Journal of Applied Horticulture, 13(1): 56-59, 2011

Combining ability for yield and associated traits in Sudanese okra (*Abelmoschus esculentus* L.) collection

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Abstract

Seven lines of okra *Abelmoschus esculentus* [L.] (MOENCH) were evaluated for general and specific combining ability using three diverse testers following a line × tester mating design as described by Kempthorne (1957). Twenty one F_1's hybrids along with ten parental lines were raised at the Demonstration Farm of the Faculty of Agriculture, University of Al Zaeim Al Azhari, Sudan, using randomized complete block design with three replications. Analysis of variance revealed significant differences among genotypes existing for yield and associated traits (*P*=0.01), indicating the presence of sufficient genetic variability in the material studied. Significant variability existed among hybrids (*P*=0.01) for number of pods per plant, length of pod, pod yield per plant and 100 seeds weight. Estimation of general combining ability effect identified lines HSD 1835, HSD1840 and HSD 2550 as a good general combiners for pod dry weight (*P*=0.05). Among testers Sinnar was found to be a good general combiner for number of pods per plant, length of pod, yield per plant, number of seed per pod and 100 seeds weight. Estimation of specific combining ability effect identified hybrids HSD 2550 × Sinnar as the best parent combination for number of pods per plant and yield per plant. HSD2543 × Sinnar and HSD1840 × Clemson Spineless recorded as the best parental combination for length of pod. The additive as well as non-additive gene effects played significant role in the inheritance of yield and yield related traits with predominance of additive gene action in the inheritance of major yield contributing traits. Testers contribution percentage were significantly higher for number of pods per plant (77.04%), pod dry weight (40.06 %) and number of seeds per pod (45.04%). The percentage contributions of the interaction were significantly higher and evident in the rest of the traits.

Key words: *Abelmoschus esculentus*, okra, combining ability, line × tester analysis

Introduction

Okra *Abelmoschus esculentus* [L.] (MOENCH) is widely spread in tropical and humid parts of Africa; it grows along with its wild relatives in almost every village of Africa. It probably originated in the Abyssinian center of origin, an area that includes Ethiopia, the mountainous part of Eritrea and part of Sudan. It grows wildly all over the rain lands of Central and Southern Blue Nile, Kordofan and Darfur states and along the alluvial banks of the White, Blue and River Nile.

Okra in Sudan is consumed as a cooked vegetable or as an additive for soups, salads and stews. The Mucilaginous nature of okra is much appreciated in Sudan; it is preserved by drying and grinding it to powder. The powder is then used as an ingredient in different types of soups and stews. Combining ability of the parents is becoming increasingly important in plant breeding, especially in hybrid seed production. It is useful in connection with the testing procedures in which it is desired to study and compare the performance of the lines in hybrid combinations. Okra hybrid breeding in Sudan has not been reported yet; all breeding efforts did not stepped beyond characterization and documentation of variability (Geneif, 1984).

With respect to the autougamous nature of okra; information on the general and specific combining abilities will be helpful in the analysis and interpretation of the genetic basis of important traits will aid in evolving okra hybrids from Sudan okra collection. This study has been carried out on selected Sudanese okra lines, without ignoring the role of an excellent yielder and a major parent such as Clemson Spineless, which has proved to be an excellent introduction and a strong competitor to local lines.

This study has been carried out to test the general combing ability of some Sudanese lines of okra and to identify suitable parent's combinations for hybrid seed production with excellent yield parameters.

Materials and methods

The present investigation was carried out during summer and autumn at the Demonstration Farm of the Faculty of Agriculture, University of Al Zaeim Al Azhari at Khartoum North locality. Nine lines of okra were obtained from the gene bank of the Agriculture Research Cooperation-ARC at Wad Madani, along with an introduced cultivar obtained from the local seed market at Khartoum North. The accession name and origin is presented in Table 1.

Ten genetically divergent parental lines of okra were crossed following line × tester fashion. Seven lines namely; HSD 1835, HSD1834, HSD1839, HSD 2543, HSD 2482, HSD 1840 and HSD 2550 were used as female lines, while Sinnar, Hejirat and Clemson Spineless were as testers. Twenty one F_1 hybrids along with 10 parents were laid out in randomized complete block design (RCBD) with three replications during July-November. Each plot consisted of three; 3 m long ridges. The space adopted was 75 cm

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Table 1. Accession name and origin

No.	Name	Source of collection	Note
1	HSD 1835	Sinnar Research Station	Line
2	HSD 1834	Sinnar Research Station	Line
3	HSD 1839	Sinnar Research Station	Line
4	HSD 2543	Darfur Research Station	Line
5	HSD 2482	Sinnar Research Station	Line
6	HSD 1840	Sinnar Research Station	Line
7	HSD 2550	Darfur Research Station	Line
8	Sinnar	Sinnar Research Station	Tester
9	Hejirat	Sinnar Research Station	Tester
10	Clemson Spineless	Seed Market	Tester

between ridges and 30 cm between plants. Observations on yield and seven yield associated traits were recorded and referred in the results on single plant basis. Mean performance on number of pods per plant and pods yield per plant (g) were recorded from five competitive plants, selected randomly from the middle row of each plot. Mean performance on number of ridges per pod, length of pod (cm), pod fresh weight (g), pod dry weight (g), number of seeds per pod and weight of 100 seeds (g) were recorded from ten randomly selected pods from each plot.

Line × tester analysis: The general combining ability (GCA) variance effects of the parents and the specific combining ability (SCA) variance effects of the hybrids were estimated using line × tester analyses method described by Kempthorne (1957).

The linear models assumed are:

$Y_{ijk} = \mu + g_i + g_j + S_{ij} + e_{ijk}$

Where,

Y_{ijk} = value of the ijth observations of the cross involving ith line and jth tester in kth replication;
μ = general mean (an effect common to all crosses in all the replications);
g_i = general combining ability (GCA) effect of ith line;
g_j = general combining ability (GCA) effect of jth tester;
s_{ij} = specific combining ability (SCA) effect of the cross involving ith line and jth tester;
e_{ijk} = error associated with ijth observation;
i = ith line (1, 2,… 7);
j = jth tester (1, 2, 3); and
k = kth replication (1, 2, 3).

Estimation of general and specific combining ability effects: The GCA and SCA effects were obtained from a two way table of female vs. male parents in which each value represent the total over replications. The individual effects were estimated as follows:

(a) GCA effects of i^{th} line

$g_i = (x_{i.}/Tr) - (x_{\ldots}/LTr)$

Where,

$x_{\ldots}$ = sum total of all crosses;
$x_{i.}$ = total of ith line over all testers and replications;
r = number of replications;
L = number of lines/female parents; and
T = number of testers/male parents.

(b) GCA effects of j^{th} tester

$g_j = (x_{j.}/Lr) - (x_{\ldots}/LTr)$

Where,

x_j = total of j^{th} male parent over all females and replications.

(c) SCA effects of ij^{th} cross

$S_{ij} = (x_{ij}/r) - (x_{i.}/Tr) - (x_{j.}/Lr) + (x_{\ldots}/LTr)$

Where,

x_{ij} = ij^{th} line×tester combination total over all replications.

Test of significance for GCA and SCA effects

T_i (cal) = GCA line /SE GCA line

T_j (cal) = GCA tester /SE GCA tester

T_{ij} (cal) = SCA /SE SCA

The GCA effects of lines and testers and SCA effects of crosses were marked as significant (*) and (**), when calculated values of T_i, T_j and T_{ij} were ≥ the tabulated two tail student's T probabilities value at error degree of freedom at $P = 0.05$ and 0.01, respectively, (Singh and Chaudhary, 1977).

Estimation of GCA and SCA variances: Estimation of GCA and SCA was calculated as per the following formulae (Singh and Chaudhary, 1977):

$$\sigma^2\ gca = \frac{(ML + MT - 2MLT)}{r(L+T)}$$

$$\sigma^2\ sca = \frac{(MLT - Mr)}{r(L+T)}$$

Where,

M_l = Mean squares line
M_T = Mean squares tester
M_{LT} = Mean squares line×tester
L = number of lines/female parents;
T = number of testers/male parents; and
r = number of replications.

Estimation of additive *(σ²A)* and dominance *(σ²D)* components of variance: Additive and dominance components of variances were computed following formulae by Singh and Chaudhary (1977). Since okra is a self pollinated crop and in the formulae as equal to 1.

$$\sigma^2\ gca = \left[\frac{(1+F)}{4}\right]\sigma^2 A$$

$$\sigma^2\ sca = \left[\frac{(1+F)}{4}\right]\sigma^2 D$$

Contribution of line, testers and their interactions to total variance: Proportional contribution of line, testers and their interactions to total variance were computed using the following formulae (Singh and Chaudhary, 1977):

Where,

$$\text{Contribution of line} = \frac{SS\ (L)}{SS\ (Crosses)} \times 100$$

$$\text{Contribution of tester} = \frac{SS\ (T)}{SS\ (Crosses)} \times 100$$

$$\textit{Contribution of line x tester} = \frac{SS\ (L \times T)}{SS\ (Crosses)} \times 100$$

SS_L = sum squares line;
SS_T = sum squares tester;
$SS_{crosses}$ = sum squares crosses; and
$SS_{line \times tester}$ = sum squares line × tester.

Results and discussion

Analysis of variance for yield and its components (Table 2) revealed that significant differences exist among hybrids/crosses for number of pods per plant, length of pod, pod dry weight, plant yield (g) and 100 seeds weight indicating the presence of variation among the hybrids produced during the study. Significant differences were recorded among lines for pod dry weight and 100 seeds weight. Testers recorded significant differences in major yield contributing traits such as number of pods per plant, yield per plant (g), number of seeds per pod, pod dry weight, and number of pod ridges, reinforcing the genetic value and the divergence. The interaction for line x tester was significant for length of pod and number of seeds per pod.

Estimation of general combining ability effect (Table 3) identified lines HSD 1835, HSD1840 and HSD 2550 as a good general combiner for pod dry weight (g), these lines can be used in developing varieties that meet market demand for dry okra powder in Sudan. Line HSD 1839 was identified as a good general combiner for pod length. HSD 1835 and HSD 2482 were identified as good general combiner for 100 seeds weight. Among testers, Sinnar was found to be a good general combiner for number of pods per plant, length of pod, yield per plant (g), number of seeds per pod and 100 seeds weight. Sinnar has also recorded a negative GCA value for number of ridges per pod, which indicate its value in producing less ridge and rounded shape pods that might look appealing among okra consumers in Sudan.

Estimation of specific combining ability effect (Table 4) summarized hybrids combinations that produced significant and positive SCA values. Accordingly, HSD2550 x Sinnar was identified as the best parent combination for number of pod per plant and yield per plant (g). HSD2543 x Sinnar and HSD2482 x Clemson Spineless recorded significant and positive SCA value for pod length (cm), ranking them among parent combinations that produce longer type pods.

The proportional contributions of lines (females) and testers (males) and their interactions to the total variance (Table 5) indicated that testers contribution was significantly higher for number of pods per plant, pod dry weight and number of seeds per pod, whereas interaction due to line x tester was significantly higher in all trait except number of pods per plant and pod dry weight. The variance due to line × tester interaction was the major contributor to the total variation in all major yield associated traits studied when compared with either lines or testers.This clearly indicated that upon crossing, sufficient genetic variability had been created for these traits in the collection under the study.

The ratio due to GCA and SCA variance (σ^2GCA)/(σ^2SCA) was smaller than zero for number of ridges per pod and pod fresh

Table 2. Analysis of variance for line×tester involving parents for yield and associated traits

Source of variation	df	Number pods per plant	Number of pod ridges	Pod length (cm)	Pod fresh weight (g)	Pod dry weight (g)	Yield per plant (g)	Number seeds per pod	100 seeds weight (g)
Crosses	20	2.12**	1.42	1.43**	0.26	0.02**	0.23**	138.18	0.65**
Lines/females	6	0.65	1.35	1.35	0.22	0.06**	0.10	58.83	1.74*
Testers/males	2	16.65**	2.92*	2.92	0.15	0.21*	0.68**	861.40**	0.58
Line x tester	10	0.58	1.46	1.46*	0.33	0.01	0.26	227.05*	0.60
Error	60	0.88	0.47	0.47	0.27	0.01	0.20	94.64	0.27

Table 3. Estimates of general combining ability effects of yield and associated traits

Parents	Number of pods / plant	Number of pod ridges	Length of pod (cm)	Pod fresh weight (g)	Pod dry weight (g)	Yield per plant (g)	Number of seeds /pod	100 seeds weight (g)
Lines								
HSD 1835	0.08	-0.08	0.19	0.08	0.05**	1.30	1.91	0.30*
HSD1834	0.24	-0.08	0.16	0.12	-0.03	1.88	1.57	0.08
HSD 1839	-0.10	0.14	0.40*	0.17	-0.03	-1.11	3.46	-0.39*
HSD 2583	0.13	0.03	-0.04	-0.28	-0.04*	-1.85	-2.21	-0.07
HSD 2482	0.02	-0.08	-0.33	-0.11	-0.05**	1.00	-2.32	0.31*
HSD 1840	-0.43	0.14	-0.69**	-0.06	0.04*	-0.76	0.79	-0.19
HSD 2550	-0.21	-0.08	0.31	0.08	0.05**	-0.38	-3.21	-0.05
Testers								
Sinnar	0.87**	-0.21*	0.35*	-0.04	0.06	5.03**	6.06**	0.25*
Hejirat	-0.89**	0.13	0.04	-0.10	-0.05	-4.17**	-6.70**	-0.32**
Clemson spineless	0.02	0.08	-0.39**	0.14	-0.01	-0.86	0.64	0.18
Standard error								
S E (gca) line	0.31	0.15	0.23	0.17	0.02	1.13	3.24	0.17
S E (gca) tester	0.21	0.10	0.15	0.11	0.14	0.74	2.12	0.11

*Significant at P=0.05. **Significant at P=0.01.

Table 5. Estimates of genetic components of variance and percent contribution of lines, testers and their interaction

Character	σ^2gca	σ^2sca	σ^2gca/ σ^2sca	Contribution (%)		
				Line (%)	Tester (%)	Interaction (%)
Number of pods per plant	0.16	-0.40	0.12	9.15	77.04	13.81
Number of ridges per pod	-0.07	0.04	-0.18	13.04	29.67	57.28
Length of pod (cm)	-0.001	1.31	0.00	28.43	20.49	51.08
Pod fresh weight (g)	-0.34	0.08	-4.25	25.23	11.98	62.80
Pod dry weight (g)	0.0002	0.004	0.05	34.07	40.06	25.87
Yield per plant (g)	4.39	13.44	3.88	21.00	21.02	58.00
Number of seeds per pod	6.85	17.65	0.39	12.77	45.04	42.19
100 seeds weight (g)	0.04	0.44	0.08	26.89	26.73	46.37

Table 4. Parent combinations with significant specific combining ability (SCA) at *P*=0.01

Parameters	Parent combinations
Number of pods per plant	HSD2550× Sinnar
Number of pod ridges	HSD1840×Clemson spineless
Pod length (cm)	HSD2543× Sinnar, HSD1840×Clemson spineless
Yield per plant (g)	HSD2543× Sinnar, HSD2550× Sinnar

weight (Table 5). This indicated the predominantly non-additive gene action (dominant or epistasis) for these characters and this is in agreement with Ahmed *et al.* (1997) and Prakash *et al.* (2002). The ratio due to GCA and SCA variance (σ^2GCA)/(σ^2SCA) was greater than zero for number of pods per plant, pod dry weight , yield per plant (g), number of seeds per pod and 100 seeds weight which indicated the predominance of additive gene action in the inheritance for these traits. This is in agreement with reports by Nichal *et al.* (2000) and Soni Sood and Kalia (2001) for pod dry weight, number of seeds per pod and hundred seeds weight. The ratio due to GCA and SCA variance (σ^2GCA)/(σ^2SCA) is equal to zero for length of pod (cm) indicating the importance of both additive and non-additive gene action and this is in agreement with reports by Rajani *et al.* (2001) and Singh and Singh (2003).

The study has clearly identified the breeding value of Sinnar as a strong candidate for any future breeding programmes. Sinnar showed consistent excellent results for yields and associated traits, producing six positive GCA results out of eight traits. Out of the six significant SCA values obtained on parent combinations; Sinnar was a parent in four combinations reinforcing the above conclusion. The study on the inheritance of traits confirmed previous reports by a number of researchers.

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Received: June, 2010; Revised: February, 2011; Accepted: February, 2011