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# GENETIC STUDIES ON YIELD AND ITS ATTRIBUTES IN SOME FLAX HYBRIDS UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

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## ABSTRACT

The present investigation was conducted using six flax genotypes with their 15 $F_1$ crosses grown under two environments (Giza Exp.Station, Giza Governorate and Ismailia Exp.Station, Ismailia Governorate) to determine combining ability and gene action of some agronomic flax characters in these entries (parents and their crosses). In 2007/08 season, the six parents {$P_1$ (S.541-A/5), $P_2$ (Sakha 3) , $P_3$ (S.435/11/10/3), $P_4$ (Gentiana), $P_5$ (Elona) and $P_6$ (Escalina)} and their 15 progenies were evaluated in a randomized complete block design with three replications at the two above-mentioned locations.

High ratio of GCA/SCA revealed that additive played greater role than non-additive genetic effects in the inheritance of straw weight and its two important components (plant height and technical stem length) as well as seed weight and its two important components (No. of capsules per plant and 1000-seed weight) under the two environments and combined analysis. On the other hand, the non-additive genetic effects played an important role in the inheritance of No. of basal branches per plant. Mean squares of interaction between environment and both types of combining ability for most studied traits revealed that the magnitude of both additive and non-additive types of gene action varied from environment to another. Whereas the non-additive genetic effects are more influenced by drought environment than additive effects in each of straw weight, plant height, seed weight and No. of capsules per plant. In contrast, additive genetic effects were more influenced by environment than non-additive effects in both technical stem length and No. of seeds/capsule. The two parents, $P_1$ and $P_3$ showed significant positive $g_i$ effects for straw weight, seed weight, No. of capsules per plant and 1000-seed weight in both environments and the combined data. For $S_{ij}$ effects, the two crosses, $P_1xP_4$ and $P_1xP_6$ for straw weight in addition the two crosses, $P_1xP_5$ and $P_2xP_3$ for seed weight and 1000-seed weight included low x high general combiner parents. Therefore, these crosses are suitable in breeding program for increasing the previous characters. Concerning drought tolerance, $P_3$ for each of straw weight, seed weight, No. of capsules and 1000-seed weight; $P_4$ for plant height; $P_5$ for technical stem length and $P_1$ for each of plant height, No. of basal branches per plant and 1000-seed weight exhibited high yielding ability with tolerance to drought. Also, the cross, $P_4xP_5$ exhibited high yield potential with moderate tolerance to drought for each of straw weight, plant height and technical stem length. While, the cross $P_1xP_5$ only exhibited high yielding potential and stress tolerance for all seed characters. In the meantime's this cross ($P_1xP_5$) showed high SCA effects for seed weight and its two important components. Hence the two crosses, $P_1xP_5$ and $P_4xP_5$ may be useful as potential breeding material for developing genotypes tolerant to sandy soil conditions for seed and straw weight, respectively.

**Keywords**: Flax, Diallel analysis, Gene action, Drought tolerance.

## INTRODUCTION

The extension of flax (*Linum usitatissimum* L.) cultivation in Egypt is hampered by several factors. During the winter season the land is occupied by wheat, berseem, fababean …*etc*, which need to be cultivated in the ancient Valley lands. Therefore, the extension of the flax cultivated area in sandy soil has become a must. But, such soil has low water-holding capacity and irrigation water is limited. Flax investigators try to solve this problem by releasing drought tolerant cultivars and/or the best management of irrigation under sandy soil conditions. Therefore, any breeding program must be initiated and evaluated in sandy areas, before releasing a flax cultivar for sandy reclaimed soil. Also, developing drought tolerant varieties is important for the successful production of a cultivar that is adapted to the sandy soil conditions.

Information about combining ability and type of gene action of traits related to sandy soil conditions or to drought tolerance are necessary for flax breeder to design an appropriate breeding program for producing flax varieties have ability to drought tolerance. Published work on the combining ability and type of gene action of flax traits under sandy soil conditions is generally lacking. On the other hand, many investigations studied the combining ability in flax under normal conditions, *i.e.* Patil, *et al.,* (1997), Foster *et al.,* (1998), Abo El-Zahab and Abo-Kaied (2000) and Abo-Kaied (2002), who found that additive genetic variance had more important role in the inheritance of straw yield, plant height, technical stem length and 1000-seed weight. ON the contrary, non-additive variance had an important role in the inheritance of No. of basal branches per plant, seed yield per plant and capsules per plant as reported by Shehata and Comstock (1971), Patil and Chopde (1981) and Abo-Kaied (2006).

Therefore, the present study aimed 1) to estimate combining ability of 21 flax entries (6 parents and their 15 $F_1$ crosses) under both normal and sandy soil conditions and 2) to identify the best parents and crosses which could be recommended for breeding flax lines adapted to sandy soil conditions.

## MATERIALS AND METHODS

This investigation was carried out during the two successive seasons 2006/2007 and 2007/2008. In the first season, all possible crosses were made, excluding reciprocals, in a diallel mating design involving six parental flax genotypes {$P_1$ (S.541-A/5), $P_2$ (Sakha 3) , $P_3$ (S.435/11/10/3), $P_4$ (Gentiana), $P_5$ (Elona) and $P_6$ (Escalina)} to obtain 15 $F_1$ crosses at Giza Agric. Res. Station, Agric. Res. Center. Genotype characteristics of the material used according to their pedigree, origin and type are presented in Table (1).

**Table 1: Identification of parental genotypes used, pedigree, classification (dual, oil, fiber types) and origin.**

| Genotypes | Pedigree | Type | Origin |
|---|---|---|---|
| $P_1$=S.541-A/5 | Giza 7 x Giza 8 | dual | Local strain |
| $P_2$=Sakha 3 | I. Belinka x I. 2569 | fiber | Local *cv*. |
| $P_3$=S.435/11/10/3 | S.162/12 x S.2467/1 (Hira) | dual | Local strain |
| $P_4$=Gentiana | Introduction from Romania | oil | Romania |
| $P_5$=Elona | Introduction from Holland | fiber | Holland |
| P6=Escalina | Introduction from Holland | fiber | Holland |

In the second season, the hybrid seeds of the 15 diallel crosses were used to evaluate its $F_1$ progenies with the six parents at two locations viz: Giza Exp.Station, Giza Governorate (clay, organic matter of 2.44%, available nitrogen 38.45 ppm, E.C. 1.97 and pH = 7.95) and Ismailia Exp.Station, Ismailia Governorates (sandy soil, organic matter of 0.045 %, available nitrogen 6.65 ppm, E.C. 0.15 and pH value of 7.21).

The experiment was laid out in a randomized complete block design with three replications with restricted randomization where each replicate consisted of 21 entries (6 parents and 15 $F_1$ crosses) and each entry was sown in one plot. Each plot consisted of one row. Row was 3 m long, spaced 20 cm apart. Single seeds were hand drilled in 5 cm spacing within rows. The normal cultural usually recommended for flax cultivation were applied at the proper time in both environments. Observations and measurements were recorded for each plot on 10 guarded plants chosen at random from each plot for the following characteristics:

**1- Straw weight per plant and its components:**

(1) Straw weight/plant: Total weight in grams of the air dried straw per plant after removing the capsules, (2) Plant height (cm): Measured as the distance from the cotyledonary nodes up to uppermost capsule, (3) Technical stem length (cm): The length of the main stem between the cotyledons and the apical branching point and (4) No. of basal branches: Measured for stems at the base more than 10 cm in length and bearing at least one capsule.

**2- Seed weight per plant and its components:**

(1) Seed weight/plant (gm), (2) No. of capsules/plant, (3) 1000-seed weight (gm), and (4) No. of seeds/capsule: Measured as average number of seeds/capsule from 5 random capsules per plant.

**Combining ability analysis:**

Plot means were used for statistical analysis. Data from each environment (combinations of locations) were analyzed and Barteltt's test for heterogeneity of error variances across environments indicated that error terms were homogeneous. In the combined analysis across environmental effect was assumed to be fixed. Combining abilities, general (GCA) and specific (SCA) were calculated according to Griffing's method 2, model 1 (fixed effects). Forms of analysis for individual environments as given by Griffing (1956) and for combined analysis as suggested by Singh (1973).

**Susceptibility analysis:**

A stress - susceptibility analysis index (S) was used to characterize each genotype in the stress environments and the index was calculated using genotype means and a generalized formula (Fisher and Maurer 1978) in which

S = (1-YS/YN)/D, where YS = mean yield with stress environment, YN = mean yield with normal environment, and D = environment stress intensity = 1- (mean YS of all genotypes/mean YN of all genotypes).

The "S" was used to characterize the relative drought stress tolerance of the various genotypes, where S<0.50 indicated highly stress tolerant, S>0.50<1.00 designated moderately stress tolerant and S>1.00 referred to susceptible.

# RESULTS AND DISCUSSION

**1-Combining ability:**

**1-1-Straw weight per plant and its components :**

Table (2) shows mean square estimates for straw weight and its components, plant height, technical stem length and No. of basal branches/plant due to 21 flax genotypes (6 parents and 15 $F_1$ crosses) under normal ($E_1$= Giza) and drought ($E_2$= Ismailia) environments and their combined data. Mean squares due to environments and genotypes were highly significant for straw weight and its components. This indicated the presence of true differences among the genotypes and the wide diversity between the parental materials used in the present study under the two environments. The significant differences among parents and crosses observed for straw weight and its components at both environments and their combined analysis, indicated that sufficient genetic variability was existed in the population and increase the chance of isolating good new recombinations in the following generations. In this connection, significant differences between flax genotypes for straw weight and its attributes were detected by Abo El-Zahab and Abo-Kaied (2000) and Abo-Kaied *et al.*, (2007). Also, the parents *vs.* crosses mean squares, as an indication to average heterosis over all hybrids were significant, revealing that heterotic effect was pronounced for straw weight and its components at the two environments and in the combined analysis.

Mean squares due to general (GCA) and specific (SCA) combining ability were highly significant for straw weight and its components under normal and drought environments. These results indicate that both additive and non-additive genetic effects were involved in the inheritance of straw weight and its components. Whereas, the magnitude of mean squares due to GCA with that for SCA revealed that GCA/SCA ratio was more than unity for straw weight and its two important components (plant height and technical stem length) under the two environments and combined analysis. On the other hand, the non-additive genetic effects play an important role in the inheritance of No. of basal branches/plant. Therefore, effective selection could be possible within $F_2$ and subsequent generations of the involved crosses for straw weight/plant, plant height and technical stem length. These results were similar to those obtained by Patil, *et al.,* (1997); Foster *et al.,* (1998); Abo El-Zahab and Abo-Kaied, (2000), Abo-Kaied, (2002) and Abo-Kaied *et al.*, (2007).

The interaction between each of genotypes, parents, crosses and parent *vs.* crosses with environment was highly significant for all traits except crosses x E interaction was insignificant for No. of basal branches/plant, revealing inconsistent responses for these sources of variations from drought to normal conditions. Also, the mean squares of interaction between environment and both types of combining ability were highly significant for straw weight and its two important components, plant height and technical stem length except only GCAxE interaction was insignificant for plant height, revealing that the magnitude of both additive and non-additive types of gene action varied from environment to another.

Table 2. Mean squares of ordinary and combining ability analyses for straw weight and its components in $F_1$ generation under normal ($E_1$) and drought ($E_2$) environments and their combined data (C.).

| S.O.V | df S. | df C. | Straw weight/plant (g) $E_1$ | | $E_2$ | | C. | | Plant height/plant (cm) $E_1$ | | $E_2$ | | C. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Environment (E) | | 1 | | | | | 487.970 | ** | | | | | 6951.806 | ** |
| Reps/ E | | 4 | | | | | 0.989 | ** | | | | | 44.117 | ns |
| Genotypes(G ) | 20 | 20 | 6.240 | ** | 2.158 | ** | 6.131 | ** | 235.640 | ** | 238.772 | ** | 428.503 | ** |
| Parents (P) | 5 | 5 | 7.780 | ** | 1.363 | ** | 9.728 | ** | 260.020 | ** | 214.297 | ** | 424.829 | ** |
| Crosses(C.) | 14 | 14 | 4.570 | ** | 3.695 | ** | 3.509 | ** | 201.330 | ** | 239.943 | ** | 394.564 | ** |
| P.vs.C | 1 | 1 | 21.940 | ** | 5.604 | ** | 24.859 | ** | 594.130 | ** | 344.751 | ** | 922.015 | ** |
| G x E | | 20 | | | | | 6.355 | ** | | | | | 331.579 | ** |
| P x E | | 5 | | | | | 8.230 | ** | | | | | 332.708 | ** |
| C x E | | 14 | | | | | 2.425 | ** | | | | | 46.707 | ** |
| P vs C xE | | 1 | | | | | 19.255 | ** | | | | | 631.539 | ** |
| GCA | 5 | 5 | 3.914 | ** | 1.278 | ** | 4.700 | ** | 96.987 | ** | 89.403 | ** | 182.618 | ** |
| SCA | 15 | 15 | 1.469 | ** | 0.533 | ** | 1.158 | ** | 72.400 | ** | 76.320 | ** | 129.573 | ** |
| GCA x E | | 5 | | | | | 0.492 | ** | | | | | 3.771 | ns |
| SCA x E | | 15 | | | | | 0.844 | ** | | | | | 19.147 | ** |
| Error | 40 | 80 | 0.125 | | 0.030 | | 0.078 | | 3.822 | | 3.468 | | 3.645 | |
| GCA/SCA | | | 2.664 | | 2.398 | | 4.059 | | 1.340 | | 1.171 | | 1.409 | |
| **S.O.V** | **S.** | **C.** | **Technical stem length/plant (cm)** | | | | | | **Number of basal branches/plant** | | | | | |
| Environment (E) | | 1 | | | | | 5909.769 | ** | | | | | 1.218 | ** |
| Reps/ E | | 4 | | | | | 98.906 | ** | | | | | 0.265 | ns |
| Genotypes(G ) | 20 | 20 | 261.950 | ** | 155.188 | ** | 391.161 | ** | 0.560 | ** | 0.554 | ** | 1.105 | ** |
| Parents (P) | 5 | 5 | 323.810 | ** | 112.343 | ** | 394.864 | ** | 0.700 | ** | 0.739 | ** | 1.437 | ** |
| Crosses(C.) | 14 | 14 | 225.920 | ** | 163.831 | ** | 368.514 | | 0.500 | ** | 0.489 | ** | 0.973 | ** |
| P.vs.C | 1 | 1 | 457.100 | ** | 248.399 | ** | 689.710 | ** | 0.760 | ** | 0.538 | ** | 1.286 | ** |
| G x E | | 20 | | | | | 286.751 | ** | | | | | 0.746 | ** |
| P x E | | 5 | | | | | 304.535 | ** | | | | | 0.965 | ** |
| C x E | | 14 | | | | | 21.235 | ** | | | | | 0.011 | ns |
| P vs C xE | | 1 | | | | | 475.594 | ** | | | | | 0.867 | ** |
| GCA | 5 | 5 | 172.797 | ** | 55.319 | ** | 209.724 | ** | 0.046 | ** | 0.055 | ** | 0.100 | ** |
| SCA | 15 | 15 | 58.823 | ** | 50.533 | ** | 103.941 | ** | 0.234 | ** | 0.228 | ** | 0.458 | ** |
| GCA x E | | 5 | | | | | 18.392 | ** | | | | | 0.001 | ns |
| SCA x E | | 15 | | | | | 5.415 | ** | | | | | 0.004 | ns |
| Error | 40 | 80 | 1.494 | | 2.955 | | 2.225 | | 0.008 | | 0.007 | | 0.007 | |
| GCA/SCA | | | 2.938 | | 1.095 | | 2.018 | | 0.197 | | 0.241 | | 0.218 | |

ns,*,** non- significant, significant at 0.05 and 0.01 levels of probability, respectively..

S. Single environment C. Combined over environments

It is fairly evident that mean squares of GCAxE/GCA were lower than SCAxE/ SCA ratios indicating that non-additive genetic effects were much more influenced by the drought conditions than additive effects in both straw weight and plant height. In contrast, additive genetic effects were more influenced by environment (drought conditions) than non-additive effects for technical stem length. While, concerning No. of basal branches/plant both additive and non-additive genetic effects were the same influenced by the environmental conditions. These results are more or less in harmony with those obtained by Abo-Kaied *et al.*, (2007).

Estimates of GCA effects ($g_i$) for six parental genotypes as affected by normal and drought environments as well as the combined for straw weight and its components are presented in Table (3). In both environments and combined analysis $P_1$(S.541-A/5) and P3(S.435/11/10/3) exhibited good general combining ability effects for straw weight as well as $P_1$ and $P_5$(Elona) for both plant height and technical stem length in addition $P_1$ for No. of basal branches/plant. Therefore, using these parents in hybridization programs may result in isolating desirable segregates for the above-mentioned characters. In general $P_1$(S.541-A/5) was more efficient under both environments (drought and normal) as it had favourable genes and straw weight improvement can be attained by it use in a breeding program at irrespective drought conditions. The correlation coefficient (r ) between mean performance (Table 8) of parents and their GCA values (Table 3) was significant and positive at both environments and combined data for straw weight and its components. These results indicated that the parents showing higher mean performance proved to be the highest general combiners for these traits. Therefore, high mean performance of the parents could be transferred to crosses in such cases.

The specific combining ability effects($S_{ij}$) for straw weight and its components under normal and drought environments and their combined data are presented in Table (4). The results indicated that there was no cross combination which was consistently good for all traits. Out of the 15 $F_1$ crosses, two crosses ($P_1 \times P_4$ and $P_1 \times P_6$) exhibited highly significant positive SCA effects for straw weight/plant. Five crosses ($P_1 \times P_2$, $P_2 \times P_3$, $P_2 \times P_5$, $P_3 \times P_6$ and $P_4 \times P_6$) for plant height, four crosses ($P_1 \times P_4$, $P_2 \times P_3$ ,$P_3 \times P_6$ and $P_4 \times P_5$) for technical stem length and six crosses ($P_1 \times P_6$,, $P_2 \times P_3$, $P_2 \times P_4$, $P_3 \times P_4$, $P_3 \times P_5$ and $P_4 \times P_5$) for number of basal branches/plant , exhibited significant positive SCA effects in the desirable direction under the two environments and their combined data. In general. The cross $P_1xP_4$ involved high x low general combiners for straw weight and technical length as well as $P_1xP_6$ (high x low general combiners) for straw weight and No. of basal branches/plant. While, the cross $P_2 \times P_3$ involved low x low for plant height, technical stem length and No. of basal branches/plant as well as $P_3 \times P_6$ (low x low) for both plant height and technical stem length. Therefore, these crosses ($P_1xP_4$, and $P_1xP_6$) are likely to throw good segregates for these traits if the allelic genetic systems are present in good combination and epistatic effects present in the crosses act in the same direction to maximize the desirable characteristics. Therefore, these crosses ($P_1xP_4$ and $P_1xP_6$ ) may prove useful for simultaneous improvement of the above-mentioned traits. The correlation between cross means (Table 8) and their SCA values (Table 4) was significant and positive indicating that high performing crosses were high specific combinations. Therefore, the choice of promising cross combinations would be based on SCA effects or mean performance of a cross.

Table 3. Estimates of general combining ability effects(ĝi) for six parental genotypes as affected by normal ($E_1$) and drought ($E_2$) environments and their combined data (C.) for staw weight and its combonents.

| Parents | $E_1$ | | $E_2$ | | C. | | $E_1$ | | $E_2$ | | C. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Straw weight/plant (g)** | | | | | | **Plant height/plant (cm)** | | | | | |
| **P1** | 0.879 | ** | 0.375 | ** | 0.627 | ** | 3.041 | ** | 3.611 | ** | 3.326 | ** |
| **P2** | 0.198 | ns | 0.125 | * | 0.162 | * | 0.307 | ns | 1.103 | ns | 0.705 | ns |
| **P3** | 0.258 | * | 0.162 | ** | 0.210 | ** | -2.291 | ** | -3.565 | ** | -2.928 | ** |
| **P4** | -0.169 | ns | 0.160 | ** | -0.005 | ns | 0.498 | ns | 0.047 | ns | 0.273 | ns |
| **P5** | 0.072 | ns | -0.055 | ns | 0.009 | ns | 3.944 | ** | 3.156 | ** | 3.550 | ** |
| **P6** | -1.239 | ** | -0.767 | ** | -1.003 | ** | -5.498 | ** | -4.353 | ** | -4.925 | ** |
| LSD **5%** | 0.357 | | 0.176 | | 0.197 | | 1.975 | | 1.882 | | 1.350 | |
| (Sij-Sik)**1%** | 0.477 | | 0.236 | | 0.261 | | 2.643 | | 2.518 | | 1.789 | |
| r | **0.977** | | **0.870** | | **0.960** | | **0.846** | | **0.890** | | **0.880** | |
| | **Technical stem length/plant (cm)** | | | | | | **Number of basal branches/plant** | | | | | |
| **P1** | 4.670 | ** | 2.881 | ** | 3.776 | ** | 0.114 | ** | 0.128 | ** | 0.121 | ** |
| **P2** | 0.036 | ns | -0.098 | ns | -0.031 | ns | -0.031 | ns | -0.048 | ns | -0.039 | ns |
| **P3** | -2.317 | ** | -1.278 | * | -1.797 | ** | 0.004 | ns | -0.001 | ns | 0.002 | ns |
| **P4** | 1.471 | ** | -0.185 | ns | 0.643 | ns | 0.049 | ns | 0.062 | * | 0.056 | ** |
| **P5** | 4.037 | ** | 2.784 | ** | 3.410 | ** | -0.033 | ns | -0.041 | ns | -0.037 | ns |
| **P6** | -7.897 | ** | -4.105 | ** | -6.001 | ** | -0.105 | ** | -0.101 | ** | -0.103 | ** |
| LSD **5%** | 1.235 | | 1.737 | | 1.055 | | 0.089 | | 0.086 | | 0.061 | |
| (Sij-Sik)**1%** | 1.653 | | 2.324 | | 1.398 | | 0.119 | | 0.115 | | 0.081 | |
| r | **0.928** | | **0.900** | | **0.930** | | **0.750** | | **0.770** | | **0.760** | |

ns,*,** non- significant, significant at 0.05 and 0.01 levels of probability, respectively..

# P1 (S.541-A/5), P2 (Sakha 3) , P3 (S.435/11/10/3), P4 (Gentiana), P5 (Elona) and P6 (Escalina)}

Table 4: Estimates of specific combining ability ($\hat{s}_{ij}$) for 15 $F_1$ crosses as affected by normal ($E_1$) and drought ($E_2$) environments and their combined (C.) data for staw weight and its combonents.

| Parents | $E_1$ | $E_2$ | C. | $E_1$ | $E_2$ | C. | $E_1$ | $E_2$ | C. | $E_1$ | $E_2$ | C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Straw weight/plant (g) | | | Plant height/plant (cm) | | | Technical stem length/plant (cm) | | | Number of basal branches/plant | | |
| **P1xP2** | 0.042 ns | -0.675 ** | -0.316 ns | 4.825 ** | 8.344 ** | 6.584 ** | 0.974 ns | 1.062 ns | 1.018 ns | -0.418 ** | -0.291 ** | -0.355 ** |
| **P1xP3** | -1.565 ** | -0.031 ns | -0.798 ** | -9.988 ** | -5.825 ** | -7.906 ** | -10.486 ** | -7.766 ** | -9.126 ** | -0.460 ** | -0.561 ** | -0.511 ** |
| **P1xP4** | 0.933 ** | 1.217 ** | 1.075 ** | 6.583 ** | -4.534 ** | 1.025 ns | 7.993 ** | 4.915 ** | 6.454 ** | -0.551 ** | -0.528 ** | -0.540 ** |
| **P1xP5** | -0.332 ns | 0.848 ** | 0.258 ns | 5.378 ** | 0.981 ns | 3.179 * | 4.427 ** | 2.683 ns | 3.555 ** | -0.330 ** | -0.298 ** | -0.314 ** |
| **P1xP6** | 1.932 ** | 0.357 * | 1.145 ** | -1.765 ns | -2.323 ns | -2.044 ns | 2.627 * | 1.435 ns | 2.031 * | 0.599 ** | 0.465 ** | 0.532 ** |
| **P2xP3** | 1.639 ** | -0.275 ns | 0.682 ** | 14.947 ** | 10.213 ** | 12.580 ** | 16.415 ** | 15.107 ** | 15.761 ** | 0.568 ** | 0.588 ** | 0.578 ** |
| **P2xP4** | 1.010 ** | -0.503 ** | 0.253 ns | -0.109 ns | 5.134 ** | 2.513 ns | 0.360 ns | 1.027 ns | 0.694 ns | 0.314 ** | 0.398 ** | 0.356 ** |
| **P2xP5** | -0.028 ns | 0.845 ** | 0.408 * | 4.535 * | 5.715 ** | 5.125 ** | 2.171 ns | 2.985 ns | 2.578 * | -0.098 ns | -0.209 ** | -0.154 * |
| **P2xP6** | -0.317 ns | 0.547 ** | 0.115 ns | 0.123 ns | -9.276 ** | -4.576 ** | 0.348 ns | -4.956 ** | -2.304 * | 0.094 ns | 0.117 ns | 0.106 ns |
| **P3xP4** | -0.640 * | 0.167 ns | -0.237 ns | -13.911 ** | -12.035 ** | -12.973 ** | -12.687 ** | -11.367 ** | -12.027 ** | 0.489 ** | 0.434 ** | 0.461 ** |
| **P3xP5** | 0.709 * | -0.388 * | 0.160 ns | -2.717 ns | 0.020 ns | -1.348 ns | 0.148 ns | 0.781 ns | 0.464 ns | 0.437 ** | 0.360 ** | 0.399 ** |
| **P3xP6** | 0.826 * | -0.336 * | 0.245 ns | 11.645 ** | 17.692 ** | 14.668 ** | 6.274 ** | 11.746 ** | 9.010 ** | -0.107 ns | -0.036 ns | -0.072 ns |
| **P4xP5** | 1.843 ** | -0.010 ** | 0.916 ** | 1.504 ns | 7.708 ns | 4.606 ** | 4.226 ** | 4.525 ** | 4.376 ** | 0.726 ** | 0.777 ** | 0.751 ** |
| **P4xP6** | -0.193 ns | 0.385 ns | 0.096 ns | 5.332 ** | 6.880 ** | 6.106 ** | 1.456 ns | 0.693 ns | 1.075 ns | -0.132 ns | -0.283 ns | -0.208 ** |
| **P5xP6** | -0.261 ns | 0.683 ns | 0.211 ns | 2.750 ns | -6.502 ns | -1.876 ns | 1.307 ns | -4.032 ns | -1.362 ns | -0.090 ns | -0.057 ns | -0.074 ns |
| LSD **5%** | 0.944 | 0.466 | 0.482 | 5.227 | 4.979 | 3.307 | 3.268 | 4.596 | 2.584 | 0.235 | 0.228 | 0.150 |
| (Sij-Sik)**1%** | 1.263 | 0.624 | 0.639 | 6.993 | 6.661 | 4.382 | 4.373 | 6.149 | 3.423 | 0.314 | 0.304 | 0.199 |
| r | **0.739** ** | **0.720** ** | **0.550** * | **0.862** ** | **0.900** ** | **0.870** ** | **0.769** ** | **0.910** ** | **0.830** ** | **0.977** ** | **0.970** ** | **0.970** ** |

**# P1 (S.541-A/5), P2 (Sakha 3) , P3 (S.435/11/10/3), P4 (Gentiana), P5 (Elona) and P6 (Escalina)}**

**ns,*,** non- significant, significant at 0.05 and 0.01 levels of probability, respectively..**

**r # Simple correlation coefficients between SAC values and means of crosses.**

**1-2-Seed weight per plant and its components :**

Ordinary and combining ability analysis of variance (Table 5) showed highly significant differences existed among 21 flax genotypes (6 parents and 15 $F_1$'s crosses), parents and crosses for seed weight and its components viz., No. of capsules per plant, 1000-seed weight and No. of seeds/capsule. The results indicated that the parental genotypes and $F_1$ crosses showed reasonable degree of variability for these traits. Significant differences were also noted for the component parents *vs*. crosses for seed weight and 1000-seed weight at individual environments and combined except $E_2$ (drought environment) for seed weight. While, No. of capsules/plant and No. of seeds/capsule were insignificant except in combined analysis for No. of capsules/plant. Also, both mean squares due to general (GCA) and specific(SCA) combining abilities were highly significant for all characters in both environments and combined. In general, the magnitude of mean squares due to GCA were greater than that due to SCA except $E_2$ for No. of seeds/capsule. High ratio of GCA/SCA were also detected. These results revealed that additive played greater role than non-additive gene effects in the inheritance of seed weight/plant and its two important components (No. of capsules/plant and 1000-seed weight). Similar results were reported by Shehata and Comstock (1971), Patil and Chopde (1981) and Abo El-Zahab and Abo-Kaied (2000) and Abo-Kaied *et al*., (2007).

The interaction between each of genotypes, parents and crosses with environment was significant or highly significant for seed weight and its components except crosses x E for 1000-seed weight, revealing inconsistent responses for these sources of variations from drought to normal environments. Also, GCAxE mean squares were highly significant or significant for seed weight, No. of capsules/plant and No. of seeds/capsule. Only, SCAxE mean squares were highly significant for No. of capsules/plant. This indicates that both additive and non-additive gene effects are influenced by drought environment. It is fairly evident that mean squares of GCAxE/GCA were lower than SCAxE/SCA ratios except No. of seeds/capsule, this indicated that non-additive gene effects were much more influenced by drought environment than additive effects for the above-mentioned traits (seed weight and No. of capsules/plant). These results are in harmony with those reported by Patil and Chopde (1981) and Abo El-Zahab and Abo-Kaied (2000) and Abo-Kaied *et al*., (2007).

Table 5. Mean squares of ordinary and combining ability analyses for seed weight and its components in $F_1$ generation under normal ($E_1$) and drought ($E_2$) environments and their combined data (C.).

| S.O.V | df S. | df C. | $E_1$ | $E_2$ | C. | $E_1$ | $E_2$ | C. |
|---|---|---|---|---|---|---|---|---|
| | | | **Seed weight/plant (g)** | | | **No. of capsules/plant** | | |
| **Environment (E)** | | 1 | | | 12.928 ** | | | 3163.915 ** |
| **Reps/ E** | | 4 | | | 0.204 ** | | | 40.412 ** |
| **Genotypes(G )** | 20 | 20 | 0.570 ** | 0.245 ** | 0.746 ** | 65.520 ** | 69.293 ** | 116.711 ** |
| **Parents (P)** | 5 | 5 | 1.160 ** | 0.451 ** | 1.499 ** | 115.990 ** | 67.148 ** | 157.082 ** |
| **Crosses(C.)** | 14 | 14 | 0.380 ** | 0.184 ** | 0.505 ** | 51.530 ** | 74.604 ** | 109.585 ** |
| **P.vs.C** | 1 | 1 | 0.330 ** | 0.067 ns | 0.347 ** | 9.160 ns | 5.665 ns | 14.615 ** |
| **G x E** | | 20 | | | 0.566 ** | | | 95.913 ** |
| **P x E** | | 5 | | | 1.110 ** | | | 130.774 ** |
| **C x E** | | 14 | | | 0.056 ** | | | 16.545 ** |
| **P vs C xE** | | 1 | | | 0.281 ** | | | 9.952 * |
| **GCA** | 5 | 5 | 0.664 ** | 0.232 ** | 0.831 ** | 55.435 ** | 35.880 ** | 82.063 ** |
| **SCA** | 15 | 15 | 0.032 ** | 0.031 ** | 0.055 ** | 10.643 ** | 18.837 ** | 24.517 ** |
| **GCA x E** | | 5 | | | 0.066 ** | | | 9.252 ** |
| **SCA x E** | | 15 | | | 0.009 ns | | | 4.963 ** |
| **Error** | 40 | 80 | 0.008 | 0.003 | 0.006 | 1.957 | 1.330 | 1.643 |
| **GCA/SCA** | | | 20.750 | 7.484 | 15.109 | 5.209 | 1.905 | 3.347 |
| **S.O.V** | **S.** | **C.** | **1000-seed weight (g)** | | | **No. of seeds/capsule** | | |
| **Environment (E)** | | 1 | | | 2.640 ** | | | 4.592 ** |
| **Reps/ E** | | 4 | | | 1.019 ns | | | 0.434 * |
| **Genotypes(G )** | 20 | 20 | 4.580 ** | 4.391 ** | 8.952 ** | 1.310 ** | 1.411 ** | 2.414 ** |
| **Parents (P)** | 5 | 5 | 7.470 ** | 7.602 ** | 15.068 ** | 2.190 ** | 0.713 * | 2.127 ** |
| **Crosses(C.)** | 14 | 14 | 3.520 ** | 3.250 ** | 6.747 ** | 1.080 ** | 1.761 ** | 2.685 ** |
| **P.vs.C** | 1 | 1 | 4.920 ** | 4.322 ** | 9.234 ** | 0.170 ns | 0.010 ns | 0.048 ns |
| **G x E** | | 20 | | | 5.983 ** | | | 1.915 ** |
| **P x E** | | 5 | | | 10.050 ** | | | 2.191 ** |
| **C x E** | | 14 | | | 0.019 ns | | | 0.151 * |
| **P vs C xE** | | 1 | | | 6.166 ** | | | 0.164 ns |
| **GCA** | 5 | 5 | 4.812 ** | 4.678 ** | 9.484 ** | 0.601 ** | 0.432 ** | 0.865 ** |
| **SCA** | 15 | 15 | 0.429 ** | 0.392 ** | 0.817 ** | 0.381 ** | 0.483 ** | 0.784 ** |
| **GCA x E** | | 5 | | | 0.006 ns | | | 0.168 * |
| **SCA x E** | | 15 | | | 0.005 ns | | | 0.080 ns |
| **Error** | 40 | 80 | 0.025 | 0.024 | 0.025 | 0.052 | 0.084 | 0.068 |
| **GCA/SCA** | | | 11.217 | 11.934 | 11.608 | 1.577 | 0.894 | 1.103 |

ns,*,** non- significant, significant at 0.05 and 0.01 levels of probability, respectively..

S. Single environment C. Combined over environments

Estimates of GCA effects ($g_i$) for seed weight and its components for individual parents in both environments as well as combined data are presented in Table (6). The two parents, $P_1$(S.541-A/5) and $P_3$(S.435/11/10/3) showed significant positive $g_i$ effects for seed weight, No. of capsules/plant and 1000-seed weight in both environments as well as the combined data. Also, $P_4$(Gentiana) expressed significant positive $g_i$ effects for No. of basal branches/plant in both environments as well as combined. Therefore, the two parents ($P_1$ and $P_3$) could be considered as an excellent parents in breeding programs towards releasing flax varieties characterized by high value for the three above-mentioned traits. The simple correlation between GCA values (Table 6) and parental means (Table 9) for seed yield/plant and all its components were highly significant and positive in both environments as well as combined data. These results indicated that the parents showing high mean performance proved to be the high general combiners for these traits under drought or normal conditions. In general, using the promising strain 541-A/5 in hybridization programs may result in isolating desirable segregates for both straw and seed weights (producing dual purpose type of flax).

SCA effects for seed weight/plant and its components for 15 $F_1$ crosses as affected by normal ($E_1$) and drought ($E_2$) environments as well as combined data are given in Table (7). Out of the 15 $F_1$ crosses, two crosses ($P_1 \times P_5$ and $P_2 \times P_3$) for seed weight/plant, two crosses ($P_1$x$P_5$ and $P_3$x$P_4$) for No. of capsules/plant, six crosses ($P_1$x$P_2$, $P_1$x$P_5$, $P_1$x$P_6$, $P_2$x$P_3$, $P_2$x$P_4$ and $P_3$x$P_6$) for 1000-seed weight and four crosses ($P_1$x$P_3$, $P_2$x$P_5$, $P_3$x$P_5$ and $P_5$x$P_6$) for No. of seeds per capsule exhibited significant positive SCA effects at the two environments and combined. In general, the specific combining ability estimates indicated that there was no cross combination which was consistently good for all characters. Out of the previous crosses, the cross $P_1$x$P_5$ showed high SCA effects for seed weight and its two important components, No. of capsules and 1000-seed weight. Also, the cross $P_2$x$P_3$ exhibited high SCA effects for both seed weight and 1000-seed weight. The two crosses ($P_1$x$P_5$ and $P_2$x$P_3$) included low x high general combiner parents for the previous traits. Therefore, it could be concluded that the two crosses are suitable in breeding for increasing the above mentioned traits (seed weight and 1000-seed weight). The simple correlation between cross means (Table 9) and their SCA values (Table 7) was significantly positive for all traits under the two environments and combined except $E_1$ and combined for seed weight/plant as well as $E_2$ for 1000-seed weight. These results, indicate that high performing crosses were high specific combinations specially for No. of capsules/plant and No. of seeds/capsule.

Table 6. Estimates of general combining ability effects(ĝi) for six parental genotypes as affected by normal ($E_1$) and drought ($E_2$) environments and their combined data (C.) for seed weight and its combonents.

| Parents | $E_1$ | | $E_2$ | | C. | | $E_1$ | | $E_2$ | | C. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Seed weight/plant (g)** | | | | | | **No. of capsules/plant** | | | | | |
| **P1** | 0.430 | ** | 0.240 | ** | 0.335 | ** | 3.577 | ** | 2.657 | ** | 3.117 | ** |
| **P2** | -0.112 | ** | -0.132 | ** | -0.122 | ** | -1.640 | ** | -3.116 | ** | -2.378 | ** |
| **P3** | 0.262 | ** | 0.159 | ** | 0.210 | ** | 2.858 | ** | 1.880 | ** | 2.369 | ** |
| **P4** | -0.044 | ns | 0.017 | ns | -0.013 | ns | -0.326 | ns | 0.215 | ns | -0.056 | ns |
| **P5** | -0.225 | ** | -0.098 | ** | -0.162 | ** | -2.906 | ** | -0.210 | ns | -1.558 | ** |
| **P6** | -0.311 | ** | -0.187 | ** | -0.249 | ** | -1.563 | ** | -1.426 | ** | -1.494 | ** |
| LSD **5%** | 0.092 | | 0.054 | | 0.053 | | 1.414 | | 1.165 | | 0.906 | |
| (Sij-Sik)**1%** | 0.123 | | 0.072 | | 0.070 | | 1.891 | | 1.559 | | 1.201 | |
| **r** | **0.995** | ** | **0.980** | ** | **0.990** | ** | **0.947** | ** | **0.980** | ** | **0.980** | ** |
| | **1000-seed weight (g)** | | | | | | **No. of seeds/capsule** | | | | | |
| **P1** | 1.285 | ** | 1.271 | ** | 1.278 | ** | -0.364 | ** | -0.395 | ** | -0.379 | ** |
| **P2** | -0.175 | ** | -0.160 | ** | -0.168 | ** | 0.142 | ns | 0.197 | * | 0.170 | ** |
| **P3** | 0.461 | ** | 0.408 | ** | 0.434 | ** | 0.074 | ns | 0.061 | ns | 0.067 | ns |
| **P4** | -0.139 | ** | -0.075 | ns | -0.107 | ** | 0.216 | ** | 0.252 | * | 0.234 | ** |
| **P5** | -0.532 | ** | -0.536 | ** | -0.534 | ** | 0.256 | ** | -0.086 | ns | 0.085 | ns |
| **P6** | -0.900 | ** | -0.908 | ** | -0.904 | ** | -0.325 | ** | -0.029 | ns | -0.177 | ** |
| LSD **5%** | 0.161 | | 0.156 | | 0.111 | | 0.230 | | 0.293 | | 0.184 | |
| (Sij-Sik)**1%** | 0.215 | | 0.209 | | 0.147 | | 0.308 | | 0.392 | | 0.244 | |
| **r** | **0.958** | ** | **0.96** | ** | **0.96** | ** | **0.912** | ** | **0.92** | ** | **0.89** | ** |

ns,*,** non- significant, significant at 0.05 and 0.01 levels of probability, respectively.

# P1 (S.541-A/5), P2 (Sakha 3) , P3 (S.435/11/10/3), P4 (Gentiana), P5 (Elona) and P6 (Escalina)}.

Table 7: Estimates of specific combining ability ($\hat{s}_{ij}$) for 15 $F_1$ crosses as affected by normal ($E_1$) and drought ($E_2$) environments and their combined (C.) data for seed weight and its combonents.

| Parents | $E_1$ | $E_2$ | C. | $E_1$ | $E_2$ | C. | $E_1$ | $E_2$ | C. | $E_1$ | $E_2$ | C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Seed weight/plant (g)** | | | **No. of capsules/plant** | | | **1000-seed weight (g)** | | | **No. of seeds/capsule** | | |
| **P1xP2** | 0.157 ns | 0.107 * | 0.132 * | -1.410 ns | -0.205 ns | -0.807 ns | 1.029 ** | 1.084 ** | 1.056 ** | 0.198 ns | 0.170 ns | 0.184 ns |
| **P1xP3** | -0.290 ** | -0.428 ** | -0.359 ** | -6.055 ** | -9.271 ** | -7.663 ** | -0.494 ** | -0.537 ** | -0.516 ** | 0.867 ** | 1.263 ** | 1.065 ** |
| **P1xP4** | -0.132 ns | -0.003 ns | -0.067 ns | -1.927 ns | 0.157 ns | -0.885 ns | -0.265 ns | -0.328 * | -0.296 ** | 0.158 ns | 0.045 ns | 0.102 ns |
| **P1xP5** | 0.243 ** | 0.306 ** | 0.275 ** | 3.350 * | 4.829 ** | 4.089 ** | 0.601 ** | 0.667 ** | 0.634 ** | -1.069 ** | -0.594 * | -0.832 ** |
| **P1xP6** | 0.145 ns | 0.188 ** | 0.167 ** | 2.463 ns | 6.465 ** | 4.464 ** | 0.733 ** | 0.529 ** | 0.631 ** | -0.335 ns | -1.247 ** | -0.791 ** |
| **P2xP3** | 0.285 ** | 0.128 * | 0.206 ** | 2.983 * | -0.211 ns | 1.386 ns | 0.597 ** | 0.494 ** | 0.545 ** | -0.206 ns | -0.093 ns | -0.149 ns |
| **P2xP4** | 0.157 ns | 0.076 ns | 0.116 * | 1.893 ns | 1.977 ns | 1.935 * | 0.603 ** | 0.629 ** | 0.616 ** | -0.548 ** | -0.640 * | -0.594 ** |
| **P2xP5** | -0.055 ns | -0.142 ** | -0.098 ns | -2.563 * | -3.825 ** | -3.194 ** | 0.022 ns | -0.003 ns | 0.010 ns | 0.805 ** | 0.981 ** | 0.893 ** |
| **P2xP6** | -0.053 ns | 0.114 * | 0.030 ns | -0.517 ns | 4.054 ** | 1.769 * | -0.270 ns | -0.204 ns | -0.237 * | 0.300 ns | -0.179 ns | 0.060 ns |
| **P3xP4** | -0.034 ns | 0.105 * | 0.036 ns | 5.192 ** | 6.201 ** | 5.697 ** | -0.823 ** | -0.728 ** | -0.776 ** | -0.646 ** | -0.604 * | -0.625 ** |
| **P3xP5** | -0.035 ns | 0.017 ns | -0.009 ns | -0.025 ns | 2.473 * | 1.224 ns | 0.360 * | 0.247 ns | 0.303 ** | -0.520 * | -0.930 ** | -0.725 ** |
| **P3xP6** | 0.153 ns | 0.016 ns | 0.085 ns | -0.372 ns | -2.611 * | -1.492 ns | 0.500 ** | 0.472 ** | 0.486 ** | 0.647 ** | 0.691 * | 0.669 ** |
| **P4xP5** | 0.170 * | -0.014 ** | 0.078 ns | 4.630 ** | -0.186 ** | 2.222 * | -0.207 ns | -0.131 ns | -0.169 ns | -0.162 ns | 0.129 ns | -0.016 ns |
| **P4xP6** | 0.015 ns | -0.179 ns | -0.082 ns | -1.794 ns | -6.060 ns | -3.927 ** | 0.245 ns | 0.184 ns | 0.215 * | 0.433 * | 0.420 ns | 0.427 * |
| **P5xP6** | -0.040 ns | 0.017 ns | -0.011 ns | -2.231 ns | -0.942 * | -1.586 ns | 0.020 ns | 0.112 ns | 0.066 ns | 0.569 ** | 0.467 * | 0.518 ** |
| LSD **5%** | 0.243 | 0.143 | 0.129 | 3.740 | 3.083 | 2.220 | 0.425 | 0.414 | 0.272 | 0.609 | 0.775 | 0.451 |
| (Sij-Sik) **1%** | 0.326 | 0.191 | 0.171 | 5.004 | 4.125 | 2.942 | 0.568 | 0.554 | 0.360 | 0.814 | 1.037 | 0.598 |
| r | **0.285** | **0.580** * | **0.380** | **0.657** ** | **0.860** ** | **0.780** ** | **0.518** * | **0.480** | **0.500** * | **0.847** ** | **0.930** ** | **0.910** ** |

# P1 (S.541-A/5), P2 (Sakha 3) , P3 (S.435/11/10/3), P4 (Gentiana), P5 (Elona) and P6 (Escalina))

ns,*,** non- significant, significant at 0.05 and 0.01 levels of probability, respectively..

r #: Simple correlation coefficients between SAC values and means of crosses.

**2-Stress-susceptibility index (S):**

**2-1-Straw weight per plant and its components :**

A stress susceptibility index (S) proposed by Fisher and Maurer (1978) can be used as indicator for measuring drought tolerance under stress conditions could help for isolating improved tolerant genotypes (Winter *et al.*, 1988). Drought reduces the ability of plants to take up elements, and this quickly causes reductions in growth rate, along with a number of metabolic changes identical to those caused by water stress. (Munns, 2002).

Table (8) shows mean performance of six parents and their 15 $F_1$ crosses for straw weight and its components under normal ($E_1$) and drought ($E_2$)environments as well as their combined data and the susceptibility index (S). For straw weight/plant, out of six parental genotypes, $P_2$ (Sakha3) and $P_3$ (S.435/11/10/3) were identified as high yield potential with moderate tolerance to drought (sandy soil conditions). Although, $P_1$(S.541-A/5) had high straw weight/plant but it was identified as high susceptibile. Out of 15 $F_1$ crosses, the cross, $P_1xP_4$ followed by $P_4xP_5$ exhibited highest straw weight than other crosses with moderate tolerance to drought, while the cross $P_2xP_3$ had relatively high straw weight with high susceptibility. On the other hand, six crosses ($P_1xP_3$, $P_2xP_5$, $P_2xP_6$, $P_3xP_4$, $P_4xP_6$ and $P_5xP_6$) exhibited desirable level of both stress tolerance and straw weight. Concerning plant height, $P_1$ and $P_4$ (Gentiana) showed moderate tolerance to drought and high record than other parents, while $P_2$ and $P_5$ (Elona) were identified as moderately tolerant genotypes as well as moderately for plant height. However, the cross, $P_1xP_2$ followed by $P_2xP_5$ and $P_4xP_5$ exhibited the highest plant height with high susceptibility. On the other hand, the five crosses ($P_1xP_3$, $P_2xP_4$, $P_3xP_5$, $P_3xP_6$ and $P_4xP_6$) were identified as tolerant crosses but had low plant height. Concerning technical stem length, $P_5$ gave moderate technical stem length with moderate stress tolerance. On the other hand, $P_1$ followed by $P_4$ had highest technical stem length but low tolerance, while $P_6$ (Escalina) had low technical stem length but had high tolerance. Out of 15 $F_1$ crosses, the cross, $P_2xP_3$ gave highest technical stem length with moderate tolerance. Although, the two crosses, $P_1xP_4$ and $P_1xP_5$ exhibited the highest technical stem length but had low tolerance to drought. On the contrary, the five crosses ($P_1xP_3$, $P_1xP_6$, $P_2xP_5$, $P_3xP_5$ and $P_4xP_6$) had low or moderate technical stem length but exhibited high tolerance. Regarding No. of basal branches/plant, $P_1$ was high for both No. of basal branches and tolerance followed by $P_6$ but, it had moderate tolerance. Out of 15 $F_1$ crosses, the cross, $P_4xP_5$ exhibited high value for both No. of basal branches and tolerance to drought. Also, the cross, $P_1xP_4$ had high No. of basal branches/plant and moderate tolerance, while the cross, $P_1xP_6$ had high No. of basal branches and high susceptibility. On the other hand, the two crosses, $P_2xP_4$ and $P_3xP_6$ had high tolerance but had low No. of basal branches/plant.

It can be concluded that, $P_2$ and $P_3$ for straw weight, $P_1$ and $P_4$ for plant height, $P_5$ for technical stem length and $P_1$ for No. of basal branches/plant exhibited high yielding ability with tolerant to drought. Out of 15 $F_1$ crosses, the cross, $P_4xP_5$ exhibited high yield potential with moderate tolerance to drought for each of straw weight, plant height and technical stem length in addition the cross, $P_2xP_3$ for technical stem length and No. of basal branches/plant. Whereas, the two crosses, $P_1xP_3$ and $P_2xP_5$ showed low or moderate yield with moderate tolerance for straw weight and its two important components, plant height and technical stem length. Also, the cross, $P_2xP_6$ for straw weight and technical stem length; $P_3$ x $P_6$ for all components (plantheight, technical stem length and No. of basal branches/plant); $P_4xP_6$ for each of straw weight, technical stem length and No. of basal branches; $P_2xP_4$ for both plant height and No. of basal branches and finally $P_3xP_5$ for both plant height and technical stem length exhibited low or moderate yield with moderate tolerance.

Table 8: Mean performance for straw weight and its components recorded under normal and drought environments as well as their combined data and the susceptibility index (S)

| genotype | $E_1$ | $E_2$ | C. | S | $E_1$ | $E_2$ | C. | S | $E_1$ | $E_2$ | C. | S | $E_1$ | $E_2$ | C. | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parents** | **Straw weight/plant (g)** | | | | **Plant height/plant (cm)** | | | | **Technical stem length/plant (cm)** | | | | **Number of basal branches/plant** | | | |
| P1 | 9.59 a | 4.29 c | 6.94 a | 1.18 | 105.74 a | 96.22 a | 100.98 a | 0.64 | 82.91 a | 67.23 a | 75.07 a | 1.08 | 2.40 a | 2.26 a | 2.33 a | 0.49 |
| P2 | 7.56 c | 4.68 b | 6.12 b | 0.81 | 90.62 c | 79.46 d | 85.04 c | 0.87 | 66.27 c | 54.83 cd | 60.55 d | 0.99 | 1.30 b | 1.00 b | 1.15 b | 1.94 |
| P3 | 8.37 b | 5.16 a | 6.76 a | 0.82 | 97.60 b | 75.15 e | 86.38 c | 1.63 | 71.87 c | 55.83 c | 63.85 c | 1.28 | 1.14 c | 1.00 b | 1.07 b | 1.03 |
| P4 | 6.52 d | 4.09 c | 5.31 c | 0.79 | 103.47 a | 85.83 c | 94.65 b | 1.21 | 78.60 b | 62.37 b | 70.49 b | 1.18 | 1.27 bc | 1.12 b | 1.19 b | 1.00 |
| P5 | 7.52 c | 3.30 d | 5.41 c | 1.20 | 104.33 a | 89.67 b | 97.00 b | 1.00 | 78.27 b | 64.73 b | 71.50 b | 0.99 | 1.20 bc | 1.03 b | 1.12 b | 1.19 |
| P6 | 4.87 e | 2.05 e | 3.46 d | 1.23 | 82.13 d | 75.37 e | 78.75 d | 0.58 | 54.53 d | 51.98 d | 53.26 e | 0.27 | 1.20 bc | 1.09 b | 1.15 b | 0.77 |
| **Mean** | **7.41** | **3.93** | **5.67** | | **97.32** | **83.62** | **90.47** | | **72.08** | **59.50** | **65.79** | | **1.42** | **1.25** | **1.34** | |
| **Crosses** | | | | | | | | | | | | | | | | |
| P1xP2 | 9.46 bd | 4.23 de | 6.84 ce | 1.17 | 110.34 b | 100.37 a | 105.36 a | 0.61 | 82.01 c | 66.48 de | 74.25 d | 1.04 | 1.26 gh | 1.18 eg | 1.22 fg | 0.51 |
| P1xP3 | 7.91 g | 4.91 c | 6.41 ef | 0.80 | 92.93 i | 81.54 g | 87.24 h | 0.83 | 68.20 h | 56.47 h | 62.34 h | 0.95 | 1.25 gh | 0.96 h | 1.11 h | 1.87 |
| P1xP4 | 9.98 ab | 6.15 a | 8.07 a | 0.81 | 112.29 ab | 86.44 f | 99.37 cd | 1.56 | 90.47 a | 70.25 bc | 80.36 b | 1.23 | 1.20 h | 1.06 gh | 1.13 g | 0.94 |
| P1xP5 | 8.96 de | 5.57 b | 7.26 bc | 0.80 | 114.53 a | 95.06 cd | 104.80 a | 1.16 | 89.47 a | 70.98 bc | 80.23 bc | 1.14 | 1.34 fh | 1.18 eg | 1.26 fg | 0.96 |
| P1xP6 | 9.91 ac | 4.37 de | 7.14 bd | 1.18 | 97.95 g | 84.25 f | 91.10 g | 0.95 | 75.73 e | 62.85 g | 69.29 f | 0.94 | 2.20 ab | 1.89 b | 2.04 b | 1.13 |
| P2xP3 | 10.43 a | 4.41 de | 7.42 b | 1.22 | 115.13 a | 95.07 cd | 105.10 a | 1.18 | 90.47 a | 76.37 a | 83.42 a | 0.86 | 2.13 bc | 1.93 b | 2.03 b | 0.76 |
| P2xP4 | 9.38 cd | 4.18 e | 6.78 df | 1.17 | 102.87 ef | 93.60 d | 98.23 de | 0.61 | 78.20 d | 63.38 fg | 70.79 ef | 1.05 | 1.92 d | 1.81 bc | 1.87 cd | 0.46 |
| P2xP5 | 8.58 ef | 5.32 b | 6.95 cd | 0.80 | 110.96 bc | 97.29 ac | 104.12 ab | 0.84 | 82.58 c | 68.31 cd | 75.44 d | 0.95 | 1.43 e | 1.10 fh | 1.26 fg | 1.86 |
| P2xP6 | 6.98 h | 4.31 de | 5.64 g | 0.81 | 97.10 h | 74.79 h | 85.95 h | 1.56 | 68.82 h | 53.48 i | 61.15 h | 1.23 | 1.55 ef | 1.36 d | 1.46 e | 0.99 |
| P3xP4 | 7.79 g | 4.89 c | 6.34 f | 0.79 | 86.47 j | 71.76 h | 79.12 i | 1.16 | 62.80 i | 49.81 j | 56.30 i | 1.14 | 2.13 bc | 1.89 b | 2.01 bc | 0.91 |
| P3xP5 | 9.38 cd | 4.12 e | 6.75 df | 1.19 | 101.11 fg | 86.93 ef | 94.02 f | 0.95 | 78.20 d | 64.92 eg | 71.56 ef | 0.94 | 2.00 cd | 1.71 c | 1.86 d | 1.17 |
| P3xP6 | 8.18 fg | 3.46 f | 5.82 g | 1.22 | 106.03 de | 97.09 bc | 101.56 bc | 0.57 | 72.39 fg | 69.00 bd | 70.70 ef | 0.26 | 1.38 fg | 1.26 de | 1.32 ef | 0.70 |
| P4xP5 | 10.08 a | 4.50 d | 7.29 bc | 1.17 | 108.12 cd | 98.23 ab | 103.17 ab | 0.62 | 86.07 b | 69.76 bc | 77.91 ef | 1.05 | 2.33 a | 2.19 a | 2.26 a | 0.48 |
| P4xP6 | 6.74 h | 4.18 e | 5.46 g | 0.80 | 102.50 f | 89.89 e | 96.20 f | 0.84 | 71.36 g | 59.04 h | 65.20 g | 0.95 | 1.40 eg | 1.07 gh | 1.24 fg | 1.90 |
| P5xP6 | 6.91 h | 4.26 de | 5.59 g | 0.81 | 103.37 ef | 79.62 g | 91.49 g | 1.56 | 73.78 ef | 57.28 h | 65.53 g | 1.23 | 1.36 fg | 1.20 ef | 1.28 f | 0.95 |
| **Mean** | **8.71** | **4.59** | **6.65** | | **104.11** | **88.80** | **90.36** | | **78.04** | **63.89** | **66.60** | | **1.66** | **1.45** | **1.47** | |

Means identified by the same letter are not significantly different at 0.05 level of probability according to FLSD.

P1 (S.541-A/5), P2 (Sakha 3) , P3 (S.435/11/10/3), P4 (Gentiana), P5 (Elona) and P6 (Escalina)).

**2-2-Seed weight per plant and its components:**

Mean performance for seed weight and its components recorded under normal and drought environments as well as their combined data and the susceptibility index (S) are shown in Table (9). S values for seed weight/plant, $P_3$(S.435/11/10/3) was identified as moderately stress tolerant genotype in addition to high mean performance. Although, $P_1$(S.541-A/5) had high seed weight/plant but it possessed high susceptibility. On the other hand, $P_4$(Gentiana) and $P_5$(Elona) showed moderate tolerance to drought with low or moderate seed weight. Out of 15 $F_1$ crosses, four crosses ($P_1xP_4$, $P_1xP_5$, $P_1xP_6$ and $P_3xP_4$) was showed moderate tolerance to drought as well as superiority for seed weight compared with other crosses. However the cross $P_1xP_2$ revealed high seed weight with high susceptibility. Although, the three crosses, $P_2xP_6$, $P_3xP_5$ and $P_5xP_6$ had low or moderate seed weight/plant but showed moderate tolerance to drought. Regarding No. of capsules/plant, $P_3$ revealed high capsules/plant with moderate stress tolerance, while $P_1$ showed high susceptibility with high of capsules/plant. While, $P_4$ and $P_5$ had low No. of capsules/plant (undesirable trait) with tolerance to drought. Out of 15 $F_1$ crosses, the three crosses, $P_1xP_5$, $P_1xP_6$ and $P_3xP_4$ were identified high yielding potential as well as tolerant to drought. While, the four crosses, $P_1xP_4$ $P_2xP_6$, $P_3xP_5$ and $P_5xP_6$ possessed low or moderate No. of capsules/plant with stress tolerant. Concerning 1000-seed weight, $P_1$ and $P_3$ exhibited moderate stress tolerance with high 1000-seed weight than other parents. While, $P_4$ was low of 1000-seed weight with stress tolerance. Out of 15 $F_1$ crosses, the two crosses, $P_1xP_2$ and $P_1xP_5$ had the highest 1000-seed weight than other crosses with stress tolerance. However, six crosses ($P_1xP_4$, $P_2xP_4$, $P_2xP_6$, $P_3xP_4$, $P_4xP_5$ and $P_5xP_6$) had moderate 1000-seed weight with stress tolerance. For No. of seeds/capsule, $P_2$ showed high tolerance to drought as well as high No. of seeds/capsule, while $P_4$ was identified as high or moderate stress tolerant genotype as well as had high No. of seeds/capsule. Out of 15 $F_1$ crosses, three crosses ($P_1xP_3$, $P_3xP_6$ and $P_4xP_6$) showed high tolerance to drought and also had high No. of seeds/capsule. While, the cross, $P_2xP_5$ had high No. of seeds/capsule and high susceptibility. On the other hand, six crosses ($P_1xP_2$, $P_1xP_5$, $P_2xP_3$, $P_2xP_4$, $P_3xP_4$ and $P_4xP_5$) were identified as moderate tolerants to drought and had moderate No. of seeds/capsule.

In general, $P_3$ exhibited high yielding potential and moderate tolerance to drought for seed weight and its two important components, No. of capsules and 1000-seed weight in addition $P_1$ for 1000-seed weight as well as $P_2$ for No. of seeds/capsule. While $P_1$ was high susceptible (undesirable trait) with high yielding potential for seed weight and No. of capsules/plant, $P_4$ and $P_5$ had low or moderate seed weight and No. of capsules/plant with stress tolerance to drought. Out of 15 $F_1$ crosses, one cross ($P_1xP_5$) only exhibited high yielding potential and stress tolerance for all studied characters. Also this cross ($P_1xP_5$) showed high SCA effects for seed weight and its two important components, No. of capsules and 1000-seed weight. Therefore, the cross, $P_1 x P_5$ is more efficient under drought and normal environments as it possesses favourable genes and yield improvement can be attained by its use in a breeding program at irrespective conditions.

However, two crosses ($P_1xP_6$ and $P_3xP_4$) for both seed weight and No. of capsules/plant; two crosses ($P_2xP_6$ and $P_5xP_6$) for each of seed weight, No. of capsules/plant and 1000-seed weight and three crosses ($P_1xP_3$, $P_3xP_6$ and $P_4xP_6$) for No. of seeds/capsule exhibited high or moderate yield with stress tolerance to drought. It could be concluded that the previous crosses are suitable in breeding for increasing the above mentioned traits at irrespective conditions.

Table 9: Mean performance for seed weight and its components recorded under normal and drought environments as well as their combined data and the susceptibility index (S)

| genotype | $E_1$ | $E_2$ | C. | S | $E_1$ | $E_2$ | C. | S | $E_1$ | $E_2$ | C. | S | $E_1$ | $E_2$ | C. | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parents** | **Seed weight/plant (g)** | | | | **No. of capsules/plant** | | | | **1000-seed weight (g)** | | | | **No. of seeds/capsule** | | | |
| P1 | 2.28 a | 1.23 a | 1.76 a | 1.09 | 35.24 a | 20.60 a | 27.92 a | 1.08 | 8.44 a | 8.22 a | 8.33 a | 0.62 | 7.65 d | 7.30 c | 7.48 c | 0.84 |
| P2 | 1.01 d | 0.43 d | 0.72 d | 1.36 | 22.83 cd | 9.15 d | 15.99 d | 1.56 | 5.33 d | 5.07 d | 5.20 d | 1.17 | 8.30 c | 8.18 b | 8.24 b | 0.27 |
| P3 | 1.96 b | 1.24 a | 1.60 b | 0.87 | 31.15 b | 21.75 a | 26.45 a | 0.78 | 7.53 b | 7.23 b | 7.38 b | 0.95 | 8.37 c | 7.87 b | 8.12 b | 1.10 |
| P4 | 1.30 c | 0.88 b | 1.09 c | 0.76 | 21.65 d | 15.66 b | 18.66 bc | 0.72 | 6.62 c | 6.42 c | 6.52 c | 0.72 | 9.10 a | 8.74 a | 8.92 a | 0.73 |
| P5 | 0.89 de | 0.55 c | 0.72 d | 0.90 | 18.91 e | 14.68 bc | 16.80 c | 0.58 | 5.21 d | 4.87 d | 5.04 d | 1.56 | 8.99 b | 7.71 bc | 8.35 b | 2.63 |
| P6 | 0.75 e | 0.39 d | 0.57 e | 1.13 | 24.40 cd | 12.97 c | 18.69 b | 1.22 | 4.26 e | 4.02 e | 4.14 e | 1.35 | 6.83 c | 6.77 c | 6.80 d | 0.16 |
| **Mean** | **1.37** | **0.79** | **1.08** | | **25.70** | **15.80** | **20.75** | | **6.23** | **5.97** | **6.10** | | **8.21** | **7.76** | **7.98** | |
| **Crosses** | | | | | | | | | | | | | | | | |
| P1xP2 | 1.95 a | 1.05 bc | 1.50 ab | 1.06 | 26.83 c | 15.61 cd | 21.22 d | 1.10 | 8.81 a | 8.58 a | 8.70 a | 0.60 | 8.27 fg | 7.88 ef | 8.07 fg | 0.93 |
| P1xP3 | 1.88 ab | 0.81 f | 1.35 c | 1.30 | 26.68 c | 11.54 f | 19.11 e | 1.49 | 7.93 b | 7.53 bc | 7.73 bc | 1.15 | 8.87 b | 8.84 ab | 8.85 ab | 0.07 |
| P1xP4 | 1.73 bd | 1.09 b | 1.41 bc | 0.85 | 27.62 c | 19.31 b | 23.47 c | 0.79 | 7.56 c | 7.25 d | 7.41 d | 0.94 | 8.30 ef | 7.81 ef | 8.06 fg | 1.16 |
| P1xP5 | 1.93 a | 1.29 a | 1.61 a | 0.76 | 30.32 b | 23.55 a | 26.94 b | 0.59 | 8.03 b | 7.79 b | 7.91 b | 0.68 | 7.11 h | 6.83 g | 6.97 i | 0.78 |
| P1xP6 | 1.74 bc | 1.08 bc | 1.41 bc | 0.87 | 30.78 b | 23.97 a | 27.38 ab | 0.58 | 7.79 bc | 7.28 cd | 7.54 cd | 1.50 | 7.27 h | 6.24 h | 6.75 j | 2.79 |
| P2xP3 | 1.91 a | 0.99 cd | 1.45 bc | 1.10 | 30.50 b | 14.83 ce | 22.67 cd | 1.35 | 7.56 c | 7.13 d | 7.34 d | 1.30 | 8.30 df | 8.07 de | 8.19 dg | 0.55 |
| P2xP4 | 1.48 ef | 0.80 f | 1.14 de | 1.05 | 26.23 c | 15.35 ce | 20.79 de | 1.09 | 6.96 d | 6.78 e | 6.87 e | 0.59 | 8.10 fg | 7.72 f | 7.91 gh | 0.92 |
| P2xP5 | 1.09 g | 0.47 i | 0.78 f | 1.30 | 19.19 e | 9.13 g | 14.16 g | 1.38 | 5.99 ef | 5.69 h | 5.84 h | 1.14 | 9.49 a | 9.00 a | 9.25 a | 1.02 |
| P2xP6 | 1.00 gh | 0.63 g | 0.82 f | 0.85 | 22.58 d | 15.79 cd | 19.19 e | 0.79 | 5.33 g | 5.11 i | 5.22 i | 0.94 | 8.41 cf | 7.90 ef | 8.15 eg | 1.19 |
| P3xP4 | 1.66 cd | 1.12 b | 1.39 bc | 0.75 | 34.02 a | 24.57 a | 29.30 a | 0.73 | 6.17 e | 5.99 g | 6.08 g | 0.67 | 7.93 g | 7.62 f | 7.78 gh | 0.77 |
| P3xP5 | 1.48 ef | 0.92 de | 1.20 d | 0.87 | 26.23 c | 20.42 b | 23.32 c | 0.58 | 6.96 d | 6.50 f | 6.73 ef | 1.51 | 8.10 fg | 6.95 g | 7.53 h | 2.80 |
| P3xP6 | 1.58 de | 0.83 ef | 1.21 d | 1.09 | 27.22 c | 14.12 de | 20.67 de | 1.27 | 6.74 d | 6.36 f | 6.55 f | 1.29 | 8.69 bc | 8.63 ac | 8.66 bc | 0.14 |
| P4xP5 | 1.38 f | 0.74 f | 1.06 e | 1.06 | 27.70 c | 16.10 c | 21.90 cd | 1.10 | 5.80 f | 5.64 h | 5.72 h | 0.63 | 8.60 be | 8.20 ce | 8.40 cf | 0.91 |
| P4xP6 | 1.14 g | 0.49 hi | 0.82 f | 1.31 | 22.62 d | 9.01 f | 15.81 fg | 1.59 | 5.88 f | 5.59 h | 5.73 h | 1.13 | 8.61 be | 8.55 bd | 8.58 bc | 0.14 |
| P5xP6 | 0.90 h | 0.57 gh | 0.74 f | 0.84 | 19.60 e | 13.70 e | 16.65 f | 0.79 | 5.26 g | 5.05 i | 5.16 i | 0.91 | 8.79 bc | 8.26 ce | 8.53 be | 1.19 |
| **Mean** | **1.52** | **0.86** | **1.19** | | **26.54** | **16.47** | **20.40** | | **6.85** | **6.55** | **6.36** | | **8.32** | **7.90** | **7.54** | |

Means identified by the same letter are not significantly different at 0.05 level of probability according to FLSD.
P1 (S.541-A/5), P2 (Sakha 3) , P3 (S.435/11/10/3), P4 (Gentiana), P5 (Elona) and P6 (Escalina)).

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# دراسات وراثية علي المحصول ومكوناته في بعض هجن الكتان تحت ظروف بيئية مختلفة

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أجريت هذه الدراسة بهدف تقدير القدرة علي الائتلاف والفعل الجيني لمحصولي القش والبذرة/للنبات ومكوناتهما في الكتان من خلال تقييم ١٥ هجين ناتجة من التهجين بين ستة أباء (١= س ٥٤١-أ/٥ ، ٢= سخا٣ ، ٣= س ٣/١٠/١١/٤٣٥ ، ٤= جنتيانا ، ٥ = ايلونا، ٦= اسكالينا) باستعمال نظام الهجن الدائرية . في موسم ٢٠٠٧ /٢٠٠٨ تم تقييم الـ٦ آباء ، ١٥ هجين في الجيل الأول في موقعين (الأول حقل تربية الكتان بمركز البحوث الزراعية بالجيزة- والثاني بمحطة تجارب البحوث الزراعية بالإسماعيلية) في تجربة قطاعات كاملة العشوائية ذات ثلاثة مكررات . وتشير النتائج إلى أن تأثير العوامل الوراثية المضيفة كان أكثر أهمية في توريث صفات وزن القش وأهم مكونين من مكوناته (الطول الكلي والطول الفعال) وكذلك في توريث صفات محصول وزن البذور وأهم مكونين من مكوناته (عدد الكبسولات/نبات ووزن الألف بذرة) تحت ظروف البيئة العادية والرملية ، بينما كان تأثير العوامل الغير مضيفة له النصيب الأكبر في توريث صفة عدد الأفرع القاعدية للنبات. كذلك أشارت نتائج التفاعل بين القدرة العامة والخاصة علي الائتلاف مع البيئة ، أن كلا من العوامل المضيفة والغير مضيفة قد تأثرت بالظروف البيئة لمعظم الصفات المدروسة. وكان تأثر العوامل الغير مضيفة أكبر من المضيفة بالظروف البيئة لصفات وزن القش والطول الكلي ووزن البذور وعدد الكبسولات /نبات. وعلى العكس من ذلك كان تأثر العوامل المضيفة أكبر من الغير مضيفة بالظروف البيئية لصفتي الطول الفعال وعدد البذور بالكبسولة. كما تشير النتائج إلى أن الأبوين س ٥٤١-أ/٥ ، س ٣/١٠/١١/٤٣٥ أظهرا قدرة عامة عالية علي الائتلاف لصفات وزن القش والطول الكلى ووزن البذور وعدد الكبسولات/نبات ووزن الألف بذرة تحت ظروف البيئة العادية والرملية والتحليل التجميعي. كما تشير النتائج إلى أن الهجينين (١×٤ ، ١×٦ ) أظهرا تفوق في القدرة الخاصة علي الائتلاف لصفة وزن القش/نبات وكذلك الهجينين (١×٦ ، ٢×٣ ) لوزن الألف بذرة وأن آباء هذه الهجن عبارة عن (عالي × منخفض) للقدرة العامة علي الائتلاف لذلك تعتبر الهجن السابقة واعدة في برامج التربية لزيادة وتحسين الصفات سالفة الذكر.

كما تشير النتائج الخاصة بتحمل ظروف الجفاف أن الأب س ٣/١٠/١١/٤٣٥ أظهر تحملا لظروف الجفاف مع إنتاج محصول عالي من وزن القش وعدد الكبسولات/نبات ووزن الألف بذرة ، كذلك الأب جنتيانا للطول الكلي والأب ايلونا للطول الفعال وكذلك الأب س ٥٤١-أ/٥ لصفات الطول الكلي وعدد الأفرع القاعدية ووزن الألف بذرة، أظهر الهجين (٤×٥) تحملا لظروف الجفاف مع إنتاج محصول عالي لصفات وزن القش والطول الكلي والطول الفعال بينما هجين واحد فقط (١×٥) أظهر تحملا الظروف الجفاف بالإضافة للمحصول العالي لكل صفات وزن البذور ومكوناتها علاوة علي أن هذا الهجين أظهر قدرة خاصة علي الائتلاف لصفات وزن البذرة وأهم مكونين من مكوناتها (عدد الكبسولات ووزن الألف بذرة) . لذلك فان هذين الهجينين (٤×٥ ، ١×٥) ربما يكون من الأهمية بمكان تصعيدهما لمراحل تالية في برنامج التربية للحصول علي تراكيب وراثية تكون متحملة لظروف الأراضي الرملية (الجفاف) وعالية في محصولي القش والبذور.