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Research Article

GENETIC VARIABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS IN SESAME *[Sesamum indicum L.]*

BAMROTIYA M.M., PATEL J.B.*, MALAV ASHOK, CHETARIYA C.P., AHIR D. AND KADIYARA J.

Department of Seed Science & Technology, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India
*Corresponding Author: Email-grapesfarmer555@gmail.com

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Abstract The study was conducted during summer 2015 at the Sagdividi Farm, Department of Seed Science and Technology, JAU, Junagadh to assess the information on genetic variability, character association and path analysis among 40 genotypes of sesame (*Sesamum indicum* L.). The high values of GCV and PCV were recorded for number of capsules per leaf axil followed by seed yield per plant, number of capsules per plant and height to first capsule. Moderate to high estimates of heritability coupled with high genetic advance expressed as percentage of mean were observed for seed yield per plant, height to first capsule, number of seeds per capsule, number of capsules per plant, length of capsule, number of capsules per leaf axil, plant height and number of branches per plant. Seed yield per plant was found to be significantly and positively correlated with days to flowering, days to maturity, plant height, height to first capsule, number of seeds per capsule and harvest index at both genotypic and phenotypic levels. Characters, number of seeds per capsule followed by number of branches per plant and number of capsules per plant exhibited high and positive direct effect on seed yield per plant.

Keywords- Genetic variability, Heritability, Genetic advance, Path analysis, *Sesamum indicum* L.

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Introduction

Sesame (*Sesamum indicum* L., 2n = 26) is a very ancient oilseed crop grown next to groundnut, rapeseed and mustard in India. It belongs to the order *Tubiflorae*, family *Pedaliaceae*. It is basically considered a crop of tropical and sub-tropical regions, but it has also spread to the temperate parts of the world. Africa has been considered to be the primary centre of origin of sesame and it spread early through West Asia to India, China and Japan, which themselves became secondary distribution centres (32]. Sesame is a self pollinated crop with an average cross pollination to the extent of 4 to 5 per cent. However, the amount of out crossing ranges from 0 to 50 per cent depending upon the pressure of pollinating agents, whereas wind plays no part in natural cross pollination. Sesame is one of the oldest oilseed crops from which oil was extracted by the ancient Hindus, which was used for certain ritual purposes (32].

At present, Myanmar is the largest producer of sesame seed in the world followed by India, China, Turkey and Pakistan in Asia; Egypt and Sudan in Africa; Greece in Europe; Venezuela, Argentina and Columbia in South America; Nicaragua and El-Salvador in Central America; and Mexico and the U.S.A. in North America. India is still the world leader with maximum (25.80 %) production from the largest (29.30 %) area and highest (40.00 %) export of sesame in the world. In India, during 2013-14, sesame is cultivated in an area of 16.67 lakh ha with a production of 6.75 lakh tones annually and productivity of 405 kg/ha [6]. Being the fourth important oilseed crop in Indian agriculture after groundnut, rapeseed and mustard, it is widely cultivated in the states of Uttar Pradesh, Rajasthan, Orissa, Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, West Bengal, Bihar and Assam. In Gujarat, during 2013-14, sesame is cultivated in an area of 2.36 lakh ha with a production of 1.24 lakh tones and productivity of 525 kg/ha [6]. This crop is generally cultivated as sole or mixed crop during *kharif*, semi-*rabi* and summer season. The productivity of sesame is very low as compared to other oilseeds, hence it is necessary to raise the productivity and thereby total oilseeds production in order to meet edible oil requirements of the country.

The phenotypic and genotypic variations of the yield contributing characters are considerably high in sesame [14, 28, 30], which points to the possibility of developing a variety with high yield. Heritability is the heritable portion of phenotypic variation and it is a good index of transmission of a character from parents to their off springs. Heritability determines the expressivity of genes carried by a genotype. If the heritability of a character is high, the phenotypic value provides a fairly close measure of the genotypic value and thus, breeder can base his selection on the phenotypic performance, thereby the knowledge of heritability helps the plant breeder in pre-assessing the results of selection for a particular character.

The knowledge of the interrelationships between yield and yield components is necessary; determination of correlation among plant characteristics is a matter of considerable importance in selection of correlated response. Correlation studies between yield and other traits of the crop will be of interest to breeders in planning the hybridization programme and evaluating the individual plants in segregating populations. But it does not give an exact position of the relative importance of direct and indirect effects of various traits on yield or any other attributes. Path coefficient analysis is useful for evaluating the relative contribution of each component traits both direct and indirect to the yield. Path co-efficient analysis helps to specify the cause and effect and to measure their relative significance. Following correlation analysis, the path coefficient analysis would provide a true picture of genetic association among different traits [10]. So, correlations in combination with the path co-efficient analysis quantify the direct and indirect contributions of one characteristic upon another [13].

Materials and Methods

The study was conducted at the Sagdividi Farm, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh during *summer*-2015 to assess the genetic diversity among 40 genotypes of sesame (*Sesamum indicum* L.). The germpasm were selected from the gene pool maintained at Agricultural Research Station, Junagadh Agricultural University, Amreli, Gujarat. Forty genotypes of sesame were sown in a Randomized Block Design (RBD) with three replications. Each genotype was accommodated in a single row of 4.0 m length with a spacing of 45 cm between rows and 15 cm between plants within the row. The experiment was surrounded by two guard rows to avoid damage and border effects. Recommended agronomic practices were followed to raise a good crop. Observations were recorded from five randomly selected plants from each genotype on different characters *viz*., plant height (cm), number of branches per plant, number of capsules per plant, height to first capsule (cm), length of capsule (cm), width of capsule (mm), number of capsules per leaf axil, number of seeds per capsule, 1000 seed weight (g), seed yield per plant (g) and harvest index (%). Days to flowering and days to maturity was measured on plot basis. The analysis of variance for experimental design was carried out as per the method suggested by [25]. The genotypic and phenotypic coefficients of variation, which measures the magnitude of genetic and phenotypic variation present in a particular character, were estimated as per the formula suggested by [11]. Heritability was calculated according to formula suggested by [4]. Genetic advance as percentage of mean was categorised as low, moderate and high as given by [22]. The phenotypic and genotypic correlation coefficients of all the characters were worked-out as per [3]. The path coefficient analysis was carried-out as per the method suggested by [13].

Results

Analysis of variance revealed that mean squares due to genotypes were significant for all the traits except 1000 seed weight indicating the presence of sufficient amount of genetic variability among the genotypes for seed yield per plant and other yield contributing traits [Table-1]. These findings are in accordance with the findings of [23, 26, 19], who also observed significant variability in sesame germplasm. Hence, it can be noted that systematic crossing among selected genotypes in crops like sesame generates variability in subsequent generation.

Table-1 *Analysis of variance showing mean squares for 13 characters in 40 genotypes of sesame.*

Source of variation	d. f.	Days to flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Height to first capsule (cm)	Length of capsule (cm)
Replications	02	61.72**	134.11**	47.89	0.49	180.56	0.34	0.34**
Genotypes	39	11.40*	49.42**	220.00**	0.57**	393.86**	62.89**	0.47**
Error	78	5.00	18.31	67.10	0.20	58.53	1.16	0.02
Source of variation	**d. f.**	**Width of capsule (cm)**	**Number of capsules per leaf axil**	**Number of seeds per capsule**	**1000 seed weight (g)**	**Seed yield per plant (g)**	**Harvest Index (%)**	
Replications	02	0.003	0.003	991.40**	0.14	2.25	266.23**	
Genotypes	39	0.008**	0.81**	520.23**	0.16	57.95**	58.35**	
Error	78	0.002	0.003	69.08	0.11	3.32	17.12	

*, ** Significant at 5% and 1% levels, respectively

The experimental material showed a wide range of variation for number of branches per plant, number of seeds per capsule, number of capsules per plant, plant height, 1000 seed weight, seed yield per plant and harvest index. Height to first capsule, days to maturity, length of capsule and width of capsule expressed a moderate range of variation [Table-2]. Genotypes AT 324 (24.80g) followed by AT 235 (24.17g), Wild Dhandhuka (*w)*(23.63g), Patan 64 (22.73g), China (22.70g), AT 255 (22.33g) and AT 332 (22.10g) recorded the highest seed yield per plant, while U 76-10 (72.23), China (64.27), Nana Bhamodra (62.80), Wild Dhandhuka (*w)* (61.33), B 90-1 and AT 262 (57.53) possessed the maximum number of capsules per plant and genotypes GT 3 (104.55), AT 332 (100.23), GT 2 (97.36), AT 306 (94.55) and Nana Bhamodra (94.46) were the best genotypes with respect to number of seeds per capsule. Therefore, these genotypes could be utilized in further breeding improvement programme for the sesame yield improvement.

The estimates of genotypic (GCV) and phenotypic (PCV) coefficients of variability indicated that the values of PCV were higher than the corresponding GCV for all the traits due partly to interaction of the genotypes with the environment or other environmental factors influencing the expression of these characters. Similar results were obtained by [28] and [8] for seed yield and its components in sesame. The high values of GCV and PCV were recorded for number of capsules per leaf axil followed by seed yield per plant, number of capsules per plant and height to first capsule [Table-2]. High estimates of GCV and PCV in sesame have been observed for seed yield per plant by [28, 20, 30, 17]; for number of capsules per plant by [26, 19, 30]; and for height to first capsule by [19, 20]. The moderate values of GCV and PCV were observed for number of branches per plant, number of seeds per capsule, plant height, length of capsule and harvest index. Similar results were reported in sesame by [31] for number of seeds per capsule; by [14] for number of seeds per capsule, number of branches per plant and length of capsule; and by [7] for plant height. Low values of GCV and PCV were observed for width of capsule, 1000 seed weight, days to flowering and days to maturity. Similar results were reported in sesame by [14] for days to flowering and maturity.

High values of heritability in broad sense are helpful in identifying the appropriate character for selection and in enabling the breeder to select superior genotypes on the basis of phenotypic expression of quantitative traits [22]. The maximum heritability (broad sense) was observed for number of capsules per leaf axil followed by height to the first capsule, length of capsule, seed yield per plant, number of seeds per capsule, number of capsules per plant, harvest index and width of capsule [Table-2]. High heritability estimates indicated that the characters were least influenced by the environmental effects and high capacity of the characters for transmission to subsequent generation. This also suggested that the phenotypes were the true representative of their genotypes for these traits and selection based on phenotypic value could be reliable. The high magnitude of heritability in sesame has also been reported by [14, 19, 20, 8, 17] for seed yield per plant; by [19] for height to first capsule; by [4, 26, 14, 19, 20, 8] for number of capsules per plant; by [4, 17] for harvest index; by [14] for length of capsule; and by [4, 26, 14] for number of seeds per capsule. The heritability estimates were found to be moderate for days to flowering, plant height, number of branches per plant and days to maturity, whereas low for 1000 seed weight. Moderate heritability for number of branches per plant and plant height was reported by [1], while. low to moderate heritability for yield and its components was reported by [2]. The high values for genetic advance were observed for number of seeds per capsule and number of capsules per plant [Table-2]. Moderate genetic advance was observed for plant height, while remaining all the traits, height to first capsule, seed yield per plant, harvest index, days to maturity, days to flowering, number of capsules per leaf axil, length of capsule, number of branches per plant,1000 seed weight and width of capsule recorded low genetic advance. The high values of genetic advance were observed for number of seeds per capsule by [14, 21]; and for number of capsules per plant by [23, 31, 14, 8, 21].

The genetic advance expressed as percentage of mean was found maximum for number of capsules per leaf axil followed by seed yield per plant, height to first capsule, number of capsules per plant, number of seeds per capsule, length of capsule, number of branches per plant and plant height [Table-2]. Similar results have also been reported by [4, 26, 30, 31] for seed yield per plant and number of capsules per plant; by [15] for height to first capsule; by [26] for number of seeds per capsule; by [4] for length of capsule; by [4, 26, 31, 1, 15] for number of branches per plant; and by [4, 26,1] for plant height.

Table-2 *Range of variation, mean, phenotypic and genotypic coefficients of variation, heritability (Broad Sense), genetic advance and genetic advance expressed as percentage of mean for 13 characters in 40 genotypes of sesame.*

Character	Range	Mean	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (Broad Sense) (%)	Genetic advance	Genetic advance expressed as percentage of mean
Days to flowering	43.00-52.00	46.52	4.19	3.13	56.15	2.25	4.85
Days to maturity	75.67-95.67	84.91	4.78	3.79	62.94	5.26	6.20
Plant height (cm)	38.76-78.37	55.69	15.38	12.82	69.50	12.26	22.02
Number of branches per plant	1.62-3.47	2.57	17.01	13.60	63.88	0.58	22.40
Number of capsules per plant	20.60-72.23	45.93	24.94	23.02	85.14	20.10	43.75
Height to first capsule (cm)	10.78-31.88	19.81	23.12	22.91	98.16	9.26	46.75
Length of capsule (cm)	2.12-4.12	2.85	13.91	13.61	95.68	0.78	27.43
Width of capsule (cm)	0.50-0.73	0.58	9.04	7.58	70.12	0.08	13.07
Number of capsules per leaf axil	1.00-3.00	1.16	44.47	44.39	99.63	1.06	91.28
Number of seeds per capsule	56.57-104.55	78.47	16.78	15.63	86.72	23.52	29.98
1000 seed weight (g)	2.48-3.40	2.89	8.09	4.44	30.09	0.15	5.01
Seed yield per plant (g)	9.93-24.80	16.95	25.94	25.18	94.28	8.54	50.31
Harvest index (%)	28.91-48.72	37.09	11.89	10.00	70.66	6.42	17.31

Heritability and genetic advance when considered together would be more reliable and useful in predicting the resultant effects of selection [22]. In the present study, high estimates of heritability coupled with high genetic advance expressed as percentage of mean were observed for seed yield per plant, height to first capsule, number of seeds per capsule, number of capsules per plant, length of capsule and number of capsules per leaf axil [Table-2], which may be attributed to the preponderance of additive gene action and possess high selective value and thus, selection pressure could profitably be applied on these characters for their rationale improvement [24]. Similar results in sesame have been reported by [4, 26, 31] for seed yield per plant and number of capsules per plant; by [15] for height to first capsule; by [26] for number of seed per capsule; and by [4] for length of capsule. High estimates of heritability along with moderate genetic advance were observed for harvest index and width of capsule, while plant height and number of branches per plant recorded moderate heritability along with high genetic advance expresses as per cent of mean, which indicated non - additive type of gene action controlling these characters, so selection might be useful. Moderate heritability coupled with high genetic advance as per cent of mean was reported for number of branches per plant and plant height by [1].

In general, the values of genotypic correlation were higher than their corresponding phenotypic correlation in the present investigation for most of the characters [Table-3]. This indicated that though there was high degree of association between two variables at genotypic level, its phenotypic expression was deflated by the influence of environment. It also indicated that there was an inherent relationship between the characters studied, which is in agreement with the conclusions of [29, 5, 12]. Seed yield per plant was found to be significantly and positively correlated with days to flowering, days to maturity, plant height, height to first capsule, number of seeds per capsule and harvest index at both the genotypic and phenotypic levels [Table-3]. Such positive

Table-3 *Genotypic (r_g) and phenotypic (r_p) correlation coefficients among 13 characters in 40 genotypes of sesame.*

Characters		Days to flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Height to first capsule (cm)	Length of capsule (cm)	Width of capsule (cm)	Number of capsules per leaf axil	Number of seeds per capsule	1000 seed weight (g)	Harvest index (%)
Seed yield per plant (g)	r_g	0.8665**	0.5158**	0.2809**	0.0977	0.1487	0.3139**	-0.2396**	-0.1378	0.1468	0.5259**	-0.1433	0.3959**
	r_p	0.6400**	0.3982**	0.2311*	0.0654	0.1426	0.3020**	-0.2238*	-0.1115	0.1444	0.4765**	-0.0412	0.3761**
Days to flowering	r_g		0.3089**	0.1997*	0.2626**	0.2819**	0.3115**	-0.3338**	0.0356	-0.0915	0.6838**	-0.0023	0.3814**
	r_p		0.2317*	0.1476	0.1729	0.1538	0.2300*	-0.2441**	0.0298	-0.0727	0.4723**	0.0326	0.2270*
Days to maturity	r_g			-0.1507	0.2243*	-0.0801	-0.1126	-0.0409	0.3376**	0.0557	0.4671**	-0.1453	-0.0314
	r_p			-0.0555	0.0812	-0.0930	-0.0707	-0.0421	0.2044*	0.0456	0.2965**	-0.0247	-0.0438
Plant height (cm)	r_g				0.0560	0.4744**	0.5020**	-0.0906	-0.1113	-0.1412	-0.0038	-0.0360	0.6517**
	r_p				-0.0095	0.3277**	0.4152**	-0.0946	-0.0518	-0.1123	-0.0101	-0.0140	0.4842**
Number of branches per plant	r_g					0.1510	-0.0171	-0.0775	-0.2312*	-0.2790**	-0.2220*	0.1806*	0.1048
	r_p					0.1127	-0.0207	-0.0611	-0.0764	-0.2284*	-0.1709	0.0596	0.0536
Number of capsules per plant	r_g						0.3493**	-0.0060	-0.0013	0.0054	-0.2814**	0.2512**	0.4278**
	r_p						0.3223**	0.0047	-0.0263	0.0073	-0.2301*	0.1090	0.3357**
Height to first capsule (cm)	r_g							-0.0773	-0.0522	0.1487	0.0480	0.2673**	0.2028*
	r_p							-0.0721	-0.0406	0.1458	0.0560	0.1462	0.1652
Length of capsule (cm)	r_g								0.4616**	0.1876*	-0.1050	-0.6409	-0.0793
	r_p								0.3693**	0.1817*	-0.0935	-0.3266**	-0.0621
Width of capsule (cm)	r_g									-0.0139	-0.0653	-0.5736**	0.0206
	r_p									-0.0145	-0.0326	-0.2154*	-0.0087
Number of capsules per leaf	r_g										0.0005	-0.1338	0.2072*
	r_p										-0.0001	-0.0838	0.1833*
Number of seeds per capsule	r_g											-0.2720**	-0.0595
	r_p											-0.1300	-0.0426
1000 seed weight (g)	r_g												-0.2041*
	r_p												0.0244

*, ** Significant at 5% and 1% levels, respectively.

interrelationship between seed yield per plant and these attributes has also been reported in sesame by several researchers. The positive genotypic association has been reported between seed yield per plant and days to 50 per cent flowering, days to maturity and height tp first capsule [18]; plant height [18, 5, 9, 27]; number of seeds per capsules [5, 9]; and harvest index [15]. Thus, on the basis of correlations, the days to flowering, days to maturity, plant height, height to first capsule, number of seeds per capsule and harvest index were proved to be the outstanding characters influencing seed yield in sesame and needs to be given due importance in selection to achieve higher seed yield.

The genotypic path coefficient analysis revealed that number of seeds per capsule followed by number of branches per plant and number of capsules per plant exhibited high and positive direct effect on seed yield per plant [Table-4] and was found to be the most important yield components. The characters height to first capsule and width of capsule had moderate and positive direct on seed yield per plant, while harvest index had low and positive direct effect on seed yield per plant. High and positive direct effect of number of seeds per capsule on seed yield per plant has also been reported in sesame by [18, 9]; of number of branches per plant on seed yield per plant by [28, 30]; of number of capsules per plant on seed yield per plant by [23, 12, 18, 9]; and of harvest index on seed yield per plant by [16]. Thus, these characters *viz*., number of seeds per capsule, number of branches per plant, number of capsules per plant, height to first capsule and width of capsule turned out to be the major components of seed yield and direct selection for these traits will be rewarding for yield improvement. The residual effect of the present study was 0.7134 indicating that the characters studied contributed 29 per cent of the yield. It is suggested that maximum emphasis should be given on the above characters in selecting sesame with higher yield. It is also suggested that further study should be made with more characters to find out other traits, which contribute rest of the percentage of the yield

Table-4 *Genotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on seed yield per plant in 40 genotypes of sesame.*

Characters	Days to flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Height to first capsule (cm)	Length of capsule (cm)	Width of capsule (cm)	Number of capsules per leaf axil	Number of seeds per capsule	1000 seed weight (g)	Harvest index (%)	Genotypic correlation with seed yield/plant
Days to flowering	**-1.1076**	-0.1044	-0.0890	0.2619	0.2588	0.1741	0.4342	0.0115	-0.0506	1.0232	0.0024	0.0519	0.8665**
Days to maturity	-0.3422	**-0.3379**	0.0672	0.2237	-0.0735	-0.0629	0.0533	0.1089	0.0308	0.6990	0.1539	-0.0043	0.5158**
Plant height (cm)	-0.2211	0.0509	**-0.4458**	0.0558	0.4356	0.2805	0.1178	-0.0359	-0.0781	-0.0057	0.0381	0.0888	0.2809**
Number of branches per plant	-0.2909	-0.0758	-0.0250	**0.9974**	0.1387	-0.0096	0.1008	-0.0745	-0.1542	-0.3322	-0.1913	0.0143	0.0977
Number of capsules per plant	-0.3123	0.0271	-0.2115	0.1507	**0.9182**	0.1952	0.0078	-0.0004	0.0030	-0.4210	-0.2661	0.0582	0.1487
Height to first capsule (cm)	-0.3451	0.0381	-0.2238	-0.0171	0.3208	**0.5587**	0.1006	-0.0168	0.0822	0.0718	-0.2831	0.0276	0.3139**
Length of capsule (cm)	0.3697	0.0138	0.0404	-0.0773	-0.0055	-0.0432	**-1.3010**	0.1489	0.1037	-0.1572	0.6788	-0.0108	-0.2396**
Width of capsule (cm)	-0.0394	-0.1141	0.0496	-0.2306	-0.0012	-0.0291	-0.6005	**0.3225**	-0.0077	-0.0977	0.6075	0.0028	-0.1378
Number of capsules per leaf axil	0.1013	-0.0188	0.0630	-0.2782	0.0050	0.0831	-0.2440	-0.0045	**0.5528**	0.0007	-0.1417	0.0282	0.1468
Number of seeds per capsule	-0.7573	-0.1579	0.0017	-0.2214	-0.2584	0.0268	0.1366	-0.0210	0.0003	**1.4965**	0.2881	-0.0081	0.5259**
1000 seed weight (g)	0.0026	0.0491	0.0160	0.1802	0.2307	0.1493	0.8338	-0.1850	0.0740	-0.4070	**-1.0592**	-0.0278	-0.1433
Harvest index (%)	-0.4225	0.0106	-0.2905	0.1045	0.3928	0.1133	0.1032	0.0066	0.1145	-0.0890	0.2162	**0.1362**	0.3959**

*, ** Significant at 5 % and 1% levels, respectively

Residual effect, R = 0.7134

N.B.: Values at diagonal indicated direct effects of respective character.

Conclusion

From the results, it can be concluded that plant should be selected, which having more number of branches, number of capsules, seeds per capsule. height to first capsule and harvest index for yield improvement in sesame.

Conflict of Interest: None declared

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