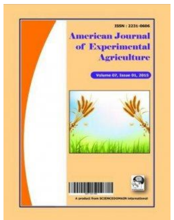

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Selection Criteria for Improvement in Sesame (*Sesamum indicum* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Author HSBM designed the study, wrote the first draft of the manuscript. Author EUH reviewed the manuscript. Author M. Anwar managed the data of the study. Author QA final reviewed and completed all respective requirements of manuscript. Authors M. Aftab and TM supervised the whole study. All authors read and approved the final manuscript.

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ABSTRACT

Pakistan is facing severe scarcity of edible oil and spending a huge amount of foreign exchange on its annual import. Sesame is the best option as an edible oilseed crop due to less water requirement. Various statistical analyses are used to test the contribution of different yield related traits for developing high yield potential cultivars. Correlation analysis illustrates the association among different yield related traits exist in plant population under study. Genotypic and phenotypic coefficients of variability reveal the extent of differences among the accessions, due to the genetic factors and their response to environmental condition of the experiment. Path coefficient analysis reveals the relationship between variables in multivariable system is considered. Previous studies of various sesame breeders proved that plant height, number of branches per plant, capsules per plant, seeds per capsules, 1000-seed weight are the traits which have significant and positive

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correlations with yield per plant at both genotypic and phenotypic levels. These characters also have high path analysis values especially capsules per plant had highest direct effect on seed yield followed by 1000-seed weight. So, these traits may be used as selection criteria in future breeding programs for the improvement of seed yield of sesame.

Keywords: Sesamum indicum; correlation; path coefficient analysis; accessions; genotypic; phenotypic.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.), a conventional oilseed crop grown well in tropical and subtropical areas of the world. There are 37 species in the genus *Sesamum*; out of which only *indicum* is widely cultivated. There are branched and single stem varieties. Sesame plant has deep root system and well adapted to water deficit conditions. It is sound suited to smallholder farming with a relatively short harvest period allowing other crops to be grown in the field [1-3]. The best range of temperature for growth blossoms and fruit ripening is 26-30ºC [2]. Sesame is a short duration crop which completes its cycle within 100-110 days. It is fit as catch crop in Zaid Kharif because wheat can be timely cultivate after sesame. Therefore, there is a great scope of horizontal expansion of sesame without affecting current area under different crops. Sesame is a very rewarding crop due to its low cost of production and high price [4].

During 2012-13, 29.10 thousand tons of sesame seed was produced in Pakistan from an area of 70.90 thousand hectares [5]. During 2013-14, 37.63 million tons sesame seed worth Rs. 7342 million was exported [6]. The chemical composition of sesame seed shows that the seed is a good source of carbohydrate (13.5%), protein (18-25), ash (5%) [7,8] and about 50% oil of high quality [9]. Sesame seed also contains high percentage of some essential amino acids [10-12] and vitamin B complex, important for cell oxygenation influencing liver cells favorably [13]. Sesame seeds are used as raw food as well as in confectionery, sweets, bakery products and also oil is used for industry in preparation of soap, perfume and carbon papers as well as vegetable oil [14-15].

Genetic variability shows the difference among genetic material of individuals. It is a measure of the tendency of individual genotypes in a population to vary from one another [16]. Correlation analysis explains relations of the morphological characters with each other, while path coefficient analysis examines direct and indirect effects of various traits on seed yield [17]. Information on the nature and level of genetic variability present in a crop species is important for crop improvement and development programs and also for the development of any desired character [18].

Pakistan is facing an acute shortage of edible oil. Demand of edible oil in Pakistan is increasing with the increase in population while production of edible oil is decreasing every year. Development of a suitable and high yielding oilseed cultivars are dire need to overcome the upcoming food and health threats. The aim of present review is to understand that how correlation and path analysis are useful to categorize the different yield contributing traits in sesame production. So that, information may be use to design further breeding program for the development of disease resistant, insect/pest resistant and high yielding sesame cultivars. The genetic variability, heritability, genetic advance, correlation, combining ability, heterosis, gene action and path coefficient analysis provide plant breeder to select higher yielding crop plant genotypes [19-27].

2. GENETIC VARIABILITY STUDIES

2.1 Heritability and Genetic Advance

Heritability estimates were recorded moderate to high for all of the measured traits (number of capsules/plant, capsule length, number of seeds/capsule, seed weight/capsule, 1000-seed weight and 5-plant yield). Number of capsules/plant showed the highest correlation with yield [28]. Biswas and Akbar [29] derived information on genotypic variation, heritability and yield correlations from data on 8 yield components in 18 genetically diverse genotypes and their F1 hybrids. Genotypic coefficients of variation were highest for seed yield/plant (34.45) followed by number of branches/plant (19.71). Heritability in the broad sense was highest for days to flowering (89.20%), days to maturity (89.16%) and 1000-seed weight (80.10%) [30].

Shadakshari et al. [31] found higher heritability and genetic advance for number of capsules per axil, seed yield per plant, number of locules per capsule, total number of capsules and total number of branches. Days to first branching, days to second branching, capsule length and oil content had high heritability with low genetic advance. The highest genotypic coefficient of variability, heritability and genetic advance were observed for stem weight, indicating additive gene action. The lowest heritability and genetic advance, as a proportion of the mean, were for root weight and seed yield. Stem weight had the highest genotypic correlation with seed yield, followed by capsule weight, root weight and leaf weight [32-34]. Patil and Sheriff [35] observed that heritability estimates were high for seed yield per plant, oil yield per plant, oil contents, days to maturity, harvest index, number of capsules, days to 50% flowering and capsule length.

Estimates of broad sense heritability, genetic advance and the genotypic coefficient of variation indicated the importance of seed yield, number of capsules, husk weight, number of branches and 1000-seed weight in the selection of genotypes with high yield potential. Seed yield was positively associated with number of capsules, husk weight, number of branches, number of seeds and seed weight [36]. High heritability coupled with high genetic advance was recorded for days to maturity, productive capsules/plant and seed yield/plant [37]. All populations in F2 and F3 recorded desirable means and moderate to high heritability for primary branches, capsule number, seed number, percentage oil and yield/plant. Number of capsules and seeds, 1000-seed weight and single plant yield decreased from F2 to F3 in all populations [38-39].

The number of seeds per capsule and 1000-seed weight showed higher heritability values, but they were relatively lower for culm length and seed yield per plant [42]. Solanki and Gupta [43] seed yield, branches per plant, and capsules per plant were characterized by high heritability and high genetic advance, indicating that these traits were controlled by additive gene [43]. Krishnaiah et al. [44] found high GCV and heritability coupled with high genetic advance were observed for capsules on secondary branches, number of secondary branches, capsules on primary branches, capsules on main stem and plant height suggesting simple selection as effective to improve these traits. Babu et al. [45] assessed variability, heritability, genetic advance and genetic advance as percent of mean in white seeded genotypes of sesame. High heritability coupled with high genetic advance was observed for number of primaries, number of capsules per plant, seed yield per plant and oil yield per plant. 1000-seed weight and oil content showed low heritability as well as low genetic advance besides narrow range of variability.

Sarwar et al. [46] revealed that branches per plant and capsules per plant seemed to be governed by additive type of genes as they showed a high heritability along with a high genetic advance. High heritability was recorded for seed yield per plant, plant height, number of branches per plant, number of capsules per plant and 1000-seed weight. High heritability coupled with high genetic advance was recorded for seed yield per plant and number of branches per plant [47]. Mubashir et al. [48] concluded that there were highly significant differences among genotypes for all the traits studied. High heritability estimates were observed for days to flower initiation and completion, days to maturity, plant height, Number of branches/plant, capsules/plant, seed yield/plant and seed yield m^{-2}. Number of capsules and branches/plant, seed yield/plant and seed yield m^{-2} possessed high genetic advance as % of mean indicating prospects of improving seed yield from 30.58 to 57.91%.

Thirumala et al. [49] high genetic advance coupled with high heritability as percent of mean was observed for capsule/plant, seed yield and plant height representing the role of additive gene in expressing these characters. Path coefficient analysis showed that Number of capsules/plant and test weight were important characters to be considered for realizing the progress in yield. Tsehaye et al. [50] found that harvest index, primary branches/plant and height to first capsule depicted high heritability and genetic advance. Genetic advance indicated additive type of gene action that can be fixed in next coming generations and selection may help to develop synthetic varieties of crop plants while higher broad sense heritability indicated the dominance type of gene action and can't be fixed in next generations but used to develop hybrids in crop plant [51-56].

2.2 Correlation and Path Coefficient Studies

Seed yield was significantly and positively correlated with days to maturity, plant height, number of branches/plant, number of capsules/plant and 1000-seed weight at the genotypic level. It is suggested that number of branches/plant, 1000-seed weight, days to flowering and number of capsules/plant are the most important characters for improving yield [30]. Seed yield was positively and significantly correlated with the number of primary branches and productive capsules/plant. Path coefficient analysis revealed that selection pressure should be exercised simultaneously for increased numbers of productive capsules and primary branches per plant [37].

The correlation coefficients between general combining ability effects and parental means were non-significant. A maximum of 9.73, 3.90 and 55.00% negative heterosis were observed for days to 50% flowering, days to maturity and height up to first fruiting node, respectively. The correlation coefficients of specific combining ability effects with F1 mean and relative heterosis were highly significant [40]. The extent of genetic coefficient of variability, heritability and genetic advance as percent of mean were studied for plant height, Number of branches/plant, Number of capsules/plant, Number of seed/capsule, 1000-seed weight and yield/plant. They concluded that the Number of capsules/plant contributes the highest towards yield followed by 1000-seed weight and plant height. Selection emphasis on these characters could result in progress of yield [41].

Shim et al. [42] found that genetic correlations were slightly higher than the corresponding phenotypic correlations. Culm length showed positive genetic correlation with both the number of capsules per plant and seed yield per plant, whereas the number of capsules per plant showed positive genetic correlation with seed yield per plant. In the analysis of path coefficients, culm length and number of capsules exerted a great effect on grain yield. The seed yield per plant showed a high and positive association with all the characters except number of days to flowering and maturity. Plant height was positively correlated with number of branches and capsules per plant. A positive correlation was observed between the branches per plant and capsules per plant, and between 1000-seed weight and oil content. Path analysis revealed that 1000-seed weight had the greatest direct effect on seed yield, followed by branches per plant, oil content, capsules per plant, days to flowering and number of days to maturity [43].

Branches/plant and capsules/plant were positively and significantly correlated with yield/plant of sesame [32]. Number of primaries per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight, leaf area index, harvest index and seed yield per plant had highly significant positive association with oil yield per plant and also had positive direct as well as indirect effects through many other characters [45]. Correlation studies showed that single plant yield had a strong significant and positive association with capsule number in both generations of the two cross combinations indicating the close link between the two characters. The path coefficient analysis showed direct and indirect contributions by different characters i.e. primary branches, secondary branches, capsules per plant, seeds per capsule and 1000-seed weight and all these characters had to be considered as the most important for determination of seed yield and selection of parents [57].

Seed yield per plant had significant positive correlations with number of secondary branches, capsules on primary branches, number of capsules per plant, capsule length, 1000-seed weight, harvest index and oil yield per plant. Path analysis indicated that number of capsules, seed weight and number of seeds per capsule had the greatest positive direct effect on seed yield [58]. Ali et al. [59-60] investigated string genotypic correlation of grain yield with 100-grain weight. Seed yield was positively and significantly correlated with plant height, number of leaves, primary branches, length of main branch, number of capsules on main branch, number of capsules per plant, capsule length and seeds per capsule in both varieties. Number of capsules per plant and seeds per capsule were the only two characters which contributed to seed yield directly [61].

Rao [62] reported that seed yield/plant was positively correlated with plant height, number of branches, leaf area, number of capsules/plant, capsule length, number of seeds/plant and seed weight under all irrigation schedules. They revealed that the traits, capsules on the main stem as well as on branches, leaf area and shoot weight showed a positive correlation with yield and an intensive positive selection for these traits will improve the yield automatically [63].

Guirguis et al. [64] found significant positive correlation occurred between plant height and number of branches/plant and fruiting zone length. Yield/plant was positively correlated with first pod height and the number of branches/plant. Highly significant positive correlation occurred between seed yield/plant and yield/feddan, suggesting that single plant selection would be effective for increasing yield. Sudharani et al. [65] calculated the direct and indirect correlation coefficients from path analysis of data on 10 yield-related traits in the bi-parental progenies and F3 bulk population of cross R84-4-2X X X198. The direct effects of plant height, capsules on main stem and 1000-seed weight were greater in bi-parental progenies than in the F3 bulk population. The similarities between estimates of genotypic and phenotypic coefficients of variation for 100-seed weight, capsule length, capsule breadth, oil content, days to 50% flowering, days to maturity and seed number per capsule showed high heritability for these traits, indicated that selection for these characters should be effective. The results indicated a predominance of additive gene effects for seed yield [66].

Plant height, capsules/plant, branches/plant and 1000-seed weight showed significant and positive correlations with seed yield. High heritability estimates along with moderate to high genetic advance were observed for branches/plant, capsules/plant, 1000-seed weight and seed yield/plant [67-68]. Biological yield, harvest index and secondary branches/plant had a positive direct effect on seed yield. It is suggested that due emphasis should be given to harvest index, biological yield and secondary branches/plant while selecting plants for improving seed yield in sesame [69]. Correlation studies revealed that capsules/plant were highly significantly and positively associated with seed yield/plant followed by percentage oil content and plant height. Likewise, path analysis showed high direct effects of capsules/plant, percentage oil contents and plant height on seed yield [70].

Seed yield exhibited significant and positive correlation with siliqua per plant, seeds per siliqua and primary branches per plant [71-72]. The 1000-seed weight had the greatest direct effect on seed yield, but its utility is doubtful because of its negative indirect effects through other yield-related traits. Number of primary branches per plant, silique per plant and seeds per siliqua had high degrees of direct and indirect effects on seed yield. Path analysis revealed that capsules on branches had high direct effect on seed yield [73]. The genetic correlation showed that the largest yield per plant was obtained from genotypes with larger number of fruits [74].

Oil yield/plant was positively associated with seed yield/plant. The highest direct and positive contribution at genotypic level was made by maturity followed by root length at 40 days age, harvest index, capsules/plant root weight at 20 days age, branch/plant and seeds/capsule [75]. The inter-correlation between the yield components, apart from the number of capsules on the main stem, showed high associations with each other. The characters viz., plant height, number of capsules on main stem and number of capsules on branches, showed a high positive direct effect on single plant yield [76].

Karuppaiyan and Ramasamy [77] revealed that significant correlation with seed yield was observed in plant height, number of capsules, Number of branches, test weight, days to maturity, days to 50% flowering and oil content. They observed that number of capsules has the highest positive direct effect on yield. There was maximum and positive indirect effect of number of branches, plant height, days to maturity, days to percent flowering and test weight on seed yield via number of capsules.

Kathiresan and Gnanamurthy [78] showed that the dry matter accumulation and number of capsules per plant contributed significantly to seed yield, which exhibited a positive association that was higher than other traits. Correlation studies revealed that seed yield was positively and significantly correlated with plant height, number of branches per plant, number of seeds per capsule, total dry matter production and total dry matter production at maturity. In contrast, the number of seeds per capsule and oil content were negatively and significantly correlated with the number of leaves [79].

Path analysis revealed that greatest positive direct effects for plant height and capsules/plant, suggesting that selection for yield improvement based on these characters will be effective [80]. Sakila et al. [81] showed that single plant yield was positively correlated with total capsules, capsules on main stem, height to first capsule and plant height but only the character number of branches showed a non-significant and negative correlation with yield.

Gnanasekaran et al. [82] reported that seed yield per plant showed highly significant relationship with branches/plant capsules/plant and seed/capsules. According to path analysis, number of branches per plant via number of capsules per plant or vice-versa showed positive indirect effects on seed yield and played important role to increase seed yield in sesame, therefore, these characters should be given due importance for selecting high yielding varieties of sesame. Kumhar et al. [83] found that maximum positive direct effects on seed yield was observed by capsules per plant followed by test weight and plant height, while days to maturity, days to 50% flowering and capsule bearing height had negative effect. They revealed that capsules/plant, test weight and plant height were the major components contributing to the yield in sesame. Path coefficient analysis showed that number of branches and number of capsules per plant had high positive direct effect on yield/plant. They concluded that number of branches and Number of capsules/plant may be good selection criteria for seed yield/plant [84].

The greatest difference between PCV and GCV was observed for number of primary branches per plant (5.7%) and number of leaves per plant (5.3%), indicating that these characters were more influenced by the environment [85]. Correlation studies revealed that seed yield was significant and positively associated with number of branches and number of capsules per plant. The path analysis revealed the maximum direct effects of number of branches, number of capsules and 1000-seed weight on seed yield [86]. Hika et al. [87] showed that seed yield had positive and significant genotypic and phenotypic correlations with all traits except for plant height and biomass yield. Further analysis by path coefficient method indicated that at genotypic level days to maturity, capsules filling period and harvest index exerted high positive direct effects on seed yield and strong and positive correlation with seed yield.

Similarly, at phenotypic level positive and high direct effects were exerted by capsules filling period, number of primary branches and harvest index on seed yield and these traits had also strong positive associations with seed yield. Observations were recorded for seed yield, number of capsules per plant, number of seeds per capsule, stem height to the first capsule, plant height, fruiting zone length, 1000-seed weight, and number of fruiting branches. Number of capsule per plant was highly correlated with seed yield. However, plant height had the greatest direct effect on seed yield of determinate growth habit [88]. Pawar et al. [89] concluded that seed oil and protein content positively correlated with seed yield, morphological and growth parameters. Considering these correlations as well as correlations of these characters with remaining others, the characters for which selection is to be exercised for achieving improvement in higher seed yield, protein content and oil content are listed for different groups.

Yingzhong and Yishou [90] showed that number of capsules per plant and plant height had significant positive correlations and direct path coefficients on seed yield per plant. Anitha et al. [91] found that positive association was shown in plant height with number of capsules on main stem. Positive correlation was observed for plant height, capsule seed weight, 1000 seed weight and number of nodes to first flower with seed yield per plant [92]. Anash et al. [93] studied 21 high yielding accessions to select suitable cultivar for local environment and revealed that capsules per plant had strongest correlation (72%) with seed yield.

Raghuwanshi et al. [94] found that seed yield was positively correlated with plant height, number of capsules per plant and 100-seed weight. The number of days to 50% flowering, number of days to maturity and number of branches per plant were negatively correlated with seed yield. All the characters showed significant and positive correlation with seed yield except days to 50 per cent flowering and oil content. They showed that these characters had also significant and positive correlation with each other [95]. Mothilal [96] showed that plant height and number of capsules exhibited significant positive association with seed yield indicating its true relationship. Other characters such as number of branches, fruiting stem length, number of seed per capsule and 1000-seed weight showed positive association with seed yield. No of capsules/plant, 1000-seed weight and Number of seeds/capsule showed the highest positive direct effects on seed yield per plant. Highest positive indirect effect on seed yield/plant was exhibited by number of primary branches via Number of capsules per plant [97].

Fazal et al. [98] reported that yield per plant had highly significant positive correlation with all other traits both at genotypic and phenotypic level (Table 1). Path analysis revealed that capsules per plant had highest direct effect on seed yield per plant and Seeds per capsules had highest indirect effect via capsules per plant on seed yield per plant (Table 2). Strong positive direct effects were observed for plant height, days to 50% flowering and weight of seed per capsule. The indirect negative effects on yield were observed for days to first flowering, days to maturity, number of branches per plant, number of capsules per plant and length of capsule [99].

Correlation studies showed that characters i.e. number of capsules/plant, plant height and number of primary branches had positive significant association with yield. Path analysis revealed the presence of high positive direct effect of number of capsules/plant and plant height on yield and they considered it as selection indices for selection program for yield in sesame improvement program [100]. Sumathi and Muralidharan [101] observed high heritability combined with high genetic advance for plant height, Number of branches, Number of capsules and seed yield/ plant. Significant positive correlation was observed on seed yield/plant with plant height, Number of branches/plant, Number of capsules/plant, days to 50% flowering, days to maturity and 100 seed weight and significant negative correlation was observed on capsule breadth with seed yield/plant.

Sumathi et al. [102] found high positive direct effects by capsules/plant were found on grain yield. Number of capsules/plant showed high indirect effect on grain yield through plant height, oil contents and days to maturity. Path analysis showed that the number of capsules per plant and number of primary and secondary branches per plant had relatively high direct positive effects on seed yield per plant [103]. Path coefficient analysis and factor analysis divided the 15 measured variables into 5 factors. The 5 factors explained 81% of the total genetic variation in the dependence structure. Factor 1 was strongly associated with number of capsules in the main stem, length of floral axis, number of capsules per plant and plant height. Other factors (2, 3, 4 and 5) explained the rest of genetic variations and may not be important in sesame breeding programs [104].

Parameshwarappa et al. [105] revealed that seed per plant had significant and positive correlation with Number of primary branches per plant, Number of seeds per capsule and capsule length. They revealed that path coefficient analysis had maximum positive direct effect of Number of capsules on seed yield followed by capsule length and plant height. Path analysis and relationship between seven different yield contributing characters in rainfed areas planted during Kharif season. They concluded that Number of capsules/plant should be given prime importance while selecting high yielding sesame cultivars [106]. The path coefficient analysis based on seed yield, as a dependent variable implicated that it is highly affected by plant height. The overall results demonstrated that plant height, Number of capsules per plant, Number of branches and 1000 seed weight were the most contributing characters for sesame seed yield and these characters were of great importance in making indirect selection for seed yield [107].

Akbar et al. [108] concluded that correlation coefficient analysis showed that plant height, capsules plant-^{1}; capsule length and 1000-seed weight had the significant positive and characters related to maturity, days to flower initiation and days to 50% flowering showed negative correlation on yield. Principal component (PC) analysis revealed that first three PC axes explained 54.21% of the total multivariate variation, while the first four PC axis explaining 63.64%. Plant height, days to maturity, capsules plant-1 and seed yield plant-1 were the major determinants of the genetic diversity in the collection. Cluster analysis placed all the accessions into seven groups.

The magnitude of correlation was the highest in case of Number of capsules/plant. High direct effect on seed yield was depicted by Number of capsules per plant, Number of seeds per capsule and 1000 seed weight. High and positive indirect effect on seed yield by Number of capsules/plant via days to 50% flowering, plant height and Number of branches/plant was observed [109].

Daniya et al. [110] found that seeds per capsule contributed more to seed yield compared with other growth and yield characters measured. Path analysis revealed that greatest direct effect and individual factor contribution to seed yield were made by Number of seeds per capsule. Alege et al. [111] studied genetic diversity and correlation coefficient on 23 genotypes of different origin for phytochemical nature. The results revealed high genetic diversity among the 23sesame genotypes and showed that the phenolic contents had negative correlation with tannin while flavonoid had positive correlation with saponin and alkaloid.

Table 1. Genotypic and phenotypic correlations for different traits in sesame (Fazal et al. [98])

Traits	r	CPP	BPP	SPC	1000 SW	YPP
PH	r_g	0.573**	0.749**	0.078	-0.013	0.357*
	r_p	0.571**	0.746**	0.076	-0.015	0.355*
CPP	r_g		0.554**	0.653**	0.477**	0.917**
	r_p		0.553**	0.648**	0.474**	0.916**
BPP	r_g			0.146	0.035	0.414**
	r_p			0.146	0.033	0.414**
SPC	r_g				0.487**	0.749**
	r_p				0.480**	0.741**
1000SW	r_g					0.761**
	r_p					0.758**

***= Highly significant; PH = Plant height, CPP = Capsules per plant, BPP= Branches per plant, SPC= Seeds per capsule, 1000SW = 1000 Seeds weight, YPP= Yield per plant*

Table 2. Direct and indirect effects of different plant characters on seed yield per plant (Fazal et al. [98])

	Indirect effects					Direct effect
	PH	CPP	BPP	1000SW	SPC	
PH		0.3710	0.0635	-0.0051	0.0102	-0.0830
CPP	-0.048		0.047	0.183	0.087	0.6480
BPP	-0.0621	0.3588		0.0133	0.0193	0.0849
1000SW	0.0011	0.3087	0.0029		0.0645	0.3837
SPC	-0.0064	0.4232	0.0123	0.1867		0.1326

PH = Plant height, CPP = Capsules per plant, BPP= Branches per plant, 1000SW= 1000 Seeds weight, SPC= Seeds per capsule

3. CONCLUSION

Correlation and path coefficient are the best statistical tools to study the amount of variation exist in plant population, inter-relationship of different yield related traits and the relationship between variables in multivariable system relatively for developing high yield potential cultivars. Previous studies of various sesame breeders proved that plant height, number of branches per plant, number of capsules per plant, seeds per capsules and1000-seed weight are the major yield associated traits, controlled by additive gene action. This indicates that these traits are important yield contributing components and can be used for yield improvement in sesame breeding program.

These traits especially capsules/plant may be used as selection criteria in future breeding programs for the development of high seed yield sesame varieties/hybrids. As demand of sesame is growing gradually, so it is obligatory to make efforts for the development of disease resistant, insect/pest resistant and high yielding sesame cultivars.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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