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# SIMULTANEOUS SELECTION FOR HIGH YIELDING AND STABILITY OF SOME ECONOMIC FLAX CHARACTERS

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## ABSTRACT

The materials used for the present study consisted of sixteen flax genotypes (G) which were evaluated over six environments (E), 2 seasons (2004/05 and 2005/06) x 3 locations (two locations at El-Fayoum Governorate and one location at El-Beheira Governorate), Egypt.

The analysis of variance revealed highly significant differences among genotypes, environments and G x E interaction for all studied traits, indicating a wide range of variation among genotypes, environments and these genotypes exhibited differential response to environmental conditions. The significant variance due to residual for all characters indicated that genotypes differed with respect to their stability suggesting that prediction would be difficult, which means that mean performance alone (mean yield) would not be appropriate. Interaction component of variance ($\sigma^2$ge) was less than the genotypic variance ($\sigma^2$g) for all characters except each of straw weight per plant, seeds number per capsule and fiber fineness. This means that genotypes differ in their genetic potential for these traits. This was reflected in high heritability and low discrepancy between PCV and GCV values for these traits. These results indicate the possibility of using these characters as selection index for improving both of straw and seeds weight per plant.

The criterion, yield stability ($YS_i$) statistic indicated that S.31/3/2 (local strain classified as dual purpose type) was proved to be superior in yield and stability for most characters studied as well as Daneila (introduction classified as fiber type) was stable for fiber characters (straw yield, fiber yield, fiber fineness and fiber percentage). Therefore, the two genotypes (S.31/3/2 and Daneila) maintained mean performance advantage across nearly all the environments sampled by maintaining high level of the previous mention traits and they are recommended to be released as commercial stable high yield cultivars and/or to be incorporated in breeding program for producing stable high yield lines.

Phenotypic ($r_p$) and genotypic ($r_g$) correlation coefficients indicated that straw weight per plant was significantly positively correlated with each of plant height, technical stem length, 1000-seed weight and oil percentage. Also, plant height exhibited positive correlation with technical stem length, indicating possibility of using both of plant height and technical stem length as selection index for improving straw weight per plant. Seed weight per plant, exhibited positive association with each of capsules number per plant, 1000-seed weight and oil percentage. Also, the relationship between capsules number per plant and 1000-seed weight was significant and positive in direction, indicating possibility of using both of capsules number per plant and 1000-seed weight as selection indices for improving seed weight per plant. Fiber percentage was positively correlated with fiber fineness, indicating that selection for genotypes had high fiber percentage and high fiber fineness is possible.

## INTRODUCTION

Flax (*Linum usitatissimum* L.) has been grown since the beginnings of civilization, and people all over the world have celebrated its usefulness throughout the ages, both as a food and in the manufacture of clothing. In

Egypt, flax is one of the important oil and fiber crops (cultivated for two purposes).

Stable performance of varieties under different environments with regard to the economic characters like straw yield and/or seed yield is of major significance in any breeding program. In order to initiate the development of stable genotypes, information on various stability aspects and their mode of transmission would be very essential. The yield level, yield stability and genetic variance of the base populations would thus determine the success of any selection programs (Kofoid *et al.*, 1978). Efforts have been made to combine yield and performance stability into a single selection criterion (Kang *et al.*, 1991 and Bachireddy *et al.*, 1992). Benefit to farmers of emphasizing stability of performance during the selection process has been demonstrated (Kang, 1993 and Kang and Magari, 1995). Identification of yield–contributing traits, and a knowledge of GE interactions and yield stability are important for breeding new cultivars with improved adaptation to the environmental constraints prevailing in the target environments. With the availability of improved statistical tools to analyze and understand GE interactions, it is now possible to develop improved cultivars for target environments by exploiting GE interactions and marker – based selection integrated with traditional plant breeding (Boema and Kang, 1998 and Kang, 1998). Many investigators studied GE interactions and stability of flax genotypes under different environments, and recorded different results for their stability across different environments (Abo El-Zahab *et al.*, 1994; Mahto, 1995; Mahmoud, 1998 and El-Hariri *et al*, 2004). The ultimate goal of flax breeding program in Egypt is to select genotype, which has high yielding potentiality and stable under different environments.

Therefore, the main objective of this study was to evaluate the yield potential of sixteen flax genotypes via a new yield-stability ($YS_i$) statistics using the data of flax trials conducted in Fiber Research Section, ARC, Egypt. Another objective was to estimate genetic and GE variance for deriving statistics, unbiased by GE variance such as heritability and genetic coefficient of variation, and to discuss the possibility of implications of these genotypes for obtaining stable lines to be released as cultivars or to be used as stable experimental lines to be incorporated in breeding program for selecting stable high yielding potential cultivars.

## MATERIALS AND METHODS

The materials used for the present study consisted of sixteen flax genotypes (five local varieties, seven local strains and four introductions). The classification and pedigree of the sixteen genotypes used are partially described in Table1.

These sixteen genotypes were evaluated in two successive seasons (2004/05 and 2005/06) at three locations viz: Etay El-Baroud Exp. Sta., El-Beheira Governorate (clay, organic matter of 3.5%, available nitrogen 42.12 ppm and pH = 8.05); Dar El-Ramad Exp. Farm of Faculty of Agric. El-Fayoum, El-Fayoum Univ., (clay, organic matter of 1.63 %, available nitrogen 33.16 ppm and pH = 8.62) and Demo Exp. Farm of Faculty of Agric. El-

Fayoum, El-Fayoum Univ., El-Fayoum Governorate (loamy sand, organic matter of 0.92 %, available nitrogen 17.25 ppm and pH = 8.32). The experimental design was randomized complete block with three replications per each of the six environments (combination of locations x years). Flax seeds of each genotype were sown during the last week of October for all trials in both seasons. Plot consisted of 10 rows, 3 m long and 2 m wide (1/700 fed.). Plant density of 2000 seeds / $m^2$ was used. Recommended agronomic practices were followed.

**Table 1. Pedigree of the sixteen flax genotypes under study, origin and the classification (fiber type, F; dual type, D; oil type, O).**

| No. | Genotypes | Pedigree | Origin | Type |
|---|---|---|---|---|
| 1 | Giza 4 | Giza oil x Giza purple | Local variety | D |
| 2 | Giza 8 | Giza 6 x I. Santa Catalina 6 (I. Argentina) | ≈ ≈ ≈ ≈ ≈ ≈ | D |
| 3 | Sakha 1 | I. Bombay (U.S.A.) x I.1485 (U.S.A.) | ≈ ≈ ≈ ≈ ≈ ≈ | D |
| 4 | Sakha 2 | I. 2348 (Hungary) x I. Hira (India) | ≈ ≈ ≈ ≈ ≈ ≈ | D |
| 5 | Sakha 3 | I. Belinka x I. 2569 | ≈ ≈ ≈ ≈ ≈ ≈ | F |
| 6 | S.2419/1/2 | Selected from I. Humpata (Hungarian) | Local strain | O |
| 7 | S.2465/1/3 | Selected from I. Neelum (India) | ≈ ≈ ≈ ≈ ≈ ≈ | O |
| 8 | S.402/12 | Giza 5 x I. 235 (U.S.A.) | ≈ ≈ ≈ ≈ ≈ ≈ | D |
| 9 | S.402/2/2/5 | Giza 5 x I. 235 (U.S.A.) | ≈ ≈ ≈ ≈ ≈ ≈ | O |
| 10 | S.402/3/18/9 | Giza 5 x I. 235 (U.S.A.) | ≈ ≈ ≈ ≈ ≈ ≈ | O |
| 11 | S.402/21/10/9 | Giza 5 x I. 235 (U.S.A.) | ≈ ≈ ≈ ≈ ≈ ≈ | O |
| 12 | S.31/3/2 | S.402/21/19/3 x S.400/5/6 | ≈ ≈ ≈ ≈ ≈ ≈ | D |
| 13 | Gentiana | Introduction from Romania | Introduction | O |
| 14 | Daniela | Introduction from Romania | ≈ ≈ ≈ ≈ ≈ ≈ | F |
| 15 | Jitka | Introduction from Czech | ≈ ≈ ≈ ≈ ≈ ≈ | F |
| 16 | Belinka | Introduction from Dutch | ≈ ≈ ≈ ≈ ≈ ≈ | F |

At harvest, data on ten randomly guarded plants from each plot were recorded to determine the averages of the individual plant traits. Straw, seed and fiber yields / fed was calculated on plot basis. Oil percentage (%) was determined as an average of two random seed samples / plot using Soxhlet apparatus (A.O.A.C. Society, 1995). The following characters were recorded:

**I) Straw yield, fiber yields and their related characters**:

(1) Straw yield (ton) / fed, (2) Fiber yield (ton) / fed, (3) Straw weight (g) / plant, (4) Plant height (cm), (5) Technical stem length (cm) and (6) Fruiting zone length (cm).

**II) Seed yield, oil yield and their related characters**:

(1) Seed yield (kg) / fed (2) Oil yield (kg) / fed, (3) Seed weight (g) / plant, (4) capsules number / plant, (5) 1000-seed weight (g), and (6) seeds number / capsule.

**III) Technological characters:**

(1) Fiber fineness (Nm) were determined according to the technique described by Radwan and Momtaz (1966), (2) Fiber percentage (%), and (3) Oil percentage (%).

**Statistical analysis:**

Plot means were used for statistical analysis. Data from each of six environments (combination of years and locations) were analyzed. Bartlett' test of homogeneity was used before combined analysis. The estimates of the variance components were calculated by using the expected mean squares as outlined by the procedures described by Johnson *et al.*, (1959). Analysis of variance was conducted, which revealed that genotype x environment interaction was significant for each trial.

A yield – stability statistic ($YS_i$) developed for simultaneous selection for yield and stability was calculated according to Kang (1993). The various steps involved in the calculation of the $YS_i$ statistic are as follows:

**1**) Genotypes were ranked according to yield with the lowest-yielding genotype receiving a rank of 1;

**2**) An adjustment to the yield rank was made; +1 if genotype mean yield was > overall mean yield (OMY) for a test, +2 and +3 if genotype mean yield was ≥ OMY by1 LSD, respectively; -1 if genotype mean yield < OMY, -2 and –3 if genotype mean yield was ≤1 LSD below OMY;

**3**) The adjusted rank was labeled Y;

**4**) A stability rating (S) was assigned as follows; 0, if $\sigma^2$ was not significant; and -2, -4, and -8 if $\sigma^2$ was significant at 10%, 5% and 1% probability level, respectively ;

**5**) The adjusted rank, Y and the stability rating, S, for each genotype were summed; and

**6**) The genotypes that had $YS_i > \sum YS_i$ / t(No. of genotypes) were selected.

Phenotypic ($r_p$) and genotypic ($r_g$) correlation coefficients were calculated according to the formula suggested by Al-Jibouri *et al.*, (1958).

## RESULTS AND DISCUSSION

**Variability:**

The analysis of variance (Table2) showed that genotypes (G) displayed highly significant differences for all characters, indicating the presence of genetic variability among the tested genotypes for all characters studied. Environments (E) differed highly significantly for all traits, indicating a wide range of variation among the environments studied. Also, GxE interaction was significant for all characters. This result indicated that genotypes had considerable different responses to environmental conditions. The ratio between the two variances (G and GxE) was greater for all characters studied indicating that improvement of these characters could be achieved by selection. Whereas, heterogeneity due to all characters studied was significant except each of technical stem length, fruiting zone length, fiber percentage and oil percentage.

When GxE interaction was partitioned into heterogeneity due to the environmental index and residual, the variances due to heterogeneity (GxE linear) were statistically significant for all traits, suggesting that linear components of genotype – environment was present. This means that heterogeneity among genotypes for these traits relative to the environmental index was significant (Table 2). The environmental index ranged from 5.65% (oil percentage) to 82.93% (seeds number / capsule) of the total GxE sum of squares for these traits. The significant variance due to residual (pooled deviation) for all characters indicated that genotypes differed with respect to their stability suggesting that prediction would be difficult, which means that mean performance alone (mean yield) would not be appropriate. In such situation, methods that combine yield and stability of performance are useful (Bachireddy *et al.,* 1992).

**Variance components:**

Estimates of variance components among sixteen flax genotypes grown at six environments for straw, seed weight / plant and their components as well as some technological characters are shown in Table 3. Interaction components variances ($\sigma^2$ge) were less than the genotypic variance ($\sigma^2$g) for all characters except each of straw weight per plant, seeds number per capsule and fiber fineness. This means that genotypes differ in their genetic potential for these traits. This was reflected in high heritability and low discrepancy between PCV and GCV values for plant height (H 92.90%, PCV = 10.14%, GCV = 10.77%), technical stem length (H = 98.55, PCV = 21.17%, GCV = 21.02%), seed weight / plant (H = 98.30, PCV = 38.64%, GCV =38.31%), capsules number / plant (H = 96.92%, PCV = 28.03%, GCV =27.60%), 1000-seed weight (H = 99.90%, PCV = 25.44%, GCV 25.42%), fiber percentage (H = 99.15%, PCV = 8.40%, GCV = 8.36%) and oil percentage (H = 97.79%, PCV = 6.06%, GCV = 6.00%). These results indicating the possibility of using both of plant height and technical stem length as selection indices for improving straw weight / plant and both of capsules number / plant and 1000-seed weight as selection indices for improving seed weight per plant. In contrast, Interaction component of variance ($\sigma^2$ge) was more than the genotypic variance ($\sigma^2$g) for both seeds number / capsule and fiber fineness. This was reflected in low or mediate heritability values and the clear gap between PCV and GCV for seeds number / capsule (H 59.05%, PCV = 10.38%, GCV = 7.98%) and fiber fineness (H 50.21%, PCV = 27.28%, GCV = 19.33%). This result clearly indicates that variation among flax genotypes in the two previous traits are mainly due to environmental variation plus the GE interaction ones. These results are in harmony with that reported by Abo El-Zahab *et al.,* (1994), Mourad *et al*., (2003) and Abo-Kaied *et al.,(*2006).

**Stability analysis:**

Mean performance, ranking of means and yield stability statistic ($YS_i$) for straw, fiber, seed and oil yields / fed as well as some technological characters for sixteen flax genotypes are shown in Table 4. S.31/3/2 followed S.2419/1/2 showed high mean performance (high ranking) for each of seed yield / fed (769.29, 754.52 kg), oil yield / fed (323.14, 316.27 kg) and oil percentage (41.87, 41.83 %), respectively. Also, Daniela and Sakha 3 mean performance exhibited high ranking for both of fiber fineness (356.80, 309.90 Nm) and fiber percentage (18.30, 18.15%). Whereas, S.402/12 and Sakha 1 for straw yield / fed (4.048, 3.950 ton), in addition Sakha 1 and Sakha 3 for fiber yield / fed (678.40, 645.44kg) exhibited first or second ranking for mean performance for above-mentioned characters, respectively.

T2-3

Results indicated that S.31/3/2 and S.2419/1/2 proved maximum mean performance for seed yield / fed and its related traits as well as Sakha 1 and Sakha 3 for straw yield, fiber yield and fiber percentage, in addition Daniela for fiber technological traits (fiber fineness and fiber percentage).Therefore, the previous mentioned genotypes specially S.31/3/2 and S.2419/1/2 may be released as commercial cultivars and/or to be incorporated as breeding stocks in flax breeding program aiming at producing high yielding lines.

The presence of GE interaction (Table 2) indicated that conclusions based solely on genotypes means were not reliable. Genotypes responded differently to changes in environments; therefore, measure of stability ($Ys_i$) was deemed appropriate (Table 4). Yield stability according to Kang (1993), revealed that Sakha 2 and S.2419/1/2 exhibited high degree of stability for all characters studied except for fiber fineness. Whereas, S.2465/1/3 and S.402/12 were stable for all characters except fiber fineness and fiber percentage but, S.402/3/18/9 was unstable only for fiber yield and fiber percentage and finally S.31/3/2 exhibited high degree of stability for all characters with the exception of fiber percentage. These results indicated that, the above mentioned genotypes are considered as ideal stable genotypes (according $Ys_i$ measurement) to all characters except fiber fineness. On the other hand, Giza 4 showed superiority for all characters except for oil percentage and also Sakha 1 exhibited the same trend except for oil percentage and fiber fineness. Concerning Daniela exhibited high degree of stability for straw yield, fiber yield, fiber fineness and fiber percentage. Also, Sakha 3 showed degree of stability for fiber yield, fiber fineness and fiber percentage. In contrast, S402/21/10/9 was unstable for all characters, while S.402/2/2/5 was stable only for oil percentage.

It is worth to mention here that S.31/3/2 (local strain classificed as dual purpose type) was proved to be superior in yield and stability for most characters studied as well as Daneila (introduction classificed as fiber type) was stable for fiber characters (straw yield, fiber yield, fiber fineness and fiber percentage). Therefore, the two genotypes (S.31/3/2 and Daneila) maintained mean performance advantage across nearly all the environments sampled by maintaining high level for the above-mentioned traits and they are recommended to be released as commercial stable high yielding cultivars and/or to be incorporated in breeding program for producing stable high yielding lines.

**Genotypic mean performance for straw, seed weight / plant and their components:**

Mean performance for straw, seeds weight / plant and their components of sixteen flax genotypes averaged over six environments are presented in Table 5. The strain 31/3/2 gave the highest values for straw weight / plant (1.87 g) and its important components; plant height (113.274 cm), and technical stem length (91.944 cm). Followed by S.402/3/18/9 for straw weight (1.773 g) as well as Sakha 1 for both plant height (98.735 cm) and technical stem length (79.048 cm). On the other hand, Belinka gave the lowest value for straw weight (1.100 g) and Gentiana for both plant height (70.959 cm) and technical stem length (54.776 cm).

T4

Concerning seed weight per plant and its components, S.2419/1/2 gave the highest value for both seed weight / plant (0.741 g) and capsules number / plant (11.384); S.31/3/2 for 1000-seed weight (10.284 g) and Jitka for seeds number / capsule (7.318). In contrast, the lowest values were recorded by Deniela for seed weight / plant (0.183 g); Jitka for capsules number / plant (4.095); Belinka for 1000-seed weight (4.393 g) and Sakha 2 for seeds number / capsules (4.844).

**Table 5. Mean values for straw weight, seed weight per plant and their components of sixteen flax genotypes (combined over six environments).**

| Genotypes | Straw weight / plant and its components | | | | Seed weight / plant and its components | | | |
|---|---|---|---|---|---|---|---|---|
| | Straw weight / plant (g) | plant height (cm) | Technical stem length (cm) | Fruiting zone length (cm) | Seed weight / plant (g) | Capsules number / plant | 1000-seed weight (g) | Seeds number / capsule |
| **Giza 4** | 1.341 fg | 87.927 k | 66.578 k | 21.348 c | 0.512 h | 8.731 j | 8.421 k | 6.909 f |
| **Giza 8** | 1.499 d | 88.564 j | 61.897 n | 26.667 a | 0.463 i | 8.212 k | 9.199 g | 6.121 k |
| **Sakha 1** | 1.398 e | 98.735 b | 79.048 b | 19.687 f | 0.411 k | 6.144 m | 9.491 h | 7.013 d |
| **Sakha 2** | 1.458 de | 90.456 g | 72.522 g | 17.933 j | 0.408 l | 8.769 i | 9.667 e | 4.844 p |
| **Sakha 3** | 1.272 g | 86.358 l | 70.439 i | 15.919 n | 0.432 j | 11.092 c | 5.579 m | 7.182 c |
| **S.2419/1/2** | 1.603 c | 89.226 i | 63.687 m | 25.538 b | 0.741 a | 11.384 a | 9.918 c | 6.883 g |
| **S.2465/1/3** | 1.754 b | 93.848 d | 75.149 f | 18.698 h | 0.558 f | 9.154 h | 9.947 b | 6.090 l |
| **S.402/12** | 1.608 c | 81.546 n | 61.459 o | 20.086 d | 0.585 e | 9.367 g | 9.709 d | 6.464 i |
| **S.402/2/2/5** | 1.528 cd | 90.707 h | 71.809 h | 18.897 g | 0.540 g | 9.714 e | 9.407 i | 5.862 n |
| **S.402/3/18/9** | 1.773 b | 93.463 e | 75.751 d | 17.713 k | 0.629 c | 11.127 b | 9.533 g | 5.729 o |
| **S.402/21/10/9** | 1.360 f | 85.186 m | 68.555 i | 16.631 n | 0.594 d | 9.368 f | 9.659 f | 6.524 h |
| **S.31/3/2** | 1.870 a | 113.274 a | 91.944 a | 21.330 c | 0.646 b | 10.719 d | 10.284 a | 6.027 m |
| **Gentiana** | 1.326f g | 70.959 p | 54.776 p | 20.592 d | 0.226 m | 4.987 o | 6.381 l | 7.272 b |
| **Daniela** | 1.272 g | 96.004 c | 77.376 c | 18.629 k | 0.183 o | 5.025 n | 5.069 o | 6.435 j |
| **Jitka** | 1.158 h | 80.946 o | 66.127 l | 19.760 e | 0.188 o | 4.095 p | 5.253 n | 7.318 a |
| **Belinka** | 1.100 h | 92.641 f | 75.441 e | 17.200 l | 0.210 n | 6.605 l | 4.393 p | 6.928 e |
| General mean | ***1.458*** | ***89.990*** | ***70.785*** | ***19.789*** | ***0.458*** | ***8.406*** | ***8.244*** | ***6.475*** |

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

In general, S.31/3/2 exhibited high straw weight / plant potential and its important components (plant height and technical stem length), in addition to the highest value of 1000-seed weight. Also, S.2419/1/2 (oil type) gave highest values for seed weight / plant and capsules number / plant. The previous collected data support the evidence that these two strains (S.31/3/2 and S.2419/1/2) may be recommended to be included in any breeding program for improving straw weight per plant by using S.31/3/2 and also, improving seed weight per plant by using S.2419/1/2.

**Correlation studies:**

Phenotypic ($r_p$) and genotypic ($r_g$) correlation coefficients among straw, seeds weight per plant and their components as well as some technological characters in sixteen flax genotypes on based data of six environments are shown in Table 6.

T6

Straw weight / plant was significantly positively correlated with each of plant height, technical stem length, seed weight / plant, capsules number / plant, 1000-seed weight and oil percentage. Also, plant height exhibited positive correlation with technical stem length indicating that maximization of straw weight per plant may be obtained by selection for these two component variables. These results are in harmony with that reported by Momtaz *et al*., (1977), Abo El-Zahab *et al*., (1994) and Abo-kaied *et al*., (2006). On the other hand, straw weight / plant showed significant negative correlation with each of seeds number / capsule, fiber fineness and fiber percentage. Seed weight per plant, exhibited positive association with each of capsules number / plant, 1000-seed weight and oil percentage. Also, the relationship between capsules number / plant with 1000-seed weight was significant and positive in direction. These results indicated that capsules number / plant with 1000-seed weight are main components for seed weight / plant. In contrast, seed weight per plant exhibited negative correlation with both of fiber fineness and fiber percentage. In respect to oil percentage, significant positive correlation was obtained with each of straw weight, fruiting zone length, seed weight and 1000-seed weight, but exhibited significant negative correlation with each of fiber fineness and fiber percentage. Fiber percentage exhibited positive correlation with fiber fineness only, indicating that selection for a genotype which had high fiber percentage and high fineness is possible. But it was negatively correlated with each of straw weight, seed weight and 1000-seed weight. These results are in agreement with those obtained by Momtaz *et al*.(1977), Kumar and Chauhan (1979), Abo El-Zahab *et al*. (1994) and Abo-kaied *et al*., (2006). In general, these results indicated that plant height and technical stem length are main components of straw weight / plant and also, capsules number / plant and 1000-seed weight are the main components of seed weight / plant. These results indicate the possibility of using both of plant height and technical stem length as selection indices for improving straw weight / plant and both of capsules number / plant and 1000-seed weight as selection indices for improving seeds weight per plant.

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# الانتخاب للقدرة المحصولية العالية وثبات السلوك لبعض الصفات الاقتصادية في الكتان

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****قسم المحاصيل- كلية زراعة الفيوم- جامعة الفيوم**

استخدم في هذه الدراسة ١٦ تركيب وراثي من الكتان تم تقييمها في ٦ بيئات (موقعين بمحافظة الفيوم وموقع واحد بمحافظة البحيرة - مصر - خلال موسمي ٢٠٠٥/٢٠٠٤ ، ٢٠٠٦/٢٠٠٥) .

تشير نتائج تحليل التباين أن كل من التراكيب الوراثية (G ) والبيئات (**E** ) والتفاعل بينهم (**GxE**) جميعها كانت معنوية ، مما يدل علي مدي الاختلاف الواسع بين التراكيب الوراثية والبيئات وكذلك اختلاف استجابة هذه التركيب للظروف البيئية ، كذلك المعنوية العالية للتباين الراجع للجزء المتبقي من التفاعل يشير إلى اختلاف هذه التراكيب فيما بينها علاوة علي صعوبة التنبؤ بثبات سلوكها الوراثي عند الاعتماد علي القيمة المحصوليه (متوسط المحصول) فقط ٠كانت تقديرات مكونات تباين التفاعل بين الأصناف والبيئات ($\sigma^2$ge) أقل من تباين الأصناف ($\sigma^2$g ) لكل الصفات المدروسة فيما عدا وزن القش / النبات وعدد البذور / كبسولة ونعومة الألياف . هذا يعني أن هذه الأصناف تختلف فيما بينها في القدرة المحصولية لهذه الصفات وهذا انعكس في تقديرات درجة التوريث العالية والفارق المنخفض بين معاملي التباين الظاهري والوراثي لصفات الطول الكلي والطول الفعال وعدد الكبسولات للنبات ووزن الألف بذرة لذلك يمكن استخدام هذه الصفات كدلائل انتخابية لتحسين صفتي وزن القش والبذور للبنات.

كما أشار مقياس الثبات ($YS_i$ ) والذي يقيس ثبات السلوك مع المحصول العالي إلى أن السلالة ٢/٣/٣١ (سلالة محلية ثنائية الغرض ) ظلت محتفظة بتفوقها في المحصول وثبات السلوك لمعظم الصفات المدروسة ، كذلك المستورد دانيال ( مستورد ليفي ) أظهر ثباتا عاليا ومحصول عاليا لصفات محصول القش / فدان ، ومحصول الألياف / فدان ، والنعومة ، والنسبة المئوية للألياف . لذلك هذان التركيبان (س ٢/٣/٣١ ، دانيال) يمكن التوصية باستخدامهما كأصناف تجارية لإنتاج محصول عالي وثابت في سلوكه الوراثي كما يمكن استخدامهما في برنامج التربية لإنتاج سلالات ثابتة في سلوكها الوراثي وعالية المحصول للصفات سالفة الذكر .

كما تشير نتائج الارتباط الظاهري والوراثي إلي ان هناك ارتباط موجب ومعنوي بين وزن القش / نبات وكل من الطول الكلي والطول الفعال ووزن الألف بذرة ، والنسبة المئوية للزيت . كذلك كان هناك ارتباط موجب ومعنوي بين الطول الكلي والطول الفعال ، لذلك يمكن استخدامهما كدلائل انتخابية لتحسين وزن القش للنبات . كذلك كان هناك ارتباط موجب ومعنوي بين وزن البذور للنبات وكل من عدد الكبسولات / نبات ، ووزن الألف بذرة ، والنسبة المئوية للزيت ، كذلك كان هناك ارتباط موجب ومعنوي بين كل من عدد الكبسولات ووزن الألف بذرة . لذلك يمكن استخدامهما كدلائل انتخابية لتحسين وزن البذرة للنبات . كذلك كان هناك ارتباط موجب ومعنوي بين النسبة المئوية للألياف ونعومة الألياف وهذا يدل علي إمكانية استنباط صنف كتان عالي في كل من نسبة الألياف والنعومة.

**Table 2. Genotype x environment interaction mean squares and its partitioning into heterogeneity due to environmental index and residual from the combined analysis of variance over six environments for straw , seed yields and their related characters.**

| Characters / S.O.V. | Genotypes(G) ( 15)# | Environment (E) (5)# | Interaction (GxE) (75)# | Heterogeneity ( 15)# | | Residual (60)# | Pooled Error ( 180)# |
|---|---|---|---|---|---|---|---|
| Straw yield / fed (ton) | 3.872 ** | 25.993 ** | 0.213 ** | 0.375 * | (35.25)$ | 0.375 ** | 0.0058 ** |
| Fiber yield / fed (kg) | 139149.600 ** | 724684.800 ** | 6233.440 ** | 13067.713 ** | (41.93)$ | 4524.872 ** | 192.0320 ** |
| Straw weight / plant (g) | 0.885 ** | 4.457 ** | 0.134 ** | 0.228 * | (34.10)$ | 0.110 ** | 0.0026 ** |
| plant height (cm) | 1497.487 ** | 5375.062 ** | 106.388 ** | 241.249 ** | (45.35)$ | 72.672 ** | 0.7686 ** |
| Technical stem length(cm) | 4042.048 ** | 3624.112 ** | 85.708 ** | 88.554 ns | (20.66)$ | 51.246 ** | 1.1103 ** |
| Fruiting zone length (cm) | 154.430 ** | 147.839 ** | 13.622 ** | 16.612 ns | (24.39)$ | 12.875 ** | 0.7903 ** |
| Seed yield / fed (kg) | 68246.867 ** | 670609.200 ** | 5226.080 ** | 20741.667 ** | (79.38)$ | 1347.183 ** | 34.1510 ** |
| Oil yield / fed (kg) | 130722.333 ** | 124016.860 ** | 1252.450 ** | 4855.167 ** | (77.53)$ | 351.771 ** | 7.0659 ** |
| Seed weight / plant (g) | 0.563 ** | 0.350 ** | 0.010 ** | 0.033 ** | (68.98)$ | 0.004 ** | 0.0002 ** |
| Capsules number / plant | 99.955 ** | 62.648 ** | 3.076 ** | 5.417 * | (35.21)$ | 2.491 ** | 0.0677 ** |
| 1000-seed weight (g) | 79.159 ** | 10.920 ** | 0.077 ** | 0.178 ** | (46.08)$ | 0.052 ** | 0.0010 ** |
| Seeds number / capsule | 8.129 ** | 12.436 ** | 3.329 ** | 13.804 ** | (82.93)$ | 0.710 ** | 0.0165 ** |
| Fiber fineness (Nm) | 64452.100 ** | 1444.800 ** | 32092.717 ** | 89146.435** | (55.55)$ | 17829.287 ** | 4.1012 ** |
| Fiber percentage (%) | 33.948 ** | 25.118 ** | 0.287 ** | 0.189 ns | (13.21)$ | 0.311 ** | 0.0251 ** |
| Oil percentage (%) | 100.547 ** | 143.363 ** | 2.218 ** | 0.627 ns | (5.65) $ | 2.615 ** | 0.0415 ** |

**Table 3. Variance component estimates from combined ANOVA, phenotypic (PCV) and genotypic (GCV) coefficients of variability and broad sense heritability (H) for the combined analysis of variance over six environments of straw weight, seed weight / plant and other related traits as well as some technological characters.**

| Characters | $\sigma^2_g$ | $\sigma^2_{ge}$ | $\sigma^2_e$ | H% | PCV% | GCV% |
|---|---|---|---|---|---|---|
| Straw weight / plant (g) | 0.042 ** | 0.044 ** | 0.003 | 84.90 | 15.22 | 14.02 |
| plant height (cm) | 77.283 ** | 35.206 ** | 0.769 | 92.90 | 10.14 | 10.77 |
| Technical stem length(cm) | 221.297 ** | 19.199 ** | 1.110 | 98.55 | 21.17 | 21.02 |
| Fruiting zone length (cm) | 7.823 ** | 4.277 ** | 0.790 | 91.18 | 14.80 | 14.13 |
| Seed weight / plant (g) | 0.031 ** | 0.003 ** | 0.000 | 98.30 | 38.64 | 38.31 |
| Capsules number / plant | 5.382 ** | 1.003 ** | 0.068 | 96.92 | 28.03 | 27.60 |
| 1000-seed weight (g) | 4.393 ** | 0.025 ** | 0.001 | 99.90 | 25.44 | 25.42 |
| Seeds number / capsule | 0.267** | 1.104 ** | 0.016 | 59.05 | 10.38 | 7.98 |
| Fiber fineness (Nm) | 1797.744 ** | 10696.205 ** | 4.102 | 50.21 | 27.28 | 19.33 |
| Fiber percentage (%) | 1.870 ** | 0.087 ** | 0.025 | 99.15 | 8.40 | 8.36 |
| Oil percentage (%) | 5.463 ** | 0.725 ** | 0.042 | 97.79 | 6.06 | 6.00 |

** = Indicate significant and highly significant, respectively.

$\sigma^2_g$, $\sigma^2_{ge}$, $\sigma^2_e$ are the variance attributed to , genotypes , genotype x environment interaction and plot error, respectively.

**Table 4. Mean yield, rank (assigned before stability analysis was made), yield stability statistic ($YS_i$) and stable genotypes of straw, fiber, seed and oil yields / fed as well as some technological characters for sixteen flax genotypes .**

| Genotypes | Straw yield / fed (ton) | | | Fiber yield / fed (kg) | | | Seed yield / fed (kg) | | | Oil yield / fed (kg) | | | Fiber fineness (Nm) | | | Fiber percentage (%) | | | Oil percentage (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Means | Rank | $Ys_i$ | Means | Rank | $Ys_i$ | Means | Rank | $Ys_i$ | Means | Rank | $Ys_i$ | Means | Rank | $Ys_i$ | Means | Rank | $Ys_i$ | Means | Rank | $Ys_i$ |
| Giza 4 | 3.586 | 10 | 5# | 640.57 | 14 | 9# | 515.15 | 8 | 10# | 194.30 | 7 | 4# | 260.03 | 12 | 7# | 17.84 | 13 | 8# | 37.56 | 4 | 1 |
| Giza 8 | 3.446 | 7 | -2 | 528.87 | 6 | -5 | 704.12 | 13 | 8# | 288.92 | 14 | 9# | 180.26 | 4 | 1 | 15.37 | 5 | 2 | 40.91 | 13 | 16# |
| Sakha 1 | 3.950 | 15 | 10# | 678.40 | 16 | 11# | 563.18 | 10 | 5# | 220.98 | 10 | 5# | 187.28 | 9 | 6 | 17.13 | 11 | 6# | 39.00 | 7 | 0 |
| Sakha 2 | 3.728 | 11 | 14# | 631.32 | 13 | 8# | 623.15 | 11 | 6# | 247.29 | 11 | 6# | 183.36 | 7 | 4 | 16.93 | 10 | 9# | 39.56 | 9 | 12# |
| Sakha 3 | 3.543 | 8 | 3 | 645.44 | 15 | 10# | 345.95 | 4 | -7 | 121.89 | 4 | -7 | 309.90 | 15 | 10# | 18.15 | 15 | 10# | 34.94 | 2 | -9 |
| S.2419/1/2 | 3.837 | 14 | 9# | 618.57 | 11 | 6# | 754.52 | 15 | 10# | 316.27 | 15 | 10# | 173.56 | 2 | -1 | 16.13 | 8 | 5# | 41.83 | 15 | 10# |
| S.2465/1/3 | 3.767 | 12 | 7# | 588.34 | 7 | 6# | 694.22 | 12 | 7# | 287.29 | 13 | 8# | 169.05 | 1 | -2 | 15.60 | 6 | 3 | 41.29 | 14 | 9# |
| S.402/12 | 4.048 | 16 | 11# | 588.39 | 8 | 3# | 705.52 | 14 | 9# | 286.55 | 12 | 7# | 181.66 | 5 | 2 | 14.53 | 3 | 0 | 40.51 | 12 | 15# |
| S.402/2/2/5 | 3.338 | 5 | 2 | 509.20 | 4 | 1 | 495.70 | 7 | -4 | 199.16 | 8 | -3 | 175.71 | 3 | 0 | 15.26 | 4 | 1 | 40.01 | 10 | 13# |
| S.402/3/18/9 | 3.577 | 9 | 4# | 516.18 | 5 | -6 | 559.25 | 9 | 4# | 218.42 | 9 | 12# | 184.56 | 8 | 5# | 14.42 | 2 | -1 | 38.92 | 6 | 5# |
| S.402/21/10/9 | 2.642 | 2 | -9 | 372.84 | 1 | -10 | 437.06 | 6 | -5 | 171.24 | 6 | -5 | 182.50 | 6 | 3 | 14.23 | 1 | -2 | 39.06 | 8 | 1 |
| S.31/3/2 | 3.777 | 13 | 8# | 606.21 | 10 | 5# | 769.29 | 16 | 11# | 323.14 | 16 | 11# | 197.49 | 11 | 8# | 16.02 | 7 | -4 | 41.87 | 16 | 11# |
| Gentiana | 2.856 | 3 | -8 | 489.06 | 3 | -8 | 347.42 | 5 | -6 | 141.62 | 5 | -6 | 192.36 | 10 | 7# | 17.21 | 12 | 7# | 40.34 | 11 | 6# |
| Daniela | 3.372 | 6 | 4# | 620.36 | 12 | 7# | 224.88 | 3 | -8 | 84.34 | 3 | -8 | 356.80 | 16 | 11# | 18.30 | 16 | 11# | 37.67 | 5 | -6 |
| Jitka | 2.407 | 1 | -10 | 399.70 | 2 | -9 | 212.28 | 1 | -10 | 77.84 | 2 | -9 | 286.78 | 13 | 8# | 16.55 | 9 | 4 | 36.15 | 3 | -8 |
| Belinka | 3.287 | 4 | 1 | 596.35 | 9 | 4# | 218.23 | 2 | -9 | 74.58 | 1 | -10 | 288.90 | 14 | 9# | 18.06 | 14 | 9# | 34.03 | 1 | -10 |
| General mean | *3.447* | | 3.06 | *564.36* | | 2.00 | *510.62* | | 1.31 | *203.36* | | 1.5 | *219.39* | | 4.875 | *16.36* | | 4.25 | *38.98* | | 4.125 |
| $LSD_{0.05}$ | **0.123** | | | **22.40** | | | **9.45** | | | **4.30** | | | **3.27** | | | **0.26** | | | **0.33** | | |

**#= Genotype selected on the basis of $YS_i$**

**Table 6. Phenotypic (rp) and genotypic (rg) correlation coefficients among straw, seed weight / plant and their components as well as some technological traits of sixteen flax genotypes data of combined data.**

| *characters* | | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1- Straw weight / plant (g)** | | | | | | | | | | | |
| **2- plant height (cm)** | **rp** | **0.476 *** | | | | | | | | | |
| | **rg** | 0.504 | | | | | | | | | |
| **3-Technical stem length(cm)** | **rp** | **0.535 *** | **0.934 **** | | | | | | | | |
| | **rg** | 0.486 | 0.784 | | | | | | | | |
| **4- Fruiting zone length (cm)** | **rp** | **0.272** | **0.006** | **-0.320** | | | | | | | |
| | **rg** | 0.401 | 0.367 | -0.101 | | | | | | | |
| **5- Seed weight / plant (g)** | **rp** | **0.793 **** | **0.313** | **0.135** | **0.269** | | | | | | |
| | **rg** | 0.351 | 0.214 | -0.143 | -0.147 | | | | | | |
| **6- Capsules number / plant** | **rp** | **0.665 **** | **0.314** | **0.195** | **0.044** | **0.888 **** | | | | | |
| | **rg** | 0.209 | 0.211 | 0.317 | 0.334 | 0.669 | | | | | |
| **7- 1000-seed weight (g)** | **rp** | **0.818 **** | **0.319** | **0.141** | **0.323** | **0.853 **** | **0.622 **** | | | | |
| | **rg** | 0.431 | 0.108 | 0.258 | 0.219 | 0.798 | 0.516 | | | | |
| **8- Seeds number / capsule** | **rp** | **-0.566 *** | **-0.394** | **-0.347** | **0.067** | **-0.356** | **-0.406** | **-0.564 *** | | | |
| | **rg** | 0.222 | 0.025 | 0.078 | 0.140 | 0.069 | -0.112 | 0.117 | | | |
| **9- Fiber fineness (Nm)** | **rp** | **-0.678 **** | **-0.008** | **0.131** | **-0.333** | **-0.665 **** | **-0.432** | **-0.865 **** | **0.431** | | |
| | **rg** | 0.159 | 0.418 | 0.507 | 0.247 | -0.254 | -0.314 | -0.491 | 0.133 | | |
| **10- Fiber percentage (%)** | **rp** | **-0.631 **** | **0.024** | **0.098** | **-0.138** | **-0.656 **** | **-0.453** | **-0.703 **** | **0.409** | **0.738 **** | |
| | **rg** | 0.437 | 0.508 | 0.486 | 0.058 | -0.159 | -0.310 | -0.513 | 0.293 | 0.658 | |
| **11- Oil percentage (%)** | **rp** | **0.794 **** | **0.171** | **-0.037** | **0.567 *** | **0.624 **** | **0.347** | **0.813 **** | **-0.429** | **-0.795 **** | **-0.588 *** |
| | **rg** | 0.313 | 0.247 | 0.254 | 0.478 | 0.719 | 0.481 | 0.694 | 0.094 | -0.325 | -0.341 |

***,** = Indicate significance at the 0.05 and 0.01 levels of probability, respectively.**