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Review Article

SELECTION CRITERIA FOR YIELD AND YIELD RELATED TRAITS IN SESAME (*Sesamum indicum* L.)

Abstract

Sesame (*Sesamum indicum*L.) is sown in tropical and subtropical areas of the world. High temperature is favorable for high seed production. 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 stastical analysis are used to test the contribution of different yield related traits for developing high yield potential cultivars. Analysis of variance 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 prove that plant height, number of branches per plant, number of capsules per plant, seeds per capsules, 1000-seed weight are the traits which have significant and positive 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.

Key words: *Sesamum indicum*, correlation, path coefficient analysis, accessions, genotypic, phenotypic.

Introduction

Pakistan is facing an acute shortage of edible oil. Demand of edible oil in Pakistan is increasing with increase in population and production of edible oil is decreasing every year. The indigenous edible production does not match with growing demand of population. Pakistan is spending millions of dollars on the import of major food items, which is a major drain in shrinking foreign reserves of the country. Total availability of edible oil was 3.069 million tonnes as against the local production of 0.567 million tonnes, importing 2.502 million tonnes of

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edible oil worth US$ 2.50 billion during the year 2012-13 (Govt. of Pakistan, 2013-14). So the gap should be filled to save revenue which is used to import the edible oil.

Sesame (*Sesamum indicum* L.), a conventional oilseed crop from Pedaliaceae family (Ashri, 1998) and Tubeflorae order (Nayar, 1976), is grown well in tropical and subtropical areas of the world (Gandhi, 2009). It is an erect and herbaceous annual crop. There are 37 species in the genus Sesamum; out of which only *indicum* is widely cultivated (Kobayashi, 1981). It bears bell shaped flowers and opposite leaves. Its fruit is about 2.5cm long with oblong capsule containing medium to small seed 64-128 in number. Plants and fruits take 80-100 days after sowing for maturity (Hu *et al*., 2007). There are branched and single stem varieties. Sesame plant bears deep root system and it is fine adapted to water deficit conditions. It is usually grown on poor soils and marginal lands, unsuitable for growing other crops and so is extensively valued for its financial and nutritional yield from otherwise inclement areas. It is well suited to smallholder farming with a relatively short harvest period allowing other crops to be grown in the field (Chemonics, 2002; Naturland, 2002). Sesame requires long duration of sun shine and is usually a short day plant, however, there are some photo insensitive varieties as well (Naturland, 2002). Areas with 350-600mm rainfall are well suited for its cultivation. A rainfall up to 800mm can be harmfull and only tolerated by well drained soil (Osman, 1985). The best range of temperature for growth blossoms and fruit ripening is 26-30^{0}C. The lowest temperature for germination is about 12^0 C; whereas, temperatures above 18^{0}C can be harmful at the time of germination (Naturland, 2002). Temperature more than 40^{0}C adversely affects fertilization and seed setting in sesame crop (Weiss, 1971).

The leading producers of sesame are India, China, Ethiopia, Uganda, Myanmar, Sudan and Nigeria (Hansen, 2011). About 70% of the world's sesame crop is grown in Asia, while Africa grows 26% (Hansen, 2011). Farmers consider the sesame as rewarding crop and have no problem for its marketing (Anwar *et al.,* 2012). During year 2012-13, 29.10 thousand tons of sesame seed was produced in Pakistan from an area of 70.90 thousand hectares (Agricultural Statistics of Pakistan, 2012-13). During 2013-14, 37.63 million tons sesame seed worth Rs. 7342 million was exported (Federal Bureau of Statistics, 2013-14).

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

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and carbon papers as well as vegetable oil (Khan *et al*., 2001; Yol *et al.,* 2010). Sesame seed contains more than 50% oil and about 25% protein. Due to the presence of natural antioxidants like sesamin and sesamol it is considered as an excellent source of edible oil (Brar and Ahuja, 1979). Sesame seed also contains high percentage of some essential amino acids (Kanu *et al*., 2007a, 2007b, 2009) and vitamin B complex, important for cell oxygenation influencing liver cells favorably (Sarwar and Hussain, 2010). The chemical composition of sesame seed shows that the seed is a good source of carbohydrate (13.5%), protein (18-25), ash (5%) (Borchani *et al*., 2010) and about 50% oil of high quality (Roy *et al*., 2009). Seed contains high quality protein with better amino acid profile having nutritional value. It serves as a source of nutrient-rich food for human consumption (Abou-Gharbia *et al*., 1997). Seed of sesame also possesses the essential fatty acids (EFAs) such as linoleic acid and high lignin that comprises of sesaminol sesamin, sesamol and sesamolinol (Katsuzaki *et al*., 1994). It is rich source of calcium, protein, vitamin E and contains a little amount of vitamin A, B_1 and B_2 (Morris, 2002). Sesame oil is mostly used for culinary purposes as in kitchen and for preparation of salad and margarine. It is also used in preparation of cosmetics, pharmaceutical, paints, insecticides and soaps (Ashri, 1989, 1998).

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 (Safavi *et al*., 2010). Correlation analysis explains interactions of the morphological characters with each other, while Path coefficient analysis examines direct and indirect effects of various traits on seed yield (Marinkovic, 1992). 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 (Dabholkar, 1999).

The aim of present review is to study the role of genetic variability, association and path analysis among different yield related traits in sesame. This information may be useful to plan further breeding program for the development of high yielding sesame varieties.

Genetic Variability, Correlation and Path Coefficient Studies

Reddy and Priya (1991) studied the parents and all possible F1s from a nine parent cross in sesame. Branches/plant and capsules/plant were positively

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and significantly correlated with yield/plant of sesame.

Fendel and Monteverde (1994) evaluated three Venezuelan commercial sesame cultivars, 15 exotic accessions and their F1 hybrids for 6 yield components. Heritability estimates were 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.

Subramanian and Subramanian (1994) investigated the genotypic character relationship in sesame. The F4 and F5 generations of TSS6 X TMV3 and TMV3 X TSS6 were raised and eight genotypic traits were recorded i.e. plant height, primary branches, secondary branches, No. of capsules/plant, No. of seeds/capsule, 1000-seed weight, oil content and seed yield/plant. Correlation studies showed that the magnitude and direction of correlation between eight pairs of traits varied with generations in both crosses involving two accessions reciprocally. Their results showed that single plant yield had a strong significant and positive association with capsule No. 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, capsule No. per plant, seed No. 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.

Vanisri *et al* (1994) compared 29 sesame genotypes for 21 characters by character association and path analysis. Seed yield per plant in sesame 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.

Biswas and Akbar (1995) derived information on genotypic variation, heritability and yield correlations from data on 8 yield components in 18 genetically diverse lines of sesame 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%). Seed yield was significantly and positively correlated with days to maturity,

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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.

Chaudhary (1995) carried out path analysis on data on seed yield and its components in sesame *(Sesamum indicum)* varieties JLT26 and JLT27.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.

Shadakshari *et al*. (1995) evaluated 225 indigenous and exotic sesame genotypes for genetic diversity in 20 quantitative characteristics. A wide range of variability was observed for all the characters studied. Phenotypic and genotypic coefficients of variability were high for number of capsules per axil, total number of capsules, total number of branches, seed yield per plant and first flowering node, and low for days to 50% flowering, days to first branching, days to second branching, capsule length, capsule girth, oil content and days to maturity. Heritability and genetic advance were high 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.

Rao (1995) studied in field trials at Parbhani, Maharashtra, sesame was irrigated at irrigation water: cumulative pan evaporation ratios of 0.6, 0.9 or 1.2. 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.

Reddy and Dorairaj (1995) compared fifty sesame genotypes for heritability of and correlations among 5 components of dry matter production. 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. It is suggested that the variance in these characters was influenced more by environment than genetic components. Stem weight had the highest genotypic correlation with seed yield, followed by capsule weight, root weight and leaf weight.

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Ananda and Sivasamy (1996) studied the six high-yielding homozygous genotypes (TSS6, TNAU12, TNAU17, TNAU86, VS117 and DPI1589) in sesame. They revealed that the traits of number of 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.

Guirguis *et al* (1996) evaluated 20 sesame genotypes for yield and seed characters. Differences among genotypes in plant height, first capsule height, fruiting zone length, number of branches/plant, number of capsules/plant, 1000-seed weight, yield/plant and yield/feddan [1 feddan = 0.42 ha] were significant or highly significant. 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/feddan.

Patil and Sheriff (1996) reported that the 100 genotypes of sesame (*Sesamum indicum*) from different climatic regions in India were sown during kharif 1992. Data on 16 quantitative characters were recorded for 5 competitive plants in each genotype. The genotypes exhibited significant variability for the characters studied. 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.

Backiyarani *et al*. (1997 a) recorded correlation and regression coefficients between F3 means and the corresponding parental F2 values for 8 yield-related traits in the sesame (*Sesamum indicum)* crosses SVPR1 X TNAU22, SVPR1 X TMV3, SVPR1 X Co1 and TMV3 X SVPR1 at 3 selection levels. The data obtained indicated that selection for single plant yield should be effective in these crosses.

Backiyarani *et al* (1997 b) evaluated F2 and F3 generations of varieties of different GCA (high=H and low=L) for variability, heritability and genetic advance of 7 traits. H X H populations had higher mean values than H X L and L X L for all traits, except for seed number and percentage oil, respectively. 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

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yield decreased from F2 to F3 in all populations.

Sudharani *et al* (1996) calculated the direct and indirect correlation coefficients from path analysis of data on 10 yield-related traits in the biparental progenies and F3 bulk population of the sesame (*Sesamum indicum* L.) 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.

Joel and Thangavelu (1997) derived information on variability, heritability and genetic advance from data on 17 qualitative traits in 95 diverse genotypes of sesame *(Sesame indicum* L.). 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.

Mishra *et al*. (1997) evaluated the 12 varieties of sesame; Krishna gave the highest seed yield of 3.28 g/plant followed by Karnak with 3.2 g/plant and OMT30 with 3.08 g/plant. 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.

Rai *et al*. (1997) observed that in 25 genotypes of sesame (*Sesamum indicum* L.*)* the genotypic correlations were higher than the phenotypic correlations. Seed yield had significant positive phenotypic and genotypic association with secondary branches/plant, capsules/plant, capsules/main shoot, seeds/capsule, biological yield and harvest index. 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.

Singh *et al*. (1997 a) studied, 35 diverse lines of sesame (*Sesamum indicum* L.*)* to determine the association of seed yield with various yield components such as plant height, days to flowering, days to maturity, number of primary branches, number of secondary branches, capsules/plant, 1000-seed weight and oil content. Correlation studies revealed that capsules/plant were highly significantly and positively associated with seed yield/plant followed by

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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.

Singh *et al.* (1997 b) suggested that the range and coefficient of variability in sesame (*Sesamum indicum* L.) has better scope for improvement of productive capsules/plant, primary branches/plant and seed yield/plant through simple selection. High heritability coupled with high genetic advance was recorded for days to maturity, productive capsules/plant and seed yield/plant in 28 genotypes of sesame. 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.

Subrata and Maity (1997) evaluated 34 cultivars of (*Sesamum indicum* L.) for 8 yield components. Significant inter-varietal differences were observed without any cultivar X year interactions. 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.

Tak (1997) derived information on correlation and path coefficients from data on 6 yield-related traits in 25 promising genotypes of sesame, of diverse eco-geographic origin. The variability among the genotypes was large for all the characters studied. Seed yield exhibited significant and positive correlation with siliqua per plant, seeds per siliqua and primary branches per plant. 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, siliquae per plant and seeds per siliqua had high degrees of direct and indirect effects on seed yield.

Govindarasu *et al.* (1998) irradiated six sesame *(Sesamum indicum* L.) varieties and their nine hybrids with gamma rays (20 and 30 kRad doses). Correlation coefficients between seed yield and 6 quantitative traits were estimated for the parental, M3, F3 and F3M3 generations. Capsule number and branch number had consistently strong positive genotypic correlations and high positive direct effects with seed yield in all the populations.

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Manivannan (1998) analysed simple correlation in sesame (*Sesamum indicum*) back crosses B1 and B2. The analysis revealed branches, capsules on main stem and capsules on branches were positively correlated with seed yield. Path analysis revealed that capsules on branches had high direct effect on seed yield. The association analysis of B1 and B2 showed slight difference in the association of characters. However, the selection on capsules on branches will give simultaneous selection on seed yield in both backcrosses.

Arriel (1999) estimated the heritability and genetic gain and obtain genetic and phenotypic correlations between flowering characters, plant height, capsule number per plant, maturation and yield per plant in (*Sesamum indicum* L.) cultivars. Estimates of high heritability and percent genetic gain in relation to the average were recorded from seed yield, 72.63 and 28.77%, respectively, showing a considerable success in the selection of that character. Highly significant genetic correlation was observed between the yield and the total number of capsules (0.77) and this variable was significantly correlated with plant height (0.69), showing that the selection of the number of capsules and plant height can contribute to the increase in production. The genetic correlation showed that the largest yield per plant was obtained from genotypes with larger number of fruits.

Alam *et al*. (1999) carried out correlation and path analysis in a set of seven parents and their all possible F1 generation with respect to yield and yield components. Seed yield/plant and oil yield/plant were highly significant and positively correlated with root length and root dry weight at 40 days age, maturity, plant height, branches/plant, capsule on main branch, capsules/plant, 1000-seed weight and harvest index. 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.

Ganesh and Sakila (1999) studied 114 accessions of sesame by correlation and path coefficient analysis for single plant yield and other yield contributing components. All the studied characters showed significant and positive correlation with single plant yield. 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.

Govindarasu (2000) irradiated seeds of 3 varieties, TMV 3, TMV 4 and

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TMV 6, with gamma rays at LD50 value of 20 kR and crossed individually with RJS 199. Variability analysis was made in the second and third generations. The mean performance of F2 in all the 3 crosses was significantly better than M2 of all the 3 varieties for seed yield, branch number, capsule number and 1000-seed weight. A similar trend was also noticed in F3 and M3 populations. For plant height and seed number, F2 of TMV 3 x RJS 199 and TMV 6 x RJS 199 had higher mean values than the M2s, except M2 of TMV 6 for plant height. However, these characters showed non-significant mean values in the third generation. Genotypic variability was relatively of higher magnitude in F2s and F3s than M2s and M3s for seed yield, branch number and capsule number. Estimates of heritability and genetic advance also showed the same trend.

Karuppaiyan and Ramasamy (2000) studied 80 sesame F_1 hybrids derived from 20 (lines) × 4 (testers) mating design for 10 quantitative traits conducted during kharif 1996 in Coimbatore, Tamil Nadu, India, and performed genotypic correlation and path coefficient analysis. They revealed that significant correlation with seed yield was observed in plant height, No. of capsules, No. of branches, test weight, days to maturity, days to 50% flowering and oil content. They observed that No. of capsules has the highest positive direct effect on yield. They also concluded that there was maximum and positive indirect effect of No. of branches, plant height, days to maturity, days to percent flowering and test weight on seed yield via No. of capsules.

Kathiresan and Gnanamurthy (2000) studied two sesame cultivars to evaluate the different growth and yield related traits on the yield of sesame. The data showed that the dry matter accumulation and the No. of capsules per plant contributed significantly to seed yield, which exhibited a positive association that was higher than other traits.

Kavitha and Ramalingam (2000) recorded the correlations among eight yield components from 50 segregating families of *Sesamum indicum*. 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.

Sakila *et al*. (2000) studied on association analysis. Their results showed that single plant yield in sesame (*Sesamum indicum* L.) was positively correlated with total No. of 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.

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Singh *et al.* (2000 b) studied the components of dry matter production in relation to improvement of seed yield in 17 newly developed genotypes of sesame. Observations of growth and yield parameters were conducted on 5 plants of each genotype at 35, 55 and 75 days after sowing (DAS). Analysis of variance revealed that the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all plant characters analyzed. The highest PCV and GCV were obtained for number of primary branches per plant (31.1 and 24.5%, respectively), while the lowest values were obtained for seed oil content (5.1 and 5.0%, respectively). The greatest difference between PCV and GCV was observed for number of primary branches per plant (5.7%) and number of leaves per plant at 75 DAS (5.3%), indicating that these characters were more influenced by the environment. High heritability with high genetic advance (as percent of mean) was obtained for number of capsules per plant, total dry matter produced at all stages and seed yield per plant. High heritability with low genetic advance was observed for 1000-seed weight, plant height, oil content and total dry matter produced at 75 DAS. Low heritability with high genetic advance was observed for number of leaves at 75 DAS. 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 at 75 DAS 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 at 55 and 75 DAS.

Arulmozhi *et al.* (2001) studied twelve lines, six testers and their 72 F1's to assess the association between seed yield and its components and to trace the direct and indirect effects of characters on seed yield per plant in sesame (*Sesamum indicum)*. 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.

Kar *et al.* (2001) studied 42 hybrids of sesame involving 14 lines and three testers for seed yield and three earliness characters such as, days to 50% flowering, days to maturity and height up to first fruiting. 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

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ability effects with F1 mean and relative heterosis were highly significant.

Khan *et al*. (2001) studied 21 accessions of sesame under Faisalabad conditions and reported correlation and genetic variability between seed yield and its related characters. The extent of genetic coefficient of variability, heritability and genetic advance as percent of mean were studied for plant height, No. of branches/plant, No. of capsules/plant, No. of seed/capsule, 1000-seed weight and yield/plant. They concluded that the No. 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.

Shim *et al*. (2001) conducted their experiment to analyze the responses of some agronomic traits to the different cultural environments and the relationships among the agronomic traits; with the objective of selecting sesame varieties with higher stabilities. 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. 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.

Uzun and Cagrgan (2001) studied seed yield and related characteristics of sesame population involving 8 determinate and 4 indeterminate types using simple correlation coefficients and path coefficient analysis techniques. 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.

Kumaresan and Nadarajan (2002) studied 64 genotypes including 48 hybrids and 16 parents for correlation between yield and six yield contributing characters, namely days to 50 per cent flowering, plant height, number of branches, number of capsules, 1000 seed weight and oil content and three physiological characters viz., leaf area index, photosynthetic rate and harvest index. 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.

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Krishnaiah *et al*. (2002) evaluated 36 entries (8 parents and 28 F1's) of sesame for variability, heritability, genetic advance and genetic advance as per cent of mean in 13 quantitative characters. Close resemblance between GCV and PCV was observed for all the characters indicating that selection for these characters would be much effective. 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.

Pawar *et al*. (2002) studied relationship of different traits with seed yield, protein yield and oil content with ten different accessions of sesame. They concluded that irrespective of accessions the different growth and yield parameters were correlated. They 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 (2002) studied twenty seven core accessions and three genetic male sterile lines for genotypic correlations and path coefficient analysis in sesame. They investigated Nine characters i.e. days to flowering, plant height, height to first capsule, No. of capsules /plant, capsule length, capsule width, No. of seeds/capsule, 1000-seed weight and seed yield/plant. Their results showed that number of capsules per plant and plant height had significant positive correlations and direct path coefficients on seed yield per plant.

Deepa and Ananda (2003) studied ‘8 x 4’ line x tester analysis in sesame to evaluate eight important economic characters in sesame i.e. days to 50 %flowering, plant height, No. of primary branches/plant, capsule length, No. of capsules/plant, 1000 seed weight, oil per cent and single plant yield. They revealed that yield/plant had positively and significantly correlated with plant height, No. of primary branches/plant, capsule length, No. of capsules/plant and 1000 seed weight. They concluded that partitioning of total correlation coefficient into components of direct and indirect effects that number of capsules/plant was the only trait which contributed to yield directly and the rest of the traits contributed indirectly through No. of capsules/plant. They suggested that No. of capsules/plant can be taken as an index for improving yield in sesame.

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Raghuwanshi *et al.* (2003) carried out correlation, regression and path analysis studies on 576 accessions of sesame in a field experiment. 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.

Solanki and Gupta (2003) conducted genetic variation and correlation analyses for yield and yield components for 90 exotic germplasm lines of sesame and 2 local controls (RT 46 and TC-25). Seed yield per plant, number of branches per plant and number of capsules per plant exhibited high PCV and GCV estimates. Seed yield, number of branches per plant, and number of capsules per plant were characterized by high heritability and high genetic advance, indicating that these traits were controlled by additive gene effects. The seed yield per plant showed a high and positive association with all the characters except number of days to flowering and maturity. The number of days to flowering was negatively correlated with 1000-seed weight and oil content, but was positively correlated with number of branches per plant. Plant height was positively correlated with number of branches and capsules per plant. A positive correlation was observed between the number of branches per plant and number of 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 number of branches per plant, oil content, number of capsules per plant, number of days to flowering and number of days to maturity.

Babu *et al.* (2004 a) assessed variability, heritability, genetic advance and genetic advance as per cent of mean in white seeded genotypes of sesame (*Sesamum indicum* L.) of indigenous origin. A wide range of variation was recorded for plant height, number of capsules per plant, number of seeds per capsule, 1000-seed weight, leaf area index, harvest index, seed yield per plant and oil yield per plant. The coefficients of variation were high for plant height and seed yield per plant. 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.

Babu *et al.* (2004 b) studied 18 diverse genotypes of sesame for association between yield and yield component characters at genotypic and phenotypic level, besides estimating the direct and indirect effects through path

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coefficient analysis. 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.

Bhuyan and Sarma (2004) analyzed 30 cultivars of sesame belonging to different agro-climatic zones for character associations under rain fed conditions. Seed yield was significantly and positively correlated with number of capsules per plant, number of branches per plant, plant height and 1000-seed weight. 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.

Habib (2004) used trial for the evaluation of seed properties of sunflower. He determined genetic variability, phenotypic and genotypic coefficient for the different properties of the seed. He found high heritability for the traits and positive correlations with the studied traits. He explained that late seed emergence had great affect on the other properties of seed. He also showed through his results that early emergence of roots had great relation with the yield than other characteristics. He found great positive correlations of root emergence with the studied traits.

Solanki and Gupta (2004) determined the genetic diversity, variability and heritability in 48 sesame genotypes import from Mexico, Russia, Nepal, Italy, Chile, Pakistan, Afghanistan and India. Variation was highest for number of capsules per plant and lowest for 1000-seed weight. High phenotypic and genotypic variations were recorded for number of branches per plant, seed yield per plant and number of capsules per plant. 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.

Babu *et al.* (2005) computed the analysis of variance of 4 lines, 3 testers and 12 hybrids obtained from line × tester mating indicating significant differences among all the 19 sesame genotypes for all the characters under study. The analysis of genetic parameters revealed a narrow difference between the genotypic and phenotypic coefficients of variation. Estimates of heritability were high for all the characters, while genetic advance as percent of mean was high for

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seed yield per plant, number of seeds per capsule, number of primaries, number of capsules per plant and 1000-seed weight. Medium genetic advance as per cent of mean was recorded by days to 50% flowering and plant height. Oil content and days to maturity had a low genetic advance as percent of mean.

Mothilal (2005) studied the association of seed yield with other yield components among 24 sesame hybrids and their parents. The results 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.

Ratna *et al.* (2005) reported analysis of variance of four lines, three testers and 12 hybrids of sesame obtained from line x tester mating indicated significant differences among all the 19 genotypes of sesame for all the characters under study. The analysis of genetic parameters revealed narrow difference between GCV and PCV. Estimates of heritability were high for all the characters, while genetic advance as per cent of mean was high for seed yield per plant, number of seeds per capsule, number of primaries, number of capsules per plant and 1000-seed weight.

Sarwar *et al*. (2005) studied 73 lines of sesame (white seeded) of diverse origin and evaluated for different morphological characters such as: days to flower, days to maturity, plant height, branches per plant, capsule number, capsule length and breadth, seeds per capsule, 100 seed weight and seed yield. They calculated genetic parameters and correlation coefficients of these attributes. They 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 significant and positive phenotypic correlations were also showed by branches per plant and capsule number with seed yield.

Singh (2005) evaluated 40 diverse genotypes of sesame during kharif 1998, 1999 and 2000 to understand the variability and relative contribution of eight quantitative characters (days to 50% flowering, days to maturity, plant height, number of primary branches, number of capsules per plant, capsule length, capsule width and seeds per capsule) towards the yield. The seed yield exhibited highly significant and positive correlation with days to maturity, number of capsules per plant, capsule length and seeds per capsule at both genotypic and phenotypic level.

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Siddiqui *et al*. (2005) conducted an experiment to study correlation and path analysis on the yield and yield components of seven parents (Krishna Z-4-Co-1, TKG 32, TC 25, AHT 123, TKG 105, TKG 117 and RT 161) and 21 F_1 hybrids of sesame using diallel mating design. In most of the traits, the values of genotypic correlations were higher than those of phenotypic correlations. The seed yield was significantly and positively correlated with days to first flowering, days to 50% flowering, days to maturity, number of branches per plant, plant height, number of capsules per plant, weight of seed per capsule, length of capsule and 1000-seed weight. 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.

Vidhyavathi *et al*. (2005) conducted an experiment in sesame with the aim of understanding the relationship of seven metric traits i.e. days to 50 %flowering, days to maturity, plant height, No. of primary branches, No. of capsules/plant, 100-seed weight and oil content with yield/plant. Correlation studies showed that characters i.e. No. of capsules/plant, plant height and No. of primary branches had positive significant association with yield. Path analysis revealed the presence of high positive direct effect of No. of capsules/plant and plant height on yield and they considered it as selection indices for selection programme for yield in sesame improvement programme.

Mubashir *et al*. (2007) studied 14 diverse sesame accessions. They 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, No. of branches/plant, No. of capsules/plant, seed yield/plant and seed yield m^{-2}. They observed high heritability estimates together with high genetic advance for No. of branches/plan1, No. of capsules/plant, seed yield/plant and seed yield m^{-2} predicting additive gene action governing these traits. 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%.

Sumathi *et al*. (2007) found slightly higher genotypic correlation coefficients than phenotypic correlation coefficients, which indicated masking effect of the environment in the total expression of the genotypes. Plant height

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and No. of capsules/plant showed significant and positive correlations with single plant yield at both genotypic and phenotypic levels. Plant height and No. of capsules/plant showed positive association with all the other traits except 100 seed weight. Whereas, negative correlation was found between No. of branches/plant and oil contents. High positive direct effects by capsules/plant were found on grain yield. No. of capsules/plant showed high indirect effect on grain yield through plant height, oil contents and days to maturity.

Biabani and Pakniyat (2008) studied 15 sesame accessions grown in a randomized complete block design with three replications. 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.

Gnanasekaran *et al.* (2008) studied 40 accessions of sesame and reported relationship between seed yield and its contributing traits. They also reported that seed yield per plant showed highly significant relationship with branches/plant capsules/plant and seed/capsules. Positive and significant relationship among capsule length and 1000-seed weight. According to path analysis, number of branches per plant via No. 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.* (2008) studied 82 accessions of sesame (*Sesamum indicum* L.) in randomized block design during rainy season to evaluate the character association and variability. Their results showed that mean sum of squares were significant for all the studied traits except oil content showing the existence of variability. Traits like seed yield, primary branches/plant, capsules/plant and capsule bearing height exhibited high heritability coupled with high genetic advance revealing that these characters were controlled by additive gene action. They revealed that seed yield had significant positive correlation with capsules/plant, oil content, test weight; capsule bearing height and primary branches per plant. The 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

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effect. They revealed that capsules/plant, test weight and plant height were the major components contributing to the yield in sesame.

Kumhar and Solanki (2009) studied 82 accessions of sesame (*Sesamum indicum* L.) and worked out on genetic divergence. The mean sum of squares were significant for all the traits studied except oil content which indicating the presence of variability. Traits like seed yield, primary branches per plant, capsules per plant and plant height to first capsule exhibited heritability coupled with high genetic advance revealing that these traits were controlled by additive gene action. They concluded that hierarchical cluster analysis shows the presence of considerable genetic divergence between accessions. They grouped accessions into eight clusters using Ward's minimum variance method. The inter-cluster Euclidean2 distance was maximum between cluster V and VIII followed by cluster V and VII and cluster II and V which indicated that the accessions included in these clusters will give high heterotic response and thus better segregants. The maximum cluster means were revealed by cluster V for seed yield, plant height and No. of capsules per plant, cluster II for No. of primary branches per plant and cluster III for test weight, while cluster VIII showed minimum cluster means for plant height to first capsule, days to 50% flowering and maturity.

Kumar and Vivekanandan (2009) studied correlation and path analysis of 45 hybrids and 14 parents in sesame for the characters like days to maturity, plant height, No. of branches/plant, No. of capsules/plant, capsule length, No. of seeds/capsule, thousand seed weight, oil content and seed yield/plant. They revealed that character association analysis had strong positive association of seed yield/plant with No. of branches and No. of capsules/plant. 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 No. of capsules/plant may be good selection criteria for seed yield/plant.

Parame shwarappa *et al*. (2009) studied 151 sesame accessions and evaluated them during Kharif 2006 for genetic diversity in respect of nine quantitative attributes. They revealed that analysis of variance showed significant difference among accessions for all studied characters. They observed high GCV and PCV for seed yield per plant, No. of capsules per plant, No. of primary branches per plant, No. of seeds per capsule and plant height. They observed high heritability and genetic advance as percent mean for seed yield, No. of primary

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branches per plant, No. of capsules per plant, number of seeds per capsule, plant height and days to 50% flowering. They revealed that seed per plant had significant and positive correlation with No. of primary branches per plant, No. of seeds per capsule and capsule length. They revealed that path coefficient analysis had maximum positive direct effect of No. of capsules on seed yield followed by capsule length and plant height.

Anitha *et al*. (2010) studied two genotypes of sesame namely TMV4 (branched) and CS601 (shy branch) selected for the correlation study to assess the accosiation among yield and its components for selection criteria to develop new varieties. They revealed that correlation analysis had positive association of seed yield/plant with No. of capsules on branches/plant in both TMV 4 and CS 601. They also revealed that No. of branches and No. of capsules on main stem had positive association in both accessions. However, the association between No. of branches and seed yield, between No. of branches and No. of capsules on branches, between number of capsules on main stem and number of capsules on branches had positive association in TMV 4 only. Positive association was shown in plant height with number of capsules on main stem in CS 601 only.

Chowdhury *et al*. (2010) studied 21 sesame lines for genetic variability, path analysis and relationship between seven different yield contributing characters in rainfed areas planted during Kharif season. They concluded that No. of capsules/plant should be given prime importance while selecting high yielding sesame cultivars.

Sumathi and Muralidharan (2010) conducted an experiment with 30 hybrids produced by line x tester mating design from 11 sesame accessions involving five branched and six mono stem/shy branching types. High PCV and GCV estimates were observed for No. of branches/plant, No. of capsules/plant and yield/plant. They also observed high heritability combined with high genetic advance for plant height, No. of branches, No. of capsules and seed yield/ plant. Significant positive correlation was observed on seed yield/plant with plant height, No. of branches/plant, No. 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.

Yol *et al*. (2010) stated that plant height, No. of branches, No. of capsules/plant and 1000 seed weight had the significant positive effect on seed yield. The characters related to maturity, days to first flowering and 50% flowering, showed negative correlation with seed yield. The path coefficient

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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, No. of capsules per plant, No. 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.

Akbar *et al*. (2011) studied 105 sesame genotypes to evaluate the phenotypic variability by using 16 qualitative and quantitative characters. They 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. Multivariate analysis was performed in order to establish similarity and dissimilarity patterns. 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

Goudappagoudra *et al.* (2011) presented that seed yield/plant significantly and positively associated with No. of capsules, No. of seeds, No. of branches /plant, plant height and 1000 seed weight. The magnitude of correlation was the highest in case of No. of capsules/plant. High direct effect on seed yield was depicted by No. of capsules per plant, No. of seeds per capsule and 1000 seed weight. High and positive indirect effect on seed yield by No. of capsules/plant via days to 50% flowering, plant height and No. of branches/plant was observed.

Vanishree *et al*. (2011) studied 124 F_4 families of a cross E8 x Tamil Nadu Local to evaluate the interrelationship between yield and yield attributing characters and contributions of yield related traits to seed yield through correlation & path coefficient analysis. They revealed that seed yield per plant had highest magnitude of correlation with number of capsules per plant (r=0.932). They also concluded that No. of capsules/plant had highest positive direct effect (0.9525) followed by equal contribution by No. of seeds/capsule (0.1826) and 1000 seed weight (0.1821). They suggested that selection for capsules/plant shall improve yield in sesame.

Ibrahim and Khidir (2012) found highly significant correlations among seed yield/plant and seed yield ha^{-1}. Each of them also showed positive genotypic correlation with plant height, No. of capsules/plant, No. of primary branches,

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height to first capsule, days to 50% flowering and days to maturity. No of capsules/plant, 1000-seed weight and No. 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 No. of capsules per plant.

Menzir and Markos (2012) tested 64 sesame genotypes by using an 8x8 simple lattice design in main cropping season. They concluded that there was high phenotypic coefficient of variation (PCV) for No. of branches/plant, No. of capsules/plant, biomass yield ha^{-1}, yield ha^{-1}. They observed high heritability value for days to maturity followed by thousand seed weight and oil content. They also observed moderate heritability coupled with high genetic advance as % of mean for No. of branches/plant and plant height. They also worked out on cluster analysis and revealed that the 64 genotypes were grouped in 9 distinct clusters. Principal component analysis showed that the first four principal components explained about 75.59% of the total variation of characteristics of the different Ethiopian sesame local land races. Agronomic traits i.e. yield/plot, biomass yield, capsule filling period and days to maturity had contributed a lot in the formation of the clusters since they are the most contributor for variation in the first principal component (PC1).

Daniya *et al.* (2013) found seed yield correlated with plant height, branches/plant, leaves/plant, capsules/plant, seeds/capsule and 1000 - seed weight. They also 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 No. of seeds per capsule.

Thirumala *et al*. (2013) studied character association, genetic variability and path analysis between yield and its related traits in 48 sesame accessions. They revealed that analysis of variance shows significant differences among accessions for all the studied traits. High genetic advance coupled with high heritability as percent of mean was observed for No. of capsule/plant, seed yield and plant height representing the role of additive gene in expressing these characters. Path coefficient analysis showed that No. of capsules/plant and test weight were important characters to be considered for realizing the progress in yield.

Tsehaye *et al.* (2013) studied the genetic variability and relationship among different traits in 81 sesame genotypes and found that low grain yield and

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oil contents were correlated with each other. Harvest index, No. of primary branches/plant and height to first capsule depicted high heritability and genetic advance. Harvest index indicated positive phenotypic and genotypic association with seed yield. Grain yield is considered as dependent variable in path coefficient analysis and it showed positive effect on seed.

Vanishree *et al*. (2013) studied interrelationship between yield and yield related traits in F_4 families of sesame by using correlation coefficient and path coefficient analysis. Their results showed that magnitude of correlation was highest in case of capsules/plant and seed yield/plant and path coefficient analysis had maximum positive direct effect of capsules/plant on seed yield/plant followed by number of seeds/capsule and 1000 seed weight.

Conclusion

Genetic variability, 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 prove that plant height, number of branches per plant, number of capsules per plant, seeds per capsules, 1000-seed weight are the traits, controlled by additive gene action. These traits have major contribution in the production of sesame variety. So, it is concluded that these traits may be used as selection criteria in future breeding programs for the improvement of seed yield of sesame. As demand of sesame is increasing day by day, so it is obligatory to make efforts for the development of high yielding, disease and insect/pest resistant sesame cultivars.

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