Identification of potential traits and selection criteria for yield improvement in sesame (*Sesamum indicum* L.) genotypes under rainfed conditions

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ABSTRACT
Sesame is an important oilseed crop in India. To determine potential traits and selection criteria for yield improvement, ninety sesame (*Sesamum indicum* L.) genotypes were studied in a randomized complete block design with three replications. The data collected on 13 characters were subjected to three different analyses. In variability analysis, high heritability was accompanied by a high genetic advance and a high genotypic coefficient of variation (GCV) for capsule numbers, biomass yield, harvest index and seed yield. In correlation analysis, biomass yield, capsule number and harvest index showed a significant positive correlation among them and with seed yield. In path analysis, reproductive period was the highest direct contributor, while capsule number was the highest indirect contributor via primary branches. The indirect effect of days to maturity was negative via primary branches and positive via biomass yield per plant. Plant height had a direct effect and an indirect effect via biomass yield and harvest index. Biomass yield and harvest index showed a substantial direct effect on seed yield. Therefore, plant height, biomass yield, days to maturity and harvest index should be used in selection, while care should be taken for the handling of reproductive period and capsules per plant in breeding programmes to increase sesame yield.

Keywords: Genetic variability, Morpho-physiological trait, Path analysis, Relationship, Sesame.

INTRODUCTION

Because of its high oil quality and a wide use in raw foods, confectioneries and bakery industries, the demand of sesame seed is increasing in the global market (Ashri, 1989). Cultivation of sesame is concentrated in the developing, tropical countries where it is grown mainly by small holders (Weiss, 1983). In India, the antiquity of sesame is known from the use of its seeds in religious ceremonies and its mention in old Hindu literature. It is third major oilseed crop after groundnut and rapeseed-mustard. It is grown in different seasons in different regions of the country covering practically all agro-ecological zones (Sharma, 1994). India is the leading country worldwide in the production and export of sesame (FAO, 2010). Sesame has a great potential of production for domestic and export markets but comparatively low seed yield is one of the most important reasons that sesame needs breeding to produce more yield (Furat and Uzun, 2010). The low average yield is due to the low standards of husbandry, poor soils and low yielding varieties. The average productivity of sesame in India (430 kg/ha) is far below that of China (1,222 kg/ha) and Egypt (1,250 kg/ha). This indicates that a good increase in productivity level of Indian sesame could be obtained through developing high yielding varieties by adopting appropriate breeding programmes (Duhoon and Singh, 2003).

Sesame (*Sesamum indicum* L.) is an annual, indeterminate plant with a diploid chromosome number of 2n=2x=26 and belonging to family *Pedaliacea*. It is a plant breeder's dream crop because it presents a great genetic variability (Janick and Whipkey, 2002). India is a rich source of different forms of cultivated sesame (Van Rheenen, 1981). A wide range of genetic variability has been reported for the morphological characters in extensive germplasm collections of sesame (Bisht *et al*., 1998). However, it is essential to know the genetic architecture of traits related to yield for breeding ideotypes with special emphasis on certain characters. Trait-based approaches rather than yield alone may be more beneficial in sesame breeding, if such yield related traits are well documented (Ranganatha *et al*., 2012). In fact, available literature evidences equivocal nature of yield contributing traits with regard to yield improvement in sesame (Chowdhury *et al*., 2010; Roy and Sinhamahapatra , 2010; Yol *et al*., 2010).

The objective of this research was to know the relative importance of morpho-physiological traits through estimation of genetic parameters and path coefficients and to determine selection criteria for developing sesame genotypes possessing a high yield potential.

MATERIALS AND METHODS

Ninety sesame germplasm lines were used for this study. All of the germplasm lines represent genotypes developed by breeders through selection or hybridization with special attention for yield potential at regional, national and international research institutes and that were maintained at the Agricultural Research Station, Junagadh Agricultural University, Amreli, Gujarat. The location receives low annual rainfall. Moreover, erratic rainfall makes the area vulnerable either to water lodge condition or to terminal moisture stress. Average annual rainfall varies from 500 to 800 mm. The material was sown during 2008 on medium black soil in a randomized complete block design with three replications. Each genotype was relegated to single rows of 4 m length. Plant to plant and row-row distance was 10 cm and 60 cm, respectively. Before sowing, the seeds were treated with a fungicide to prevent soil born and seed born diseases. Seeds were sown with hand drilling and plants were thinned 15 days after germination to maintain plant to plant distance. All other recommended cultural practices were followed to raise the crop.

Observations were recorded on five randomly selected plants of each genotype in each replication. The data were collected for days to flower initiation, days to 50% flowering, reproductive period, days to maturity, plant height (cm), number of primary branches, number of capsules per plant, capsule length (cm), number of seeds per capsule, 1000 seed weight (g), oil content (%), biomass yield per plant (g), harvest index (%) and seed yield per plant (g). The average values of all the characters were subjected to statistical analysis using SAS statistical software (SAS Institute, 1994). The phenotypic, genotypic and environmental variances and coefficient of variation were calculated according to Burton (1952) as follows:

$$Environmental\ variance\ (\sigma_e^2) = MSE$$

$$Genotypic\ variance\ (\sigma_g^2) = \frac{MSG - MSE}{r}$$

$$Phenotypic\ variance\ (\sigma_p^2) = \sigma_g^2 + \sigma_e^2$$

Where, MSE is mean square due to error, MSG is mean square due to genotypes and r is the number of replication.

$$PCV\ (\%) = \frac{\sqrt{\sigma_p^2}}{\bar{X}} \times 100$$

$$GCV\ (\%) = \frac{\sqrt{\sigma_g^2}}{\bar{X}} \times 100$$

Where, σ^2p = Phenotypic variance, σ^2g = Genotypic variance and $\bar{X}$ = General mean of the character.

Heritability in broad sense (h^2) and genetic advance as the percentage of mean were worked out according to Allard (1960).

$$h^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

The expected genetic advance at 5% selection intensity was estimated by using formula as:

$$Gs = k \times \sigma_p \times h^2$$

Where, Gs = Expected genetic advance under selection, k = Selection differential (value of k at 5% selection intensity is 2.06), σ_p = Phenotypic standard deviation and h^2 = Heritability value of the character

The genetic advance (GA) expressed as the percentage of mean was calculated as under:

$$\text{GA as}(\%)\text{ of mean} = \frac{\text{Gs}}{\overline{\text{X}}} \times 100$$

Genotypic correlation and path coefficient analysis was carried out following the standard procedure described by Singh and Chaudhary (1977) as:

$$r = \frac{\mathrm{cov}_{g(xy)}}{\sqrt{\sigma^2_{gx} \times \sigma^2_{gy}}}$$

Where, Cov g(xy) is genotypic covariance between two characters x and y, σ^2_{gx} is genotypic variance for character x and σ^2_{gy} is genotypic variance for character y.

The coefficients of genotypic correlation were tested using 'r' tabulated value at n-2 degrees of freedom at 5 and 1 % probability level, where n denote as number of genotypes studied.

Path analysis split up the total correlation coefficients into direct and indirect effects of various characters and helps to understand the relationship among variables based on a priori model. Direct and indirect path coefficients were estimated using genotypic correlation coefficients based on the following relationship:

$$r_{ij} = p_{ij} + \sum r_{ik} \times p_{kj}$$

r_{ij}= Mutual association between the independent character (i) and dependent character (j) as measured by the genotypic correlation coefficients

p_{ij} = Components of direct effects of the independent character (i) on the dependent character (j) as measured by the genotypic path coefficients

$\sum r_{ik} \times p_{kj}$ = Summation of components of indirect effect of a given independent character (i) on a given dependent character (j) via all other characters (k).

RESULTS

The variance for genotypes was highly significant for all the characters (Table 1), which revealed the presence of a wide spectrum of variability in the material studied. The magnitude of genetic variation is better assessed from GCV and phenotypic coefficient of variation (PCV). There were close estimates of GCV and PCV for all characters (Table 2), except primary branches per plant and days to flower initiation, for which, the difference between two estimates was wider. High magnitude of broad sense heritability (> 70%) was recorded for all the characters except primary branches per plant and days to flower initiation. The expected genetic advance, expressed as the percentage of mean, varied from 6.49% for oil content to 67.54% for biomass production. The magnitude of genetic advance was high (> 20%) and ranged between 29.24% and 67.54% for seeds per plant, reproductive period, harvest index, capsules per plant, seed yield per plant and biomass production, while oil content, days to 50% flowering and days to flower initiation had relatively low values (< 10%) of genetic advance (Table 2).

The values of genotypic correlation coefficient showed that capsules per plant, biomass production and harvest index had a significant positive correlation with seed yield per plant (r=0.57**, r=0.73** and r=0.22**, respectively), but the correlation between days to maturity and seed yield per plant was significantly negative (r=-0.19**) (Table 3). These results suggest that selection for higher harvest index and earliness would tend to increase seed yield in sesame. Reproductive period exhibited non significant correlation with seed yield per plant (r=-0.10), but its association was significantly positive with days to maturity (r=0.80**) and significantly negative with days to 50% flowering (r= -0.24**) and flower initiation (r=-0.25**). This situation will favour shortening of length of the reproductive period by developing early genotypes without reduction in seed yield. The relation between capsule length and seeds per capsule was significant and positive (r= 0.56**). Similarly, biomass production showed a significant and positive correlation with capsules per plant (r=0.44**) and harvest index (r=0.43**).

Partitioning the correlation coefficient into direct and indirect effects (Table 4) revealed that the reproductive period (0.66) had the highest positive direct effect on seed yield followed by plant height (0.50), biomass production (0.47) and harvest index (0.43). The direct effects of remaining characters were too low to be considered important. Capsules per plant contributed the highest positive indirect effects via primary branches per plant (1.24) and also showed considerable negative indirect effects via biomass yield per plant (-0.65) on seed yield. Reproductive period and plant height contributed negatively via capsules per plant (-0.77) and

Table 1. Analysis of variance for 14 characters in sesame.

Source of variation	DF	Mean squares													
		Days to flowering initiation	Days to 50% flowering	Reproductive period	Days to maturity	Plant height	Primary branches / Plant	Cap-sules / Plant	Capsule length	Seeds / Capsule	1000-seed wt	Oil content	Biomass yield / Plant	Harvest index	Seed yield / Plant
Replication	2	21.02**	36.31**	0.71^{ns}	7.22^{ns}	1.13^{ns}	1.27**	12.86**	0.01^{ns}	21.40**	0.11**	0.89**	2.94**	19.99**	0.21**
Genotype	89	13.00**	13.27**	179.08**	151.11**	250.04**	1.00**	245.02**	0.21**	223.75**	0.23**	9.00**	55.75**	166.46**	3.61**
Error	178	1.67	1.35	2.59	7.55	16.90	0.51	6.35	0.05	7.79	0.01	0.49	2.11	7.66	0.08

** and ^{ns}: significant at $P \leq 0.01$ and non significant, respectively.

Table 2. Mean, range, PCV, GCV, h^2 and GA for 14 characters in sesame.

Characters	Mean	Range	PCV (%)	GCV (%)	h^2 (%)	GA as % of mean
Days to flowering initiation	36.62	32.33-41.66	6.37	5.30	69.35	9.10
Days to 50% flowering	39.67	35.33-44.00	5.81	5.02	74.61	8.94
Reproductive period	49.78	36.66-67.66	15.74	15.40	95.78	31.06
Days to maturity	85.58	76.33-101.00	8.69	8.08	86.37	15.47
Plant height (cm)	97.18	74.93-117.90	10.00	9.07	82.14	16.93
Primary branches / Plant	2.25	1.07-3.87	36.44	17.94	24.25	18.20
Capsules / Plant	35.43	17.66-52.33	26.15	25.16	92.60	49.89
Capsule length (cm)	2.54	1.74-3.26	10.82	10.22	89.32	19.91
seeds / Capsule	56.77	38.40-73.16	15.73	14.94	90.23	29.24
1000-seed wt (g)	3.11	2.44-3.74	9.38	8.76	87.37	16.88
Oil content (%)	49.29	45.27-54.36	3.70	3.41	85.14	6.49
Biomass yield / Plant (g)	12.19	4.56-23.48	36.66	34.67	89.44	67.54
Harvest index (%)	29.45	19.53-55.40	26.42	24.69	87.36	47.55
Seed yield / Plant (g)	8.47	1.36-6.20	32.61	31.49	93.25	62.65

Table 3. Genotypic correlation coefficients among 14 characters in sesame.

Characters	Days to 50% flowering	Reproductive period	Days to maturity	Plant height (cm)	Primary brances / Plant	Capsules / Plant	Capsule length (cm)	Seeds / Capsule	1000-seed wt (g)	Oil content (%)	Biomass yield / Plant (g)	Harvest index (%)	Seed yield / Plant (g)
Days to flowering initiation	0.90**	-0.25**	-0.02	0.21**	0.26**	-0.01	-0.16**	-0.00	-0.01	0.06	-0.05	0.01	-0.02
Days to 50% flowering		-0.24**	0.01	0.19**	0.25**	-0.05	-0.17**	-0.03	0.00	-0.10	-0.11	-0.01	-0.10
Reproductive period			0.80**	0.06	-0.04	-0.12*	0.00	-0.08	0.00	0.06	-0.13*	0.05	-0.10
Days to maturity				0.13*	-0.03	-0.23**	-0.11	-0.12*	0.05	-0.00	-0.12*	-0.14*	-0.19**
Plant height (cm)					0.13*	0.08	-0.07	-0.00	-0.03	0.07	0.02	0.02	0.05
Primary branches / Plant						0.17**	-0.29**	-0.29**	-0.21**	-0.15*	0.15*	-0.03	0.13*
Capsules / Plant							-0.04	-0.10	-0.04	-0.03	0.44**	0.10	0.57**
Capsule length (cm)								0.56**	-0.02	0.10	0.06	0.03	0.06
Seeds / Capsule									-0.01	-0.06	0.01	0.14*	0.05
1000-seed wt (g)										0.01	0.04	0.08	0.00
Oil content (%)											0.18**	-0.03	0.21
Biomass yield / plant (g)												0.43**	0.73**
Harvest index (%)													0.22**

*, ** and ns: significant at P ≤ 0.05, P ≤ 0.01 and non significant, respectively.

days to flower initiation (-0.77), respectively. Days to maturity and days to 50% flowering exerted high order negative indirect effects via primary branches per plant (-0.83 and -0.72, respectively) and considerable positive indirect effects via biomass yield per plant (0.41 and 0.56, respectively). Plant height was equally responsible for indirect positive contribution via biomass production (0.26) and harvest index (0.26) to seed yield.

DISCUSSION

Selection for yield contributing traits deserves considerable interest. A crop breeding programme aiming to increase yield potentiality requires consideration not only of yield but also of its component traits which have direct or indirect major shares towards the yield. Breeders of self fertilizing crops quite often select directly for grain yield to bring about yield improvement. Nevertheless, indirect selection may be more efficient especially if the secondary character is highly correlated with yield and is easily measurable.

A good genetic variation (high GCV) was observed in the studied material (Table 2) for capsules per plant, biomass yield per plant, harvest index and seed yield per plant, which shows that they were utilizable for specific traits required in the development of cultivars. Barring primary branches per plant and days to flower initiation, close estimates of GCV and PCV and high broad sense heritability for all characters indicated that differences among the genotypes were mostly genetic. These results further reflect on reliability of selection based on phenotypic performance. However, more information would be required to confirm these findings including the estimates of heritability in the narrow sense based on genetic analysis involving segregating generations. Earlier workers also reported high magnitude of heritability for most of the biometrical traits in sesame (Ganesan, 2005; Kumhar and Solanki, 2009).

The estimates of genetic advance (Table 2) indicate that about 29% improvement in seed yield per plant, 31% improvement in the reproductive period, 47% improvement in harvest index, 49% improvement in capsules per plant, 62% improvement in seed yield per plant and 67% improvement in biomass yield per plant should result from selection of top 5% of the genotypes under study. Johnson *et al*. (1955) suggested that the heritability and genetic advance when calculated together would give indication about the effectiveness of

Table 4. Partitioning of the correlation coefficient into direct (bold) and indirect effect to seed yield in sesame.

Characters	Days to flowering initiation	Days to 50% flowering	Reproductive period	Days to maturity	Plant height	Primary branches / Plant	Capules / Plant	Capsule length	Seeds / Capsule	1000-seed wt	Oil content	Biomass yield/ plant	Harvest index	Genotypic correlation with seed yield / Plant
Days to flowering initiation	**0.03**	-0.00	-0.00	0.29	0.01	-0.00	-0.05	-0.09	0.05	-0.25	0.01	-0.02	0.00	-0.02
Days to 50% flowering	0.11	**0.11**	0.01	0.00	-0.26	-0.72	0.15	-0.11	0.00	0.02	0.02	0.56	0.01	-0.10
Reproductive period	0.00	-0.02	**0.66**	0.00	-0.02	-0.20	-0.77	0.50	-0.06	-0.07	-0.02	-0.11	0.00	-0.10
Days to maturity	0.01	0.03	-0.02	**0.02**	-0.18	-0.83	0.13	0.00	0.05	-0.01	-0.02	0.41	0.21	-0.19**
Plant height (cm)	-0.77	0.34	-0.02	0.00	**0.50**	-0.20	0.32	-0.07	-0.02	-0.11	0.11	0.00	-0.02	0.05
Primary branches / Plant	0.00	-0.03	-0.01	-0.05	0.24	**0.01**	0.10	0.23	0.00	-0.03	-0.02	-0.24	-0.07	0.13*
Capsules / Plant	0.00	-0.05	-0.01	0.01	0.14	1.24	**0.08**	-0.23	0.10	-0.07	0.01	-0.65	0.01	0.57**
Capsule length (cm)	-0.00	-0.05	-0.00	0.00	-0.01	-0.17	-0.01	**0.20**	-0.01	0.05	0.00	0.05	0.00	0.06
seeds /Capsule	0.03	0.05	0.01	0.01	-0.04	-0.02	-0.08	0.23	**0.07**	0.20	-0.06	-0.17	-0.18	0.05
1000-seed wt (g)	-0.09	0.00	-0.00	-0.00	0.20	-0.01	-0.01	0.00	-0.01	**0.05**	-0.17	0.05	0.00	0.00
Oil content (%)	0.01	0.00	-0.04	0.01	0.02	-0.16	0.40	0.11	0.18	0.01	**-0.07**	-0.02	-0.25	0.21**
Biomass yield / Plant (g)	0.00	-0.02	-0.44	0.24	0.26	0.02	0.00	-0.13	-0.03	0.18	0.19	**0.47**	0.00	0.73**
Harvest index (%)	0.00	0.10	0.02	0.02	0.26	0.14	-0.11	0.01	-0.01	-0.41	-0.11	-0.12	**0.43**	0.22**

Residual effect = 0.09. * and ** significant at P ≤ 0.05 and P ≤ 0.01, respectively.

selection in improving the characters. High heritability coupled with high genetic advance observed for reproductive period, capsules per plant, seeds per capsule, biomass yield per plant, harvest index and seed yield per plant could be attributed to the preponderance of additive gene action and selection pressure could profitably be applied on these characters for the improvement of seed yield (Panse, 1957). Similar observations were also reported by Ganesan (2005) while studying biometrical traits in sesame. However, it is worth while to note that high estimates of GCV if accompanied with high estimates of heritability and genetic advance, it should provide very large genetic gain in response to selection. Thus, our study suggests that due weightage should be given to biomass yield per plant, seed yield per plant, harvest index and capsules per plant in selection programmes.

Genetic architecture of seed yield, in sesame as well as other crops, is based on the balance or overall net effect produced by various yield components directly or indirectly with one another. Therefore, our objective of correlation and path coefficient studies was to determine the role of various yield components in the determination of yield and to devise selection criteria. In the present study genotypic correlation of seed yield per plant was significant and positive with capsules per plant, biomass yield per plant and harvest index (Table 3). The results obtained from this study are in confirmation with the results of Ashoka Vardhan Reddy *et al.* (2001) and Anuradha and Reddy (2006). Harvest index and capsules per plant showed a significant positive correlation with biomass yield per plant. This association appears to be favourable for yield improvement because higher biomass yield may increase harvest index with increasing a high degree of photosynthesis partitioning toward the reproductive phase.

Significant positive associations of seed yield per plant with some of its component traits and a positive association among most of the yield components implies less complex interrelationships between yield and yield components. Such situation is favourable from breeding view point as selection of one trait may bring correlated response for improvement of other traits which are associated positively with it (Anuradha and Reddy, 2006).

The strong and positive correlation of reproductive period with days to maturity and significantly negative correlation with days to flower initiation and 50%

flowering (Table 3) appears logical as early onset of flowering and late maturity is likely to push genotypes towards a longer reproductive period.

In path analysis, deeper relations were identified and the rates of direct and indirect effects of the causal components were determined on the seed yield per plant. According to this analysis (Table 4), correlations of reproductive period and plant height with seed yield per plant were non-significant. In addition, both these characters showed strong and positive direct effects towards seed yield. However, a high order negative indirect effect of reproductive period via capsules per plant and of plant height via days to flowering initiation was recorded. These contrasting positive direct and negative indirect effects may be the reason for causing the non-significant correlation. A positive direct effect of plant height was reported by Yol *et al*. (2010). Plant height is the yield contributing trait because it had shown not only a high positive direct effect but also contributed negatively via days to flowering initiation, desirable for the early starting of capsule setting. Also, a considerable positive indirect effect of plant height via capsules per plant and of primary branches per plant via plant height indicates that plant height provides permanent branching and thereby capsule production (Yol *et al*., 2010).

Indirect effect of capsules per plant on seed yield was positive in a high order via primary branches per plant which was solely responsible for causing a significant correlation. However, its considerable negative indirect effect via biomass yield per plant makes it as a tricky indirect yield attribute whose handling may require very careful and balancing approach. Days to 50% flowering and days to maturity, both had shown contrasting positive and negative indirect effects via biomass yield and primary branches per plant, respectively. However, a significant negative correlation of days to maturity with seed yield per plant (which is desirable) with very high order negative indirect effect via primary branches per plant and a considerable positive indirect effect through biomass yield per plant suggest that days to maturity may be an important consideration while formulating selection indices.

Biomass yield per plant and harvest index correlated significantly and positively with seed yield per plant and exerted considerable positive direct effects. Our results are in agreement with those reported by Anuradha and Reddy (2006). These two characters also showed a substantial indirect effect through plant height. This situation indicated that these three traits may be the powerful predictors of sesame yield and may be considered together as selection criteria in sesame breeding programmes.

It seems from the present study that considerable progress in sesame breeding could be achieved by exploiting plant height, biomass yield per plant, days to maturity and harvest index. Selection of these traits might have a good impact on seed yield. However, high direct effect of reproductive period and high indirect effect of capsules per plant via primary branches per plant proved them to be potent contributors and should be used carefully for breeding programmes to increase sesame yield.

REFERENCES

Allard R.W. (1960). Principles of Plant Breeding. New York: John Wiley and Sons. Inc.

Anuradha T., and Reddy G. L. K. (2006). Effect of environment on correlations and path analysis in sesame, *Sesamum indicum* L. *Journal of Oilseeds Research*, 23: 297-300.

Ashri A. (1989). Sesame. In G. Roebbelen, R. K. Downey, and A. Ashri (Eds.), Oil Crops of the World (pp. 375-387). New York: McGraw Hill Publ. Co.

Ashoka Vardhan Reddy P., Reddy Sekhar M., and Hariprasad Reddy K. (2001). Studies on character association and path analysis in sesame (*Sesamum indicum* L.). *Andhra Agricultural Journal*, 48: 191-195.

Bisht I., Mahajan R., Loknathan T., and Agrawal R. (1998). Diversity in Indian sesame collection and stratification of germplasm accessions in different diversity groups. *Genetic Resources and Crop Evolution*, 45: 325-335.

Burton G.W. (1952). Quantitative Inheritance of Grasses. Proceedings of the 6th International Grassland Congress. Pennsylvania State College, USA, 277-283.

Chowdhury S., Datta A. K., Saha A., Sengupta S., Paul R., Maity S., and Das A. (2010). Traits influencing yield in sesame (*Sesamum indicum* L.) and multilocational trials of yield parameters in some desirable plant types. *Indian Journal of Science and Technology*, 3: 163-166.

Duhoon S.S., and Singh N. B. (2003). A manual for production of export quality sesame (p. 5). Jabalpur India :AICRP on Sesame and Niger, JNKVV Campus.

FAO (2010). Food and Agriculture Organization, Online Available: http:/faostat.fao.org/ 2010.

Furat S., and Uzun B. (2010). The use of agro-morphological characters for the assessment of genetic diversity in sesame (*Sesamum indicum* L.). *Plant Omics Journal*, 3: 85-91.

Ganesan K. N. (2005). Variability studies in determinate type sesame, *Sesamum indicum* L. germplasm lines for yield and its component traits. *Journal of Oilseeds Research*,

22: 176-177.
Janick J., and Whipkey A. (2002). Trends in New Crops and New Uses. Alexandria :ASHS Press.
Johnson H.W., Robinson H. F., and Comstock R. E. (1955). Estimates of genetic and environmental variability in soybean. *Agronomy Journal*, 47: 314-318.
Kumhar S. R., and Solanki Z. S. (2009). Genetic diversity and variability in sesame, *Sesamum indicum* L. *Journal of Oilseeds Research*, 26: 162-164.
Panse V. G. (1957). Genetics of quantitative traits in relation to plant breeding. *Indian Journal Genetics and Plant Breeding*, 17: 318-328.
Ranganatha A. R. G., Lokesha R., Tripathi A., Tabassum Aasfa, Paroha S., and Srivastava M.K. (2012). Sesame improvement-Present status and future strategies. *Journal of Oil seeds Research*, 29: 1-26.
Roy S., and Sinhamahapatra S. P. (2010). Effect of structural ideotypes on yield and yield attributes in sesame (*Sesamum indicum*). *Indian Journal of Agricultural Sciences*, 80: 838-40.
SAS Institute (1994). SAS Users' Guide, Statistics SAS Institute, Inc., USA.
Singh R. K., and Chaudhary B. D. (1977). Biometrical Methods in Quantitative Genetic Analysis. New Delhi: Kalyani Publishers. 318p.
Sharma S. B. (1994). Utilization of Natural Collections of Sesame in India. In R. K. Arora, and K.W. Riley (eds.). Sesame biodiversity in Asia-conservation, evaluation and improvement, New Delhi, India: IPGRI Office for South Asia.
Van Rheenen H. A. (1981). Genetic resource of sesame in Africa: Collection and exploration. In A. Ashri, P. Poetiray, and J. T. Sykes (Eds.). Sesame status and improvement (pp. 170-172). Rome, Italy: Food and Agriculture Organization of the United Nations.
Weiss E. A . (1983). Oil Seed Crops. Longman, London.
Yol E., Karaman E., Furat S., and Uzun B. (2010). Assessment of selection criteria in sesame by using correlation coefficients, path and factor analyses. *Australian Journal of Crop Science*, 4: 598-602.