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Trait Association and Path Coefficient Analysis for Yield Traits in Myanmar Sesame (*Sesamum indicum* L.) Germplasm

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted in randomized complete block design with three replications during the dry season, 2014 at Yezin Agricultural University, Myanmar to determine the extent of genetic variability for important yield attributes and to determine interrelationship among the traits and their direct and indirect effects on yield of forty Myanmar sesame germplasm. All genotypes were phenotyped for ten agronomic traits. All basic statistical parameters and phenotypic correlation were generated using STAR v2.0.1 and PBTools v1.4. Genotypic correlation and path analysis between yield and yield components were evaluated by SPAR 2.0 and R software package. Wide variations were observed for all traits studied in all germplasm. Primary branches, capsules and seed yield per plant showed high genotypic and phenotypic variances, PCV and GCV estimates that are enough scope for selection. Progeny selection will be effective to improve plant height and number of capsules per plant indicating high heritability with high genetic advance. In both genotypic and phenotypic correlation analysis, main seed yield contributing traits in sesame production were days

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to first and 50% flowering, plant height, primary branches, capsules per plant and capsule length. According to path analysis, positive direct effect on seed yield was contributed by days to first flowering followed by 1000 seed weight, capsules per plant, no. of primary branches per plant and capsule length. Therefore, days to first flowering, 1000 seed weight, capsules per plant, primary branches and capsule length may be good selection criteria for further sesame breeding programs related to high yielding varieties.

Keywords: Correlation; genetic advance; heritability and path analysis.

1. INTRODUCTION

Sesame (*Sesamum indicum* L., 2n=26) belongs to the Pedaliaceae family that is cultivated in Myanmar for its quality oil. It is one of the oldest and traditional oilseed crops in Myanmar and rich in vitamin 'E' and the antioxidants [1]. Sesame has a large diversity in cultivars and cultural systems around the World as well as in Myanmar. Myanmar was the second leading producer of sesame seeds in the world closely behind Tanzania and produces 812,952 tonnes of sesame seeds with 13.3% of the world production in 2016 [2].

Sesame is one of the resilient crops that are generally well suited to the types of marginal soils, hot and dry climate with limited rainfall found in Central Dry Zone of Myanmar. Myanmar still shows a great deal of sesame variation because heterogeneous landraces are grown in various growing areas for centuries. However, drought, water scarcity and high temperature in this region are now threatening sesame germplasm and reduce the sesame productivity and production stability that already have high levels of oil insecurity. Sesame production is insufficient compared to the other oilseed crops like that groundnut, sunflower and soybean although it is highly favourable advantages. Comparatively, low seed yield is one of the most important reasons that sesame needs breeding to provide more yield [3]. In Myanmar, sesame breeding program for the increment of seed yield per hectare is needed to support local sufficiency policy for healthy edible oil. Especially in the Dry Zone area of Myanmar, sesame is an important option for the oilseed crop production. Nevertheless, sesame growing areas are decreasing due to low seed yield compared to the other oilseed crops. Selection for good yield types should be very useful and contribute to breeding programs in this area.

The most important criteria in any crop improvement programme are the selection of genotypes with all possible desirable yield contributing traits [4]. Selection for yield has many complexities because it is the end product of various yield contributing characters which are naturally polygenic and majorly influenced by the environment. Like other crops, seed yield in sesame is a complex trait and is highly influenced by many genetic factors and environmental fluctuations [5] and direct selection for this trait could be misleading in a sesame breeding program. The best selection indices are the components that determine the yield. Therefore, plant breeders require the knowledge of the relationship between important yield traits and seed yield to identify suitable donors for the potential and successful breeding program [6]. The association of character between yield traits can be used as the best guide for successful yield improvement by indirect selection. Achievement of such success depends upon sort and accuracy of correlation coefficient estimated as well as plant materials, environmental conditions and their interaction [7]. Thus, the analysis of genetic variation within and among elite breeding materials is of fundamental interest to plant breeders.

Heritability coupled with genetic advance is the more useful measure for selecting the best individuals. In selecting genotypes, the level of variability in the population, the degree of character association, and the importance of the yield components are the most important for an efficient breeding program. Correlation measures the strength of the association between two traits but correlation coefficients alone may not reveal the relative importance of the causal factors about the dependent variable. This path analysis is done to partition the correlation coefficients into direct and indirect effects to identify the relative importance of yield contributing traits towards fruit yield per plant.

The information and philosophy of Myanmar sesame improvement for seed yield can be accomplished by indirect selection via other traits that are more heritable, simple and accessible to select. This selection design requires understanding the interrelationship of the traits among themselves and with the target seed yield in sesame. The association degree between the traits and heritability is essential in breeding for purposes of efficient and practical trait selection. Such information on sesame is very limited in Myanmar. Therefore, the present study was conducted to determine the extent of genetic variability for important yield attributes and to determine interrelationship among the traits and their direct and indirect effects on yield of Myanmar sesame germplasm.

2. MATERIALS AND METHODS

Thirty-eight sesame germplasm was collected from Dry Zone area of Myanmar and two from Shan State during 2013 dry season. The forty sesame genotypes were evaluated during the 2014 dry season (DS) in Yezin Agricultural University, located in Zeyar Thiri Township, Nay Pyi Taw, Myanmar, latitude 19º 52' N and longitude 96º 37' E with the elevation of 340 feet above the sea level. The experiment site was situated at the elevation of 152.11 m above the sea level where has a subtropical climate and receiving the mean annual rainfall about 1257 mm and the temperature ranges from 21ºC to 34ºC. The weekly total rainfall and mean temperature during sesame growing season were shown in Fig. 1.The experiment was laid out in a randomized complete block design (RCBD) with four replications. Each plot consisted of a single row, 3.7 m long adopting a spacing of (0.5 m × 0.15 m). Plots were over-planted and thinned at the 21 days old to a final stand of approximately 25 plants in each row. Standard plant protection measures and agronomic practices were applied to ensure good crop growth and complete seed development.

The data were collected on five random plants in each of the germplasm for each replication. All genotypes were phenotyped for ten agronomic traits such as days to first flowering (DTFF), days to 50% flowering (DTFPF), days to physiological maturity (DTPM), plant height (PH), number of primary branches per plant (PB), number of capsules per plant (NCPP), capsule length (CL), capsule width (CW), 1000 seed weight (TSW) and seed yield per plant (SYPP). All the traits were measured following Descriptor for Sesame (*Sesamum* spp.) [8].

All the basic statistical parameters and phenotypic correlation were generated using the STAR (Statistical Tool for Agricultural Research, version 2.0.1) and PB Tools (Plant Breeding Tools v1.4) [9]. Genotypic correlation and path analysis between yield and yield components were evaluated by SPAR (Statistical Package for Agricultural Research, version 2.0.1) [10] and R software package.

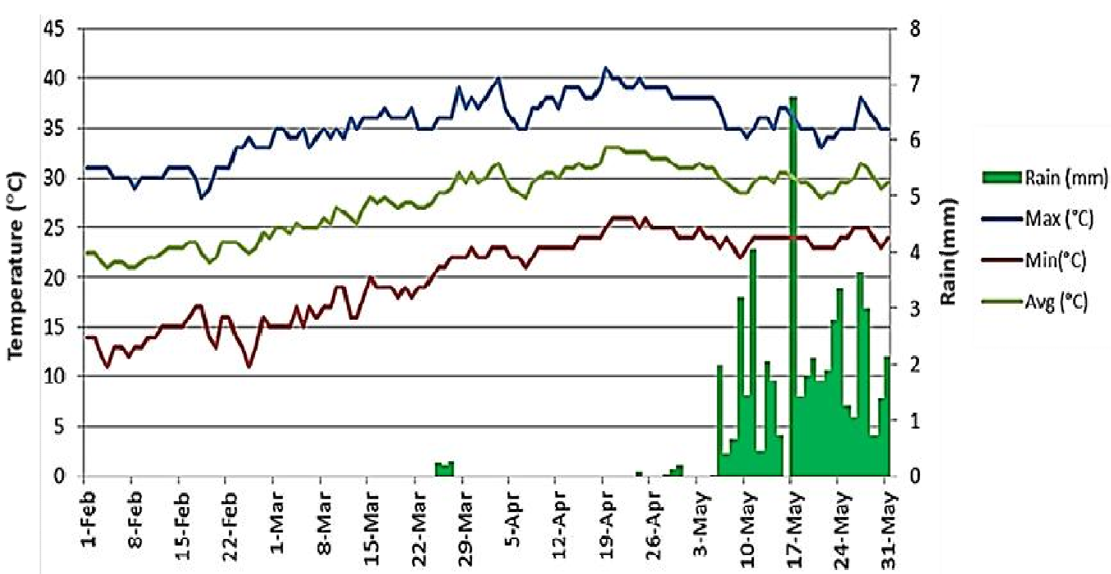

Fig. 1. Weekly total rainfall and mean temperature during sesame growing season

3. RESULTS AND DISCUSSION

3.1 Analysis of Variances for Yield Traits

Wide range of variability observed for all traits studied in all sesame germplasm (Table 1 and Fig. 2). All traits are significant differences among the germplasm for all traits at 0.1% probability level indicating the presence of much genetic variation among germplasm for all traits studied. This result agreed with the observation of Saha et al. [11].

3.2 Parameters Estimation of Variability for Yield Traits

The phenotypic variance was greater than the genotypic variance for all traits studied (Table 2). The phenotypic coefficient of variation (PCV) was greater than the genotypic coefficient of variation (GCV) for all traits indicating the important role of the environment in the expression of these traits. The traits, number of primary branches, number of capsules per plant and seed yield per plant showed high PCV and GCV estimates. This value is enough scope for selection based on these characters, and the diverse germplasm can provide materials for a sound breeding program. The high PCV and GCV observed for these traits is in confirmation with the earlier report of Sumathi and Muralidharan, Saravanan and Nadarajan, Solanki and Gupta, and Shadakshari et al. [12-15]. High coefficient of variation for the number of capsules per plant was also reported by Anitha et al. [16]. However, the low coefficient of variation for the number of seeds per capsule was reported by Thangavel et al. [17].

Plant height, capsule width and 1000 seed weight showed moderate PCV and GCV which is in agreement with the observation of Parameshwappa et al. [18]. The remaining traits such as days to first flowering, days to 50% flowering, days to maturity and capsule length recorded low PCV and GCV. Sudhakar et al. and Shadakshari et al. reported similar to these results [15-19]. Low variability for these characters has also been reported by Krishnaiah et al. [20]. The estimate of PCV and GCV values give only the extent of variability existing for various traits. Estimates of heritability and genetic advance would give a better idea about the possible gains of selection.

Table 1. Summary of statistics for agronomic traits in sesame germplasm

Trait	Range	Mean±SE	Stdev	CV(%)	F Value
Days to first flowering	31.00-39.00	33.56±0.26	2.30	6.85	16.12**
Days to 50% flowering	32.00-40.00	35.45±0.28	2.47	6.98	19.52**
Days to physiological maturity	79.00-98.00	84.26±0.43	3.83	4.54	18.00**
Plant height (cm)	68.27-142.53	94.36±1.83	16.37	17.35	22.85**
No. of primary branches plant^{-1}	0.00-6.00	2.82±0.14	1.22	43.15	14.61**
No. of capsules plant^{-1}	1 8.33-100.00	39.05±1.94	17.37	44.49	1013.94**
Capsule length (cm)	23.33-32.33	29.45±0.22	1.96	6.67	203.00**
Capsule width (cm)	6.00-9.67	7.94±0.09	0.77	9.65	86.44**
1000 seed weight (g)	1.38-4.10	2.63±0.07	0.60	22.79	1168.37**
Seed yield plant^{-1} (g)	2.01-19.84	5.80±0.36	3.25	56.12	201.88**

*" ** " Significant at 1% probability level*

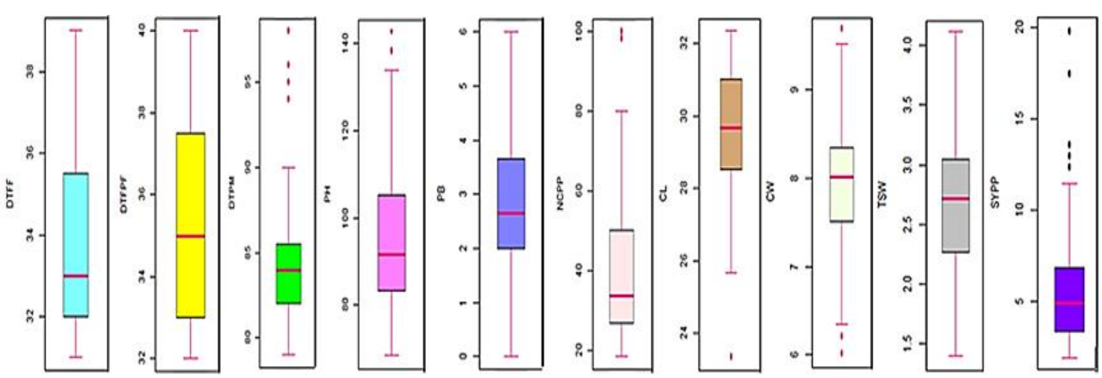

Fig. 2. Boxplots showing distributions of ten measured traits in sesame germplasm

Table 2. Parameters estimation of variability for yield and agronomic traits in sesame germplasm

Trait	Mean	σ_g^2	σ_p^2	PCV (%)	GCV (%)	Hbs (%)	GA (%)
Days to first flowering	33.56	4.73	5.35	6.68	6.47	88.41	3.60
Days to 50% flowering	35.45	5.59	6.20	6.84	6.67	90.16	3.95
Days to physiological maturity	84.28	13.27	14.83	4.44	4.32	89.48	6.06
Plant height	94.35	248.01	270.71	17.06	16.69	91.61	26.53
Primary branches per plant	2.80	1.31	1.50	41.98	40.53	87.33	1.88
No. of capsules per plant	39.04	305.03	315.63	44.72	44.7	96.64	30.22
Capsule length	29.46	3.87	3.91	6.69	6.67	98.97	3.44
Capsule width	7.95	0.58	0.60	11.84	11.8	96.66	1.32
1000 seed weight	2.63	0.36	0.37	22.96	22.8	97.30	1.04
Seed yield per plant	5.80	8.95	10.72	56.33	51.46	83.45	4.81

The broad-sense heritability estimates obtained were high for all traits studied. Estimates of heritability and genetic advance in combination are more important for selection than heritability alone. High heritability combined with high genetic advance observed for plant height and number of capsules per plant. Similar results were reported by Furat and Uzun [3], Krishnaiah et al. [20] and Reddy et al. [21]. These characters were controlled by additive gene effects and phenotypic selection for these characters would likely to be effective. Days to first flowering, days to 50% per cent flowering, days to physiological maturity, plant height, capsule length, capsule width and 1000 seed weight showed high heritability with low genetic advance. These characters may be governed by non-additive gene action. These results are similar to the findings of Sumathi and Muralidharan [12], Sudhakar et al. [19] and Reddy et al. [21].

3.3 Correlation Coefficient Analysis

The genotypic and phenotypic correlation coefficient between yield and yield components were calculated and their significance was tested at 5% and 1% level of significance (Table 3 and Fig. 4). Correlation coefficient analysis measures the mutual relationship between various characters and is used to determine the component character on which selection can be done for improvement in yield. Yield is a complex quantitative trait, greatly influenced by environmental fluctuations [22]. Selection based on yield performance alone may give a biased result and leads to ambiguity. A study of nature and degree of association of component characters with yield assumes greater importance for fixing up characters and selection would be more effective.

At the genotypic level, days to first flowering (0.66), days to 50% flowering (0.49), plant height (0.67), primary branches (0.55), number of capsules per plant (0.82) and capsule length (0.47) showed significant positive correlation with seed yield per plant (Table 3). Mishra et al. [23] also found similar observations. Days to 50% flowering (-0.27), primary branches (-0.04) and capsule length (-0.46??) showed significant negative correlation with1000 seed weight (Fig. 4). Capsule width was negatively correlated with days to 50% flowering (-0.24) and primary branches (-0.27). Capsule length, also showed a significant positive correlation with the number of capsules per plant (0.35) while days to first flowering (0.72), days to 50% flowering (0.66) and plant height (0.81) was significantly positively correlated with the number of capsules per plant. A significant positive correlation was found in plant height (0.30) with primary branches. Plant height exhibited significant positive correlation with days to first flowering (0.82), days to 50% flowering (0.80) and days to maturity (0.41).

At the phenotypic level, seed yield plant-1 showed a significantly positive correlation with days to first flowering (0.64), days to 50% flowering (0.48), plant height (0.66), primary branches (0.40), capsules per plant (0.81), capsule length (0.32). Similar results were reported by Sankar and Kumar, and Kumar and Sundararajan [24,25]. At genotypic and phenotypic levels, this was indicated that the greater the plant height, number of primary branches per plant, number of capsules per plant and capsule length, the higher the seed yield per plant. If days to first and 50% flowering were late, the number of leaves on the plant may be plenty before flowering and then more photosynthesis may take place in these leaves. Therefore, seed yield may be high due to these traits.

Table 3. Direct (diagonal) and indirect (off-diagonal) effects of agronomic traits on seed yield per plant at the genotypic level.

Trait	DTFF	DTFPF	DTPM	PH	PB	NCPP	CL	CW	TSW	r_g with SYPP
DTFF	0.8693	-0.5510	-0.0690	-0.0256	0.0608	0.3731	0.0044	0.0089	-0.0124	0.6586**
DTFPF	0.8149	-0.5878	-0.0851	-0.0247	0.0268	0.3402	0.0020	0.0249	-0.0182	0.4930**
DTPM	0.4227	-0.3526	-0.1419	-0.0129	-0.0045	0.0756	0.0003	0.0118	-0.0047	-0.0062
PH	0.7102	-0.4639	-0.0586	-0.0313	0.0965	0.4213	0.0057	0.0007	-0.0095	0.6712**
PB	0.1632	-0.0487	0.0020	-0.0093	0.3238	0.1617	0.0062	-0.0420	-0.0028	0.5542**
NCPP	0.6260	-0.3859	-0.0207	-0.0254	0.1010	0.5182	0.0079	0.0082	-0.0145	0.8147**
CL	0.1696	-0.0534	-0.0016	-0.0080	0.0900	0.1817	0.0224	-0.0021	-0.0288	0.3697**
CW	-0.0755	0.1424	0.0163	0.0002	0.1322	-0.0411	0.0005	-0.1028	0.0113	0.0835
TSW	-0.1629	0.1613	0.0100	0.0045	-0.0134	-0.1131	-0.0097	-0.0175	0.0664	-0.0746

*Note: Diagonal values are direct effects, Residual effect = 0.3754, Significant at * P < 0.05; ** P < 0.01.*
DTFF=Days to first flowering, DTFPF=Days to 50% flowering, DTM=Days to maturity, PH=Plant height, PB=Number of primary branches per plant, NCPP= Number of capsule per plant, CL=Capsule length, CW=Capsule width, TSW=1000 seed weight, SYPP= Seed yield per plant

(a)

(b)

Fig. 3. Genotypic correlation (a) and phenotypic correlation (b) among agronomic traits in sesame germplasm

DTFF=Days to first flowering, DTFPF=Days to 50% flowering, DTM=Days to maturity, PH=Plant height, PB=Number of primary branches per plant, NCPP= Number of capsule per plant, CL=Capsule length, CW=Capsule width, TSW=1000 seed weight, SYPP= Seed yield per plant. The tests of significance were indicated as ∗∗p < 0.01, ∗p < 0.05. The blue colour shows the positive association and red colour indicates the negative association and the intensity of the colour indicates the degree of association.

3.4 Path Coefficient Analysis

At genotypic level, path coefficient analysis was carried out to study the direct and indirect effects of different yield contributing traits on seed yield. The results of various causes influencing yield are presented in Table (3) and Fig. 4. Maximum positive direct effect on seed yield was contributed by days to first flowering (0.8693) followed by 1000 seed weight (0.0664), number of capsules per plant (0.5182), number of primary branches (0.3238) and capsule length (0.0224). Days to first flowering exhibited a maximum positive indirect effect on seed yield via days to 50% flowering (0.8149) followed by plant height (0.7102), number of capsules per

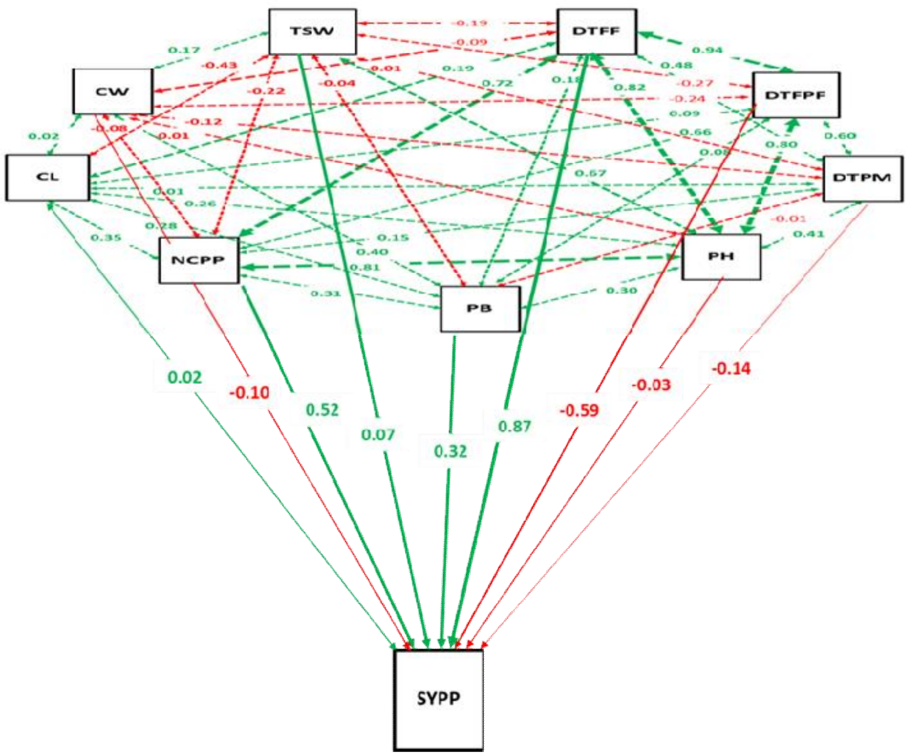

Fig. 4. Direct and indirect effects of seed yield and other related traits in path analysis
DTFF=Days to first flowering, DTFPF=Days to 50% flowering, DTM=Days to maturity, PH=Plant height, PB=Number of primary branches per plant, NCPP= Number of capsule per plant, CL=Capsule length, CW=Capsule width, TSW=1000 seed weight, SYPP= Seed yield per plant

plant (0.6260), days to maturity (0.4227), capsule length (0.1696) and primary branches (0.1632). Days to 50% flowering exerted a maximum positive indirect effect on seed yield via 1000 seed weight (0.1613) followed by capsule width (0.1424). Days to physiological maturity showed a positive indirect effect on seed yield via no. of primary branches per plant (0.0020) followed by capsule width (0.0163) and 1000 seed weight (0.0100). Plant height exhibited a positive indirect effect on seed yield via 1000 seed weight (0.0045) followed by capsule width (0.0002).

Primary branches exerted a maximum positive indirect effect on seed yield via capsule width (0.1322), followed by the number of capsule per plant (0.1010), plant height (0.0965), capsule length (0.0900), days to 50% flowering (0.0268) and days to first flowering (0.0608). The number of capsules per plant exerted a maximum positive indirect effect on seed yield via plant height (0.4213), followed by days to first flowering (0.3731), days to 50% flowering (0.3402), capsule length (0.1817), primary branches (0.1617) and days to physiological maturity (0.0756). Capsule length exhibited maximum positive indirect effect on seed yield via days to first flowering (0.0044), followed by days to 50% flowering (0.0020), days to physiological maturity (0.0003), plant height (0.0057), primary branches (0.0062), number of capsule per plant (0.0079) and capsule width (0.0005). Capsule width exhibited a maximum positive indirect effect on seed yield via days to first flowering (0.0089), followed by days to 50% flowering (0.0249), days to physiological maturity (0.0118), plant height (0.0007) and the number of capsule per plant (0.0082). Maximum positive direct effect on seed yield via 1000 seed weight was contributed by capsule width (0.0113).

4. CONCLUSION

All germplasm showed a wide range of variability for all traits. Primary branches, capsules per plant and seed yield per plant showed high heritability along with high genetic advance. Therefore, progeny selection will be effective to improve these traits. Days to first flowering, days to 50% flowering, days to physiological maturity, plant height, capsule length, capsule width and 1000 seed weight showed high heritability with low genetic advance. These characters can be exploited through heterotic breeding. In both phenotypic and genotypic correlation analysis, main seed yield contributing traits in sesame production was days to first flowering, days to 50% flowering, plant height, number of primary branches per plant, number of secondary branches per plant, number of capsules per plant and capsule length. Character association between yield components can be used as the best guide for successful yield improvement through indirect selection. Path coefficient analysis provides an efficient means of the partitioning of correlation coefficient into direct and indirect effects of the component characters. Selection based on direct and indirect effects is much more useful than selection for yield per se alone. Path analysis revealed that days to first flowering, 1000 seed weight, number of capsules per plant, number of primary branches and capsule length have a positive direct effect on seed yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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