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GENETIC VARIABILITY, CORRELATION AND PATH COEFFICIENT ANALYSES FOR SOME FLAX GENOTYPES

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ABSTRACT.

Fifteen genotypes of flax (*Linum usitatissimum* L.) were evaluated during the two consecutive seasons 2020/2021 and 2021/2022 at the Gemmeiza Agricultural Research Station, Agricultural Research Center, El-Gharbia Governorate, Egypt. Three replications of a randomized complete block design were used. The performance of Giza 11 and Giza 12 was outperformed compared to other genotypes for most studied traits in both seasons. For both the phenotypic and genotypic coefficients of variability, most studied traits under investigation showed close values. High heritability in the broad sense coupled with high genetic advance (as % of mean) for most studied traits was observed. The best selection criteria for improving straw yield/fed were plant height and technical length. To improve seed yield/fed. However, number of capsules per plant and seed index (1000 – seed weigh) was useful selection criteria.

Key Words: Flax, genetic variability, correlation, heritability, genetic advance

INTRODUCTION

Flax (*Linum usitatissimum* L.) is an ancient crop grown for market throughout the world. Flax has been domesticated into two main types: oil flax and fiber flax **(Allaby *et al.,* 2005)**. Flax seed oil is mainly cultivated for its omega-3 fatty acid content. Due to its high content of dietary straw, omega-3 oils, and anticarcinogenic lignans, flax seed is becoming increasingly popular in human diets **(Westcott and Muir, 2003)**. Due to its unique drying properties, flax seed oil is also used in paints and coatings **(Przybylski, 2005)**. Straw flax, on the other hand, is grown to provide straw for the production of linen fabrics. In recent years, the straw industry from flax stalks has prioritized the development of high value products **(Cullis, 2011)**. A diverse breeding program is essential for long-term success. Greater diversity of germplasm provides breeders with more opportunities to select parents to develop varieties that meet needs. The study of genetic variability allows better selection and the creation of high-yielding varieties. Genotype selection for a breeding program requires careful consideration of the amount of heritable variation in the variables being studied. Genetic variability is a measure of the tendency of individual genotypes within a population to differ from one another. Genetic diversity is necessary for a population to adapt to environmental changes; without it, this ability is limited, increasing the population's susceptibility to extinction. When planning a breeding program, genetic variation and how quantitative & qualitative traits are inherited must be considered **(Shah *et al.*, 2015) and Kumar, *et al.*, 2016).** The degree of genetic heterogeneity in a germplasm sample can be determined using genetic parameters such as the genotypic coefficient of variation and phenotypic coefficient of variation **(Kumar *et al.*, 2019 and Upadhyay *et al.*, 2019).** Prior to developing an appropriate breeding strategy for genetic improvement, the study of variability in yield and associated traits is critical **(Kumar *et al.*, 2019).**

Plant breeders can develop new and improved varieties with desired traits by using the diversity of plant genetic resources (pest and disease tolerance, light sensitivity, etc.), including farmer-preferred traits (high yield capacity, broad seed, etc.) and breeder-preferred traits **(Rahman *et al.*, 2016)**. Understanding the genetic variation of flax seed is necessary to improve its production in the agricultural system, characterization of germplasm is an essential component between conservation and utilization of plant genetic resources. Genetic material is the most important resource for improving varieties because it contains all the necessary traits. Estimation of the degree of variation in a set of populations is one component of characterization **(Franco, 2003 and Tripathi *et al.*, 2017).** Knowledge of genetic diversity in the current flax plant population is therefore critical for further crop improvement. Understanding the extent of relationships among the major agro-morphological traits would also help in developing an effective system for several traits **(Ottai *et al.*, 2011 ; Hassanein *et al.*, 2012 ; Omar, 2013 and El-Shimy *et al.*, 2015)**. To recognize the genetic variation among them and identify useful traits for evaluation in future flaxseed development programs, the current study was evaluated fifteen flaxseed genotypes based on morphological and yield traits.

MATERIALS AND METHODS

Fifteen flax genotypes were evaluated in the winter seasons 2020/2021 and 2021/2022 in a field trial using a randomized complete block design with three replicates at Gemmeiza Agricultural Research Station, El-Gharbia Governorate, ARC, Egypt. Table (1) shows the names and pedigrees of the seven genotypes. These materials were sown in the second week of November for both seasons. Each genotype type was subjected to standard cultural procedures for flax production as recommended. All other agricultural practices were carried out in accordance with the recommendations of the Fiber Crops Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt.

To determine the mean of the different plants traits, ten randomly selected mature plants from each plot were recorded. The yields of straw and seeds were determined on a plot basis. The measurements of the following characters were taken: plant height, cm; technical length, cm; number of capsules per plant; number of seeds per capsule, seed index (1000- seed weight) g & straw yield per plant, g; seed yield/plant, g; straw yield per fed, ton and seed yield per fed, kg.

Table 1. Pedigree of the fifteen flax genotypes under study and their classification (fiber type — F., dual type — D., oil type — O.)

No.	Genotypes	Pedigree	Type
1	Sakha 1	Bombay x I. 1485	D
2	Sakha 2	Hera x I. 2348	D
3	Sakha 3	Belinka x I. 2569	F
4	Giza9	S.420 / 140 / 5 / 10 x Bombay	F
5	Giza10	S. 420 / 140 /5 /10 x Bombay	F
6	Giza11	Giza 8 x S.2419 / 1	D
7	Giza12	S. 2419 1 x S.148/9/1	D
8	S.541/D/8	Do	D
9	S.435/11/10	I. 467 / 2 X S. 162/12	D
10	S.421/20/16	Sakha 1 x S.105/2	D
11	S.541/C/6	Do	D
12	S. 8/2	I. 1145 x I. 1150	D
13	S.2419/1	Selection from introduce I.Humpata (Hungry)	O
14	S.2467/1	Introduction from Indian	O
15	S.620/53	S. 22 x Giza 7	F

Statistical analysis

The standard statistical analysis of variance was performed using a randomized complete block design with three replications, according to **Gomez and Gomez (1984)**. According to **Singh and Chaudhury (1999)**. The phenotypic and genotypic coefficient of variability was calculated.

$$\text{PCV}\ (\%) = \frac{\sqrt{\delta^2 ph}}{\bar{x}} \times 100$$

$$\text{GCV}\ (\%) = \frac{\sqrt{\delta^2 g}}{\bar{x}} \times 100$$

Where:

$\delta^2 ph$ = phenotypic variance.
$\delta^2 g$ = genotypic variance.
$\bar{x}$ = grand mean of trait
The formula proposed by **Falconer (1989)** was used to calculate heritability in the broad sense.

$$h_b^2 = \frac{\delta^2 g}{\delta^2 ph} \times 100$$

Where:
$\delta^2 ph$ = phenotypic variance.
$\delta^2 g$ = genotypic variance.

The formula provided by **Singh and Chaudhury (1999)** was used to calculate the genetic advance.

$$\text{GA as \% of mean (GAM)} = \left(\left(k \times \delta_{ph} \times h_b^2\right)/\bar{x}\right) \times 100.$$

Where, k = standardized selection differential at 5% selection intensity and (k = 2.063). δ_{ph} = phenotypic standard deviation, h_b^2 = broad sense-heritability and $\bar{x}$ grand mean of trait.

Using the formula proposed by **Miller *et al.*, (1958) ; Kashiani and Saleh (2010)**, correlation coefficients for straw , seed yield and yield related traits were assessed at the phenotypic and genotypic levels.

$$rp_{xy} = \frac{\delta^2 p_{xy}}{\sqrt{\delta^{2\,p_x}} \times \sqrt{\delta^{2\,p_y}}}$$

Where,
rp_{xy} = phenotypic correlation coefficient between traits x and y,
$\delta^2 p_{xy}$ = phenotypic covariance of xy,
$\delta^{2\,p_x}$ = phenotypic variance of x,
$\delta^{2\,p_y}$ = phenotypic variance of y.

$$rg_{xy} = \frac{\delta^2 g_{xy}}{\sqrt{\delta^{2\,g_x}} \times \sqrt{\delta^{2\,g_y}}}$$

Where,
rg_{xy} = genotypic correlation coefficient between traits x and y,
$\delta^2 g_{xy}$ = genotypic covariance of xy,
$\delta^{2\,g_x}$ = genotypic variance of x,
$\delta^{2\,g_y}$ = genotypic variance of y.

Phenotypic and genotypic path coefficient analyses were carried out as suggested by **Dewey and Lu (1959)** using phenotypic and genotypic correlation coefficients respectively to determine the direct and indirect effects of yield related traits (independent variables, causes) on straw yield/fed and/or seed yield per fed (dependent variable, effect) at phenotypic and genotypic levels based on the following equation:

$$r_{ij} = p_{ij} + \sum r_{ik}\ p_{kj}$$

Where, r_{ij} = mutual association between the independent trait (i) and dependent trait, straw yield/fed and/or seed yield per plant (j) as measured by correlation coefficients at phenotypic and genotypic levels. p_{ij} = Components of direct effects of the independent trait (i) as measured by path coefficients at phenotypic and genotypic levels and $\sum r_{ik}\ p_{kj}$ = summation of components of indirect of a given independent trait (i) on a given dependent trait (j) via all other independent traits (k).

The contribution of the remaining unknown factor was measured as the residual factor (p_r) at phenotypic and genotypic levels, which was calculated as:

$$p_r = \sqrt{\left(1 - \sum r_{ij} p_{ij}\right)}$$

The r_{ij} = denote correlations between all possible combinations of independent traits, p_{ij} = denote direct effects of various traits on trait j.

The magnitude of p_r indicates how best the causal factors account for the variability of the dependent factor **(Singh and Chaudhary, 1999)**.

RESULTS AND DISCUSSION

1-Agronomic performance

Results given in Table 2 showed that there were significant differences among flax genotypes for all studied traits. As a consequence, the potential for further improvement for these traits within these breeding materials were effective. Giza 11 and Giza 12 outperformed for plant height (106.63 and113.33 cm), (107.67 and 113.67 cm), technical length (95.9 and 103.73 cm) , (97.67 and103.67cm), No. of capsules/plant (21.37 and 23.33) , (26.03 and 26.2), seed index (10.07 and 10.87 g) **, (**10.37 and 11.53 g), straw yield/plant (2.83 and 2.92 g) , (2.92 and 2.75 g), seed yield/plant (0.62 and 0.73 g) and (0.64 and 0.75 g), straw yield/fed (4.67 and 4.43 kg) and (4.6 and 4.7 kg) and seed yield/fed (656.33 and 757.33 kg) and (680.33 and 780.67 kg) in both first and second seasons, respectively. This indicates that these two varieties are promising dual-purpose varieties for seed and straw production, and they should be planted to improve seed and straw yields. These differences in flax genotypes for all studied traits indicating appreciable amount of genetic differences for these characters among the corresponding genotypes. These results are in agreement with the findings of **Abo – Kaied (2003) ; Kumar *et al.*, (2019) ; Upadhyay *et al.*, (2019) and Omar (2020).**

Table 2. Means of straw, seed yields and their related traits for fifteen flax genotypes in first and second seasons

Trait / Genotype	Plant height (cm)	Technical length (cm)	No of capsules /plant	No of seeds/ capsule	Seed index (g)	Straw yield/ plant (g)	Seed yield/ plant (g)	Straw yield/ fed (ton/ fed)	Seed yield/ fed (kg)
First season									
Sakha 1	104.37	95.8	17.37	7.33	7.37	1.81	0.39	4.13	370
Sakha 2	100.33	91.3	19.67	6.33	8.8	2.11	0.55	4.6	465.67
Sakha 3	97.53	90.4	15.73	7.33	6.77	1.3	0.41	4.13	315.67
Gaiza9	99.33	89.57	15.7	6.67	6.93	1.23	0.35	4.3	306.33
Gaiza10	102.21	94.4	15.8	5.67	6.77	1.5	0.31	4.23	324.33
Gaiza11	106.63	95.9	21.37	7	10.07	2.83	0.62	4.67	656.33
Gaiza12	113.33	103.73	23.33	7.33	10.87	2.92	0.73	4.43	757.33
S.541/D/8	104.8	94.7	21	7	8.43	1.76	0.52	4.37	615
S.435/11/10	97.37	89.57	17.77	8	8.2	1.7	0.62	4.27	518.33
S.421/20/16	97.63	89.43	15	7.67	7.5	1.75	0.33	3.5	568.67
S.541/C/6	98.7	90.9	17.07	7	7.27	1.97	0.52	4.3	531.33
S. 8/2	102.37	93.67	15.57	8	7.37	1.94	0.38	3.73	435.67
S.2419/1	94.94	87.87	14.93	7	7.3	1.69	0.33	3.4	450.33
S.2467/1	97.67	90.2	15.1	7	7.37	1.59	0.33	4.33	452.67
S.620/53	98.93	90.97	16.63	7.67	7.5	1.55	0.33	3.4	429.33
Mean	101.08	92.56	17.47	7.13	7.90	1.84	0.45	4.12	479.80
LSD 5%	3.75	4.14	1.36	1.2	0.43	0.15	0.03	0.34	23.22
LSD 1%	5.06	5.59	1.84	1.62	0.58	0.21	0.04	0.46	31.32
Second season									
	Plant height (cm)	Technical length (cm)	No of capsules/ plant	No of seeds/ capsule	Seed index (g)	Straw yield/ plant (g)	Seed yield/ plant (g)	Straw yield/ fed (ton/ fed)	Seed yield/ fed (kg)
Sakha 1	105.23	99.33	15.03	6.67	7.47	1.67	0.42	4.53	373.33
Sakha 2	104.5	95.53	21.8	7.33	8.17	2.28	0.55	4.6	486.33
Sakha 3	98.87	91.17	16.27	6.67	6.87	1.33	0.47	4.3	322
Gaiza9	102.97	93.9	14.6	7.33	6.67	1.29	0.36	4.23	326.67
Gaiza10	101.63	93.8	14.57	7.33	7.3	1.44	0.31	4.23	319.33
Gaiza11	107.67	97.67	26.03	6.67	10.37	2.92	0.64	4.6	680.33
Gaiza12	113.67	103.67	26.2	6.67	11.53	2.75	0.75	4.7	780.67
S.541/D/8	103.1	94	18.77	7.67	7.87	1.75	0.55	4.33	625.33
S.435/11/10	95.6	88.9	16.67	7.67	8.2	1.73	0.61	4.37	533
S.421/20/16	96.33	88.03	17.67	7	7.67	1.75	0.32	4.43	576.33
S.541/C/6	97.63	90.07	18.27	7.67	7.23	1.95	0.54	4.2	541.67
S. 8/2	102.83	94.3	17.73	7	7.37	1.91	0.35	3.3	428.67
S.2419/1	98.4	90.37	16.2	5.67	7.1	1.73	0.31	3.2	427
S.2467/1	98.37	90.37	13.87	7.67	7.27	1.62	0.33	4.37	474.33
S.620/53	96.67	90.23	16.63	6.33	7.2	1.63	0.32	3.47	449.67
Mean	101.56	93.42	18.02	7.02	7.88	1.85	0.46	4.19	489.64
LSD 5%	3.76	2.77	1.74	1.11	0.5	0.17	0.04	0.34	17.79
LSD 1%	5.07	3.74	2.34	1.5	0.67	0.23	0.06	0.47	24

2-Genetic parameters

Mean, range, genotypic & phenotypic variances, genotypic (GCV) & phenotypic (PCV) coefficients of variation, broad sense-heritability (h^2_b), and genetic advance as% of mean (GAM) were computed for agronomic traits to assess the amount of genetic variability for tested flax genotypes (Table 3). The broad range for all studied traits reflected the high magnitude of variation in the tested breeding material. These results are in confirmation with **Al-Sadek *et al.*, (2015) ; El-Borhamy *et al.*, (2017) ; Abo El-Komsan *et al.*, (2017) ; Kumar *et al.*, (2019) ; Upadhyay *et al.*, (2019) and Omar (2020)**.

The phenotypic coefficient of variation (PCV) was slightly higher than the genotypic coefficient of variation (GCV) for all studied traits (Table 3), indicating that environment had little influence on trait expression. PCV and GCV values ranged from low to moderate for the most studied traits in both seasons. There was enough focused on these traits for selection, and the diverse genotypes can involved in flax breeding program. This findings are confirmed by **Abo–Kaied (2003) ; Al-Sadek *et al.*, (2015) ; El-Borhamy *et al.*, (2017) ; Abo El-Komsan *et al.*, (2017) ; Kumar *et al.*, (2019) ; Upadhyay *et al.*, (2019) and Omar (2020).**

Heritability estimates (Table 3) were high for most studied traits in evaluated genotypes, indicating that selection could be used to improve these traits, as previously observed by **Al-Sadek *et al.*, (2015) ; El-Borhamy *et al.*, (2017) ; Abo El-Komsan *et al.*, (2017) Kumar *et al.*, (2019) ; Upadhyay *et al.*, (2019) and Omar (2020).**

Heritability estimates combined with genetic advance (as a percentage of mean) are more important for selection than heritability alone. **Johnson *et al.*, (1955)** confirmed this by finding an efficient use of broad sense-heritability along with genetic advance (as a percentage of mean), which would provide a more reliable index of selection value. High broad sense heritability and high genetic advance as a percentage of mean were found for the number of capsules per plant, seed index, straw yield per plant, seed yield per plant, and seed yield per fed (Table 3). This indicating that these traits were controlled by additive gene effects that were likely to be desirable. High broad-sense heritability and low genetic advance were found for plant height, technical length, and number of seeds/capsules. In the same context, these results are in line with those of **Al-Sadek *et al.*, (2015) ; El-Borhamy *et al.*, (2017) ; Abo El-Komsan *et al.*, (2017) ; Kumar *et al.*, (2019) ; Upadhyay *et al.*, (2019) and Omar (2020)** who observed high heritability estimates and high genetic advance as per cent of mean for most studied traits in evaluated flax genotypes.

Table 3. Genetic parameters of fifteen flax genotypes for straw, seed yields and their related traits in both first and second seasons

	Plant height	Technical length	No of capsules/plant	No of seeds/capsule	Seed index	Straw yield/plant	Seed yield/plant	Straw yield/fed	Seed yield/fed
First season									
Genotypic variance	20.47	13.85	6.82	0.21	1.42	0.23	0.02	0.16	16940.1
Phenotypic variance	25.5	19.99	7.48	0.72	1.48	0.23	0.02	0.2	17132.83
Phenotypic coefficient of variation	8.41	7.2	14.28	3.37	6.25	4.25	1.37	1.61	1190.28
Genotypic coefficient of variation	6.75	4.99	13	0.96	5.97	4.09	1.34	1.28	1176.89
heritability in broad sense	0.8	0.69	0.91	0.29	0.96	0.96	0.98	0.79	0.99
Genetic advance	8.36	6.39	5.14	0.5	2.4	0.96	0.27	0.73	266.99
Genetic advance % of mean	8.27	6.9	29.43	7.03	30.37	52.31	61.25	17.7	55.65
Second season									
Genotypic variance	22.72	17.55	14.37	0.19	1.75	0.22	0.02	0.21	18409.09
Phenotypic variance	27.76	20.3	15.44	0.63	1.84	0.23	0.02	0.25	18522.28
Phenotypic coefficient of variation	9.11	7.24	28.57	3.01	7.77	4.1	1.53	2.02	1260.93
Genotypic coefficient of variation	7.46	6.26	26.58	0.92	7.39	3.91	1.48	1.69	1253.23
heritability in broad sense	0.82	0.86	0.93	0.31	0.95	0.95	0.97	0.83	0.99
Genetic advance	8.9	8.04	7.54	0.5	2.66	0.94	0.29	0.87	279.05
Genetic advance % of mean	8.76	8.6	41.85	7.14	33.76	50.75	63.32	20.69	56.99

3-Selection criteria

3-1-Phenotypic and genotypic correlations

In order to identify the selected traits for potential improvement in seed and straw yields, correlation coefficient analysis at the phenotypic and genotypic levels was determined between different traits and seed and straw yields per fed. The phenotypic (rp) and genotypic (rg) association between seed & straw yields per fed and its relevant variables were assessed for fifteen flax genotypes in both the first and second seasons (Table 4). Seed yield per fed was positively and significantly correlated with plant height, technical length, number of capsules per plant, number of seeds per capsule, seed index, seed yield per plant and straw yield per plant at both the phenotypic and genotypic levels in both the first and second seasons. Similarly, at both the phenotypic and genotypic levels in both seasons, there was a positive and significant correlation between straw yield per plant and plant height, technical length, number of capsules per plant, number of seeds per capsule, seed index, straw yield per plant and seed yield per plant. This suggests that selection based on these traits will be more effective in improving seed and straw yields in evaluated flax genotypes. These findings are confirmed with those obtained by **Al-Sadek *et al.*, (2015) ; El-Borhamy *et al.*, (2017) ; Abo El-Komsan *et al.*, (2017) ; Kumar *et al.*, (2019) ; Upadhyay *et al.*, (2019) and Omar (2020).**

Table 4. Phenotypic (above diagonal) and genotypic (below diagonal) correlation of fifteen flax genotypes for straw, seed yields and its related traits in both first and second seasons

	Plant height	Technical length	No of capsules/ plant	No of seeds/ capsule	Seed index	Straw yield/ plant	Seed yield/ plant	Straw yield/ fed	Seed yield/ fed
First season									
Plant height	1.000	0.947**	0.736**	0.033	0.714**	0.699**	0.553*	0.392	0.544*
Technical length	1.000**	1.000	0.639*	0.077	0.642**	0.649**	0.496	0.327	0.483
No of capsules/plant	0.870**	0.846**	1.000	-0.064	0.872**	0.771**	0.848**	0.555*	0.730**
No of seeds/ capsule	-0.169	-0.186	-0.038	1.000	0.084	0.057	0.089	-0.337	0.210
Seed index	0.783**	0.754**	0.940**	0.098	1.000	0.890**	0.846**	0.416	0.847**
Straw yield/plant	0.782**	0.778**	0.814**	0.116	0.924**	1.000	0.759**	0.341	0.815**
Seed yield/plant	0.651**	0.637*	0.901**	0.193	0.867**	0.781**	1.000	0.591*	0.744**
Straw yield/fed	0.538*	0.484	0.657**	-0.567*	0.519*	0.436	0.660**	1.000	0.224
Seed yield/fed	0.604*	0.590*	0.770**	0.339	0.860**	0.833**	0.753**	0.259	1.000
Second season									
	Plant height	**Technical length**	**No of capsules/ plant**	**No of seeds/ capsule**	**Seed index**	**Straw yield/ plant**	**Seed yield/ plant**	**Straw yield/ fed**	**Seed yield/ fed**
Plant height	1.000	0.961**	0.627*	-0.017	0.680**	0.624*	0.522*	0.405	0.418
Technical length	0.984**	1.000	0.561*	-0.067	0.638*	0.563*	0.502	0.388	0.342
No. of capsules/plant	0.728**	0.627*	1.000	-0.129	0.863**	0.896**	0.753**	0.348	0.794**
No. of seeds/capsule	-0.246	-0.270	-0.169	1.000	-0.067	-0.122	0.138	0.326	0.049
Seed index	0.780**	0.721**	0.922**	-0.162	1.000	0.867**	0.771**	0.453	0.825**
Straw yield/plant	0.687**	0.616*	0.978**	-0.162	0.912**	1.000	0.709**	0.313	0.806**
Seed yield/plant	0.592*	0.553*	0.808**	0.246	0.808**	0.726**	1.000	0.555*	0.721**
Straw yield/fed	0.425	0.416	0.391	0.653**	0.498	0.344	0.612*	1.000	0.358
Seed yield/fed	0.451	0.360	0.828**	0.092	0.846**	0.820**	0.734**	0.393	1.000

* and ** indicate significant at 0.05 and 0.01 probability levels, respectively.

The phenotypic and genotypic correlations in both seasons were positive and significant for most remaining traits and others. As a consequence, selection for any of the remaining traits would improve the others, particularly seed and straw yields per plant. Thus, these traits could be considered as indicators for the evaluation of flax genotypes to achieve desired genetic improvement for seed yield per plant and straw yield per plant.

3-2-Phenotypic and genotypic path analysis

For further clarification about interrelationships between straw yield per fed & its related traits, the phenotypic & genotypic path coefficient analysis divided phenotypic & genotypic correlation into direct (in bold) and indirect effects, where straw yield per fed was considered a dependent variable and yield related traits were independent variables as shown in Table (5) and Fig. 1.

Maximum phenotypic direct effects were observed for plant height (0.6933). While genotypic direct effects were observed for technical length (6.3467). Hence, preferred improvement may be achieved through selecting genotypes with plant height and technical length. Furthermore, the highest phenotypic and genotypic indirect effects on straw yield per fed. were detected for plant height via technical length (G= 6.374), technical length via plant height(P=0.6562), straw yield per plant via plant height(P= 0.4845), straw yield per plant via technical length(G=4.938), considered as identical reflection for the previous results of correlation at both phenotypic and genotypic levels.

The residual effect being (P=0.90586 & G=1.03131) and (P=0.91096 & G=0.9020) in both first and second seasons, respectively. The high residual effects of phenotypic and genotypic path analyses, indicated that the presence of other traits that were not included in the present study were associated with the high effect on straw yield per fed. These results agree with those obtained by **Ottai *et al.*, (2011) ; Hassanein *et al.*, (2012) ; Omar (2013) and El-Shimy *et al.*, (2015).**

The phenotypic and genotypic path analyses were used to separate phenotypic and genotypic correlations into direct and joint effects, with seed yield per fed. as a dependent variable and yield related traits as independent variables, as shown in Table 6 and Figure 2. A critical perusal of phenotypic and genotypic path analyses revealed that seed index had the highest positive direct effects (P=0.7588, G=0.8764) on seed yield per fed in first season and No of capsules/plant (P=0.3229, G=0.5303), followed by seed index (P=0.4864, G=0.7245) in the second season.

Table 5: Phenotypic and genotypic path analysis of straw yield/fed and its related traits in both seasons (on diagonal are direct effects).

Traits		Plant height	Technical length	Straw yield/plant	Correlation with straw yield/fed
First season					
Plant height	P	0.6933	-0.3863	0.0847	0.3916
	G	-5.9642	6.3740	0.1284	0.5382
Technical length	P	0.6562	-0.4081	0.0786	0.3267
	G	-5.9899	6.3467	0.1277	0.4845
Straw yield/plant	P	0.4845	-0.2649	0.1211	0.3407
	G	-4.6659	4.9380	0.1641	0.4362
Residual	P	0.90586			
	G	1.03131			
Second season					
Traits		Plant height	Technical length	Straw yield/plant	Correlation with straw yield/fed
Plant height	P	0.3107	0.0311	0.0632	0.4050
	G	0.2380	0.1107	0.0766	0.4253
Technical length	P	0.2987	0.0323	0.0570	0.3880
	G	0.2343	0.1125	0.0687	0.4155
Straw yield/plant	P	0.1938	0.0182	0.1014	0.3134
	G	0.1634	0.0693	0.1116	0.3443
Residual	P	0.91096			
	G	0.90200			

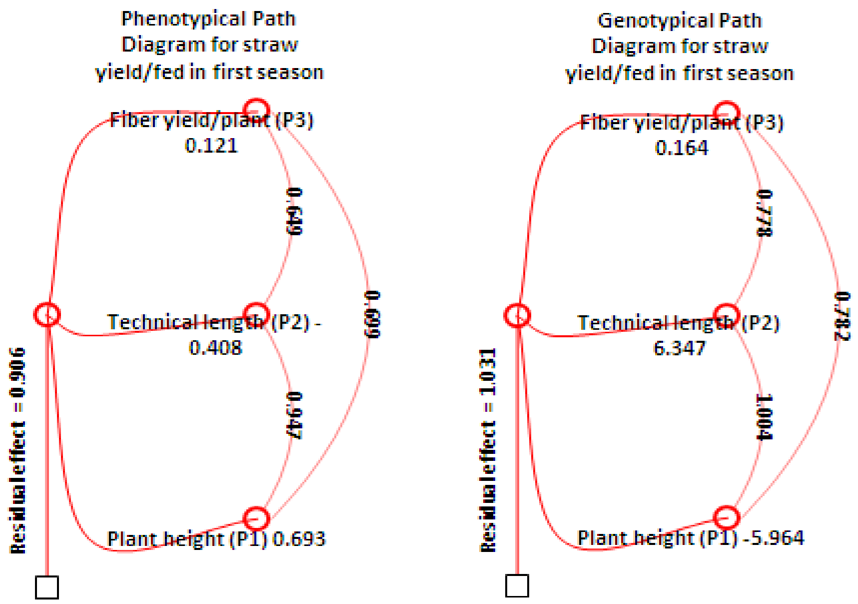

Fig. 1a: Phenotypic and Genotypic path diagram for straw yield/fed. in first season.

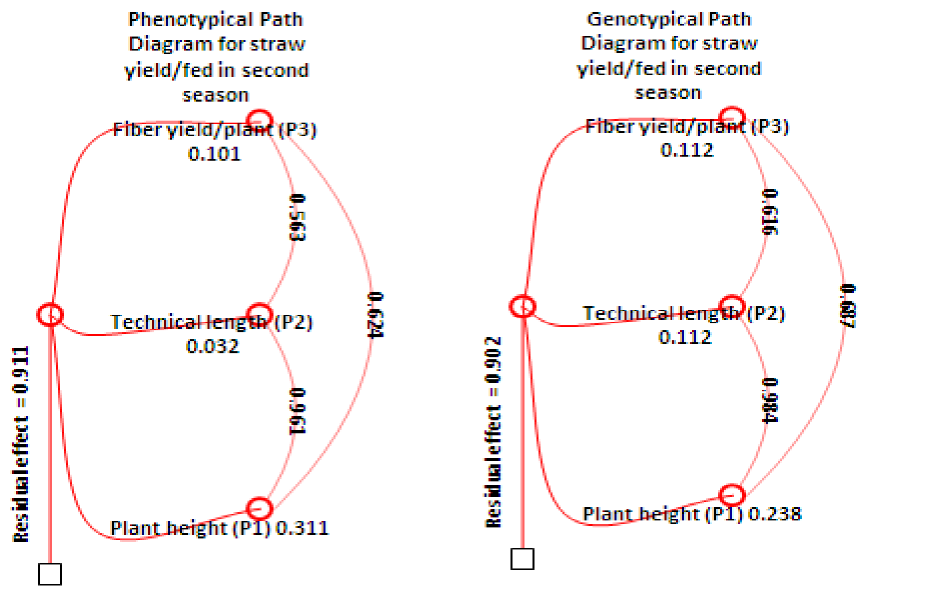

Fig. 1b: Phenotypic and Genotypic path diagram for straw yield/fed. in second season.

Table 6: Phenotypic and genotypic path analysis of seed yield /fed and its related traits in both seasons (on diagonal are direct effects).

Traits		No of capsules/ plant	No of seeds/capsule	Seed index	Seed yield/plant	Correlation with seed yield/fed
First season						
No of capsules/plant	P	0.0043	-0.0088	0.6615	0.0728	0.7298
	G	0.0578	-0.0106	0.8240	-0.1013	0.7699
No of seeds/capsule	P	-0.0003	0.1385	0.0637	0.0076	0.2095
	G	-0.0022	0.2768	0.0861	-0.0217	0.3390
Seed index	P	0.0038	0.0116	0.7588	0.0726	0.8468
	G	0.0544	0.0272	0.8764	-0.0974	0.8605
Seed yield/plant	P	0.0037	0.0123	0.6419	0.0859	0.7437
	G	0.0521	0.0534	0.7597	-0.1124	0.7527
Residual	P	0.51123				
	G	0.43833				
Second season						
Traits		No of capsules/plant	No of seeds/capsule	Seed index	Seed yield/plant	Correlation with seed yield/fed
No of capsules/plant	P	0.3229	-0.0143	0.4197	0.0659	0.7941
	G	0.5303	-0.0659	0.6681	-0.3041	0.8284
No of seeds/capsule	P	-0.0416	0.1113	-0.0327	0.0120	0.0490
	G	-0.0894	0.3909	-0.1171	-0.0927	0.0917
Seed index	P	0.2787	-0.0075	0.4864	0.0675	0.8250
	G	0.4890	-0.0632	0.7245	-0.3040	0.8464
Seed yield/plant	P	0.2432	0.0153	0.3752	0.0875	0.7211
	G	0.4285	0.0963	0.5852	-0.3763	0.7338
Residual	P	0.52323				
	G	0.43335				

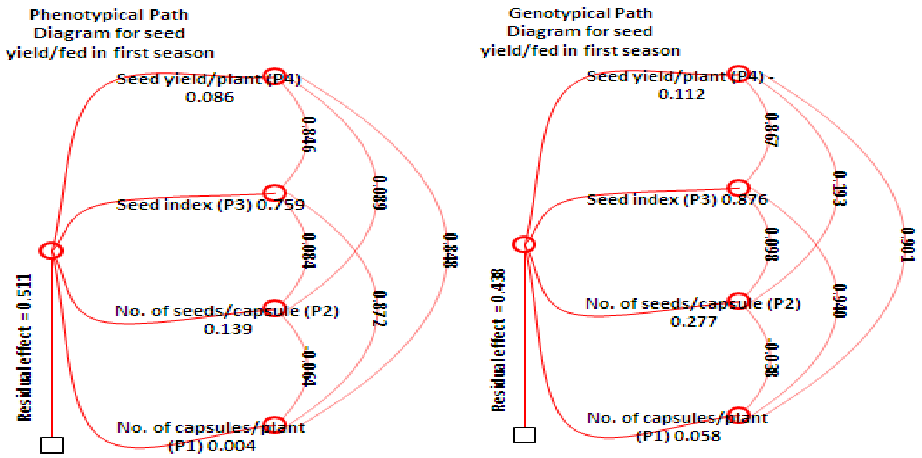

Fig. 2a: Phenotypic and Genotypic path diagram for seed yield/fed. in first season.

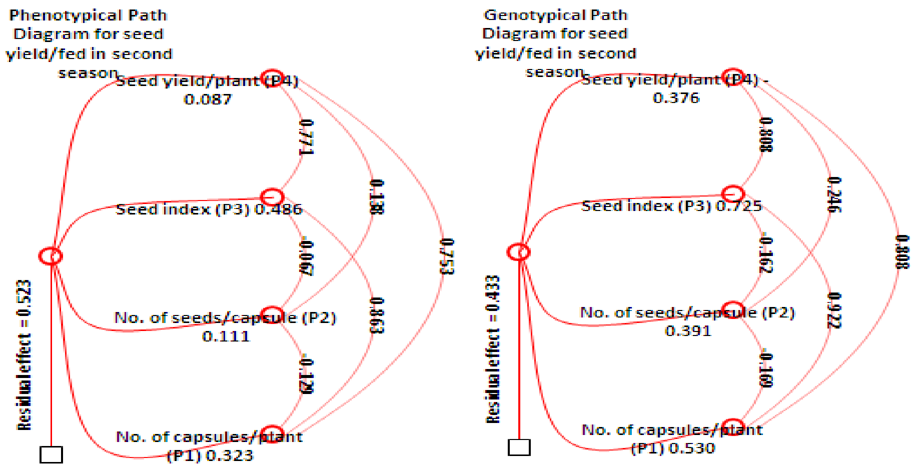

Fig. 2b: Phenotypic and Genotypic path diagram for straw yield/fed. in second season.

The high positive direct effects of the previously mentioned traits, in addition to their highly significant correlation coefficient with seed yield per fed., indicated that the direct selection through these traits would be effective for flax improvement. Consequently, the indirect effect of No of capsules/plant through seed index (P=0.6615, G=0.8240) and seed yield/plant via seed index (P=0.6419, G= 0.7597) in first season and No of capsules/plant via seed index (P=0.4197, G=0.6681) and seed yield/plant via seed index (P=0.3752 , G=0.5852) in the second season had a positive effect on improving seed yield per fed. of these materials.

The residual effect in both first and second season was (P=0.51123, G=0.43833) and (P=0.52323, G=0.43335). The largest residual effects of phenotypic and genotypic path analyses revealed that the existence of other traits , not included in the current study, were linked with the greatest influence on seed yield per fed.

It is apparent from the above-mentioned results that the preferred improvement of straw yield per fed. can be achieved through selecting genotypes having the highest plant height, technical length & straw yield per plant and seed yield/fed through selecting genotypes having the highest No of capsules/plant, seed index and seed yield per plant.

CONCLUSION

In general, assessed flax genotypes show valuable genetic variability, which provides a good chance for improving seed and straw yields. Additionally, some studied traits, such as the number of capsules per plant, seed index and seed yield per plant, were found to be effective in increasing seed yield per fed. as they had the highest broad-sense heritability and genetic advance, in addition to their significant association with seed yield per plant. Whereas, plant height, technical length and straw yield per plant were found to be effective in increasing straw yield per fed. because they had a positive correlation with that yield at both the phenotypic and genotypic levels.

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التباين الوراثي والارتباط ومعامل المرور لبعض التراكيب الوراثية من الكتان

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قسم بحوث الالياف، معهد بحوث المحاصيل الحقلية، مركز البحوث الزراعية، الجيزة، مصر

تم تقييم خمسة عشر تركيب وراثي من الكتان خلال الموسمين المتتاليين 2021/2020 و 2022/2021 في محطة الجميزة للبحوث الزراعية ، مركز البحوث الزراعية ، محافظة الغربية ، مصر. تم استخدام ثلاث مكررات لتصميم القطاعات الكاملة العشوائية. أظهرت النتائج تفوق الصنف جيزة 11 وجيزة 12 في سلوكهما المحصولي على التراكيب الوراثية الأخرى لمعظم الصفات المدروسة في موسمي التقييم. وفيما يتعلق بمعاملات التباين المظهرية والوراثية، أظهرت معظم الصفات قيد الدراسة قيمًا متقاربة. سجلت كفاءة توريث عالية مقترنة بتقدم وراثي مرتفع (كنسبة مئوية من المتوسط) لمعظم الصفات المدروسة. تعتبر أفضل معايير الانتخاب لزيادة محصول قش النبات طبقاً للارتباط المظهري والوراثي هي الطول الكلي والطول الفعال. و لتحسين محصول البذور للنبات، كان عدد الكبسولات لكل نبات، وزن الالف بذرة معايير انتخابية فعالة في تحسين محصول البذور.