

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

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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 analysis 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, 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

Sesame (*Sesamum indicum* L.), a conventional oilseed crop grown well in tropical and subtropical areas of the world (Gandhi, 2009). There are 37 species in the genus *Sesamum*; out of which only *indicum* is widely cultivated (Kobayashi, 1981). There are branched and single stem varieties. Sesame plant has deep root system and well adapted to water deficit conditions. It is sound

37 suited to smallholder farming with a relatively short harvest period allowing
38 other crops to be grown in the field (Chemonics, 2002; Naturland, 2002). The
39 best range of temperature for growth blossoms and fruit ripening is 26-30°C
40 (Naturland, 2002). Sesame is a short duration crop which completes its cycle
41 within 100-110 days. It is fit as catch crop in Zaid Kharif because wheat can be
42 timely cultivate after sesame. Therefore, there is a great scope of horizontal
43 expansion of sesame without affecting current area under different crops. Sesame
44 is a very rewarding crop due to its low cost of production and high price. (Anwar
45 *et al.*, 2013). During 2012-13, 29.10 thousand tons of sesame seed was produced
46 in Pakistan from an area of 70.90 thousand hectares (Agricultural Statistics of
47 Pakistan, 2012-13). During 2013-14, 37.63 million tons sesame seed worth Rs.
48 7342 million was exported (Federal Bureau of Statistics, 2013-14).

49 The chemical composition of sesame seed shows that the seed is a good
50 source of carbohydrate (13.5%), protein (18-25), ash (5%) (Borchani *et al.*,
51 2010) and about 50% oil of high quality (Roy *et al.*, 2009). Sesame seed also
52 contains high percentage of some essential amino acids (Kanu *et al.*, 2007a,
53 2007b, 2009) and vitamin B complex, important for cell oxygenation influencing
54 liver cells favorably (Sarwar and Hussain, 2010). Sesame seeds are used as raw
55 food as well as in confectionery, sweets, bakery products and also oil is used for
56 industry in preparation of soap, perfume and carbon papers as well as vegetable
57 oil (Khan *et al.*, 2001; Yol *et al.*, 2010).

58 Genetic variability shows the difference among genetic material of
59 individuals. It is a measure of the tendency of individual genotypes in a
60 population to vary from one another (Safavi *et al.*, 2010). Correlation analysis
61 explains relations of the morphological characters with each other, while path
62 coefficient analysis examines direct and indirect effects of various traits on seed
63 yield (Marinkovic, 1992). Information on the nature and level of genetic
64 variability present in a crop species is important for crop improvement and
65 development programs and also for the development of any desired character
66 (Dabholkar, 1999).

67 Pakistan is facing an acute shortage of edible oil. Demand of edible oil in
68 Pakistan is increasing with the increase in population while production of edible
69 oil is decreasing every year. Development of a suitable and high yielding oilseed
70 cultivars are dire need to overcome the upcoming food and health threats. The
71 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.

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 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 (1994) investigation of 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, seed number 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 genotypes for 21 traits by correlation and path analysis. 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.

Biswas and Akbar (1995) 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%). Seed yield was significantly and positively correlated with days to maturity,

107 plant height, number of branches/plant, number of capsules/plant and 1000-seed
108 weight at the genotypic level. It is suggested that number of branches/plant,
109 1000-seed weight, days to flowering and number of capsules/plant are the most
110 important characters for improving yield.

111 Chaudhary (1995) carried out path analysis on data on seed yield and its
112 components in sesame varieties JLT26 and JLT27. Seed yield was positively and
113 significantly correlated with plant height, number of leaves, primary branches,
114 length of main branch, number of capsules on main branch, number of capsules
115 per plant, capsule length and seeds per capsule in both varieties. Number of
116 capsules per plant and seeds per capsule were the only two characters which
117 contributed to seed yield directly.

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

129 Rao (1995) studied sesame cultivars in field trials at Parbhani,
130 Maharashtra. Seed yield/plant was positively correlated with plant height,
131 number of branches, leaf area, number of capsules/plant, capsule length, number
132 of seeds/plant and seed weight under all irrigation schedules.

133 Reddy and Dorairaj (1995) compared fifty genotypes for heritability and
134 correlations among 5 components of dry matter production. The highest
135 genotypic coefficient of variability, heritability and genetic advance were
136 observed for stem weight, indicating additive gene action. The lowest heritability
137 and genetic advance, as a proportion of the mean, were for root weight and seed
138 yield. Stem weight had the highest genotypic correlation with seed yield,
139 followed by capsule weight, root weight and leaf weight.

140 Ananda and Sivasamy (1996) studied the six high-yielding homozygous
141 genotypes (TSS6, TNAU12, TNAU17, TNAU86, VS117 and DPI1589). They
142 revealed that the traits, capsules on the main stem as well as on branches, leaf

143 area and shoot weight showed a positive correlation with yield and an intensive
144 positive selection for these traits will improve the yield automatically.

145 Guirguis *et al.*, (1996) evaluated 20 genotypes for yield and seed
146 characters. Differences among genotypes in plant height, first capsule height,
147 fruiting zone length, number of branches/plant, number of capsules/plant, 1000-
148 seed weight, yield/plant and yield/feddan [1 feddan = 0.42 ha] were significant or
149 highly significant. Significant positive correlation occurred between plant height
150 and number of branches/plant and fruiting zone length. Yield/plant was positively
151 correlated with first pod height and the number of branches/plant. Highly
152 significant positive correlation occurred between seed yield/plant and
153 yield/feddan, suggesting that single plant selection would be effective for
154 increasing yield.

155 Patil and Sheriff (1996) worked on 100 genotypes and 16 quantitative
156 characters were observed for 5 competitive plants in each genotype. The
157 genotypes exhibited significant variability for the characters studied. Heritability
158 estimates were high for seed yield per plant, oil yield per plant, oil contents,
159 days to maturity, harvest index, number of capsules, days to 50% flowering and
160 capsule length.

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

166 Backiyarani *et al.*, (1997b) evaluated F2 and F3 generations having
167 different GCA (high=H and low=L) for variability, heritability and genetic
168 advance of 7 traits. H X H populations had higher mean values than H X L and L
169 X L for all traits, except for seed number and percentage oil, respectively. All
170 populations in F2 and F3 recorded desirable means and moderate to high
171 heritability for primary branches, capsule number, seed number, percentage oil
172 and yield/plant. Number of capsules and seeds, 1000-seed weight and single plant
173 yield decreased from F2 to F3 in all populations.

174 Sudharani *et al.*, (1996) calculated the direct and indirect correlation
175 coefficients from path analysis of data on 10 yield-related traits in the bi-parental
176 progenies and F3 bulk population of cross R84-4-2X X X198. The direct effects
177 of plant height, capsules on main stem and 1000-seed weight were greater in bi-
178 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. 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, 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.*, (1997a) studied, 35 diverse genotypes to determine the association of seed yield with various yield components. 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.

Singh *et al.*, (1997b) suggested that the range and coefficient of variability 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. 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

214 be exercised simultaneously for increased numbers of productive capsules and
215 primary branches per plant.

216 Subrata and Maity (1997) evaluated 34 cultivars for 8 yield components.
217 Significant inter-varietal differences were observed without any cultivar X year
218 interactions. Estimates of broad sense heritability, genetic advance and the
219 genotypic coefficient of variation indicated the importance of seed yield, number
220 of capsules, husk weight, number of branches and 1000-seed weight in the
221 selection of genotypes with high yield potential. Seed yield was positively
222 associated with number of capsules, husk weight, number of branches, number of
223 seeds and seed weight.

224 Tak (1997) derived information on correlation and path coefficients from
225 data on 6 yield-related traits in 25 promising genotypes of diverse eco-
226 geographic origin. The variability among the genotypes was large for all the
227 characters studied. Seed yield exhibited significant and positive correlation with
228 siliqua per plant, seeds per siliqua and primary branches per plant. The 1000-seed
229 weight had the greatest direct effect on seed yield, but its utility is doubtful
230 because of its negative indirect effects through other yield-related traits. Number
231 of primary branches per plant, silique per plant and seeds per siliqua had high
232 degrees of direct and indirect effects on seed yield.

233 Govindarasu *et al.*, (1998) studied six mutated varieties and their nine
234 hybrids. Correlation coefficients between seed yield and 6 quantitative traits
235 were estimated for the parental, M3, F3 and F3, M3 generations. Capsule number
236 and branch number had consistently strong positive genotypic correlations and
237 high positive direct effects with seed yield in all the populations.

238 Manivannan (1998) analyzed simple correlation in back crosses B1 and
239 B2. The analysis revealed branches, capsules on main stem and capsules on
240 branches were positively correlated with seed yield. Path analysis revealed that
241 capsules on branches had high direct effect on seed yield.

242 Arriel (1999) estimated the heritability and genetic gain and obtain genetic
243 and phenotypic correlations between flowering characters, plant height, capsules
244 per plant, maturation and yield per plant in cultivars. Estimates of high
245 heritability and percent genetic gain in relation to the average were recorded
246 from seed yield, 72.63 and 28.77%, respectively, showing a considerable success
247 in the selection of that character. Highly significant genetic correlation was
248 observed between the yield and the total number of capsules (0.77) and this
249 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.

Karuppaiyan and Ramasamy (2000) studied 80 sesame F₁ hybrids derived from 20 (lines) × 4 (testers) mating design for 10 quantitative traits and performed genotypic correlation and path coefficient analysis. They 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 (2000) studied two cultivars to evaluate the different growth and yield related traits on the yield. The data 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.

Kavitha and Ramalingam (2000) recorded the correlations among eight yield components from 50 segregating families. 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 was positively correlated with total Number 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.

Singh *et al.*, (2000b) studied improvement of seed yield in 17 newly developed genotypes of sesame. 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 (5.3%), indicating that these characters were more influenced by the environment. 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.

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. 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 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, 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.

Shim *et al.*, (2001) conducted 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 percent 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.

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, capsules /plant, capsule length, capsule width, number 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, number of primary branches/plant, capsule length, capsules/plant, 1000 seed weight, oil percentage and single plant yield. They revealed that yield/plant had positively and significantly correlated with plant height, number of primary branches/plant, capsule length, number 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 number of capsules/plant. They suggested that number of capsules/plant can be taken as an index for improving yield in sesame.

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

394 was positively correlated with plant height, number of capsules per plant and
395 100-seed weight. The number of days to 50% flowering, number of days to
396 maturity and number of branches per plant were negatively correlated with seed
397 yield.

398 Solanki and Gupta (2003) conducted genetic variation and correlation
399 analyses for yield and yield components for 90 exotic genotypes with 2 local
400 controls. Seed yield, branches per plant, and capsules per plant were
401 characterized by high heritability and high genetic advance, indicating that these
402 traits were controlled by additive gene. The seed yield per plant showed a high
403 and positive association with all the characters except number of days to
404 flowering and maturity. Plant height was positively correlated with number of
405 branches and capsules per plant. A positive correlation was observed between the
406 branches per plant and capsules per plant, and between 1000-seed weight and oil
407 content. Path analysis revealed that 1000-seed weight had the greatest direct
408 effect on seed yield, followed by branches per plant, oil content, capsules per
409 plant, days to flowering and number of days to maturity.

410 Babu *et al.*, (2004a) assessed variability, heritability, genetic advance and
411 genetic advance as percent of mean in white seeded genotypes of sesame. A wide
412 range of variation was recorded for plant height, number of capsules per plant,
413 number of seeds per capsule, 1000-seed weight, leaf area index, harvest index,
414 seed yield per plant and oil yield per plant. The coefficients of variation were
415 high for plant height and seed yield per plant. High heritability coupled with high
416 genetic advance was observed for number of primaries, number of capsules per
417 plant, seed yield per plant and oil yield per plant. 1000-seed weight and oil
418 content showed low heritability as well as low genetic advance besides narrow
419 range of variability.

420 Babu *et al.*, (2004b) studied 18 diverse genotypes of sesame for
421 association between yield and yield component characters at genotypic and
422 phenotypic level, besides estimating the direct and indirect effects through path
423 coefficient analysis. Number of primaries per plant, number of capsules per
424 plant, number of seeds per capsule, 1000-seed weight, leaf area index, harvest
425 index and seed yield per plant had highly significant positive association with oil
426 yield per plant and also had positive direct as well as indirect effects through
427 many other characters.

428 Bhuyan and Sarma (2004) analyzed 30 cultivars of sesame belonging to
429 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.

Solanki and Gupta (2004) determined the genetic diversity, variability and heritability in 48 sesame genotypes. 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.

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.

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 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.

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 F₁ 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 with the aim of understanding the relationship of seven metric traits i.e. days to 50 %flowering, days to maturity, plant height, number of primary branches, capsules/plant, 100-seed weight and oil content with yield/plant. 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 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, Number of branches/plant, Number of capsules/plant, seed yield/plant and seed yield m⁻². They observed high heritability estimates together with high genetic advance for Number of branches/plant, Number 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

502 and Number of capsules/plant showed significant and positive correlations with
503 single plant yield at both genotypic and phenotypic levels. Plant height and
504 Number of capsules/plant showed positive association with all the other traits
505 except 100 seed weight. Whereas, negative correlation was found between
506 branches/plant and oil contents. High positive direct effects by capsules/plant
507 were found on grain yield. Number of capsules/plant showed high indirect effect
508 on grain yield through plant height, oil contents and days to maturity.

509 Biabani and Pakniyat (2008) studied 15 sesame accessions grown in a
510 randomized complete block design with three replications. Path coefficient
511 analysis and factor analysis divided the 15 measured variables into 5 factors. The
512 5 factors explained 81% of the total genetic variation in the dependence
513 structure. Factor 1 was strongly associated with number of capsules in the main
514 stem, length of floral axis, number of capsules per plant and plant height. Other
515 factors (2, 3, 4 and 5) explained the rest of genetic variations and may not be
516 important in sesame breeding programs.

517 Gnanasekaran *et al.*, (2008) studied 40 accessions of sesame and reported
518 relationship between seed yield and its contributing traits. They also reported
519 that seed yield per plant showed highly significant relationship with
520 branches/plant capsules/plant and seed/capsules. Positive and significant
521 relationship among capsule length and 1000-seed weight. According to path
522 analysis, number of branches per plant via Number of capsules per plant or vice-
523 versa showed positive indirect effects on seed yield and played important role to
524 increase seed yield in sesame, therefore, these characters should be given due
525 importance for selecting high yielding varieties of sesame.

526 Kumhar *et al.*, (2008) studied 82 accessions and revealed that seed yield
527 had significant positive correlation with capsules/plant, oil content, test weight;
528 capsule bearing height and primary branches per plant. The maximum positive
529 direct effects on seed yield was observed by capsules per plant followed by test
530 weight and plant height, while days to maturity, days to 50% flowering and
531 capsule bearing height had negative effect. They revealed that capsules/plant, test
532 weight and plant height were the major components contributing to the yield in
533 sesame.

534 Kumar and Vivekanandan (2009) studied correlation and path analysis of
535 45 hybrids and 14 parents in sesame for the characters like days to maturity,
536 plant height, Number of branches/plant, Number of capsules/plant, capsule
537 length, Number 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 Number of branches and Number 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 Number of capsules/plant may be good selection criteria for seed yield/plant.

Parameshwarappa *et al.*, (2009) studied 151 sesame accessions and revealed that analysis of variance showed significant difference among accessions for all studied traits. They 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.

Anitha *et al.*, (2010) studied two genotypes of sesame namely TMV4 (branched) and CS601 (shy branch), revealed that correlation analysis had positive association of seed yield/plant with Number of capsules on branches/plant in both TMV 4 and CS 601. They also revealed that Number of branches and Number of capsules on main stem had positive association in both accessions. However, the association between Number of branches and seed yield, between Number of branches and Number 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 Number 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 Number of branches/plant, Number of capsules/plant and yield/plant. They also 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.

Yol *et al.*, (2010) stated that plant height, Number of branches, Number 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 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.

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 Number of capsules, Number of seeds, Number of branches /plant, plant height and 1000 seed weight. 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.

Vanishree *et al.*, (2011) studied 124 F₄ families of a cross E8 x Tamil Nadu Local and revealed that seed yield per plant had highest magnitude of correlation with number of capsules per plant ($r=0.932$). They also concluded that Number of capsules/plant had highest positive direct effect (0.9525) followed by

610 equal contribution by Number of seeds/capsule (0.1826) and 1000 seed weight
611 (0.1821). They suggested that selection for capsules/plant shall improve yield in
612 sesame.

613 Ibrahim and Khidir (2012) found highly significant correlations among
614 seed yield/plant and seed yield ha⁻¹. Each of them also showed positive genotypic
615 correlation with plant height, Number of capsules/plant, Number of primary
616 branches, height to first capsule, days to 50% flowering and days to maturity. No
617 of capsules/plant, 1000-seed weight and Number of seeds/capsule showed the
618 highest positive direct effects on seed yield per plant. Highest positive indirect
619 effect on seed yield/plant was exhibited by number of primary branches via
620 Number of capsules per plant.

621 Daniya *et al.*, (2013) found seed yield correlated with plant height,
622 branches/plant, leaves/plant, capsules/plant, seeds/capsule and 1000 - seed
623 weight. They also found that seeds per capsule contributed more to seed yield
624 compared with other growth and yield characters measured. Path analysis
625 revealed that greatest direct effect and individual factor contribution to seed
626 yield were made by Number of seeds per capsule.

627 Thirumala *et al.*, (2013) studied 48 sesame accessions having significant
628 differences for all the studied traits. High genetic advance coupled with high
629 heritability as percent of mean was observed for Number of capsule/plant, seed
630 yield and plant height representing the role of additive gene in expressing these
631 characters. Path coefficient analysis showed that Number of capsules/plant and
632 test weight were important characters to be considered for realizing the progress
633 in yield.

634 Tsehaye *et al.*, (2013) studied the genetic variability and relationship
635 among different traits in 81 sesame genotypes and found that low grain yield and
636 oil contents were correlated with each other. Harvest index, Number of primary
637 branches/plant and height to first capsule depicted high heritability and genetic
638 advance. Harvest index indicated positive phenotypic and genotypic association
639 with seed yield. Grain yield is considered as dependent variable in path
640 coefficient analysis and it showed positive effect on seed.

641 Vanishree *et al.*, (2013) studied interrelationship between yield and yield
642 related traits in F₄ families of sesame. Their results showed that magnitude of
643 correlation was highest in case of capsules/plant and seed yield/plant and path
644 coefficient analysis had maximum positive direct effect of capsules/plant on seed
645 yield/plant followed by number of seeds/capsule and 1000 seed weight.

Alege *et al.*, (2014) studied genetic diversity and correlation coefficient on 23 genotypes of different origin for phytochemical nature. The results revealed high genetic diversity among the 23 sesame genotypes and showed that the phenolic contents had negative correlation with tannin while flavonoid had positive correlation with saponin and alkaloid.

Hika *et al.*, (2014) studied 64 sesame genotypes to reveal the association between different yield related traits. The results 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.

Perere and Pushpakumara (2014) worked on 43 sesame accessions and 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.

Anash *et al.*, (2015) 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.

Fazal *et al.*, (2015) conducted a study to estimate the genetic variability and trait correlation among 13 sesame genotypes. Analysis of variance showed that genotypes differed highly significantly from each other for all the characters. Yield per plant had highly significant positive correlation with all other traits both at genotypic and phenotypic level. 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-1: Genotypic and phenotypic correlations for different traits in sesame
(Fazal *et al.*, 2015)

		CPP	BPP	SPC	1000SW	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.*, 2015)

	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.

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 and 1000-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

705 to make efforts for the development of disease resistant, insect/pest resistant and
706 high yielding sesame cultivars.

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