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Research Article

Studies on trait association and path co-efficient analysis of sesame (Sesamum sp.) for quantitative traits and oil quality parameters

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Abstract
Sesame is called as Queen of Oilseed crops because of its high oil content. The current study was focused on the association and path co-efficient analysis of 17 yield components with yield and six oil quality parameters with oil content. From 17 traits days to 50 per cent flowering, days to maturity, number of primary branches per plant, number of secondary branches per plant, top petiole length, capsule length, capsule width, seed weight were associated with single plant yield and oil content. The outcome of the study gives a tremendous scope in identifying plants with high yielding early plant type with increased oil content and more number of branches. For six oil quality parameters, oil content had a positive correlation with saponification value and peroxide value, negative correlation with sesamin, sesamol and iodine value. Path analysis for yield components revealed that the number of primary branches made the highest direct effect on single plant yield of sesame, while the lowest direct effect was from days to maturity. The high residual effect (0.37) showed the contribution of other yield contributing characters towards the yield. The direct effect of the traits acid number, saponification value and peroxide value were negative and positive direct effect was recorded by sesamin content. Based on correlation and path analysis for oil quality parameters, the availability of high oil yielding genotypes with increased sesamin and sesamol content is extremely difficult, with a rare exception of CO 1, future breeding programmes should be aimed at utilizing genotypes with the high sesamin content having lipogenetic, cholestrogenetic character and sesamol content exhibiting anti-ageing, antitumor, anti-carcinogenic and hepatoprotective property to get superior oil quality combined with high oil yield.

Keywords
Sesame, Correlation, Path co-efficient, Sesamin, Sesamol

INTRODUCTION
Sesame (Sesamum spp.), a member of Pedaliaceae family, is an important and oldest oilseed crops known to man and was an integral part of ancient legends, has the early origins in East Africa and India as well (Nayar and Mehra, 1970; Bedigian and Harlon, 1986) mainly for edible oil and privileged as “Queen of oilseed crops” (Weiss, 1971). Sesame plays an important role in human nutrition. The oil has a mild odour and pleasant taste and as such, is a natural salad oil requiring little or no winterization (Yoshida, 1994). Sesame contains ample amounts of oleic acid (43 per cent), linoleic acid (35 per cent), palmitic acid (11 per cent) and stearic acid (7 per cent) which comprise of 96 per cent of the total fatty acids (Saydut et al., 2008). Sesame oil is known to be resistant to natural oxidation, attributed to the anti-oxidation activity of sesame lignans (Fukuda et al., 1986). Sesame is rich in furufuran lignan (Kamal- Eldin et al. 2011). Sesamin and Sesamolin is fat-soluble present in sesame seeds
and oil at a ratio of 2:1 (Yasmoto et al. 2001). Sesamin, the most abundant oil-soluble lignan and exerts diverse biological functions (Namiki, 2007). The sesaminol content plays an important role in the color and flavor of sesame oil (Reshma et al., 2010) Another major lignan of sesame is sesaminol, which exists as glucosides (Katsuzaki, 1994) and is not extractable from oil (Ide et al., 2009).

Though much importance was given to quality, quantitative parameters that contribute to yield are required basically. In plant breeding, the correlation coefficient measures the mutual relationship between various characters and determines the compound on which selection can be based for genetic improvement in yield. To increase yield, the study of direct and indirect effects of yield and its components provide the basis for its successful breeding program and this can be attained by Path co-efficient analysis. Although sesame seeds and oils are used extensively in India, the lignan profile in Indian sesame cultivars has not been reported extensively and very few are available. The present study was done to determine the lignan profile of cultivated species of sesame and a few wild species. Along with these compounds, some other quality determining characters like Iodine value, Peroxide value, Saponification value and Acid number was also analyzed. This character describes the quality of the oil like rancidity, oxidation rate. An attempt has been made in this study to know the relationship between yield and yield attributing characters along with oil quality parameters and their direct and indirect effect on yield in Sesame.

**MATERIAL AND METHODS**

A total of 53 sesame genotypes of various geographical origins were used as materials for the study are listed in Table 1. Out of 53 genotypes other than *Sesamum indicum* L., *S. malabaricum* (2 genotypes), *S. malayanum* (3 genotypes), *S. radiatum* (5 genotypes), *S. anamalyensis* (one genotype) were also used. A total of 33 genotypes collected from Regional Research Station, Vridhachalam, five genotypes from the Department of Oilseeds, TNAU, Coimbatore and 15 genotypes from National Bureau of Plant Genetic Resources, Thrissur. Fifty-three genotypes were raised in a randomized block design (RBD) with two replications at specimen plot at Indian sesame cultivars has not been reported extensively and very few are available. The present study was done to determine the lignan profile of cultivated species of sesame and a few wild species. Along with these compounds, some other quality determining characters like Iodine value, Peroxide value, Saponification value and Acid number was also analyzed. This character describes the quality of the oil like rancidity, oxidation rate. An attempt has been made in this study to know the relationship between yield and yield attributing characters along with oil quality parameters and their direct and indirect effect on yield in Sesame.

RESULTS AND DISCUSSION

Genotypic correlation coefficients between single plant yield and its 17 yield contributing traits and also inter-correlation were furnished in Table 2. Out of 171 character pairs studied, 64 pairs showed significant genotypic correlation coefficients.

Determination of seed and oil components and suitable character combinations that affect yield to a maximum extent is important in formulating various plant characters which will help in identifying the most important characters (Sarwar et al., 2005). Correlation studies provide reliable information on nature, extent and direction of selection (Ajibade, 1998). There was a negative genetic correlation between days to 50 per cent flowering, days to maturity, plant height, the number of primary branches, the number of secondary branches, capsule length, capsule width with single plant yield and oil content was in agreement with findings of Khairnar and Monopara (2013); Abate and Mekbib (2015) and Navaneetha et al. (2019) for single plant yield and with oil content by Desawi Hdru Teklu et al. (2014) and Abate (2018). There was no significant and positive association between the single plant yield and the number of capsules per plant, the number of seeds per capsule. Similar results were reported by Fazal Akbar et al. (2011) and Abate and Mekbib (2015). However, there was a positive and significant relationship between single plant yield and seed weight Daniya et al. (2013) and Abate and Mekbib (2015). With respect to leaf area and petiole length, no correlation was noticed between all the three-leaf areas base leaf area, mid leaf area and top leaf area, in case of petiole length, top petiole length was negatively correlated with single plant yield. Thus it affects the effective photosynthetic area in plant architecture. By reducing
Table 1. List of genotypes used for study

| Sl. No. | Genotypes | Species          | Source       |
|--------|-----------|------------------|--------------|
| 1.     | Mathw     | Sesamumindicum   | RRS          |
| 2.     | RT-125    | Sesamumindicum   | RRS          |
| 3.     | PonjasTil-1 | Sesamumindicum  | RRS          |
| 4.     | Swetha    | Sesamumindicum   | RRS          |
| 5.     | VRI 2     | Sesamumindicum   | RRS          |
| 6.     | CO 1      | Sesamumindicum   | TNAU         |
| 7.     | Chandana  | Sesamumindicum   | RRS          |
| 8.     | Varaha    | Sesamumindicum   | RRS          |
| 9.     | TMV 3     | Sesamumindicum   | RRS          |
| 10.    | SVPR 1    | Sesamumindicum   | RRS          |
| 11.    | Shekar    | Sesamumindicum   | RRS          |
| 12.    | VRI 1     | Sesamumindicum   | RRS          |
| 13.    | TMV 7     | Sesamumindicum   | RRS          |
| 14.    | TMV 4     | Sesamumindicum   | RRS          |
| 15.    | TMV 6     | Sesamumindicum   | RRS          |
| 16.    | Thilathara| Sesamumindicum   | RRS          |
| 17.    | Hima      | Sesamumindicum   | RRS          |
| 18.    | TKG-22    | Sesamumindicum   | RRS          |
| 19.    | ORM-17    | Sesamumindicum   | RRS          |
| 20.    | KMR-77-1  | Sesamumindicum   | RRS          |
| 21.    | RT-103    | Sesamumindicum   | RRS          |
| 22.    | N8        | Sesamumindicum   | RRS          |
| 23.    | Usha      | Sesamumindicum   | RRS          |
| 24.    | DS1       | Sesamumindicum   | RRS          |
| 25.    | Kanak     | Sesamumindicum   | RRS          |
| 26.    | JLT 7     | Sesamumindicum   | RRS          |
| 27.    | Thilothama| Sesamumindicum   | RRS          |
| 28.    | Pragathi  | Sesamumindicum   | RRS          |
| 29.    | RT 54     | Sesamumindicum   | RRS          |
| 30.    | GT-10     | Sesamumindicum   | RRS          |
| 31.    | Nirmala   | Sesamumindicum   | RRS          |
| 32.    | G Tul-1   | Sesamumindicum   | RRS          |
| 33.    | Krishna   | Sesamumindicum   | RRS          |
| 34.    | Rajeswari | Sesamumindicum   | RRS          |
| 35.    | Kaple     | Sesamumindicum   | RRS          |
| 36.    | Sesamumanamalyensis | Sesamumanamalyensis | TNAU |
| 37.    | Sesamumradiatum | Sesamumradiatum | TNAU         |
| 38.    | TMV 5     | Sesamumindicum   | TNAU         |
| 39.    | IC 199438 | Sesamumindicum   | NBPGR        |
| 40.    | IC 205091 | Sesamumindicum   | NBPGR        |
| 41.    | TCR 4731  | Sesamummulayanum | NBPGR       |
| 42.    | IC 208657 | Sesamumradiatum  | NBPGR        |
| 43.    | IC 208681 | Sesamumradiatum  | NBPGR        |
| 44.    | IC 208680 | Sesamumradiatum  | NBPGR        |
| 45.    | TCR 3148  | Sesamummulayanum | NBPGR        |
| 46.    | TCR 480513| Sesamummulayanum | NBPGR        |
| 47.    | TCR 3341A | Sesamummalabaricum | NBPGR    |
| 48.    | IC 208658 | Sesamumradiatum  | NBPGR        |
| 49.    | TCR 4849  | Sesamummalabaricum | NBPGR    |
| 50.    | IC 127324 | Sesamumindicum   | NBPGR        |
| 51.    | IC 199435 | Sesamumindicum   | NBPGR        |
| 52.    | IC 208660 | Sesamumindicum   | NBPGR        |
| 53.    | IC 127325 | Sesamumindicum   | NBPGR        |

RRS - Regional Research Station, Vridhachalam, Tamil Nadu, India  
TNAU - Department of Oilseeds, TNAU, Coimbatore, Tamil Nadu, India  
NBPGR - National Bureau of Plant Genetic Resources, Thrissur, Kerala, India

top petiole length, leaf area of the base and middle leaf exposed to sunlight gets increased and reduced the shadow effect, ultimately increases single plant yield. Similar reports were given by Adeoti et al., 2012. The purview of the inter-correlation between yield attributes suggested that the number of capsules per plant was
significant and negatively correlated with oil content and the number of capsules per plant exhibited no correlation with the number of seeds per capsule, seed weight, capsule length. These results were in accordance with earlier reports of Desawi Hdru Teklu et al. (2014) and Abhijatha et al (2017). Capsule length exhibited a significant and negative correlation with oil content whereas its association with the number of capsules per plant, the number of seeds per capsule, seed weight was not significant. Desawi Hdru Teklu et al. (2014) and Abate and Mekbib (2015) were reported similar results for capsule length with a number of capsules per plant, the number of seeds per capsule, 1000 seeds weight.

The trait number of seeds per capsule showed positive and significant correlation with the number of capsules per plant, capsule length, seed weight and oil content. Similar reports were given by Desawi Hdru Teklu et al. (2014) and Navaneetha et al. (2019).

Table 2. Correlation among quality component with an oil content of Sesame

| Character          | Iodine Value | Acid number | Saponification value | Peroxide value | Sesamin | Sesamol | Oil content |
|--------------------|--------------|-------------|----------------------|----------------|---------|---------|-------------|
| Iodine Value       | 1.00         | 0.234*      | -0.402**             | -0.358**       | 0.255*  | 0.112   | -0.311*     |
| Acid Number        | 1.00         | -0.132      | 0.395**              | 0.136          | 0.221   | -0.197  |             |
| Saponification     | 1.00         | 0.148       | 0.527**              | 0.324**        | 0.438** |         |             |
| Peroxide Value     | 1.00         | -0.099      | 0.061                | 0.058          |         |         |             |
| Sesamin            | 1.00         | 0.797**     | -0.367**             |               |         |         |             |
| Sesamol            | 1.00         | -0.448**    |                      |               |         |         |             |
| Oil content        | 1.00         |             |                      |               |         |         |             |

*Significance at 5% level  **Significance at 1% level

From the above results, it was seen that nine of 17 traits were not associated with single plant yield but important yield contributing traits viz., days to 50 per cent flowering, days to maturity, the number of primary branches per plant, the number of secondary branches per plant, top petiole length, capsule length, capsule width, seed weight were correlated with single plant yield and oil content. It indicates that the selection of plants with reduced capsule length with higher seed weight will boost the seed yield. The outcome of the study gives a tremendous scope in identifying a plant with a high yielding early plant with increased oil content and more number of branches.

The correlation was studied for six oil qualitative parameters were listed in Table 3. On correlating with oil content, Saponification value and peroxide value had a positive correlation and iodine value, sesamin and sesamol had a negative correlation. This study infers that it is hard to develop a variety having high oil content along with high lignan content. Inter correlation was studied among all the traits. When iodine value was compared, it was positively correlated with acid number and sesamin, while saponification value was positively associated with sesamin and sesamol. Sesamin was positively correlated with sesamol. By this study, acid number is negatively

Table 3. Correlation among quality components with an oil content of Sesame
correlated with oil content and thus by reducing acid number oil quality can be enhanced. Though sesamin and sesamol cannot be improved directly, it can be improved along with other quality traits. The sesamin content can be improved indirectly by enhancing iodine value as it is a desirable quality trait. Sesamol can be simultaneously increased by increasing sesamin. This study is the pioneering attempt to report the correlation between quality traits of sesame oil.

Path analysis is a technique used to determine the direct influence of one variable on another and is also used to separate the correlation coefficients into direct effect (path coefficient) and indirect effects (effects exerted through other independent variables) (Azeez and Morakinyo, 2011). The result of path analysis was presented in Table 4, number of primary branches made the highest direct effect on single plant yield of sesame, while the lowest direct effect was from days to maturity. Days to 50 per cent flowering has contributed maximum indirect effect on seed yield, number of primary branches. However, the effect of the number of primary branches via days to maturity on seed yield was the least. The number of primary branches had a positive direct effect on single plant yield but it showed a negative correlation with single plant yield because of the negative influence by other traits. This finding was in agreement with Desawi Hdru Teklu et al. (2014) and Navaneetha et al. (2019). Seed weight showed a positive genetic correlation with single plant yield with high negative direct effect. However, it contributes an indirect effect through capsule width and days to maturity. The negative association of capsule width and days to maturity necessitates the breeder to select plants optimum capsule width to improve seed yield and seed weight.

### Table 4. Path Coefficient analysis showing direct and indirect effects of eight quantitative traits of Sesamum on single plant yield

| Characters                  | Days to 50% flowering | Days to maturity | Number of primary branches per plant | Number of secondary branches per plant | Top petiole length | Capsule length | Capsule width | 1000 seed weight | Correlation Single plant yield |
|-----------------------------|------------------------|------------------|--------------------------------------|----------------------------------------|--------------------|----------------|--------------|------------------|-----------------------------|
| Days to 50% flowering       | 0.013                  | -1.524           | 0.970                                | -0.264                                 | -0.156             | -0.076         | -0.221       | 0.065            | -0.287                      |
| Days to maturity            | 0.009                  | -2.212           | 0.786                                | -0.314                                 | -0.099             | -0.079         | 0.266        | 0.241            | -0.360                      |
| Number of primary branches  | 0.010                  | -1.411           | 1.235                                | -0.318                                 | -0.124             | -0.072         | -0.232       | -0.064            | -0.200                      |
| Number of secondary branches| 0.006                  | -1.283           | 0.726                                | -0.541                                 | -0.207             | -0.062         | 0.113        | 0.031            | -0.293                      |
| Top petiole length          | 0.003                  | -0.370           | 0.260                                | -0.189                                 | -0.592             | -0.010         | 0.118        | -0.171            | -0.266                      |
| Capsule length              | 0.003                  | -0.521           | 0.264                                | -0.100                                 | -0.017             | -0.336         | -0.107       | 0.097             | -0.172                      |
| Capsule width               | 0.002                  | 0.440            | 0.215                                | 0.046                                  | 0.052              | -0.027         | -1.338       | 0.240             | -0.094                      |
| 1000 seed weight            | -0.001                 | 0.751            | 0.111                                | 0.023                                  | -0.142             | 0.046          | 0.453        | -0.710            | 0.365                       |

### Table 5. Path coefficient analysis showing direct and indirect effects of quality traits of Sesamum on oil content

| Character               | Iodine Value | Acid number | Saponification value | Peroxide value | Sesamin | Sesamol | Correlation Oil content |
|-------------------------|--------------|-------------|----------------------|----------------|---------|---------|------------------------|
| Iodine Value            | -0.351       | -0.011      | 0.051                | 0.006          | 0.028   | -0.055  | -0.311                 |
| Acid Number             | -0.077       | -0.045      | 0.017                | 0.001          | 0.015   | -0.108  | -0.197                 |
| Saponification Value    | 0.133        | 0.436       | -0.126               | -0.002         | -0.001  | -0.002  | 0.438                  |
| Peroxide Value          | 0.118        | 0.004       | -0.019               | -0.015         | -0.001  | -0.030  | 0.058                  |
| Sesamin                 | -0.084       | -0.006      | 0.001                | 0.000          | 0.111   | -0.389  | -0.367                 |
| Sesamol                 | -0.037       | -0.010      | 0.000                | -0.001         | 0.088   | -0.488  | -0.448                 |

Direct effects are diagonal, Residual effect = 0.08

The high residual effect (0.37) showed the contribution of other yield contributing characters towards the yield. This was in accordance with Renuka et al. (2010) and Mohan Lal et al. (2016). From the above results, it could be inferred that the characters, days to maturity, the number of primary branches, the number of secondary branches, top petiole length, capsule length, capsule width and seed weight should be given prime importance as they revealed a significant correlation coefficient and a high direct effect.

Path analysis for six quality parameters was listed in Table 5. The direct effect of the traits viz., acid number, saponification value and peroxide value were negative and positive direct effect was recorded by sesamin content. The negative direct effect of saponification value on oil content was influenced by acid number and iodine value likewise; the negative direct effect of peroxide value was hindered by iodine value. The parameter sesamin content was negatively correlated with oil content but the
direct effect was positive. The positive direct effect of sesamin was nullified through the negative and indirect effect of sesamol content on oil content. By this investigation, it is understood that the oil quality parameters cannot be enhanced simultaneously. Sesame crop improvement can be further enhanced by selecting and utilizing genotypes with high sesamin content, moderate saponification value and peroxide value, low acid number and sesamol. No reports are available either to support or contradict the current research finding related to path coefficient analysis for oil quality components in sesame. Hence, this study gives a tremendous scope for further improvement of sesame oil quality.

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