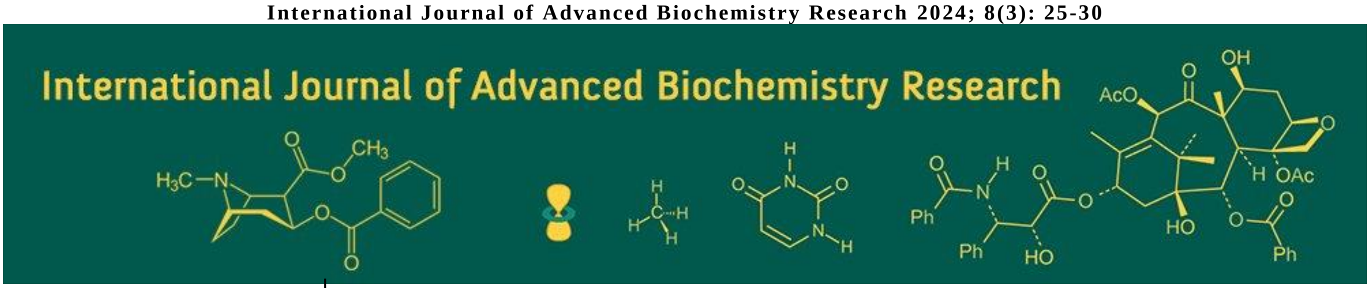

Elucidation of genetic variability and inter-relationship studies for seed yield and quality traits in advanced lines of *Mustard* spp.

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Abstract

Mustard holds significant importance as an edible oil in the region, standing out for its low levels of saturated fats compared to other oil seeds in the brassica group. It occupies a considerable area of cultivation and not only provides oil but also serves as a leafy vegetable rich in minerals, antioxidants, and flavourful condiments. A study conducted during the 2016-17 rabi season examined 64 genotypes alongside six check varieties, using an Alpha lattice design with three replications to evaluate various yield-related traits. The results revealed considerable genetic and phenotypic variation among traits such as primary branches per plant, siliqua count per plant, and grain yield per plant. Notably, traits like siliqua count per plant demonstrated high heritability (>60%) and significant genetic advances (>20%), indicating a primarily additive gene action. Examination of trait associations identified positive and significant correlations between grain yield and several yield components including plant height, shoot length, primary branches per plant, and siliqua count per plant, suggesting opportunities for concurrent improvement. Path coefficient analysis emphasized the direct and influential role of siliqua count per plant on grain yield, with the correlation coefficient between these variables closely reflecting the direct effect. This discovery highlights the prominence of enhancing grain yield by selecting for increased siliqua count per plant.

Keywords: Variability, heritability, genetic advance, correlation analysis, path analysis, mustard

Introduction

Oilseed crops play a prominent role in shaping agricultural economies, ranking as the second most important determinant following cereals. In India, mustard emerges as the second most significant oilseed crop after groundnut, contributing around 20-22% to the nation's total oilseed production. Mustard cultivation extends across more than 50 countries across Asia, Europe, America, and Australia, covering approximately 25 million hectares and yielding about 40 million tons annually. India holds a prominent position among the largest rapeseed-mustard producers globally (Duppala *et al*., 2018) [7]. Despite this, the demand for vegetable oils exceeds the available supply, leading to imports to fulfil over 50 percent of the annual requirements, fuelled by the increasing energy necessary's of the growing population. Projections suggest that by 2050, India's per capita annual requirement for vegetable oils is expected to increase to 16.7 kg, up from the current 15.9 kg (Chauhan *et al*., 2021) [3]. Conversely, the cultivated land area is decreasing rapidly, posing a significant constraint on further expansion. One approach to enhance productivity is through developing varieties with high yield potential. Yield is a crucial economic trait, influenced by various contributing factors. Additional breeding objectives aim to create new varieties with broader adaptability, early maturation, disease resistance, and increased oil content, alongside high yield potential (Nauman *et al*., 2021) [17]. Increasing yield and its elements relies on the nature and extent of genetic variability within the population. Consequently, it becomes challenging for plant breeders to directly evaluate and select for complex, polygenic traits like yield. Thus, fundamental parameters such as GCV, PCV, heritability and genetic advance serve as valuable tools in understanding the inheritance patterns of traits (Rathore *et al*., 2023) [23].

Understanding genetic correlations among different traits allows breeders to enhance selection efficiency by leveraging favourable trait combinations and mitigating the inhibitory impact of negative correlations (Snehi *et al*., 2020) [29]. Path coefficient analysis is a highly effective tool for identifying both direct and indirect causes of association among different variables. This analysis helps distinguish genuine genetic effects from exaggerated environmental correlations. Therefore, understanding the direct and indirect effects of different components on yield is crucial for selecting high-yielding genotypes. With these considerations in mind, the present study aimed to investigate genetic variability, correlation, and path analysis for yield and its contributes in Indian mustard.

Materials and Methods

The present research was carried out at the experimental farm of the Agricultural Botany Section, College of Agriculture Nagpur. Seeds of genetically pure nature, comprising 64 recombinant lines and six checks of mustard, were acquired from the mustard breeder, AICRP on rapeseed-mustard, College of Agriculture, Nagpur, during the Rabi season of 2016-17. Employing an Alpha lattice design with three replications and a spacing of 45 x 10 cm, 64 genotypes were cultivated alongside six check varieties. All recommended agricultural practices and plant protection measures were meticulously followed as per the prescribed schedule to ensure the cultivation of a healthy crop. Observations were systematically recorded on five randomly selected plants within each replication for ten yield attributing traits, including Days to 50 percent flowering, Days to maturity, Plant height (cm), Shoot length (cm), Primary branches per plant, Siliqua length (cm), Siliqua per plant, Seeds per siliqua, Test weight (g), and Grain yield per plant (g).

Genetic variability parameters, such as Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV), were calculated using the formulas outlined by Mirza *et al*. (2011). Heritability was determined following the formula provided by Allard (1960) [2], while genetic advance as a percentage of the mean was computed using the formula introduced by Johnson *et al*. (1955) [8]. Correlation coefficients were obtained using the formula described by Singh and Choudhary (1977) [27]. Path coefficient analysis, aimed at estimating both direct and indirect effects of different components on grain yield, was conducted according to the method proposed by Dewey and Lu (1959) [6]. For data visualization, the association plot was generated using R software version 1.4.1717, while SPSS16.0 software was utilized to create frequency distribution histograms for the studied traits.

Results and Discussion

The analysis of variance displayed significant disparities among all the genotypes for all examined traits, indicating substantial genetic variation within the studied genetic material. This variability likely stems from the diverse origins of the selected genotypes, developed through various breeding programs reflecting different agro-climatic conditions prevalent across the country and globally, consistent with previous studies by Chaurasiya (2019) [4] and Yadav *et al*. (2021) [31].

Table 1 presents the results concerning variability and other genetic elements for grain yield and yield constituent traits examined in this study. The widest range was observed for siliqua per plant, followed by plant height, while the narrowest range was noted for siliqua length, followed by test weight. Grain yield per plant ranged from 3.83 g to 17.57 g, with a mean of 7.63 g per plant, similar to variations reported by Ram *et al*. (2021) [22] in their research on Indian mustard.

The days to 50 percent flowering ranged from 38.33 to 66.67, while days to maturity ranged from 92.00 to 122.00, consistent with findings reported by Pawar *et al*. (2018) [21]. Plant height and shoot length varied from 109.33 cm to 176.00 cm and from 49.00 cm to 98.67 cm, respectively, with similar ranges documented by Kamdi *et al*. (2020) [9]. However, primary branches per plant and siliqua per plant ranged from 2.80 to 8.55 and from 3.33 to 5.87, respectively, with mean values of 4.25 and 4.34, respectively.

Table 1 and Figure 1 illustrate high genotypic and phenotypic coefficients of variation for primary branches per plant, number of siliqua per plant, and grain yield per plant, consistent with Pawar *et al*. (2018) [21]. Conversely, moderate genotypic and phenotypic coefficients of variation were observed for shoot length and test weight per plant, similar to Roy *et al*. (2016) [24] for shoot length and Kaur *et al*. (2022) [10] for test weight. Furthermore, low genotypic (GCV) and moderate phenotypic (PCV) coefficients of variation were noted for days to 50 percent flowering, plant height, siliqua length, and seeds per siliqua, aligning with previous studies by Patel *et al*. (2021) [20], Tantuway *et al*. (2018) [30], and Singh *et al*. (2022) [28], respectively. The results also indicated low genotypic and phenotypic coefficients of variation for days to maturity, consistent with Devi *et al*. (2018) [5].

Table 1 and Figure 1 depict high heritability (>60%) and significant genetic advance as a percentage of the mean (>20) for siliqua per plant, consistent with Pal *et al*. (2019) [18]. Conversely, high heritability accompanied with low genetic advance as percent of mean was observed for days to maturity, primary branches per plant, test weight, and grain yield per plant, similar to patterns reported by Kumar *et al*. (2019), Singh *et al*. (2022) [28], and Kumari *et al*. (2020) [13], respectively. Moderate heritability and genetic advance were noted for shoot length, whereas days to fifty percent flowering and siliqua length exhibited moderate heritability (Hb) with low genetic advance, consistent with Kumar *et al*. (2019) [12]. However, low heritability (Hb) coupled with low genetic advance (GA) as a percentage of the mean was observed for plant height and seeds per siliqua, in line with Kumar *et al*. (2018) [11]. The presence of high GCV and PCV alongside high heritability and genetic advance as a percentage of the mean for siliqua per plant suggests the predominance of additive gene action, as observed by Roy *et al*. (2018) [25], indicating that direct phenotypic selection may effectively improve these traits at initial generations.

Table 2 and Figure 2 present the findings concerning the relationships between grain yield and its component traits. Upon reviewing these results, it becomes apparent that grain yield demonstrates positive and significant associations with various yield component traits, including plant height, shoot length, primary branches per plant, and siliqua. This suggests the potential for simultaneous enhancement of these traits alongside grain yield per plant. These outcomes are consistent with previous studies by Kumari *et al*. (2020)

[13] for plant height, Patel *et al*. (2019) [19] for shoot length, and Singh *et al*. (2022) [28] for primary branches per plant and siliqua per plant.

Additionally, positive and prominent relationship were observed between days to fifty percent flowering and days to maturity, plant height, primary branches per plant, siliqua length, siliqua per plant, and seeds per siliqua; days to maturity and primary branches per plant, siliqua length, and siliqua per plant; plant height and shoot length, siliqua per plant, and test weight; primary branches per plant and siliqua length and siliqua per plant; and siliqua length and siliqua per plant, suggesting the potential for concurrent improvement of these traits. These findings are in line with reports from Sharma *et al*. (2021) [22] and Patel *et al*. (2019) [19].

Conversely, negative and substantial alliance were noted between days to fifty percent flowering and test weight; days to maturity and shoot length and test weight; shoot length and primary branches per plant; and primary branches per plant, siliqua per plant, and seeds per siliqua with test weight. These findings resemble those reported by Kumari *et al*. (2020) [13]. Such negative correlations often arise when one component gains an advantage over another, typically due to competition for shared resources like nutrient supply. Hence, a balanced selection approach is warranted to achieve simultaneous improvement in these traits, as highlighted by Manojkumar *et al*. (2022) [14].

Table 3 presents the outcomes of the path analysis investigating the influence of yield contributing traits on grain yield per plant. Upon examination of these results, it is apparent that a residual effect of 0.279 was noticed, quoting that the variables studied in this investigation accounted for approximately 72.10 percent of the variability in grain yield per plant. This suggests that factors beyond those examined in this study also contribute to grain yield per plant. A significant and highly direct positive effect was noted for siliqua per plant. The correlation coefficient between siliqua per plant and grain yield per plant nearly equals its direct effect, indicating a strong and direct relationship. This underscores the persuasiveness of direct selection based on this trait, as similarly reported by Nandi *et al*. (2021) [16].

Low direct effects (ranging from 0.10 to 0.19) were observed for plant height, while negligible effects were recorded for siliqua length, seeds per siliqua, test weight, siliqua length, and days to maturity on grain yield per plant. These results align with previous findings reported by Roy *et al*. (2018) [25] for plant height, Kumari *et al*. (2020) [13] for siliqua length and shoot length, Kaur *et al*. (2022) [10] for seeds per siliqua, Patel *et al*. (2019) [19] for test weight, and Kumar *et al*. (2018) [12] for days to maturity. Conversely, days to 50 percent flowering and primary branches per plant exhibited negligible direct effects in the negative direction, consistent with the findings reported by Kumari *et al*. (2020) [13] for primary branches per plant and Kaur *et al*. (2022) [10] for days to 50 percent flowering. Indirect effects are presumed to contribute to the correlation with grain yield per plant for all the aforementioned traits, underscoring the importance of considering indirect causal factors alongside direct traits for selection aimed at improving grain yield.

Table 1: Variability parameters in 70 genotypes of mustard studied in 2016-17

S. No.	**Character**	**Mean**	**Range**		**Coefficient of variation**		**Heritability (%)**	**Genetic advance as % of mean**
			Minimum	**Maximum**	**GCV (%)**	**PCV (%)**		
1	Days to 50 percent flowering	46.35	38.33	66.67	9.18	14.17	42.00	5.67
2	Days to maturity	100.41	92.00	122.00	4.47	5.06	78.00	8.17
3	Plant height (cm)	144.97	109.33	176.00	6.31	12.54	25.00	9.47
4	Shoot length (cm)	75.09	49.00	98.67	13.26	19.99	44.00	13.62
5	Primary branches per plant	4.25	2.80	8.55	22.56	23.44	93.00	1.90
6	Siliqua length (cm)	4.34	3.33	5.87	8.50	14.01	37.00	0.46
7	Siliqua per plant	178.40	58.31	392.16	46.79	47.35	98.00	169.95
8	Seeds per siliqua	13.90	11.33	19.33	7.30	15.32	23.00	1.00
9	1000 seed weight (g)	5.11	4.01	6.82	10.68	12.78	70.00	0.94
10	Grain yield per plant (g)	7.63	3.83	17.57	40.33	40.72	98.00	6.28

Table 2: Correlation coefficients for grain yield and yield components in advanced breeding lines during *Rabi* 2016-17

Traits	**Days to maturity**	**Plant Height**	**Shoot length**	**Primary branches per plant**	**Siliqua length**	**Siliqua per plant**	**Seeds per siliqua**	**1000 seed weight**	**Grain yield per plant**
Days to 50 percent flowering	0.508**	0.442**	-0.065	0.407**	0.221**	0.165*	0.161*	-0.206**	0.100
Days to maturity		-0.026	-0.195**	0.509**	0.333**	0.202**	0.099	-0.212**	0.109
Plant height (cm)			0.176*	0.047	0.057	0.275**	-0.083	0.159*	0.312**
Shoot length (cm)				-0.158*	0.082	0.074	0.062	0.046	0.186**
Primary branches per plant					0.266**	0.364**	0.030	-0.160*	0.240**
Siliqua length (cm)						-0.022	0.325**	-0.052	0.014
Siliqua per plant							0.036	-0.191**	0.812**
Seeds per siliqua								-0.203**	0.063
1000 seed weight (g)									-0.099

Table 3: Direct and indirect effects for yield component traits in advanced breeding lines during *Rabi* 2016-17

Traits	Days to 50 percent flowering	Days to maturity	Plant Height	Shoot length	Primary branches per plant	Siliqua length	Siliqua per plant	Seeds per siliqua	1000 seed weight	Grain yield per plant
Days to 50 percent flowering	-0.083	0.007	0.050	-0.006	-0.006	0.004	0.131	0.008	-0.005	0.100
Days to maturity	-0.042	0.014	-0.003	-0.019	-0.008	0.007	0.160	0.005	-0.005	0.109
Plant height (cm)	-0.037	0.000	0.113	0.017	-0.001	0.001	0.218	-0.004	0.004	0.312**
Shoot length (cm)	0.005	-0.003	0.020	0.096	0.002	0.002	0.059	0.003	0.001	0.186**
Primary branches per plant	-0.034	0.007	0.005	-0.015	-0.016	0.005	0.289	0.002	-0.004	0.240**
Siliqua length (cm)	-0.018	0.005	0.006	0.008	-0.004	0.020	-0.017	0.016	-0.001	0.014
Siliqua per plant	-0.014	0.003	0.031	0.007	-0.006	0.000	0.794	0.002	-0.005	0.812**
Seeds per siliqua	-0.013	0.001	-0.009	0.006	0.000	0.007	0.028	0.049	-0.005	0.063
1000 seed weight (g)	0.017	-0.003	0.018	0.004	0.003	-0.001	-0.152	-0.010	0.025	-0.099

Residual effect = 0.279; Diagonal and bold indicates the direct effects

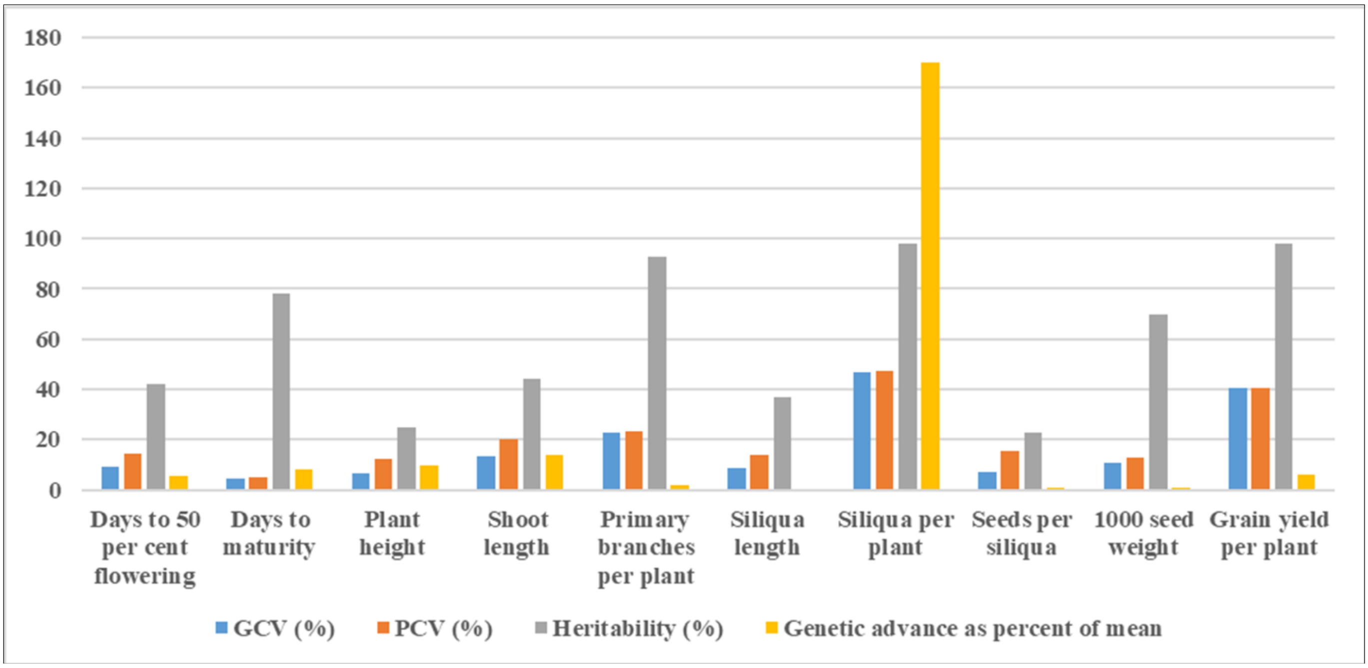

Fig 1: Genetic parameters for yield and yield components in advanced breeding lines during *Rabi* 2016-17

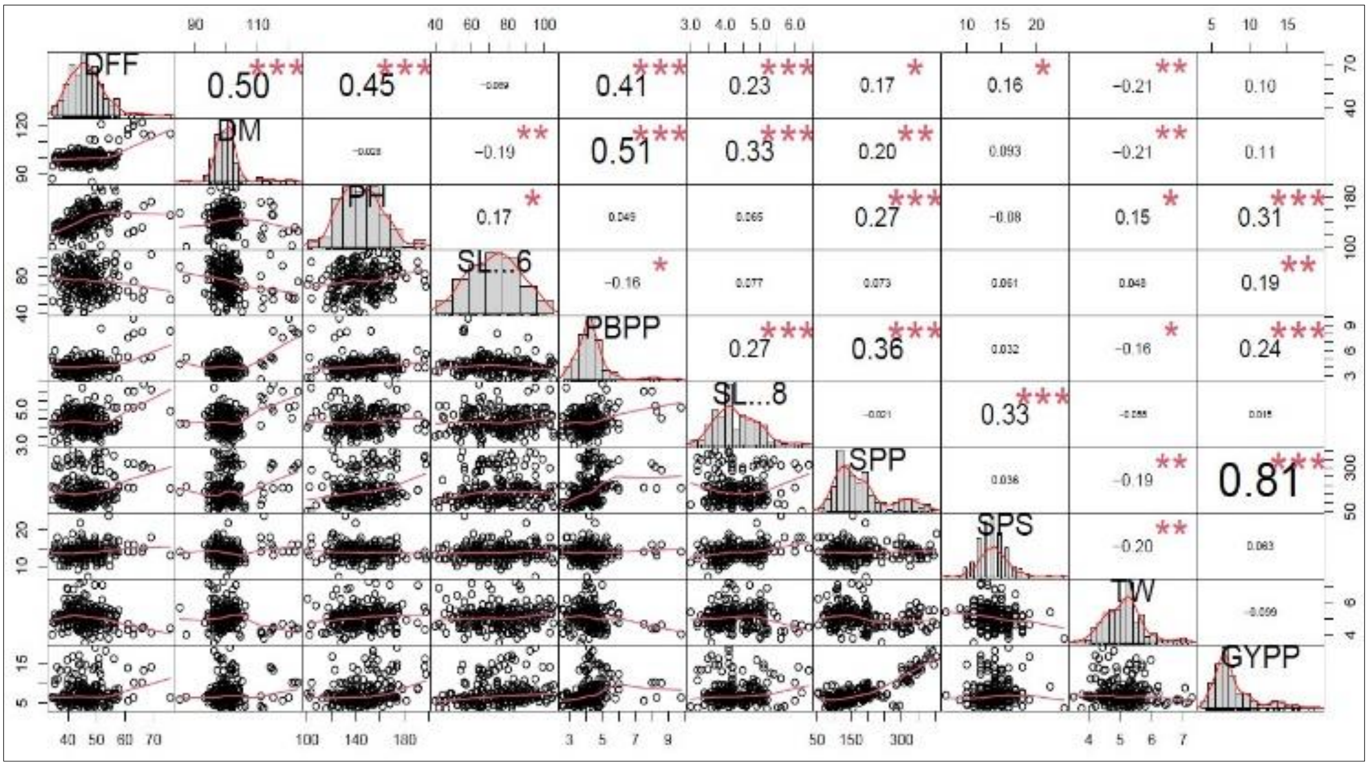

Fig 2: Correlation matrix of yield components for grain yield and yield components in in advanced breeding lines during *Rabi* 2016-17

Conclusion

The results of this study showed notable values for GCV, PCV, heritability, and genetic advance as a percentage of the mean concerning siliqua per plant. These findings emphasize the feasibility of directly selecting for the improvement of these traits. Moreover, siliqua per plant demonstrated a considerable positive direct impact, with the correlation coefficient between siliqua per plant and grain yield per plant almost mirroring its direct effect. This indicates that the correlation accurately reflects the genuine relationship, highlighting the effectiveness of directly selecting based on this trait. Consequently, siliqua per plant emerges as a promising criterion for enhancing grain yield through selection processes.

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