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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; Bediginan 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 furofuran 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 sesamol 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. mulayanum* (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 the Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai, Tamil Nadu during *Kharif*, 2014. Eighteen yield contributing traits were measured in five randomly selected plants from each replication in each genotype were labelled and taken for recording observations. The mean was worked out and used for statistical analysis. The characters *viz.,* days to 50 per cent flowering, days to maturity, plant height, the number of primary branches, the number of secondary branches, basal leaf area, basal petiole length, mid leaf area, mid petiole length, top leaf area, top petiole length, the number of capsules per plant, capsule length, capsule width, the number of seeds per capsule, 1000 seed weight, oil content and single plant yield were recorded. Leaf area was calculated by measuring mean length and width of five leaves from the main stem of randomly selected five plants; multiplied with a constant value of 0.3552 (Silva *et al*., 2002). Oil content was estimated using Soxhlet extractor installed at the Department of Food Science and Technology, Home Science College and Research Institute, Madurai. The sesamum oil quality parameters namely iodine value, acid number (mg g^{-1}), saponification value and peroxide values (milli eq. kg^{-1}) were estimated by AOAC (2000) methods. The two quality enhancing components sesamin (g kg^{-1}) and sesamol (g kg^{-1}) were determined using UV-spectrophotometer.

The genotypic correlation coefficients between yield and yield components and for quality characters were worked out. The relative influence of seventeen components on yield by themselves (direct effects) and through other traits (indirect effects) were evaluated by the method of path coefficient analysis as suggested by Dewey and Lu (1959). The direct and indirect effects were classified based on the scale given by Lenka and Mishra (1973).

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 yield 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.	Mathvi	*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 Til- 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	*Sesammulayanum*	NBPGR
42.	IC 208657	*Sesamumradiatum*	NBPGR
43.	IC 208681	*Sesamumradiatum*	NBPGR
44.	IC 208680	*Sesamumradiatum*	NBPGR
45.	TCR 3148	*Sesammulayanum*	NBPGR
46.	TCR 480513	*Sesammulayanum*	NBPGR
47.	TCR 3341A	*Sesammalabaricum*	NBPGR
48.	IC 208658	*Sesamumradiatum*	NBPGR
49.	TCR 4849	*Sesammalabaricum*	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 yield and yield contributing quantitative traits of s*esamum*

Clusters	Days to 50 % flowering	Days to maturity	Plant height	Number of primary branches per plant	Number of secondary branches per plant	Basal leaf area	Basal petiole length	Mid leaf area	Mid petiole length	Top leaf area	top petiole length	Number of capsules per plant	Capsule Length	Capsule width	Number of seeds per capsule	1000 grain weight	Oil Content	Single plant yield
Days to 50 % flowering	1.000	0.689**	0.273*	0.786**	0.489**	-0.002	0.157	0.146	0.321*	0.139	0.263*	0.175	0.226	0.165	-0.211	-0.091	-0.552**	-0.463**
Days to maturity		1.000	0.109	0.638**	0.580**	-0.014	-0.047	0.091	0.200	0.170	0.167	-0.087	0.236*	-0.199	-0.127	-0.339**	-0.554**	-0.574**
Plant height			1.000	0.279*	0.169	0.363**	0.449**	0.325**	0.325**	0.211	0.344**	0.457**	0.143	0.053	0.069	0.306*	-0.426**	-0.010
Number of primary branches per plant				1.000	0.587**	0.153	0.309*	0.373**	0.403**	0.174	0.210	0.310*	0.213	0.174	-0.105	0.090	-0.556**	-0.302*
Number of secondary branches per plant					1.000	0.306*	0.187	0.440**	0.413**	0.269*	0.349**	0.092	0.185	-0.084	-0.021	-0.043	-0.490**	-0.472**
Basal leaf area						1.000	0.782**	0.622**	0.559**	0.006	0.099	0.347	-0.006	0.024	0.219	0.159	-0.042	-0.219
Basal petiole length							1.000	0.600**	0.492**	0.153	0.331**	0.440**	-0.026	0.182	0.008	0.297*	-0.194	-0.221
Mid leaf area								1.000	0.596**	0.281*	0.401**	0.233*	0.074	0.078	0.092	0.226	-0.223	-0.174
Mid petiole length									1.000	0.152	0.259*	0.492**	-0.006	0.096	0.087	0.220	-0.336**	-0.060
Top leaf area										1.000	0.684**	0.012	0.129	-0.118	-0.208	0.344**	-0.166	-0.178
Top petiole length											1.000	0.127	0.029	-0.088	-0.237*	0.240*	-0.136	-0.504**
Number of capsules per plant												1.000	-0.125	0.236*	0.161	0.148	-0.233*	0.134
Capsule length													1.000	0.080	0.038	-0.137	-0.315*	-0.263*
Capsule width														1.000	-0.177	-0.338**	-0.187	-0.295*
Number of seeds per capsule															1.000	0.092	0.071	0.186
1000 seed weight																1.000	0.101	0.529**
Oil content																	1.000	-0.049
Single plant yield																		1.000

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

Character	Iodine Value	Acid number	Saponification value	Peroxide value	Sesamin	Sesamol	Oil content
Iodine Value	1.000	0.234*	-0.402**	-0.358**	0.255*	0.112	-0.311*
Acid Number		1.000	-0.132	0.395**	0.136	0.221	-0.197
Saponification Value			1.000	0.148	0.527**	0.324**	0.438**
Peroxide Value				1.000	-0.009	0.061	0.058
Sesamin					1.000	0.797**	-0.367**
Sesamol						1.000	-0.448**
Oil content							1.000

*Significance at 5% level **Significance at 1% level 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 per cent 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**	0.788	-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 on Oil content
Iodine Value	**-0.331**	-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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