Indian Journal of Agricultural Sciences **82** (11): 934–40, November 2012

Transgressive segregants for yield and its component traits in recombinant inbred line population from a wide cross of sesame (*Sesamum indicum*) involving *Sesamum malabaricum*

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Received: 2 June 2011; Revised accepted: 9 July 2012

ABSTRACT

The genetic variation available in wild and related species is a potential source for crop improvement. RIL population developed from a cross of *Sesamum indicum* and *S. malabaricum* consisting of 216 individuals along with the parental lines was evaluated for yield and other related traits. The traits considered were days to flowering, days to 50% flowering, days to capsule formation, leaf shape, hairiness, number of branches/plant, internode lengths (L1, L2, L3, L4 and L5), number of flowers/node, plant height, stem girth, days to maturity, capsule length, capsule width, number of capsules/node, total number of capsules/plant, seed weight/capsule, yield/plant and 100- seed weight. Transgressive segregants falling far beyond parental values were noticed for many yield related traits. Correlation analysis indicated a strong positive correlation between yield and total number of capsules/plant, seed weight/capsule and 100- seed weight. Negative correlation was noticed in case of yield and average internode length L1. The results indicate the need to explore useful variability in the germplasm of the close wild progenitor species, *S. malabaricum* so as to overcome yield barriers in sesame due to domestication bottlenecks.

Key words: Domestication bottlenecks, *Sesamum indicum*, *Sesamum malabaricum*, Transgressive segregant, Yield

Sesame (*Sesamum indicum* L) is an important oilseed crop of India with great export earning potential. India is the number one producer and exporter of sesame seed (FAO STAT 2009). Bedigian (2004) concluded that cultivated sesame (originated from the wild species *S. malabaricum* Burm) and the crop was domesticated in the Indian sub-continent during prehistoric times. Sesame is one among those crops which yield well even under low moisture content and with very less management. Cultivation of sesame is limited to the poor and marginal farmers in India, due to the very low yield obtained under field conditions. Major reasons for low yield are cultivation of low yielding dehiscent varieties, significant yield loss during threshing, indeterminate growth, uneven ripening of capsules and lack of improved varieties tolerant to biotic and abiotic stresses (Uzun and Cagirgam 2006). In addition, sesame has been condemned as a crop with very low yield potential by several workers (Singh 2003, Duhoon 2004, Furat and Uzun 2010). The productivity per hectare in India was estimated to be 332 to 421 kilogram which was found to be much lower than world average. However, commercial hybrids are cultivated in countries like China having yield potential greater than 3000 kg/ha. Among Indian cultivars Duhoon identified the existence of standard positive heterosis to the extent of 9.5 to 327% in different cross combinations and the possibility of development of CMS lines from *S.malabaricum* × *S. indicum* cross for commercial exploitation of heterosis.

The major problem noticed in the improvement of economically important traits in crop plants is the presence of limited genetic variation in the germplasm. This is usually caused by domestication bottlenecks during the course of evolution of crop plants from their wild relatives. (Harlan 1995). It is reported that human mediated domestication events have led to the loss of genetic diversity in crops like soybean (Hyten *et al*. 2006), rice (Zhu *et al*. 2007) and Kovach and McCouch (2008). In addition to this crossing with wild relatives resulted in transfer of many yield related QTLs in crops like rice (Marri *et al*. 2005), tomato (Sun *et al*. 2010) and maize (Liu *et al*. 2010).

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Chowdhury *et al*. (2010) analyzed the traits contributing to yield in sesame and identified 7 major traits which are plant height, number of primary branches per plant, total branches per plant, distance from base to first branching, capsules on main axis, total capsules per plant and capsule length) and yield (of seed, seed protein content, seed oil content). Among these total capsules per plant was predicted as the major selection criterion. In another study Yol *et al*. (2010) identified plant height, number of branches and number of capsules per plant as the three important criteria for selection based on factor analysis. While, Roy *et al*. 2010 reported branching pattern as an important yield contributing trait by constructing productive ideotypes. The present study was an attempt to finely dissect the yield contributing traits of cultivated sesame (*S. indicum*) and to quantify the yield advantage upon introgression of beneficial alleles from the wild progenitor species *S. malabaricum*.

MATERIALS AND METHODS

The Recombinant Inbred Line (RIL) population comprising 216 lines was developed from an intervarietal cross MKN6 (E3) × IC 204773 (N1). MKN6 is an F_8 generation selection from a cross between the exotic accession EC346987 and DLH2; a *S. malabaricum* line. From F_2 onwards Single Seed Descent (SSD) was followed for advancing the generations.The parental lines differed from each other in terms of plant height, earliness, branching, hairiness, yield etc. Morphological characterization of RIL's along with the parental lines was done for two consecutive *kharif* seasons in 2008 and 2009 in the fields of NBPGR, New Delhi. Augmented block design with five blocks was used for field experimentation with spacing of 45 × 30 cm and the parental lines along with four standard Indian varieties were used as checks for estimation of error variance. The checks used were Phulet-1, Tapi-A, Padma and HT 1. The morphological traits included for phenotyping were; days to flowering, days to 50% flowering, days to capsule formation, leaf shape, hairiness, number of branches/plant, internode lengths from base to top (L1, L2, L3, L4 and L5), number of flowers/node, plant height, stem girth, days to maturity, capsule length, capsule width, number of capsules/node, total number of capsules/plant, seed weight/capsule, yield/plant and 100 seed weight. The data was taken on the basis of five random plants selected from each line and the analysis was done using software package SYSTAT version 12.

RESULTS AND DISCUSSION

The data obtained for yield and related characters in *kharif* season 2008 on range, arithmetic mean, standard deviation, variance and curve fitting characteristics for sesame

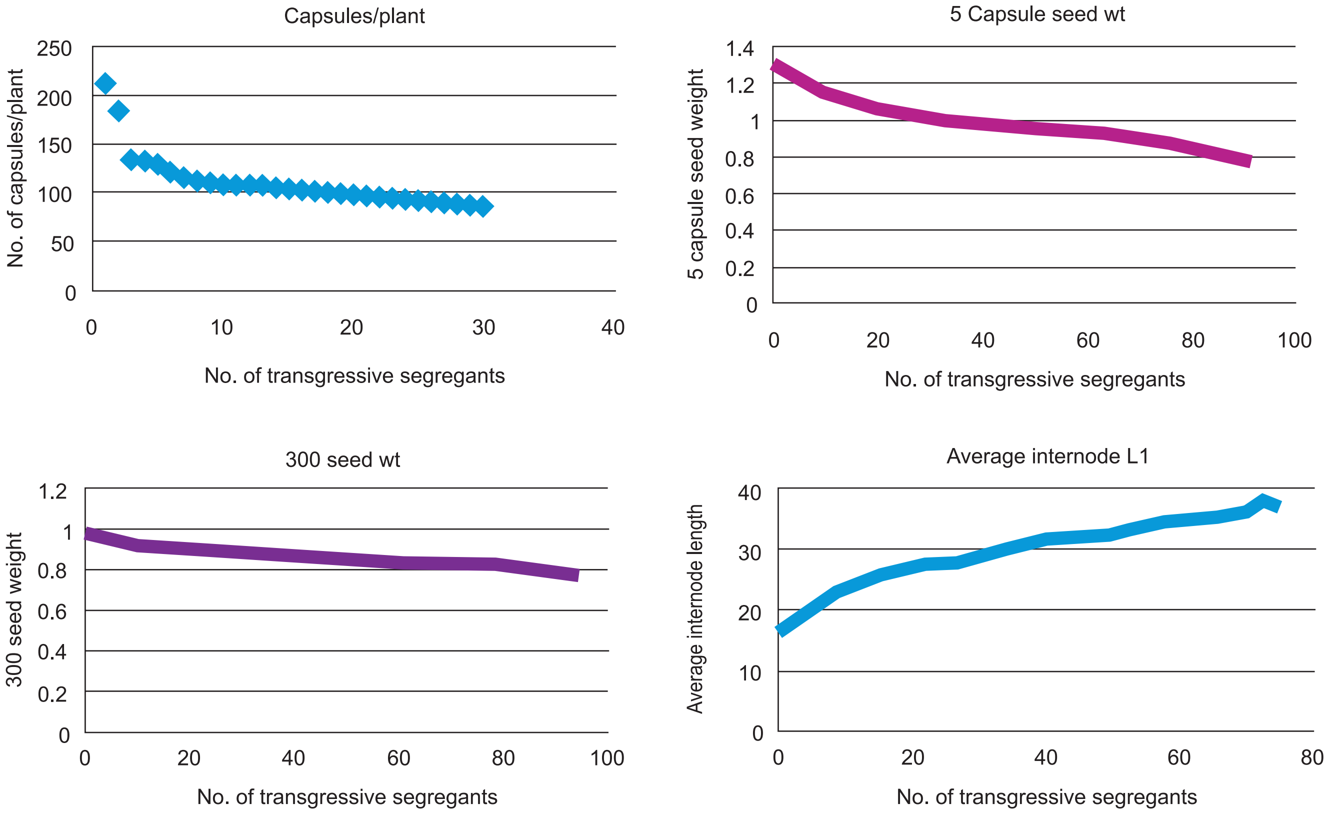

Fig 1 Total number of transgressive segregants and their range over the better parent

RIL's is given in Table 1.The total number of capsules per plant cited as the most efficient criterion for selection (Chowdhury *et al.* 2010 and Yol *et al.* 2010), showed a much larger range between 25 and 212 with a mean value of 66 in the population. The values for the parental lines were 87.2 for MKN6 and 73.8 for IC 204773. The standard deviation of mean was 24.5 and the co-efficient of variance for trait was 36.8%. Transgressive segregants beyond the parental range were noticed for the trait in the RILs while the distribution was normal (Fig 1). The total number of transgressive segregants showing positive values over the better parent is given in Fig 2. The percentage increase and decrease of the trait value over the better parent is given in Fig 3. A maximum increase of 143.4% over better parent was observed in RIL's and the yield decrease observed over the parental value was 71.45%. However the heritability estimate of the trait was quite low (32.11%); while yield as a trait was found to be highly heritable with an estimated broad sense heritability of 89.23% (Table 2).

The number of branches/plant is a secondary trait which indirectly affects yield (Roy *et al.* 2010). Since the parent MKN6 is profusely branching type there was noticeable variation in the population for this trait also. The value ranged between 1.2 and 16.6 in the RILs with the mean value of 3.08. The SD was 1.734 and the CV was 56.1%. Transgressive segregants were observed for this trait on both directions beyond parental values (Fig 1). Although the distribution appeared normal, high positive value of kurtosis was noted.

The trait earliness of flowering was measured in terms of date of flowering, date of 50% flowering and date of maturity. These traits were calculated as the number of days after sowing. Date of first flower formation varied between 30–53 days after sowing (DAS) with a mean value of 35.73 DAS. Date of 50% flowering also followed a similar trend as the parent MKN6 was early flowering in nature. For this particular trait the range was 35–57 with a mean value of 42.86, and the trait showed moderate heritability of 82.8%. The days to maturity were observed to be 81–94 DAS with mean value around 91.1 DAS. MKN6 was late maturing with 93 DAS and IC 204773 was early maturing and attained maturity within 90 DAS. The SD was 1.8 and CV was 2% while the distribution was negatively skewed and leptokurtic in nature. The heritability of the trait was very high to the tune of 98.0%. The first flower was formed on nodes ranging 3–8 with the mean value of 5.1.For MKN6 first flower was formed on 5th node while it was node number 4 for IC 204773. The number of capsules/node ranged between 2 and 6 with a mean value of 2.753, while the total number of capsule bearing nodes ranged between 2 and 32 with a mean value of 8.721. The parent IC 205773 had 4 capsules/node and capsules were borne up to the 10th node while MKN6 had 3 capsules/ node and the total number of capsule bearing nodes was 9.

For average stem girth; the range observed was between 2.82 and 8.18 cm and the mean was 4.63 cm. The distribution was normal (Fig 1) but large number of transgressive

Table 1 Data on yield and other related traits from a Recombinant Inbred Population (RIL) of sesame (*Sesamum indicum*) from *kharif* season 2008

Traits scored	Min	Max	Mean	Std. Error	S D	Variance	C.V	Skewness (G1)	Kurtosis (G2)
Days to flowering	30	53	35.74	0.36	5.3	27.99	0.15	1.46	1.72
Days for 50% flowering	35	57	42.87	0.36	5.32	28.3	0.12	0.51	-0.65
Capsules/node	2	6	2.75	0.08	1.12	1.25	0.41	1.29	0.78
1st flower node	3	8	5.1	0.05	0.76	0.58	0.15	0.97	2.54
Node with capsule	2	32	8.72	0.31	4.53	20.53	0.52	1.66	4.41
Stem girth (cm)	2.82	8.18	4.64	0.05	0.81	0.65	0.17	0.65	1.17
Capsule length (mm)	20.13	35.28	25.38	0.16	2.39	5.72	0.09	0.67	2.72
Capsule diameter (mm)	5.73	7.09	6.43	0.02	0.30	0.09	0.05	–0.27	–0.37
Branches/plant	0.6	16.6	3.09	0.12	1.73	3.01	0.56	3.99	22.41
Maturity, DAS	81	94	91.13	0.12	1.81	3.3	0.02	–4.2	20.43
Capsules/plant*	25	212	66.55	1.66	24.51	600.58	0.37	1.86	7.13
Internode L1* (cm)	16.7	92.4	44.69	1.05	15.49	239.92	0.35	0.56	–0.24
Internode L2 (cm)	18.05	83.3	41.13	0.91	13.49	181.96	0.33	0.65	0.06
Internode L3 (cm)	11.9	89.05	40.8	0.99	14.66	214.96	0.36	0.72	0.17
Internode L4 (cm)	13.5	84.65	41.51	0.87	12.88	166.01	0.31	0.68	0.58
Internode L5 (cm)	16.85	80.95	43.26	0.86	12.69	161.03	0.29	0.56	0.16
Seed wt/capsule* (g)	0.13	1.28	0.77	0.02	0.26	0.07	0.33	–0.33	–0.53
100- seed weight* (g)	0.4	1.02	0.79	0.007	0.1	0.01	0.13	–0.77	1.17
Seed wt/plant* (g)	2.99	86.95	23.75	0.87	12.92	166.89	0.54	1.42	4.18

* indicates traits which are correlated with yield

Table 2 Phenotypic variance and broad sense heritability of different traits in sesame, expressed as percentage. Yield determining characters; average number of seed weight/capsule, 100- seed weight and average internode length L1 have high heritability

Trait	RILs	Error	E variance	Genotypic variance	Phenotypic variance	H_{bs}
Av. capsule length	5.702**	0.360	0.360	5.341	5.702	93.68
50% flowering	30.439*	5.236	5.236	25.203	30.439	82.80
Maturity days	3.247**	0.065	0.065	3.182	3.247	98.00
Node with capsule	19.967*	4.915	4.915	15.052	19.967	75.38
Av internode L3	213.311*	43.972	43.972	169.339	213.311	79.28
Av internode L4	164.018**	16.119	16.119	147.899	164.018	90.17
Av internode L5	160.362**	20.566	20.566	139.796	160.362	87.17
Seed weight/capsule	0.065**	0.007	0.007	0.058	0.065	89.23
100-seed weight	0.011**	0.004	0.004	0.007	0.011	63.64
Av internode L1	238.97	69.07	69.07	169.9	238.97	71.1

*indicates significance at 5% level and **indicates significance at 1% level for F test

segregants were observed in the population. The internodal lengths were taken at five levels from ground level and this trait was found to be another important secondary character which is related to yield (Chowdhury *et al.* 2010). The average internodal length for the first internode, L1, ranged between 16.7 and 92.4 cm and the mean was 44.68 cm. The CV was 34.7% and the distribution was platykurtic in nature (Fig 1). For the second internode, L2, the range was 18.05-83.3 cm with a mean value of 41.13 cm. For the subsequent internodes the values were, L3 - 40.8 cm, L4 - 41.5 cm and L5 - 43.26 cm; and the range for L5 was 16.85-80.95 cm. The heritability of first internode length L1 was 71.1% and the trait was also found to be significantly correlated with yield. The heritability values of L3, L4 and L5 were 79.28%, 90.17% and 87.17% respectively (Table 2). Positive transgressive segregants observed for internode length L1 and their range over better parent is given in Fig 2.The percentage increase over better parent was 54.55% and the decrease was 145.55% (Fig 3).

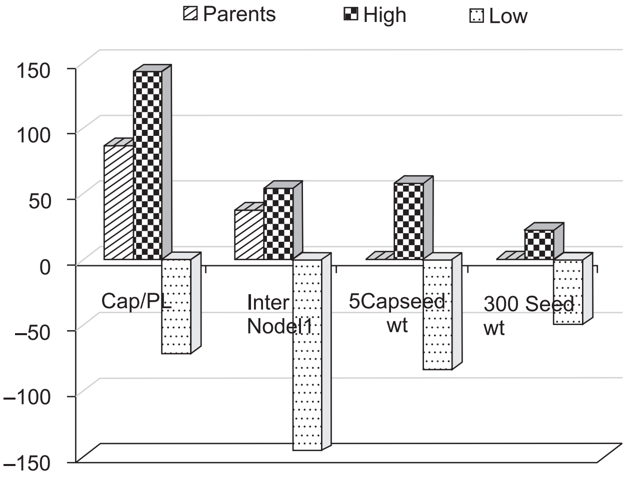

Fig 2 Percentage increase and decrease in the four traits over the better parent in the RIL population

Range for capsule length was 20.13-35.28 mm while the mean was 25.38 mm. SD was 2.393 and the CV was 9.4%. The trait followed normal distribution (Fig 1). Transgressive segregants beyond the better parent IC 204773 was also observed. The trait 'capsule length' was highly heritable in nature and the broad sense heritability estimated was 93.68%. The capsule diameter range was 5.73-7.09 with a mean of 6.428. The SD obtained was 0.3 and the CV was 4.7%. The curve obtained was normal and platykurtic in nature (Fig 1). Although this trait is not significantly correlated with yield; the heritability was found to be high, 74.26%.

The seed weight per capsule had a range of 0.026-0.256 g and the mean value was 0.154 g. The SD was.0518 and the CV was 33.6%. The distribution was normal (Fig 1). Range for seed yield per plant was 0.598-17.392 g and the mean value was 4.75 g. The SD and CV were 2.58 and 54.31% respectively; while the distribution was negatively skewed in nature. For seed yield per plant transgressive segregants thrice the range of better parent IC 204773 was noticed (Fig 3). For 100 seed weight range observed was 0.133-0.323 g and the mean was 0.262 g. SD for the trait was .0322 and CV 12.4%. The distribution was positively skewed in nature (Fig 1). The broad sense heritability of the trait; 'seed weight per capsule' and '100 seed weight' were found to be 89.23% and 63.64% respectively, and is given in Table 2.

The correlation coefficients were worked out for different yield parameters with per plant seed yield (Table 3). For most of the traits the correlation coefficients were found to lie between -0.5 to +0.5. The traits which were found to have significant positive correlation with yield include total number of capsules per plant (Chowdhury *et al.* 2010 and Yol *et al.* 2010), seed weight per capsule and 100 seed weight. Average internode length L1 was found to have significant negative correlation with yield (Chowdhury *et al.* 2010). The interaction among blocks was not found to be significant

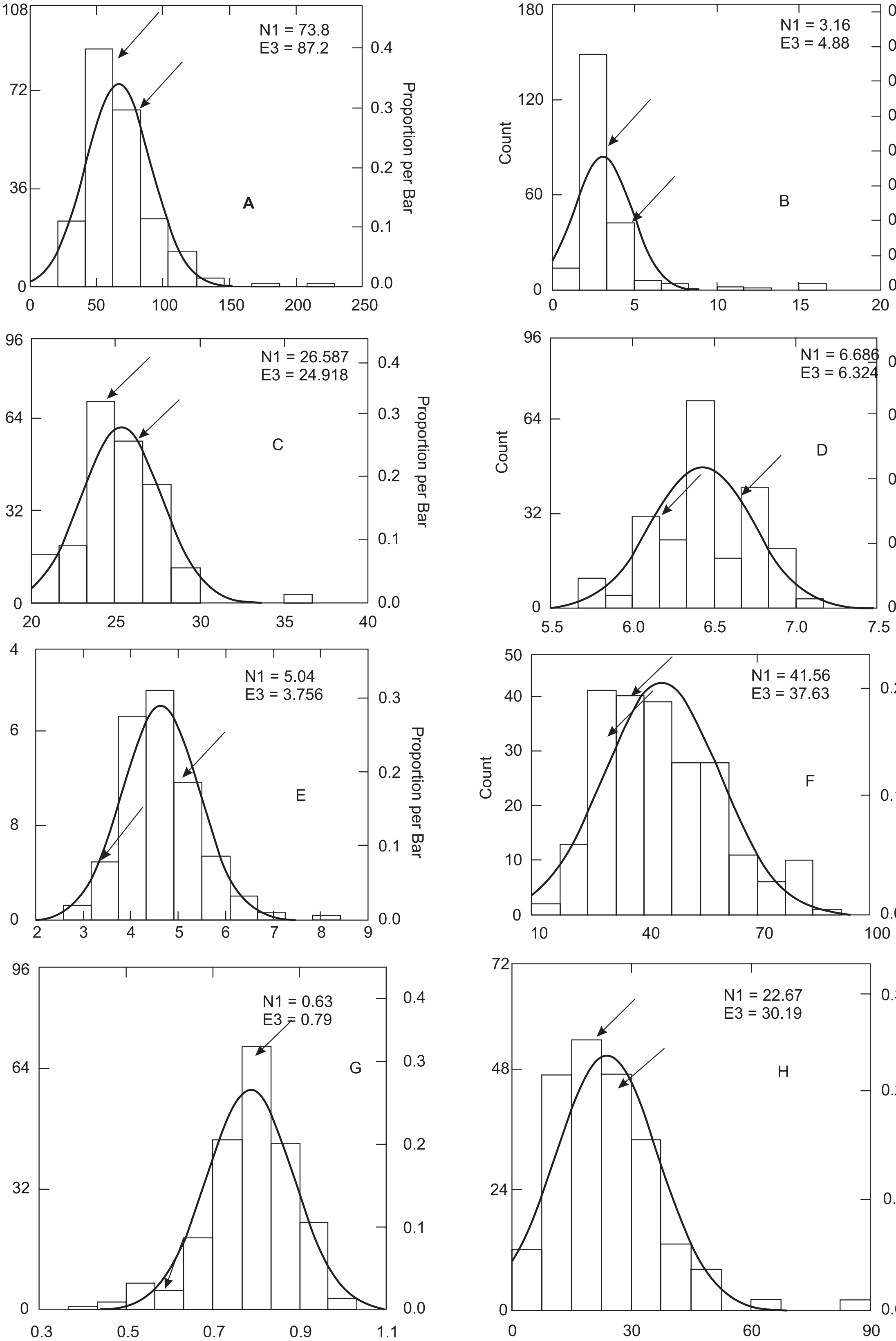

Fig 3 Distribution of yield and related traits (A) No. of capsules/plant, (B) no. of branches/plant, (C) capsule length, (D) capsule diameter, (E) average stem girth, (F) average internode length L1, (G) 100- seed weight, (H) seed yield/plant; in a RIL population of sesame

Table 3 Correlation coefficients and the significance level of various traits with the trait 'average seed weight/plant'

Trait	Correlation with av. sd wt/pl	t value	p value
Capsule length	-0.015	-0.221	0.824
Capsule diameter	-0.048	-0.71	0.478
Days to flowering	0.078	1.155	0.249
50% flowering	0.091	1.349	0.178
1st flower node	0.067	0.991	0.322
Capules/plant**	0.182	2.733	0.006
No. of branches	0.009	0.133	0.894
Capsules/node	-0.049	-0.724	0.469
Maturity, days after sowing	-0.097	-1.439	0.151
No. of nodes with capsules	0.089	1.319	0.188
Av stem girth	0.011	0.162	0.871
Av internode length, L1*	-0.128	-1.906	0.058
Av internode length, L2	-0.032	-0.473	0.636
Av internode length, L3	-0.005	-0.074	0.941
Av internode length, L4	0.040	0.591	0.555
Av internode length, L5	-0.048	-0.71	0.478
Seed weight/capsule**	0.342	5.374	0.00
100 seed weight**	0.255	3.894	0.0001

* and **indicates traits showing significant association at 5 and 1% significance level

which indicates that there are no significant differences between blocks.

The early domestication bottle neck because of preferential selection resulted in many undesirable as well as some desirable alleles being eliminated from the population and thus narrowed down the genetic variability. Studies by Zhu *et al*. 2007 revealed that cultivated rice retains only 10-20% of sequence similarity with its immediate progenitor species while soybean lost 79% of rare alleles during domestication process (Hyten *et al*. 2006). Moreover, the chances of getting novel variants are higher in a cross between an elite cultivar and a wild relative as demonstrated in rice (Kovach and McCouch 2008). The F1 hybrids between genetically divergent *indica* and *japonica* groups resulted in capitalizing heterosis while positive transgressive segregants were obtained by selective introgression of favourable alleles from wild germplasm. Introgression of favourable alleles from wild germplasm into cultivated gene pool results in creation of novel variability for yield and related traits (Marri *et al.* 2005).

Domestication in strict sense implies that the crop will become heavily dependent on humans for seed dispersal through the loss of natural seed dispersal mechanisms (Harlan 1995). In sesame seed shattering is an important problem affecting yield, so it is true to call it an incompletely domesticated crop. The rare alleles lost during domestication process can be regained by hybridization with *S. malabaricum;* the progenitor species as evident from the high positive heterosis reported by Duhoon, 2004. The overriding of domestic bottlenecks explains the presence of huge number of positive transgressive segregants observed in the field. The problem of low yield consistently plaguing the crop domesticated in India (Bedigian 2004) can be avoided by introgressing the QTLs for yield and related traits from *S. malabaricum* the wild progenitor species as done in several other crops previously (Marri *et al.* 2005, Sun *et al*. 2010, Liu *et al*. 2010).

Only limited genetic variability exists for cultivated sesame which is reflected in the low yield potential of varieties. In the study transgressive segregants were noticed for almost all the yield related traits which indicate the potential for improvement of sesame productivity. The traits showing positive correlation with yield can be used as an effective criterion for selection in further breeding programmes. Most of the traits showing correlation with yield are also found to be highly heritable and hence the traits; average seed weight per capsule, 100 seed weight and average internode length L1 are highly effective for direct selection. The huge amount of transgressive segregation observed in the population is useful for further improvement of sesame gene pool and hence raising the yield potential of the crop. Since there is no genetic barrier for crossing with *S. malabaricum;* transgressive segregation for yield related traits obtained by wide hybridization can be realized in field.

ACKNOWLEDGEMENTS

The authors are thankful to NAIP, ICAR for funding the research and NBPGR for providing the necessary facilities. Fellowship from UGC for RP also duly acknowledged.

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