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Genetic Variability and Character Association in Linseed (*Linum usitatissimum* L) Genotypes for Yield

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ABSTRACT

The study evaluated 10 accessions of linseed annonating and recording nine quantitative characters were recorded and annotated, viz., days to flowering (DTF), plant height in (cm) (H), primary branches (PB), secondary branches (SB), capsules per plant (CP), seeds per capsule (SC), plant stand (PS) and seed weight in (gms) (SW) and seed yield in (Kg/hectare) (YH). The evaluation of coefficient of variation phenotypic (PCV) and genotypic (GCV) indicated higher environmental impact revealed degree of differences in both the estimates in case of days to flowering (DTF), height (H), seeds per capsule (SC), primary branches per plant (PB), plant stand (PS), seed weight (SW) and seed yield hectare (SYH) (Kg per hectare). The PCV and GCV were highest for secondary branches with value of (33.16 ,32.39) whereas minimal value for days to flowering (DTF) (0.64,1) and seed weight(gm) (4.27,3.24). The role of additive gene action was suggested by high heritability linked with high genetic advance for capsules per plant (CP) (99.49,30.25) and secondary branches per plant (95.40,65.17). The relationship of seed yield with other components viz., high secondary branches and higher capsules per plant and moderate values for seed weight in grams (gm) and height (cm) is basis of selection criteria based on the formulation of breeding programs. The estimates of heritability were highest for capsules (99.27%) and secondary branches (97.41%) and minimum for seeds per capsule (SC) (38.37%). Likewise, highest genetic advance mean percentage was for secondary branches and lowest for days to flowering (DTF). The highest heritability for the traits like capsules per plant (CP) and secondary branches give a positive response to the selection. Traits with high (heritability) h^2 as well as genetic advance (GA) are under the control of additive genes hence, these can be improved by selection based on phenotypic performance. Invariably higher PCV as compared to GCV indicated the role of environment in the manifestation of the traits. The positive and substantial genotypic and phenotypic correlation were for days to flowering (DTF) via height (H), capsules per plant (CP) via plant stand, primary branches genotypically and negatively are important with seed weight and positively yield per hectare (YH)(Kg/hectare). Height (cm), capsules per plant (CP), secondary branches and plant stand showed major positive direct effect. The information about yield improvement is associated with yield components which is essential for the formulation of breeding programs.

Keywords Coefficient of variation phenotypic and Genotypic, Heritability, Genetic advance, Correlation

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and path analysis.

INTRODUCTION

The linseed (*Linum usitatissimum* L. 2n=30) is an ancient crop belonging to the family Linaceae genus Linum commonly known as "Alsi an annual, self-pollinating plant species" and is assumed to be originated in southwest Asia particularly in India (Vavilov 1935 and Richharia 1962). Linseed is an important multiple-purpose winter (*rabi*) oilseed crop cultivated for oil and fiber. In India it is cultivated in states of Rajasthan, West Bengal, Karnataka, Orissa, Bihar, Chhattisgarh, Madhya Pradesh, Uttar Pradesh, Maharashtra and Punjab. In Punjab state Linseed is cultivated in Gurdaspur, Hoshiarpur and Rupnagar districts in foothills of Himalayas.

Linseed crop is grown for seed, oil, stem fiber and moreover for flour purpose. Linseed plant parts are used viz., seeds are for human consumption and animal diseases. Also, Linseed oil, is used for preparing paints, inks, varnishes, other wood treatments, soap, linoleum, putty and pharmaceuticals. Likewise, linseed fiber is utilized as raw material for textiles, thread/rope and packaging materials. A special kind paper prepared from linseed fiber is used for preparing cigarettes, currency notes and artwork. Likewise, the wooden part the pulp of linseed fiber and straw act as biomass energy as reported by (Rowland 1998). Commercially, the cultivation of two species of linseed, the flax/linseed type used the extraction of fiber, whereas the other linseed species is used for the extraction of oil from seeds and cake, used as a by-product for animal feed. Reddy *et al.* 2013 reported linseed oil contains oil content in about 36 to 48% with high unsaturated fatty acids, especially alpha linolenic acid (ALA), an essential Omega-3 fatty acid and lignin oligomers which constitute about 57 % of total fatty acids.

Selection based on genetic variation shows great deal of variation prevails in our existing germplasm and the heritability shows us how much traits are transmitted from parents to offspring. For better selection of characters based on genotypic, phenotypic and environmental effects help to evaluate heritability (h^2) and genetic advance mean percentage (GA%M) to get effective approach of variability in germplasm stated by (Thakur *et al.* 2020). Likewise, the selection criteria for study of correlation among yield and its associated components is of prime importance as the positive correlation between two desirable traits helps the plant breeder to ease crop improvement whereas negative correlation expressed makes it impossible to achieve improvement for both the traits. Simple correlation does not approach the true biological relationship between the traits with yield. It allows correlation coefficient to partition by standardized partial regression analysis into path coefficient in form of direct and indirect effects of various traits independent variables towards dependent variable (yield) as reported by Wright (1921–1960) and also proposed by Dewey and Lu (1959) for effective selection. Direct effect of correlation is shown by true relationship between yield and associated characters to improve seed yield. Indirect effect of character via another component trait, through indirect selection can be done for yield improvement. Non-heritable inheritance based on the selection criteria is dependent on phenotypic values of a character of genotypes which are heritable and partly affected by environment. In the present study Linseed genotypes were evaluated for genetic variability, heritability, correlation and path coefficient analysis for their yield and associated parameters to accumulate knowledge for improvement.

MATERIALS AND METHODS

The scientific study was carried out in 9 sqm plot with 30 cm row spacing in Randomized Block Design (RBD) with three replications consisting of 10 linseed genotypes at PAU, Regional Research Station, Gurdaspur in 2018- 2020. The experiment is used to evaluate genetic diversity, and path analysis for seed yield and their associated traits. The agronomic data for flowering days (DTF) and plant height (H) of five plants were collected at preharvest time and also post-harvest agronomic data such as seed yield and their associated traits were recorded. A seed rate of 15Kgs acre-1 was utilized along with improved inputs including two-hand weeding and fertilizer application at the rate of 25/16 N/P_2O_5 kg acre^{-1} with application of 50 kg Urea and 100 kg single superphosphate (SSP). The coefficient of variation genotypically as well as phenotypically and broad sense heritability were calculated by formula given by Burton and Devane 1953. The formula used to calculate genetic advance mean percentage was described by Johnson *et al.* (1955). Software was used for analysis of heritability, genetic variability, and genetic advance parameters. The broad sense heritability refers to the proportion of genotypic variance to the total observed variance in total population was calculated according to principle given by Allard (1960). Sivasubramanian and Madhavamenon (1973) categorized (both phenotypic and genotypic) coefficients in range of <10%: low, 10-20%: moderate, >20% : High. Johnson *et al.* (1955) classified heritability (h^2) estimates as Low: 0-30%, Medium: 30-60% and High: Above 60%. Selection based on genetic advance refers to the expected gain or improvement in the next generation by selecting superior individuals. The heritability estimates helped to estimate the genetic advance were according to Burton (1952). Johnson *et al.* (1955) classified the range of genetic advance as percent of mean with low less than 10%, moderate 10-20%, high more than 20%. The correlation coefficient to determine the degree of association of various characters with yield and other associated components were detemined by using the formula given by Fisher (1918). Path coefficient analysis estimated the direct and indirect effects as suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The variation categorized broadly were indicated by character range, mean, coefficient of variation phenotypic (PCV) and genotypic (GCV), broad sense heritability (H), genetic advance (GA) and genetic advance as percentage of mean (GA% M) are presented in (Table 1) were computed to have a better understanding of gene action for various quantitative characters for an effective breeding programme. Correlation and path coefficient analysis indicates association among different characters is presented in Tables 2-3.

Character range and mean

The range among the 10 genotypes for most of the characters like flowering days (DTF) was (104.33-107.00), height (78.66-99.43), capsules per plant (142.89-189.55), primary branches (3.09-5.14), secondary branches (15.87-43.09), plant stand (1111.27-1434.07) and yield hectare^{-1}(1974.07 -2462. 96). The characters like seeds capsule^{-1} (SC) (5.00-6.8) and 1000- seed weight ranges (7.46-7.81) showed minimum variation. The mean value for flowering days, height, capsule amount, primary branches, secondary branches, plant stand, and yield is 105.63, 87.03,150.60, 4.44, 26.03,5.99, 1405.51, 7.48 and 1575.29. The estimates of mean and range for the 14 characters viz. days to flowering, maturity, number of capsules, number of seeds per capsule and harvest index depicted wide variation for traits and genotype wise mean value Dabalo *et al.* (2020). Tyagi *et al.* (2014) reported the average performance of various characters such as plant height, primary branches, secondary branches, leaf area, number of capsules, seeds in capsules, stem diameter, flowering days, maturity ,biological yield per plant, grain yield

Table 1. Range, Mean, GCV (%), PCV (%), Heritability h^2 % (BS), Genetic Advance mean percentage GA % among linseed entries. [*Days to days flowering (DTF), Height (cm) (H), Capsules per plant (CP), Seeds per capsule (SC), Primary branches (PB), Secondary branches (SB), Plant stand (PS), Seed weight of 1000 seeds (SW), Seed yield per hectare (YH)].

Characters	Range	Mean	Fratio	PCV	GCV	H2	GAM
DTF	104.33-107.00	105.63	3.03	1.00	0.64	40.35	0.83
H	78.66-99.43	87.03	3.19	8.19	5.32	42.17	7.12
CP	142.89-189.55	150.60	406.78	14.73	14.68	99.27	30.12
PB	3.90-5.14	4.44	6.45	10.48	8.41	64.51	13.92
SB	15.87-43.09	26.03	10.48	32.83	32.41	97.41	65.88
SC	5.00-6.80	5.99	114.04	14.12	8.75	38.37	11.16
PS	1117.25- 1434.07	1405.51	2.87	16.54	11.73	50.24	17.12
SW	7.46-7.81	7.48	4.03	4.271	3.24	57.76	5.08
YH	1974.07-2462.96	1575.29	5.10	17.63	12.76	52.37	19.02

Table 2. Correlation analysis among Linseed genotypes among nine different attributes among Linseed genotypes. [*Days to flowering (DTF), Height (cm) (H), capsules per plant (CP), seeds capsule^{-1}(SC), Primary branches (PB), Secondary branches (SB), plant stand (PS), seed weight of 1000 seeds (SW), seed yield hectare^{-1} (SYH)]. *Significant at 1%, **Significant at 5%.

Characters		DTF	H	CP	PB	SB	SC	PS	1000-SW	SYH
		1	2	3	4	5	6	7	8	9
DTF	GENO (r)	1	0.7380*	**-0.0134**	**-0.0871**	0.0136	-0.0171	-0.5749	-0.1218	0.0031
	PHEN(r)	1	0.2655	**-0.0028**	**-0.1999**	0.0126	0.0360	-0.3154	-0.0534	-0.0799
H	GENO (r)		1	-0.1665	0.4711	-0.2919	0.5779	-0.3834	-0.3755	0.3165
	PHEN(r)		1	-0.0867	0.3432	-0.1355	0.0543	-0.3012	-0.1454	0.1810
CP	GENO (r)			1	-0.1700	-0.2273	0.0887		0.5510	-0.3527
	PHEN(r)			1	-0.1477	-0.2231	0.0361	-0.5560	0.4167	-0.2522
PB	GENO (r)				1	0.3773	0.0589	0.0050	-0.7287 *	0.8428 **
	PHEN(r)				1	0.3036	-0.0708	-0.0954	-0.3697	0.5396
SB	GENO (r)					1	-0.5289	0.2213	-0.4765	0.4119
	PHEN(r)					1	-0.3845	0.2075	-0.3376	0.2934
SC	GENO (r)						1	-0.1197	0.3686	0.2555
	PHEN(r)						1	-0.1245	0.0508	0.0413
PS	GENO (r)							1	-0.6951 *	0.6494*
	PHEN(r)							1	-0.2886	0.3201
SW	GENO (r)								1	0.9334 **
	PHEN(r)								1	0.6329 **
SYH	GENO (r)									1
	PHEN(r)									1

per plant and harvest index revealed variability in 31 genotype. Similarly, Kasana *et al.* (2018) conveyed high variability in following characters 50% flowering, size of corolla, primary branches, plant height, capsule size, number of capsules, number of seeds capsule^{-1}, 1000-seed weight, oil percentage and seed yield in eleven traits of 151 genotypes.

Coefficient of variation phenotypic and genotypic (PCV and GCV)

The coefficient of variation phenotypic (PCV) ranged from 1.0-32.83 for number of days to flowering (DTF) to and secondary branches and in (Table 1 and Fig. 1). The coefficient of variation phenotypically (PCV) were estimated low (below 10%) for days to flowering ,1000 seed weight and height. Moderate PCV ranged from 10-20% and were observed for primary branches followed by seeds per capsule, further more capsules per plant, plant stand seed yield per hectare indicate variation among traits in population.

The highest PCV (above 20 %) were for secondary branches (32.83%).In a study conducted by Tyagi *et al.* (2014) found high phenotypic variation for traits like grain yield per plant, biological yield per plant ,harvest index, capsules per plant, secondary branches, primary branches and grain yield per plot.

Table 3. Estimation of direct and indirect effect of different traits on seed yield in linseed genotypes. [*Days to flowering (DTF), Height (cm) (H), Capsules per plant (CP), Seeds capsule^{-1}(SC), Primary branches (PB), Secondary branches (SB), Plant stand (PS), Seed weight of 1000 seeds (SW), Seed yield hectare.

Characters	DTF	H (cms)	CP	PB	SB	SC	PS	1000-SW	SYH
DTF	**-0.6238**	0.9112	-0.0129	0.0344	0.0104	-0.0037	-0.4909	0.0783	0.0031
H (cms)	-0.3866	**0.9934**	-0.1603	-0.1862	-0.2236	0.1243	-0.3274	0.2414	0.3165
CP	0.0070	-0.2056	**0.9627**	0.0672	-0.1741	0.0191	-0.6748	-0.3542	-0.3527
PB	0.0456	0.5817	-0.1636	**-0.3953**	0.2890	0.0127	0.0043	0.4685	0.8428
SB	-0.0071	-0.3604	-0.2188	-0.1492	**0.7659**	-0.1138	0.1890	0.3063	0.4119
SC	0.0090	0.7135	0.0854	-0.0233	-0.4051	**0.2151**	-0.1022	-0.2370	0.2555
PS	0.3012	-0.4734	-0.7609	-0.0020	0.1695	-0.0257	**0.8539**	0.4469	0.6494
SW	0.0638	-0.4637	0.5305	0.2881	-0.3649	0.0793	-0.5936	**-0.6429**	0.9334

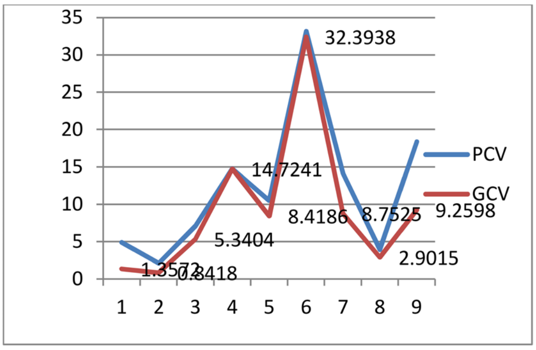

Fig. 1. Phenotypic and genotypic coefficient of Variation among Linseed genotypes. [*Days to flowering (TTF), Height (cm) (H), capsules plant^{-1}(CP), Primary branches (PB), Secondary branches (SB), Seeds per capsule (SC), Plant stand (PS), Seed weight of 1000 seeds (SW), Seed yield per hectare (YH)].

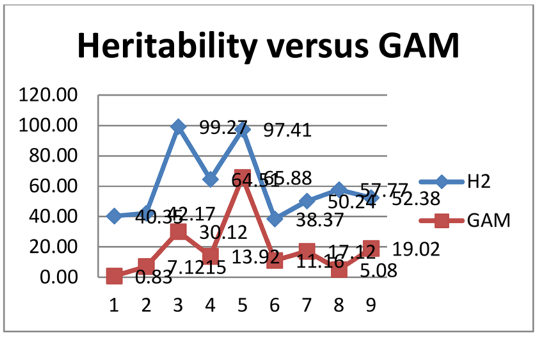

Fig 2. Heritability versus GAM among Linseed genotypes.(Days to flowering (DTF), Height (cm), Capsules plant^{-1}(CP), Primary branches (PB), Secondary branches ,Seeds per capsule (SC), Seed weight (SW), Plant Stand, Seed yield per hectare (YH)).

Additionally, moderate PCV for 1000 seed weight leaf area and plant height along with low PCV for stem diameter, seeds per capsule (SC), oil content and days to flowering were reported by Tyagi *et al.* (2014). These results showed variation in this study.

Similar pattern values of the coefficient of genotypic variation (GCV) were demonstrated in all the nine characters and ranged from 0.64 to 32.41. It was highest (>20%) for secondary branches per plant (32.41). Additionally, a high GCV value was noted for grain yield per plant, harvest index, secondary branches and primary branches per plant were consistent with the study conducted by Tyagi *et al.* in 2014, which reported elevated GCV values for these specific traits.

Moderate GCV ranged between (10-20%) were for plant stand, followed by yield hectare^{-1} (kg/ha) further ensued by a total capsules per plant (CP) 14.68. Tyagi *et al.* (2014) reported moderate GCV for 1000-seed weight (22.50%) and grain yield per plot (22.15%).

However, all other characters have minimal GCV (below 10%) with the lowest value for flowering days. Bibi *et al.* (2013) also showed high potential for effective selection of seed yield /hectare in linseed based on PCV and GCV. GCV with the lowest range for stem diameter (12.08%), seeds per capsule (5.92%), days to flowering (DTF) (3.44%) and the oil content (4.30%) was suggested by Tyagi *et al.* (2014). The PCV and GCV estimates in the current study revealed that diverse soil fertility, various environmental factors and variations in Linseed genotypes. So, the characters selected such as days to flowering (DTF) are misleading as suggested by (Reddy *et al.* 2012 and Manggoel *et al.* 2012). Several workers like (Dabalo *et al.* 2020) reported similar patterns for all or most of the characters for PCV and GCV.

Heritability (h^2)

The current study of broad sense heritability (h^2) ranges from (38.37%) for seeds capsule^{-1} (SC) to capsules per plant (CP) (99.27%) (Table 1 and Fig. 2). Medium heritability estimates ranged from (30-60%) were for seeds per capsule (SC) (38.37%), followed by days to flowering (40.35%), further for height (cms) (42.17%), pursued by the plant stand per plot-(50.24), yield hectare^{-1} kg ha^{-1} (52.37) and seed weight(g) (57.76%) is given in (Table 1 and Fig. 2) showed that the phenotypic variability in these characters are due to environmental factors. However, moderate estimates of heritability for plant height (PH) were reported by Tadesse *et al.* (2010) and (Dash *et al.* 2016) reported moderate estimate of heritability for 1000-seed weight (50.3%), plant height (43.2%) and days to flowering (37.5%) under late sown conditions.

High broad sense heritability estimates are greater than 60% and were found to be 99.27%

for capsules per plant (CP), followed by secondary branches (97.41%) and pursued by primary branches (PB)(64.51%). Correspondingly, earlier workers also found that seed weight have the higher heritability were reported by (Pali and Meheta 2013). Also, similar characters are the chief components towards crop improvement strategies controlled by additive genes (Kumar *et al.* 2012). Selection based on the strategies for characters showing more than 90% heritability are useful as it is controlled by additive genes. The study with three years pooled reported substantial heritability for bolls per plant >75% but 1000-seed weight and seed yield were greater than 89%. Moreover, >60 % heritability was observed for traits like capsule per plant, technical height, aerial biomass, primary branches,1000-seed weight, plant height harvest index ,secondary branches, seed yield per plant, seeds per capsule, days to 75 % maturity and flowering days as reported by Dogra *et al.* (2020). Previous studies by Bhushan *et al.* in 2019 and Kumar *et al.* in 2015 also reported higher heritability values, particularly notable for seed weight and various other traits.

Genetic advance

It was recommended by Johnson *et al.*(1955) that high heritability together with genetic advance mean percentage in expectation of phenotypic expression of a character. The GA % M ranged from 0.83% flowering days to 65.88% secondary branches, as illustrated (Table 1 and Fig. 2) in existent study.

The low genetic advance is (below 10%), occurred for following traits i.e. flowering (0.83%) further pursued by 1000-seed weight (gms) (5.08%), trailed by height (cms) (7.12%). The low estimates of genetic advance mean percentage were supported by (Tadesse *et al.* 2010) for days to maturity (7.1%), plant height (5.0%) and percent oil content (2.9%). The seeds per capsule (9.71%), days to 50% flowering and days to 75 per cent maturity exhibited low estimates of genetic advance <15% (Dogra *et al.* 2020).

The moderate genetic advance % ranged between 10-20%. Notably, the characters showing moderate genetic advance% within range was found to be for seeds capsule^{-1} (SC) (11.16%) and primary branches plant^{-1}(PB) (13.92%) further pursued by plant stand (17.12%), trailed by seed yield per hectare (Kg per hectare) (19.12%) indicating potential improvement through selection. Terfa and Gurmu (2020) similarly reported moderate genetic advances (>17%) for lodging and days to flowering (DTF). Moreover, the study conducted by Dogra *et al.* 2020 also reported moderate genetic advance ranged between (15-30%) were observed for 1000-seed weight (25.69%), plant height and length of flowering period. This suggests that these traits could be amenable to improve through selection strategies due to their moderate genetic advance percentages.

The highest genetic advance is greater than 20% and was estimated for following traits for secondary branches (65.88%) followed by capsules per plant (CP)(30.25%). The high genetic advance percentage of mean (>30%), were expressed for aerial biomass (67.38%), capsules per plant, primary branches, seed yield, secondary branches, technical height and harvest index as suggested by Dogra *et al.* (2020). The substantial improvement through breeding is reported Mirza *et al.* (2011) who reported high estimate of broad sense heritability, genetic advance and variances for traits like height, bolls per plant, seed weight and seed yield

Togetherness of heritaility and genetic advance

The characters are heritable and selection helps to improve phenotypic performance. The moderate heritability coupled with genetic advance mean percentage (46.87;32.59) for capsules per plant indicate influence of additive gene effects.

Similarly, the moderate heritability (50.30%) coupled with moderate GA% M (13.35%) was observed for 1000- seed weight suggests that this character seems to be heritable as reported by (Dash *et al.* 2016). The additive gene action controls all the above characters and are good enough for selection based on phenotypes. Similarly, traits like secondary branches also bear exhibit heritability coupled with high genetic advance mean percent (Table 1 and Fig 2). Vardhan and Rao (2012) also reported high heritability paired with high genetic advance for seed weight. The traits with high heritability coupled with high values of GA% were influenced by additive genes making them suitable for selection on basis of phenotypic performance as illustrated by (Mirza *et al.* 2011). Moreover, (Dabalo *et al.* 2020) observed the high heritability coupled with high genetic advance as percent of mean for seed yield, oil yield, harvest index.

The moderate heritability (24.18) with low GA% M (1.62) was observed for days to flowering (DTF), height (cms) in (Table1 and Fig. 2). Likewise, high heritability coupled with moderate genetic advance for capsules per plant suggests that this specific trait is heritable and can be improved by selective breeding efforts. Pali and Mehta (2013) also reported high heritability with moderate genetic advance for oil content and all other fatty acid components. In conflicting scenario, high heritability accompanied with low genetic advance for traits like days to flowering (DTF) and days to maturity were reported by Bibi *et al.* (2013). Also, Dabalo *et al.* (2020) stated that high heritability coupled with low genetic advance as percent of mean was observed for days to flowering and oil content showing the presence of non -additive genes.

Correlation

In the breeding programs Galton (1888) suggested that correlation studies helps to reveal mutual relationships between the various plant characters under selection for crop improvement. The phenotypic correlation is due to statiscal association between genotypic and environmental effects. The genotypic correlation is reflected by pleiotropic gene action or linkage or both. The measures of correlation coefficient help in selection of mutual relationship between various characters for genetic improvement of yield. The environmental influence on the characters is due to error of variance and is not of much importance to the breeders as it cannot be inherited. The genotypic correlation was greater than the phenotypic correlation coefficients In contrast, researchers such as Vardhan and Rao (2012) and Reddy *et al.* (2013) have proposed that environmental effects play a minor role in influencing the expression of inherited traits and their relationships, particularly at the genotypic level. It also showed that genotypic correlations was higher than the corresponding phenotypic correlation. Specifically, the substantial correlation with harvest index, capsules per plant (CP) and secondary branches were indicated that improvement in these traits, will improve grain yield under selection as suggested by (Ankit *et al.*2019).

Furthermore, in ongoing study, we observed significant and positive correlation between several traits like, days to flowering (DTF) showed a positive and significant correlation with plant height, both genotypically (rg=0.7380) and phenotypically (rp=0.2655), at a significance level of p=5%. Additionally, for primary branches were significantly and positively correlated to yield hectare^{-1} (Kg/ha) with genotypic and phenotypic correlation (rg=0.8428, rp =0.5396) both at p=1% and 5%. This indicates that a higher number of primary branches are associated with increased yield per hectare. Likewise, a significant and positive correlation genotypically (rg=0.6494) for plant stand with seed yield hectare^{-1} (Kg/ha). This suggests that a denser plant stand is linked to higher seed yield per hectare, but phenotypic correlation (rp=0.3201) was relatively lower indicating that the association between these two traits is influenced by environmental factors. In a related study Hussian *et al.* 2022 reported that both number of primary branches (NPB) (r=0.48**) and number of secondary branches (NSB) (r=0.59**) showed a significant positive correlation with seed yield plant (SYP) and also indicated impact of branch numbers over seed yield. At the phenotypic and genotypic level, showed significant positive correlations for seed yield per plant with length of flowering period, seeds per capsule, harvest index, primary branches, secondary branches, capsules per plant, aerial biomass and 1000-seed weight according to (Dogra *et al.* 2020). These findings highlight the intricate relationships between different traits and their potential implications for crop yield and performance, both in terms of genotypic influences and phenotypic responses to environmental conditions.

In this study negative and significant correlation between certain attributes like for number of capsules exhibited a negative and significant correlation with plant stand both genotypically (rg=-0.7903) and phenotypically (rp=-0.5560). It means that phenotypic value greater than genotypic correlation and have shown apparent association of characters due to genes but also due to environment. Dogra *et al.* (2020) reported a positive correlation between seed yield per plant with both plant height and technical height. It indicates taller the plant with higher technical height tend to have higher yield. The seed yield showed negative correlation with days to flowering which allows early flowering (Patial *et al.* 2018). These correlations shows the complex interactions between different traits and their potential implications for crop performance and yield.

Moreover, days to flowering (DTF) is correlated positively to secondary branches and yield per hectare. However, the days to flowering (DTF) showed negative and non-significant correlation to number of capsules, primary branches, plant stand and yield per hectare. These negative correlations implied that early flowering associated with a higher number of capsules, more primary branches, greater plant stand density, and potentially higher yield per hectare.

Similarly, height is positively correlated to the seeds per capsule (SC) and seed yield per hectare (kg/ hectare). Contrary, height is negatively correlated, albeit not significantly, with the number of capsules per plant, plant stand density, and 1000-seed weight (gms). This is suggests taller plants may have fewer capsules, lower plant stand density, and slightly lower 1000-seed weight. Also, capsules per plant were negatively and non-significantly correlated to primary branches, secondary branches, plant stand and yield per hectare (Kg /hectare) except for plant stand significantly, genotypically and negatively correlated (rg=-0.7903) to capsules per plant and seed yield in Table 3. These correlations provide valuable insights into the interrelationships between different traits, which can be useful for breeding and selection strategies to improve crop performance.

Likewise, study showed primary branches were positively correlated to secondary branches. Similarly, primary branches were significantly and genotypically correlated to yield per hectare (kg / hectare) indicating that higher numbers of primary branches may be associated with increased yield potential.Furthermore, primary branches showed negative correlations with several other traits phenotypically. Also, primary branches were positively correlated to the secondary branches and yield per hectare (kg /hectare) but significantly as well as genotypically to the seed yield per hectare (kg/ hectare) i.e rg =0.8428.Furthermore, primary branches were negatively, significantly, genotypically correlated to the seed weight (gms) with value of rg=-0.7287 and non-significantly phenotypically. Similarly, seeds per capsule (SC) were negatively correlated to the plant stand and positively to seed weight (gms) and yield per hectare (kg /hectare). Additionally, significant and positive correlations with seed yield were found for primary branches, secondary branches and seed weight, seeds /capsule and also negative and significant correlation between seed yield and days to flowering (DTF) indicating early genotypes had higher yield potential than late was confirmed by Savita *et al.* (2011). These correlations provide insights into the relationships between different traits and can guide breeding efforts to select for improved crop performance. It's important to consider these correlations when making selection decisions in a breeding program.

Path coefficent

Path coefficient analysis measures direct and indirect effect of independent character on dependent character. Also, provides yield contributing characters which are useful for indirect selection. An effective means for finding out the direct and indirect causes of association between casual factor is provided by path coefficent analysis. A significant examination shows the specific forces acting to produce a given correlation and also measures the relative importance of each causal factor. Hence, the study of direct and indirect effects of traits on the seed yield per hectare was commenced in the present study and the results obtained are presented in Table 3. Path coefficient analysis permits the partitioning of the correlation coefficients into mechanism of direct and indirect effect.

Direct effect

The results achieved are in Table 3 represents by maintaining seed yield as the dependent variable and rest as independent variable. It also shows changes in independent variable changes dependent variable.

It showed positive direct effect for height (cms) (0.9934), further capsules per plant $^{-1}$(CP) (0.9627), pursued by secondary branches (0.7659), seeds per capsule (SC) (0.2151) and plant stand (0.8539) via seed yield per hectare (kg/ha). Sahu *et al.* (2016) reported positive direct effect of plant height, total number of capsules / plant, number of seeds/capsule (SC) and seed yield/ plant. Similarly, direct positive effects for plant height, number of capsules/plant, number of seeds /capsule (SC), seed weight and yield /plot were reported by (Choudhary *et al.* 2016 and Kasana *et al.*2018). Consequently, desired improvement can be done by selecting genotypes with number of capsules, secondary branches, seeds per capsule (SC) and plant stand with positive direct effect. Though, negative direct effect for seed yield/ hectare was observed for days to flowering (DTF) (-0.6238) and primary branches (-0.3953) in present study in Table 3 which is similar to the findings of (Sahu *et al.* 2016) who reported negative direct effect for these traits.

Indirect effect

The days to flowering (DTF) contributed the positive indirect effect for height, primary branches, secondary branches, seed weight and seed yield in Table 3. Similarly, height shows positive indirect effect for number of seeds capsule^{-1} (SC), seed weight (gms) and seed yield per hectare (kg/ha) indicating that taller genotypes may tend to have higher values for these traits, leading to improved seed yield. Similarly, primary branches attributed positive indirect effect for days to flowering (DTF), height (cm), secondary branches, seeds capsule$^{-1,}$ 1000- seed weight (gms), plant stand, and yield hectare^{-1} (kg /ha) in (Table 3). On the other hand, days to flowering has negative indirect effect on capsules per plant, seeds per capsule and plant stand per plot.

Moreover, primary branches also showed negative direct effect for all other characters due to negative correlation in Table 3. Kasana *et al.* (2018) reported positive indirect effects for, harvest index and primary branches on seed yield and resulted in positive correlation of characters with seed yield. So, these attributes should be considered as important for selection criteria of seed yield improvement. However, height had strong positive direct effect on height and positive indirect effect for flowering (DTF), primary branches, secondary branches and plant stand in Table 3. Hence it is concluded that this is not a suitable trait for seed yield improvement for breeding material in hand.

The maximum positive genotypic direct effect on seed yield was exerted by oil yield kg per hectare followed by harvest index tone per hectares. The highly negative direct effects on traits like seed yield were for plant height and seed yield per plant were portrayed by Dabalo *et al.* (2020). High positive direct effects phenotypically were for days to 50% flowering (0.398) and 1000-seed weight (0.363), moderate positive direct effect for number of capsules per plant (0.219) and low positive direct effect for seeds per capsule (0.134) on seed yield were reported by Dash *et al.* (2016). The significant positive correlation of length of flowering period with seed yield was mainly due to indirect effects via capsules per plant, whereas indirect effects via other traits were low in magnitude.

The path coefficient analysis splits the correlation into direct and indirect effects by passing through alternative characters and permitting critical examination of components that influence a correlation to formulate an efficient selection strategy with possible combinations between all the traits. The traits have high direct effect for height (0.9934), capsules per plant (CP)(0.9627), secondary branches (0.7659), seeds capsule-(SC) (0.2151) and plant stand (0.8539) on seed yield per hectare (kg ha^{-1} are considered for direct selection for yield ha^{-1}.

CONCLUSION

In conclusion, the breeder should adopt suitable breeding methods to utilize in fore breeding program for varietal and hybrid development in the breeding programme. Parental selection is crucial for hybridization. The study suggests that traits such as total capsules per plant (CP) and secondary branches exhibit high genetic variability, as indicated by their high values of PCV and GCV. Traits with high variability, heritability coupled with high genetic advance as a percentage of the mean are indicative of the prevalence of additive gene effects. The positive and significant correlations observed among various traits, such as total capsules per plant, primary branches, secondary branches, plant stand and 1000-seed weight, highlight their interdependency and potential to collectively contribute to seed yield improvement. Moreover, the positive direct effects of traits like number of capsules per plant, primary branches, secondary branches, height, seeds per capsule, and plant stand on seed yield per hectare emphasize their direct contribution to enhancing seed yield. By considering these findings and insights, breeders can make informed decisions on trait selection, hybridization, and other breeding strategies to develop improved crop varieties with higher seed yield and better overall performance.

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