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Genetic studies of genetic variability and trait associations in mustard spp. (*Brassica juncea* L. & *Brassica carinata* A.)

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Abstract

Mustard is a widely cultivated oilseed crop in India, known for its high yield potential and suitability for both sole cropping and intercropping. In the rabi season of 2015-16, a study was conducted involving 64 different genotypes and six check varieties using an Alpha lattice design with three replications to assess various yield attributing traits. The findings indicated substantial genotypic and phenotypic coefficient of variation, particularly for traits such as the number of siliqua per plant and grain yield per plant. Traits like siliqua per plant and plant height showed high heritability (>60%) and significant genetic advance as a percentage of the mean (>20%), suggesting the prevalence of additive gene action. Analysis of character association revealed a positive and significant correlation between grain yield and traits like days to maturity, plant height, primary branches per plant, siliqua length, siliqua per plant, and test weight, implying the potential for simultaneous improvement of these traits alongside grain yield. Path coefficient analysis highlighted siliqua per plant as having a high direct positive effect on grain yield, with its correlation coefficient with grain yield nearly equating its direct effect. This underscores the importance of siliqua per plant as a selection criterion for enhancing mustard seed yield, suggesting a focus on this trait for further improvement.

Keywords: Correlation analysis, genetic advance, heritability, mustard, path analysis

Introduction

Oilseed crops represent the second most crucial factor in agricultural economies, second only to cereals. Mustard holds the position as the second most significant oilseed crop in India, following groundnut, contributing approximately 20-22% of the nation's total oilseed production. Its cultivation spans over 50 countries across Asia, Europe, America, and Australia, encompassing around 25 million hectares and yielding approximately 40 million tons collectively. India stands out as one of the largest producers of rapeseed-mustard globally (Rajpoot *et al.*, 2022) [15]. However, the demand for vegetable oils surpasses domestic supply, with over half of the requirement being fulfilled through imports to meet the energy needs of a growing population. Compounding this issue is the alarming decline in cultivable land, limiting opportunities for expansion. To address this, enhancing productivity through the development of high-yielding varieties becomes imperative (Gupta *et al.*, 2023) [4].

Yield, being a fundamental economic trait, results from the complex interaction of various contributing factors. Beyond mere yield enhancement, breeders aim to create varieties with broader adaptability, early maturity, disease resistance, and high oil content (Nandi *et al.*, 2021) [9]. However, improving yield and its components hinges on the extent and nature of genetic variability within the population. This complexity makes direct selection for polygenic traits like yield challenging for plant breeders (Satyanarayana *et al.*, 2023) [16]. Therefore, parameters such as genotypic and phenotypic variance, heritability, and genetic advance are crucial for understanding the inheritance patterns of traits and determining their heritability. Understanding genetic correlations between traits aids breeders in optimizing selection efficiency by identifying favourable trait combinations and mitigating negative correlations (Sharma *et al.*, 2021) [17].

Path coefficient analysis emerges as a potent tool for discerning direct and indirect causal relationships among variables, distinguishing between genuine genetic effects and environmental influences. Thus, comprehending the direct and indirect effects of various components on yield assumes paramount importance in selecting high-yielding genotypes (Duppala *et al*., 2022) [3]. In light of these considerations, the present study aims to investigate genetic variability, correlation, and path analysis concerning seed yield and its attributes in Indian mustard.

Materials and Methods

The current study was conducted at the experimental farm of the Agricultural Botany Section, College of Agriculture, Nagpur. Genetically pure seeds comprising 64 recombinant lines and six checks of mustard were obtained from the mustard breeder at AICRP on rapeseed-mustard, also located at the College of Agriculture, Nagpur, during the Rabi season of 2015-16. These genotypes were cultivated using an Alpha lattice design with three replications and a spacing of 45 x 10 cm. Standard agricultural practices and plant protection measures were implemented according to the recommended schedule to ensure optimal crop growth. Data on 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) were recorded from five randomly selected plants in each replication.

Genetic variability parameters such as Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were computed using the formulas described by Mirza *et al*. (2011) [8], while Heritability was determined using the formula provided by Allard (1960) [1], and genetic advance as a percentage of the mean was calculated using the formula from Johnson *et al*. (1955) [5]. Correlation coefficients were computed using the method outlined by Singh and Choudhary (1977) [18]. Path coefficient analysis, recommended by Dewey and Lu (1959) [2], was employed to assess the direct and indirect effects of different components on grain yield. The R software version 1.4.1717 was utilized for generating association plots, while SPSS16.0 software was used to illustrate the frequency distribution via histograms for the studied traits.

Results and Discussion

The findings regarding variability and genetic parameters for grain yield and yield component traits investigated in this study are summarized in Table 2 and depicted in Fig. 1. Analysis of the mean performance and range of yield component traits revealed the widest range for siliqua per plant, followed by plant height, while the narrowest range was observed for siliqua length, followed by test weight. Grain yield per plant varied from 0.70g to 8.53g, with a mean of 2.46g per plant. Similar variability in grain yields per plant has been previously reported by Patel *et al*. (2021) [13] in their research on Indian mustard. The duration to reach 50 percent flowering ranged from 42.00 to 68.50 days in this study, while days to maturity ranged from 87.33 to 106.00 days, consistent with findings by Yadav *et al*. (2021) [23]. Plant height and shoot length ranged from 85.10 cm to 151.24 cm (mean: 122.33 cm) and 34.00 cm to 79.67 cm (mean: 52.47 cm), respectively, aligning with earlier observations by Sur *et al*. (2023) [20].

The genotypic (GCV) and phenotypic (PCV) coefficients of variation are presented in Table 1 and Fig. 1. High genotypic and phenotypic coefficients of variation were observed for the number of siliquae per plant and grain yield per plant, consistent with the findings of Pawar *et al*. (2018) [14]. Conversely, moderate genotypic and phenotypic coefficients of variation were recorded for shoot length and primary branches per plant, similar to observations by Swetha *et al*. (2019) [21] for shoot length and Tantuway *et al*. (2018) [21] for primary branches per plant. Moderate genotypic and phenotypic coefficients of variation were also noted for days to 50 percent flowering, plant height, siliqua length, and test weight, consistent with previous studies on Indian mustard by Kumari *et al*. (2019) [6]. Additionally, low genotypic and moderate phenotypic coefficients of variation were observed for seeds per siliqua, whereas low genotypic and phenotypic coefficients of variation were recorded for days to maturity, in line with findings by Tantuway *et al*. (2018) [21] for seeds per siliqua and Pal *et al*. (2019) [11] for days to maturity.

Table 1 and Fig. 2 demonstrate a notable heritability (>60%) and significant genetic advance as a percentage of the mean (>20%) for siliqua per plant and plant height. These results align with previous findings by Devi *et al*. (2018) [24] regarding siliqua per plant and by Kumari *et al*. (2019) [6] regarding plant height. Conversely, high heritability with moderate to low genetic advance was observed for days to 50 percent flowering and days to maturity, consistent with earlier reports by Yadav *et al*. (2021) [23]. Similarly, primary branches per plant and test weight exhibited high heritability with low genetic advance, as reported by Singh *et al*. (2022) [19] for primary branches per plant and by Kumari *et al*. (2019) [6] for test weight. However, moderate heritability with low genetic advance as a percentage of the mean was noted for shoot length, siliqua length, and seeds per siliqua. These findings corroborate previous reports by Kumar *et al*. (2019) [6] for shoot length, Patel *et al*. (2019) [12] for siliqua length, and Patel *et al*. (2019) [12] for seeds per siliqua.

The combination of high Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) alongside high heritability and genetic advance as a percentage of the mean was observed for siliqua per plant. This suggests a predominance of additive gene action, implying that direct phenotypic selection could effectively improve these traits even in early generations. This finding is consistent with earlier research by Nishad *et al*. (2022) [10].

The findings regarding the associations between grain yield and its component traits are depicted in Table 2 and Fig. 3. Examination of these results revealed positive and significant correlations between grain yield and various yield component traits, including days to maturity, plant height, primary branches per plant, siliqua length, siliqua per plant, and test weight. This suggests the potential for simultaneous enhancement of these traits alongside grain yield per plant. These results align with previous studies by Patel *et al*. (2019) [12] for days to maturity, Kumari *et al*. (2019) [6] for plant height, Yadav *et al*. (2021) [23] for siliqua length, Singh *et al*. (2022) [19] for test weight, and Patel *et al*. (2021) [13] for primary branches per plant and siliqua per plant.

In addition, a negative and significant association between plant height and siliqua length was observed in the present study, consistent with the findings of Kumari *et al*. (2019) [6]. Such negative correlations typically indicate competition between components for common resources, such as nutrient supply, suggesting the need for balanced selection when simultaneously improving these traits (Manojkumar *et al*., 2022) [7].

Furthermore, positive and significant associations were noted for days to 50 percent flowering with days to maturity, siliqua length, siliqua per plant, and test weight; days to maturity with primary branches per plant, siliqua length, siliqua per plant, and test weight; plant height with primary branches per plant, siliqua per plant, and test weight; shoot length with siliqua length and siliqua per plant; primary branches per plant and siliqua with siliqua per plant and test weight; and siliqua per plant and seeds per siliqua with test weight, indicating the potential for simultaneous improvement of these traits. These findings broadly agree with reports by Chaurasiya *et al*. (2019) and Singh *et al*. (2022) [19].

The outcomes of the path analysis concerning the influence of yield component traits on grain yield per plant are summarized in Table 3 and depicted in Fig. 3. Examination of these results unveiled a residual effect of 0.1817, indicating that the variables studied in this investigation accounted for approximately 81.83 percent of the variability in grain yield per plant. This implies that other attributes, beyond those specifically studied, contribute to grain yield per plant. A notably high direct effect in a positive direction was observed for siliqua per plant, with the correlation coefficient between siliqua per plant and grain yield per plant almost equaling its direct effect. This underscores the genuine relationship between these traits, suggesting the efficacy of direct selection based on siliqua per plant, consistent with earlier findings by Patel *et al*. (2021) [13]. Conversely, low direct effects (ranging from 0.10 to 0.19) were noted for days to maturity and siliqua length, with negligible effects observed for siliqua length and test weight concerning grain yield per plant. These results align with previous research by Patel *et al*. (2021) [13] for days to maturity and Singh *et al*. (2022) [19] for plant height, siliqua length, and test weight.

Furthermore, days to 50 percent flowering exhibited a low direct effect in the negative direction, consistent with the findings of Kumari *et al*. (2019) [6]. Seeds per siliqua, siliqua length, and primary branches per plant demonstrated moderate to negligible and negative direct effects in this study. These results correspond with previous research by Singh *et al*. (2022) [19] for seeds per siliqua and Kumari *et al*. (2019) [6] for siliqua length and primary branches per plant. It is inferred that indirect effects contribute to the correlation with grain yield per plant for all the aforementioned traits, emphasizing the importance of considering indirect causal factors simultaneously when selecting traits to improve grain yield.

Table 1: Variability parameters in in advanced breeding lines of Indian mustard studied in 2015-16

S. No.	Character	Mean	Range		Coefficient of variation		Heritability (%)	Genetic advance as % of mean
			Minimum	Maximum	GCV (%)	PCV (%)		
1	Days to 50 percent flowering	48.78	42.00	68.50	10.59	10.81	96.00	10.43
2	Days to maturity	92.76	87.33	106.00	3.78	4.17	82.00	6.53
3	Plant height (cm)	122.23	85.10	151.24	11.89	13.11	82.00	27.17
4	Shoot length (cm)	52.47	34.00	79.67	13.47	20.74	42.00	9.46
5	Primary branches per plant	3.21	1.73	4.73	16.06	20.22	63.00	0.84
6	Siliqua length (cm)	3.92	2.83	5.57	12.51	16.82	55.00	0.75
7	Siliqua per plant	77.44	22.40	201.80	51.66	54.08	91.00	78.72
8	Seeds per siliqua	12.27	7.00	15.67	9.42	16.68	32.00	1.34
9	1000 seed weight (g)	3.99	2.57	5.53	16.10	18.41	76.00	1.16
10	Grain yield per plant (g)	2.46	0.70	8.53	62.50	65.39	91.00	3.03

Table 2: Correlation coefficients for grain yield and yield components in advanced breeding lines during *Rabi* 2015-16

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	0.713**	-0.090	0.087	0.050	0.221**	0.167**	0.273**	0.319**	0.132
Days to maturity		0.034	0.105	0.213**	0.303**	0.295**	0.198**	0.340**	0.325**
Plant height (cm)			0.069	0.404**	-0.176*	0.263**	0.007	0.284**	0.328**
Shoot length (cm)				0.000	0.290**	0.150*	0.029	0.050	0.103
Primary branches per plant					0.035	0.265**	0.064	0.188**	0.260**
Siliqua length (cm)						0.171*	0.034	0.145*	0.143*
Siliqua per plant							0.023	0.153*	0.769**
Seeds per siliqua								0.145*	-0.030
1000 seed weight (g)									0.248**

Table 3: Direct and indirect effects for yield component traits in advanced breeding lines during *Rabi* 2015-16

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	-0.116	0.128	-0.010	-0.002	-0.001	0.002	0.117	-0.017	0.031	0.132
Days to maturity	-0.083	0.180	0.004	-0.003	-0.004	0.003	0.206	-0.012	0.033	0.325**
Plant height (cm)	0.010	0.006	0.110	-0.002	-0.007	-0.002	0.184	0.000	0.028	0.328**
Shoot length (cm)	-0.010	0.019	0.008	-0.024	0.000	0.003	0.105	-0.002	0.005	0.103
Primary branches per plant	-0.006	0.038	0.045	0.000	-0.018	0.000	0.186	-0.004	0.019	0.260**
Siliqua length (cm)	-0.026	0.055	-0.019	-0.007	-0.001	0.010	0.119	-0.002	0.014	0.143*
Siliqua per plant	-0.019	0.053	0.029	-0.004	-0.005	0.002	0.699	-0.001	0.015	0.769**
Seeds per siliqua	-0.032	0.036	0.001	-0.001	-0.001	0.000	0.016	-0.063	0.014	-0.030
1000 seed weight (g)	-0.037	0.061	0.031	-0.001	-0.003	0.001	0.107	-0.009	0.098	0.248**

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

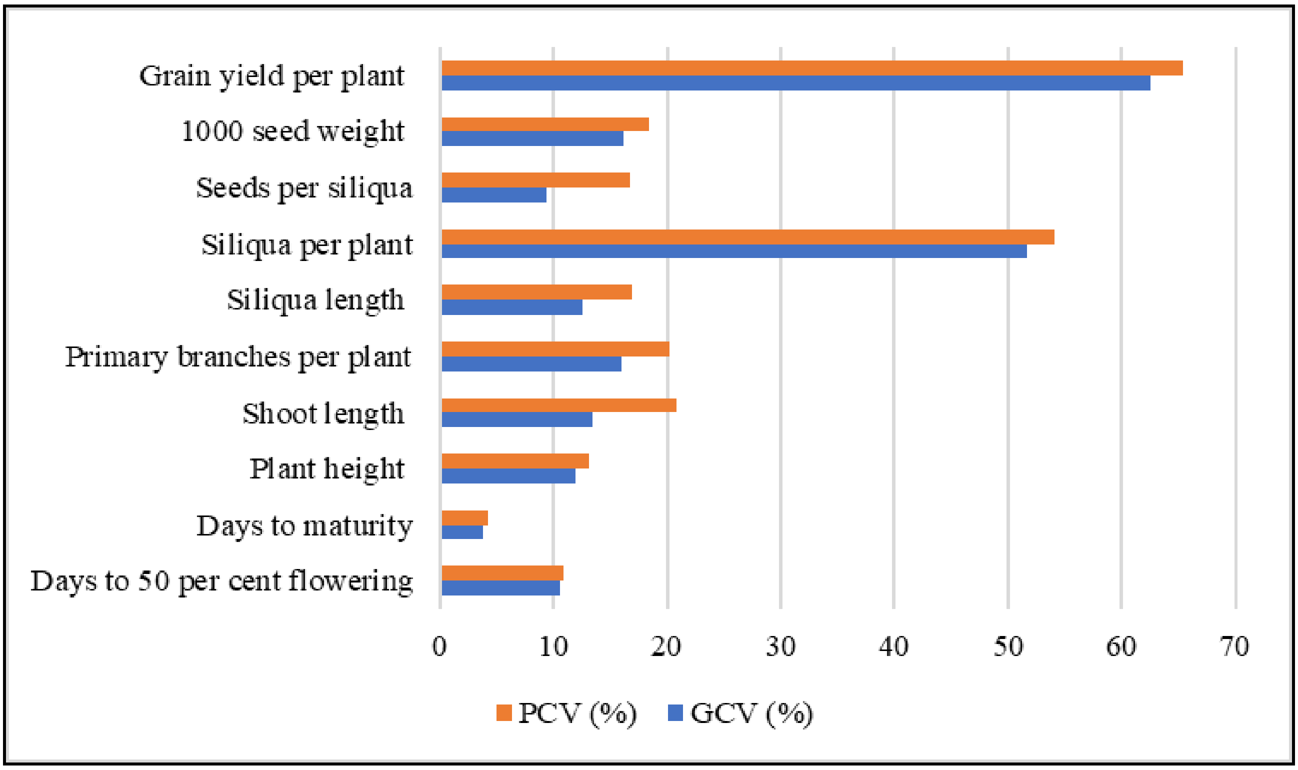

Fig 1: Genotypic and Phenotypic coefficients of variation for yield components in in advanced breeding lines during *Rabi* 201516

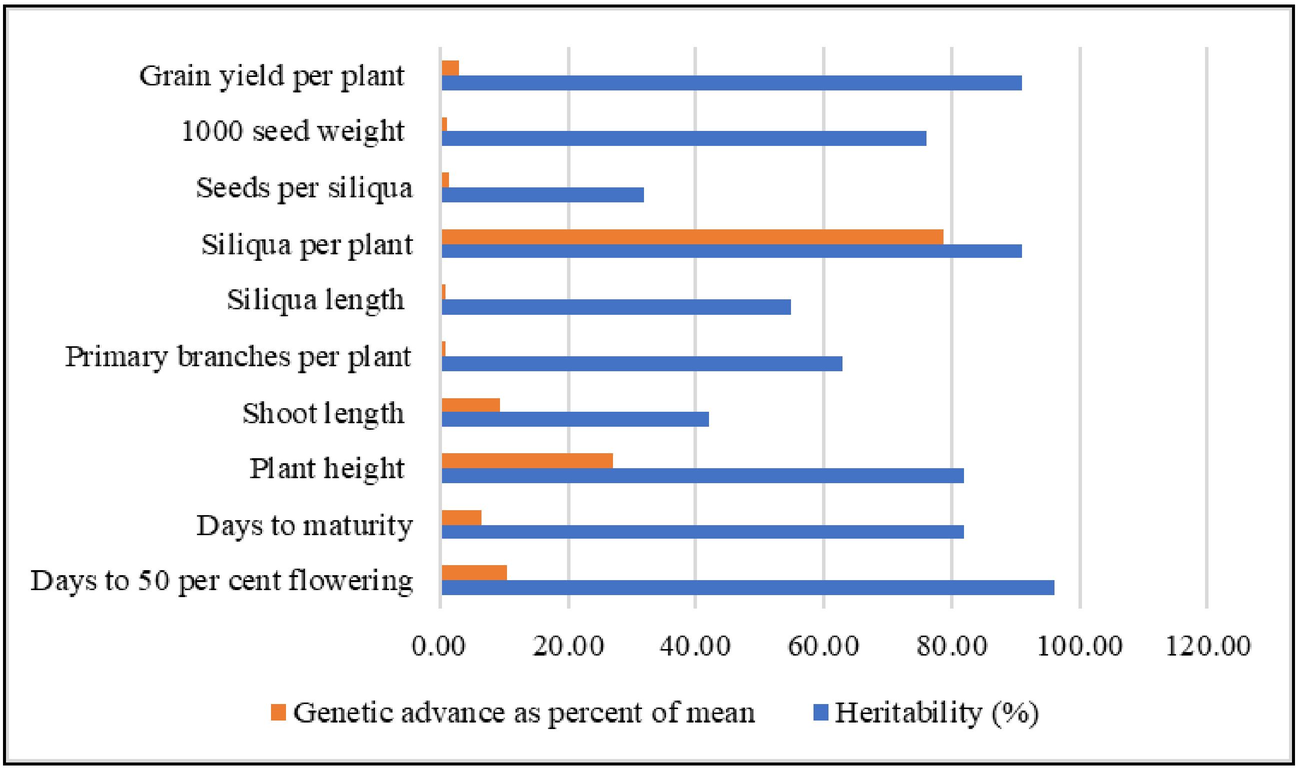

Fig 2: Heritability and genetic advance as % of mean for yield and yield component traits in advanced breeding lines during *Rabi*

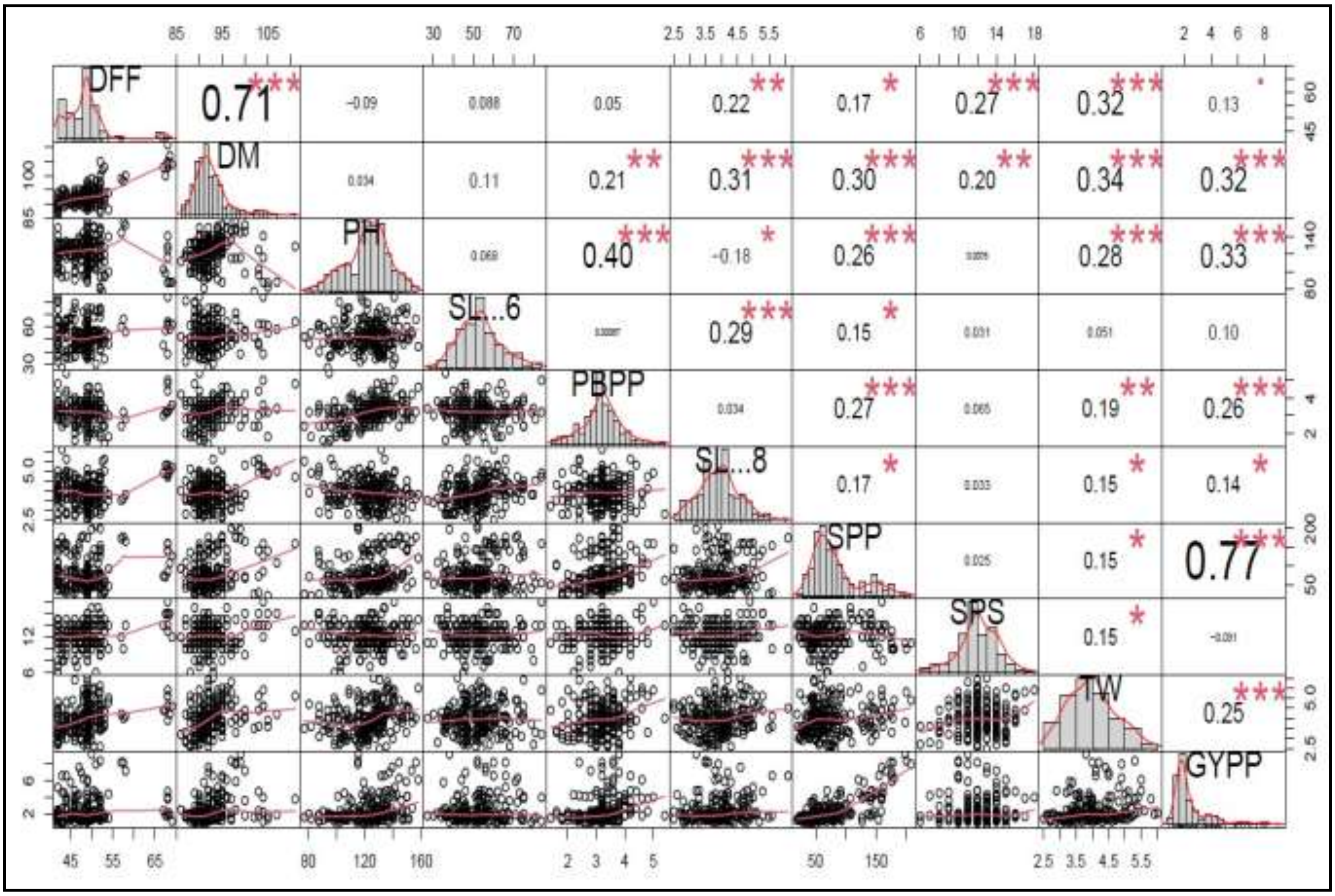

Fig 3: Correlation matrix of yield components for grain yield and yield components in advanced breeding lines during *Rabi* 2015-16

Conclusion

The findings from the present study reveal substantial Genotypic Coefficient of Variation (GCV), Phenotypic Coefficient of Variation (PCV), heritability, and genetic advance as a percentage of the mean for siliqua per plant, suggesting the efficacy of direct selection to enhance these traits. Additionally, siliqua per plant exhibited a significant positive direct effect, with the correlation coefficient between siliqua per plant and grain yield per plant nearly matching its direct effect. This correlation reflects a genuine relationship, affirming the effectiveness of direct selection based on this trait. Consequently, siliqua per plant emerges as a promising selection criterion for enhancing grain yield.

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