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BREEDING POTENTIALITIES OF YIELD AND ITS CONTRIBUTING VARIABLES OF SOME FLAX CROSSES

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ABSTRACT

Ten diallel crosses among five flax cultivars showing clear differences were made and evaluated at the Agricultural Experiments Desert Station, Faculty of Agriculture, Cairo University, in Wadi El-Natroon, El-Beheira Governorate, during three successive growing seasons starting with 2011/2014. The objectives were to estimate the mode of gene action in the inheritance and combining ability effects for studied traits. Combining ability variances were highly significant for all studied traits except plant height at F_2 generation indicating the importance of additive and non-additive genetic variances in determining the performance of these traits. Since the ratio of GCA/SCA exceeded the unity, suggesting that additive was much larger and more important than non-additive gene effects in the inheritance of all studied traits. Data indicated great and significant genotypic differences in all studied traits. The averages of F_1 crosses were generally higher than F_2 in straw yield plant^{-1} and plant height, while the averages of F_1 and F_2 were identical in seed yield plant^{-1}, No. of capsules plant^{-1}, oil % and oil yield plant^{-1}. However, crosses averages were higher than parents averages in F_1 for straw yield plant^{-1}, plant height, seed yield plant^{-1}, and oil yield plant^{-1} by 11.83, 4.12 1.39 and 0.71%, respectively. This indicated the superiority of heterozygotes over homozygotes in flax performance. The best general combiners was P_1 (Sakha 1) for all traits in F_1 while good for straw yield plant^{-1}, seed yield plant^{-1}, No. of capsules plant^{-1} and oil % in F_2. P_2 (Sakha 3) and P_3 (Sakha 4) were good combiner in F_1 and F_2 for all traits except plant height in F_2. Seed yield of 10 crosses are significantly in F_1, whereas in F_2 Sakha 4 x S 3/25 is less than zero. No. capsules plant^{-1} the all crosses significantly greater than zero in F_1, whereas in F_2 two crosses less than zero (Sakha1 x Sakha 4 and S 3/25 x Olin). However, oil % was significantly greater than zero in F_1 and F_2 for all crosses. For oil yield plant^{-1} in F_1 two crosses were less than zero (Sakha1 x S 3/25 and Sakha1 x Olin) whereas Sakha 1 x Sakha 4 is less than zero in F_2. In most significant positive SCA were usually inconsistent across either generation.

Keywords: Flax, *Linum usitatissimum,* General combining ability, Specific combining ability, Straw and Oil yield.

INTRODUCTION

The future success of linseed cultivation depends on yield potential of modern dual purpose cultivars as well as of the production system for marginal soil. Oilseed flax fiber could be used and creating the potential for dual purpose crop (Foster *et al*. 1998). The breeders try also to obtain, by crossing fiber flax and seed flax, varieties combining a high yield of fiber with a high yield of seed.

The present study assesses 10 F_1 and F_2 crosses with the objective of identifying the most potent cross or crosses for producing pure breeding lines that will give high seed/oil and high straw/fiber yields (dual - purpose) .
The breeder, therefore, needs methods which can provide reliable information about the nature of gene action present in his material.

The availability of diverse germplasm, of characterization data and evaluation data is of greatest importance realize the potential of flax in agriculture (Nozkova *et al*., 2006 and pavelek, 2002).

Several breeding method are available, but the pedigree method is the most common used in flax breeding (Salas and Friedt, 1995). Higher genetic variability lead to more opportunities for improvement though appropriate selection procedure (Akbar *et* *al*., 2003). It is important to accurately estimate the magnitude and relative proportion of the various components of genetic variance in order to understand the underlying type of gene action that controls the trait of interest. Breeders discard inferior lines at an early selfing generation so that more resources can be devoted to the further testing and selection of the more promising lines (Bernardo, 2003). A particular cross producing transgressive segregates in autogamous crop like linseed would depend upon the precise estimates of various components namely additive, dominance non-allelic interaction linkage among polygenes and gene dispersion in the parents of across, contributing to heterosis (Jinks, 1983).

A thorough understanding of the genetics and related aspects of a crop is necessary for improvement of yield and quality parameters. Progress in yield improvement or quality traits of a crop requires information about the nature of combining ability of parents to be involved in the hybridization programme along with the nature of gene effects operative in the inheritance of different traits. General and specific combining ability effects are very important in designing and execution of a breeding programme. Beside, combining ability analysis is an important tool for the selection of desirable parents together with the information regarding nature and magnitude of gene effects controlling quantitative traits of economic importance (Mahto and Rahman, 1998 and Kumar *et al*., 2000). Application of intervarietal crossing and selection in fiber flax and linseed breeding within linseed gene pool of flax was reported by Evans, (1998). The crosses showed significant and positive SCA effects for seed yield plant^{-1} and straw yield plant^{-1}, respectively, indicating that those crosses were the best combination for increasing seed and straw yields (Abd El-Monem, 2014). Additive genetic variance had more important role in the inheritance of some traits. On other hand, non additive variance had an important role in the inheritance of another traits (El-Kady and Abo Kaied, 2010).

Diallel analysis following Griffing (1956) has been extensively used by plant breeders for the selection of parents for hybridization as this analysis provides an opportunity to test parental lines in all possible combinations for their combining ability effects. Besides this analysis provides reliable information on the combining ability of parents to produce superior progenies, and detect the estimates of additive and non-additive gene effects.

The main objectives of this study are to identify superior parents and cross combinations from a 5 x 5 half diallel cross system of flax parental cultivars to estimate combining ability effects and suggested guidelines for efficient parental choice of flax parents in hybrid breeding program for developing superior cultivars.

MATERIALS AND METHODS

Plant materials and experimental design

Five flax cultivars, showing clear differences were chosen to be used as parents of this study.
The Five cultivars of flax , namely: (P_1) Sakha 1(Dual purpose), (P_2) Sakha 3, (P_3) Sakha 4 (fiber type), (P_4) S. 3/25, and (P_5) Olin (oil type) were crossed in a half diallel design at the Agricultural Experiments Desert Station, Faculty of Agriculture, Cairo University, in Wadi El-Natroon, El-Beheira Governorate, during three successive growing seasons starting with 2011/2012. The description of these cultivars is presented in Table (1).

Table 1. The name, pedigree and origin of five cultivars of flax used as parents in this study

No.	Genotypes	Types	Origin*
P_1	Sakha 1	Dual purpose	Egypt
P_2	Sakha 3	fiber type	Egypt
P_3	Sakha 4	fiber type	Egypt
P_4	S. 3/25	oil type	Egypt
P_5	Olin	oil type	Holland

* Source: Oil crops Res. Dept., Agric. Res. Center (ARC), Egypt

In 2011/2012 all possible diallel crosses (excluding reciprocals) were made among the five parents, so seeds of 10 direct F_1 crosses were obtained.

In 2012/2013 crossing among parents was taken place again in order to have more sufficient seeds for planting F_1 trails. In the same time, F_1 plants were selfed to obtain F_2 seeds.

In 2013/2014, 25 entries (5 parents, 10 F_1, 10 F_2 crosses) were evaluated in a randomized completely block design with 3 replications. The experimental plot consisted of two rows. Rows were 3m long, spaced 20cm apart, single seeds were hand drilled in 5cm spacing within rows. Fertilization, pest control and other cultural practices were done according to the recommendations for flax production.

Data collected

Five individual random guarded plants from each row, i. e., 5 plants for parent, F_1 and F_2 per each replication were used to record seed and straw yield trails : (1) straw yield plant^{-1} (g). (2) Plant height (cm), (3) seed yield plant^{-1} (g). (4) No. capsules plant^{-1} (5) oil percentage (6) oil yield plant^{-1} (g*).*

Biometrical and genetic analyses

General (GCA) and specific (SCA) combining ability variances and effects were estimated according to Griffing's (1956) Method II Model I for diallel analysis using MSTAT-C (Freed *et al.*, 1989), SPSS (2009) and Dial 98 software, based on the following formula:

$$X_{ij} = U + g_i + g_j + S_{ij} + \frac{1}{b}\sum_k e_{ijk}$$

Where, u = the population mean, g_i = the general combining ability effects of the ith parent, g_j = the general combining ability effects of the jth parent, s_{ij} = the specific combining ability effects of the cross between ith and jth parents such that $s_{ij} = s_{ji}$ and eijk = the environmental effect associated with ijkth observation.

The ratio of GCA/SCA was used to identify gene action in the inheritance for the studied traits, if GCA/SCA exceeded the unity, suggesting that additive was much larger and more important than non-additive gene effects in the inheritance and *vice-versa*.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA)

The combining ability mean squares for the 6 characters are shown in Table 2. General combining ability (GCA) and specific combining ability (SCA) mean squares for all studied traits were highly significant in F_1 and F_2 except plant height in F_2 generations that the data are reliable for further analysis by the diallel mating procedure and estimating the type gave action controlling the expression of their traits. General combining ability mean squares were several times greater than SCA mean squares for all traits. Therefore, the magnitude of additive genetic effect and the additive x additive components of the epistatic variance, if present, must be considerable for each character.Consequently, effective selection should be possible within F_2 and subsequent populations for all the characters (Patil, 1980).

Table 2. Mean Squares of general and specific combining ability for 5 parents diallel crosses in F_1 and F_2 generations for yield and its components traits in flax.

Source of Variation	d.f.	Straw yield plant^{-1}		Plant height		Seed yield plant^{-1}		No. Capsules plant^{-1}		Oil %		Oil yield plant^{-1}	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Genotypes (G)	14	4.68**	5.28**	262.12**	518.29*	1.12**	1.16**	141.03**	230.67**	2.86**	2.82**	0.21**	0.22**
GCA	4	2.35**	2.27**	213.61**	103.01	0.82**	0.74**	114.84**	87.76**	2.31**	2.42**	0.16**	0.15**
SCA	10	1.24**	1.55**	36.88**	200.66*	0.20**	0.25**	19.88**	72.54**	0.41**	0.35**	0.03**	0.04**
Error	28	0.03	0.02	2.35	73.8	0.01	0.01	1.33	15.41	0.01	0.01	0.01	0.01
GCA/SCA		1.9	1.463	5.79	0.513	4.2	3.008	5.78	1.21	5.56	6.95	4.8	3.617

* and ** denote significance at 5% and 1% levels of probability, respectively

Since the ratio of GCA/SCA exceeded the unity, suggesting that additive was much larger and more important than non-additive gene effects in the inheritance of all traits. The higher importance of GCA over SCA variance for studied traits was also reported by Kakani *et al*. (2007), Amer (2011) and Singh *et al*. (2013). On the other hand, for plant height in F_2 generation the magnitude of mean squares due to SCA was much higher than that due to GCA, since the ratio of GCA/SCA was less the unity, suggesting that non-additive was much larger and more important than additive gene effects in the inheritance of these traits. Similar results were obtained by Mansour (2007), Ciulca *et al*. (2009) and El-Naggar (2010).

Mean performance

Means of different studied traits of five flax parental cultivars and their 10 diallel F_1 crosses are presented in Table 3. Data indicated great and significant genotypic differences in all studied traits.

For straw yield plant^{-1} the mean performance of parents ranged from 9.60 g (Olin) to 12.30 g (Sakha 3), while for F_1 the range was 10.30 g (S 3/25 x Olin) to 13.60 g (Sakha 3 x Olin). However, straw yield plant^{-1} for F_2 the range was from 9.60 g (Sakha 1 x Olin) to 13.60 (S 3/25 x Olin). The previous results suggested that crosses in F_1 were higher than F_2, and higher than their parents by 11.83% for straw yield plant^{-1}.

Concerning plant height the mean performance of parents ranged from 88.00 cm (Olin) to 124.00 cm (Sakha 1), for F_1 the range was 110.70 cm (S 3/25 x Olin) to 119.20 cm (Sakha 3 x Sakha 4) and for F_2 the range was from 80.40 cm (Sakha 3 x S 3/25) to 122.00 cm (Sakha 1 x Sakha 3). The previous results suggested that crosses in F_1 were taller than F_2, and taller than their parents by 4.12% for plant height.

The mean performance of F_1 and F_2 were almost identical in seed yield plant^{-1}, No. of capsules plant^{-1}, oil % and oil yield plant^{-1}. However, mean performance of crosses were higher than parent means in F_1 for seed yield plant^{-1} and oil yield plant^{-1} by 1.39 and 0.71%, respectively. This indicated the superiority of heterozygotes over homozygotes in flax performance. Similar conclusions were also reported by Ashoush *et al*. (2001). On the other hand F_2 means were less than parent means for all studied traits.

As indicated from Table 3, Sakha 4, S 3/25 and Olin were the highest parent for the studied traits in both generations.

Table 3. Mean performance and inbreeding depression (I.D.%) of 5 parents and their 10 F_1's and F_2's crosses for yield and its components traits in Flax.

Genotypes	Straw yield plant^{-1} (g)		I.D.%	Plant height (cm)		I.D.%	Seed yield plant^{-1} (g)		I.D.%	No. Capsules plant^{-1}		I.D.%	Oil %		I.D.%	Oil yield plant^{-1} (g)		I.D.%
	F_1	F_2		F_1	F_2		F_1	F_2		F_1	F_2		F_1	F_2		F_1	F_2	
Sakha1 (P_1)	11.20	11.20		124.10	124.10		3.40	3.40		59.50	59.50		38.20	38.20		1.30	1.30	
Sakha 3 (P_2)	12.40	12.40		121.90	121.90		3.20	3.20		53.20	53.20		37.30	37.30		1.20	1.20	
Sakha 4 (P_3)	12.30	12.30		122.40	122.40		2.50	2.50		48.80	48.80		38.20	38.20		0.90	0.90	
S. 3/25 (P_4)	10.70	10.70		100.00	100.00		4.50	4.50		68.20	68.20		39.70	39.70		1.80	1.80	
Olin (P_5)	9.60	9.60		88.00	88.00		4.40	4.40		72.90	72.90		39.80	39.80		1.80	1.80	
1*2	11.90	12.40	-4.50	119.00	122.00	-2.50	3.20	3.30	-3.90	55.30	54.00	2.40	38.00	37.20	2.20	1.20	1.20	-1.60
1*3	13.10	12.60	3.90	117.10	120.60	-2.90	3.40	2.50	26.30	50.50	47.20	6.60	37.40	38.20	-2.10	1.30	1.00	24.70
1*4	11.20	9.80	12.10	116.40	89.20	23.3	3.10	4.70	-51.70	51.10	73.40	-43.60	37.10	39.90	-7.30	1.20	1.90	-62.80
1*5	12.80	9.60	25.30	111.70	87.30	21.8	3.00	4.50	-48.10	55.50	75.20	-35.50	38.20	39.80	-4.30	1.20	1.80	-54.50
2*3	13.40	13.20	1.00	119.20	115.20	3.4	3.40	3.50	-2.50	51.50	50.40	2.10	37.20	37.20	0.00	1.30	1.30	-2.50
2*4	13.00	10.80	16.80	118.70	80.40	32.3	3.70	3.00	18.30	62.90	50.80	19.20	38.10	37.40	2.00	1.40	1.10	20.00
2*5	13.20	11.40	14.10	116.30	113.60	2.4	3.80	3.30	11.30	61.00	52.90	13.30	38.40	38.60	-0.40	1.40	1.30	11.00
3*4	13.20	12.00	8.50	112.70	117.40	-4.1	4.20	3.50	15.80	60.40	60.50	-0.30	39.30	38.50	2.00	1.60	1.40	17.50
3*5	13.60	12.80	6.10	116.80	116.40	0.3	4.20	3.80	10.10	58.80	61.90	-5.30	39.70	38.60	2.80	1.70	1.50	12.70
4*5	10.30	13.60	-31.60	110.70	118.10	-6.7	4.50	4.30	4.20	63.20	46.20	27.00	39.70	39.30	0.80	1.80	1.70	5.00
LSD 5%	0.11	0.09		1.06	5.95		0.06	0.06		0.8	2.72		0.06	0.05		0.02	0.02	
LSD 1%	0.15	0.13		1.43	8.02		0.08	0.08		1.08	3.66		0.08	0.07		0.03	0.03	

The F_1 cross S 3/25 x Olin was the highest cross for seed yield plant^{-1}, No. of capsules plant^{-1}and oil yield plant^{-1}. However F_1 cross Sakha 4 x Olin was the highest cross for straw yield plant^{-1} and oil %.

On the other hand F_2 cross Sakha 4 x S 3/25 was the highest cross for straw yield plant^{-1} and oil %, while cross S 3/25 x Sakha 1 was the highest cross for seed yield plant^{-1} and oil yield plant^{-1}.

Results of inbreeding depression (ID %) in F_2 generation for all studied traits are presented in Table 3 show for straw yield plant^{-1} all crosses were positive except only two crosses (Sakha 1 x Sakha 3 and S 3/25 x Olin) were negative. The positive sign revealed that the mean values of F_2 were lower than F_1 and vice versa for the crosses exhibited negative inbreeding depression. Meanwhile, Results of ID % for remain traits (plant height, seed yield plant^{-1}, No. of capsules plant^{-1} oil % and oil yield plant^{-1}) showed positive ID % for all crosses indicated that the mean values of F_2 were lower than F_1, whereas a negative

ID % was found for 4 different crosses in each traits. Data in Table 3 showed that crosses Sakha1 x S 3/25 and Sakha 1 x Olin were negative for ID % with seed yield plant^{-1}, No. of capsules plant^{-1} oil % and oil yield plant^{-1} indicating superiority of crosses F_1 compared with F_2.

GCA effects

Data in Table 4 indicated that GCA effects for P2(Sakha 3) and P3 (Sakha 4) were good general combiner for straw yield plant^{-1} in F_1 and F_2 generations. while P4 (S. 3/25) and P5 (Olin) were good combiner for seed yield plant^{-1}, No. of capsules plant^{-1}, oil % and oil yield plant^{-1} in F_1 and F_2 generations. P_2 (Sakha 3) and P_3 (Sakha 4) were good combiner in F_1 for plant height, whereas in F_2 both parents (P_2 and P_3) were insignificant.

The *per se* performance of parent and GCA effects as expressed in the performance of their F_2 progenies is shown in Table 4. The strong association between GCA effects from F_1 and F_2 generation for the 6 traits studied suggests that F_2 populations can effectively by used for the identification of general combiners . Bhullar *et al*. (1979) reported that F_2/F_3 generations gave better predications than those from the F_1 generation

SCA effects

The SCA effects indicated that for traits in Table 5, some crosses had mean performance different than indicated from GCA effects. All crosses (10 crosses) had SCA effects that were significantly in F_1 and F_2.

Table 4. Estimation of GCA effects for yield and its components in F_1 and F_2 for 5 parental diallel crosses of flax

Parents	Straw yield plant^{-1}		Plant height		Seed yield plant^{-1}		No. Capsules Plant^{-1}		Oil %		Oil yield plant^{-1}	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Sakha1 (P_1)	-0.16**	-0.51**	3.30**	-1.51	-0.28**	-0.01**	-2.20**	3.41*	-0.44**	0.06*	-0.13**	0.01
Sakha3 (P_2)	0.44**	0.17**	3.88**	0.04	-0.17**	-0.29**	-1.50**	-3.47*	-0.51**	-0.55**	-0.09**	-0.13**
Sakha4 (P_3)	0.63**	0.64**	3.07**	5.47	-0.20**	-0.26**	-3.78**	-2.99*	-0.07*	-0.49**	-0.08**	-0.12**
S. 3/25 (P_4)	-0.45**	0.20**	-3.44**	-3.56	0.33**	0.20**	3.10**	0.79	0.39**	0.36**	0.14**	0.09**
Olin (P_5)	-0.46**	-0.51**	-6.81**	-0.45	0.32**	0.36**	4.39**	2.27	0.63**	0.61**	0.15**	0.16**
SE (gi)	0.05	0.05	0.52	2.90	0.03	0.03	0.39	1.33	0.03	0.03	0.01	0.01

* and ** denote significance at 5% and 1% levels of probability, respectively
P_1= Sakha 1, P_2= Sakha 3, P_3= Sakha 4, P_4= S. 3/25, and P_5= Olin

Table 5. Estimation of SCA effects for yield and its components for F_1 and F_2 progenies of 10 crosses of flax

Crosses	Straw yield plant^{-1}		Plant height		Seed yield plant^{-1}		No. Capsules plant^{-1}		Oil %		Oil yield plant^{-1}	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
P_1xP_2	2.05**	3.40**	21.98**	36.79**	0.80**	0.75**	13.33**	8.76*	8.80**	7.48**	0.33**	0.26**
P_1xP_3	3.15**	3.19**	20.93**	29.94**	1.07**	-0.08	10.80**	1.46	7.70**	8.36**	0.39**	-0.02
P_1xP_4	2.25**	0.79**	26.70**	7.63	0.21**	1.67**	4.47**	23.84**	7.00**	9.20**	0.04	0.69**
P_1xP_5	3.87**	1.24**	25.39**	2.60	0.15*	1.27**	7.62**	24.23**	7.78**	8.91**	0.04	0.52**
P_2xP_3	2.78**	3.12**	22.43**	22.97**	0.95**	1.19**	11.06**	11.57**	7.59**	8.02**	0.34**	0.45**
P_2xP_4	3.51**	1.14**	28.46**	-2.74	0.67**	0.23**	15.57**	8.17*	8.06**	7.32**	0.25**	0.06*
P_2xP_5	3.70**	2.37**	29.38**	27.28**	0.77**	0.39**	12.35**	8.74*	8.11**	8.29**	0.29**	0.15**
P_3xP_4	3.46**	1.87**	23.25**	28.78**	1.20**	0.71**	15.36**	17.41**	8.77**	8.39**	0.48**	0.27**
P_3xP_5	3.91**	3.32**	30.67**	24.68**	1.23**	0.79**	12.48**	17.32**	8.93**	8.20**	0.50**	0.30**
P_4xP_5	1.71**	4.58**	31.11**	35.45**	0.96**	0.84**	10.03**	-2.22	8.46**	8.13**	0.38**	0.32**
SE (sij)	0.141	0.118	1.338	7.499	0.075	0.075	1.008	3.426	0.077	0.066	0.03	0.03

* and ** denote significance at 5% and 1% levels of probability, respectively
P_1= Sakha 1, P_2= Sakha 3, P_3= Sakha 4, P_4= S. 3/25, and P_5= Olin

However, for plant height all crosses were significantly positive in F_1, whereas in F_2 7 crosses were significantly positive (Sakha 1 x Sakha 3, Sakha 1 x Sakha 4, Sakha 3 x Sakha 4, Sakha 3 x Olin, Sakha 4 x S. 3/25, and Sakha 4 x Olin *)*

For Seed yield plant^{-1}10 crosses are significantly positive in F_1, whereas in F_2 Sakha 1 x Sakha 4 was insignificant. No. capsules/plant all crosses were significantly positive in F_1, whereas in F_2 two crosses were insignificant (Sakha 1 x Sakha 4 and S 3/25 x Olin). However, oil % all crosses were significantly positive in F_1 and F_2. Oil yield plant^{-1} all crosses were significantly positive F_1 and F_2, except two crosses were insignificant (Sakha1 x S 3/25 and Sakha1 x Olin) in F_1 and one cross (Sakha1 x Sakha 4) in F_2.

To conclude, cross progenies can be predicted from the performance of their parents if only GCA is significant in a diallel analysis (Baker, 1978). The predictability of future performance will depend upon the ratio of the GCA component of variance to the total genetic variance if SCA significant (Baker ,1978*).* The results revealed that parents S. 3/25 and Olin were good combiners for GCA effects, beside their cross S. 3/25 x Olin were significantly positive for SCA effects in most of studied traits. Finally the present studied showed that breeding programme of flax for yield and its components must be intentioned to the following crosses: Sakha 1 x S. 3/25, Sakha 1 x Olin and S. 3/25 x Olin.

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