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Evaluation of yield and its components for some flax genotypes

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Abstract. Sixteen flax (*Linum usitatissimum* L.) genotypes were evaluated at Gemmeiza Agricultural Research Station, Agricultural Research Center, El-Gharbia Governorate, Egypt during the two successive seasons 2015/2016 and 2016/2017. Randomized complete block design with three replications was used. Phenotypic and genotypic coefficients of variation for all studied traits had closely values. High heritability coupled with high genetic advance (as % of mean) for most studied traits. Plant height, technical length and stem diameter were the best selection indices to improve straw yield /plant, along with number of branches, capsules and seeds were effective selection criteria for improving seed yield /plant as proven by phenotypic and genotypic correlation.

Keywords: Flax, genetic variability, correlation, heritability, genetic advance

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Introduction

Flax (*Linum usitatissimum* L.) as the oldest fiber crop in Egypt is one of the most important industrial crops for straw and seed yields. Genetically improvement of flax yield either straw and seed are considered the major challenge of flax breeder around the world. It could be achieved by identifying the nature and magnitude of genetic variability, determining the best selection criteria via phenotypic and genotypic correlation in the breeding materials.

Earlier literature of variability flax genotypes showed significant differences for yield and yield attributes and is considered as one of the most important sources of genetic variability that was reported by [1—5].

Moreover, the study of phenotypic and genotypic correlation is considered an effective selection tool for selecting the best individual traits of strong correlation with yield. This was reported by [6] who indicated that straw weight had significant positive correlation with each of plant height, seed weight/plant, number of capsules/ plant and 1000-seed weight. However, seed weight/plant was positively and significantly correlated with both number of capsules/plant and 1000-seed weight. In [7] showed that straw weight / plant was positive and significantly correlated with each of technical length, plant height and seed weight/plant. Also, plant height exhibited positive correlation with technical length. Whereas, seed weight per plant exhibited positive correlation with both capsules number/plant and 1000-seed weight. Whereas, the correlation between oil percentage with both of 1000-seed weight and capsules number per plant was positive.

Therefore, the present study aimed to evaluate sixteen flax genotypes in relation to straw and seed yields and their components, to assess genetic parameters for various traits and to estimate correlation coefficients between traits.

Materials and methods

Two field experiments were carried out at Gemmeza Agric. Res. Station during the two successive seasons 2015/2016 and 2016/2017 to evaluate sixteen flax genotypes for yield and yield components, to estimate some genetic parameters, to determinate selection criteria for improving yield of flax genotypes.

These genotypes included the local nine commercial varieties i.e. Sakha 1, Sakha 2, Sakha 3, Sakha 4, Sakha 6, Giza 9, Giza 10 Giza 11 and Giza 12, five imported varieties; Belinka, Sezir, Sofya, Prhiton and Pilton in addition to the two promising strains; S.2467/1 and S.2419/1 which were released by Fiber Crops Res Dep. The pedigree of flax genotypes is described in Table 1. These materials were planted on the second week of November at both seasons by using a randomized complete block design with three replications.

Table 1

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

Genotypes	Pedigree	Type
1- Sakha 1	Bombay × I. 1485	D
2- Sakha 2	Hera × I. 2348	D
3- Sakha 3	Belinka × 1.2569	F
4- Sakha 4	Belinka × 1.2069	F
5- Sakah 6	Giza 8 × S.2419/1	D
6- Giza 9	S.420/140/5/10 × Bombay	F
7- Giza 10	S.420/140/5/10 × Bambay	F
8- Giza 11	Giza 8 × S.2419/1	D

Ending Table 1

Genotypes	Pedigree	Type
9- Giza 12	S.2419/1 × S.148/6/1	D
10- Belinka	Introduction from Holand	F
11- Sezir	Introduction from Belgium	F
12- Sofya	Introduction from Belgium	F
13- S.2467/1	Introduction from indian (selection from Hira 17/34—1)	O
14- S.2419/1	I.715 × I.2465	O
15- Prhiton	Introduction from Ethiopia	O
16- Pilton	Introduction from Ethiopia	O

Normal cultural practices for flax production as recommended were followed for each genotype type. At full maturity, ten randomly guarded plants from each plot were recorded to determinate the averages of the individual plant traits. Straw and seed yields were calculated on plot basis. Oil percentage was determined as an average of two random seed samples / plot using Soxhlet apparatus [8]. The following characters were recorded i. e. Plant height, cm, Technical length, cm, Main stem diameter, mm, number of fruiting branches., Straw yield /plant, g, Straw yield/fad, ton, Fiber percentage, %, number of capsules/plant., number of seeds /capsule., Seed yield/plant., g, Seed yield/fad, kg and Oil percentage, %.

Standard statistical techniques of the mean values for all traits such as analyses of variance using randomized complete block design with three replications was performed according to [9]. The combined analyses of variance (across the two seasons) were done after confirmed of error variance of homogenous according to [9] for two evaluated seasons. Genotypic and phenotypic coefficients of variation were estimated according to [10], broad sense heritability (H2b) [11], genetic advance as percent of the mean [12], phenotypic and genotypic correlation coefficient [13].

Results and discussion

Mean performance. Highly significant differences were detected among flax genotypes for all studied traits in both seasons and their combined analyses as presented in Table 2. This result indicating the presence of sufficient magnitude of genetic variability allow to effective selecting of superior or preferred genotypes.

As shown in the combined analyses (Table 2), Giza 11 gave the highest values for straw yield / fad (5.05 ton) followed by Giza 12 (5.02 ton) and Giza 9 (4.45 ton). While Giza 11 gave the highest values for seed yield/fad (743.83 kg) followed by introduced variety Prhiton (683.00 kg) and Giza 12 (649.50 kg). The maximum values were in Giza 12 for plant height; 94.69 for technical stem length; 2.19 for stem diameter; 20.07 for number of fruiting branches / plant; 8.20 for number of seeds / capsule; 0.92 for seed yield / plant and 35.82 for oil % based on combined data. Several investigators found varietal differences among flax genotypes such as [2—5, 7, 14—16].

Table 2

Means of straw, seed yields and their related characters for sixteen flax genotypes in 2015/16 (1st) and 2016/17 (2nd) seasons and their combined analyses (Com.)

Genotypes	Plant height (cm)			Technical stem length (cm)			Stem diameter (mm)		
	1st	2nd	com	1st	2nd	com	1st	2nd	com
Sakha 1	100.38	105.22	102.80	85.59	87.47	86.53	1.05	1.07	1.06
Sakha 2	104.92	105.70	105.31	88.40	89.48	88.94	2.33	2.04	2.19
Sakha 3	100.85	101.62	101.24	89.00	81.90	85.45	1.55	1.43	1.49
Sakha 4	96.33	96.48	96.41	86.75	88.86	87.81	0.95	1.01	0.98
Sakha 6	103.06	102.33	102.70	89.58	88.41	88.99	1.01	1.02	1.02
Giza 9	99.66	101.04	100.35	89.99	91.90	90.95	0.91	1.05	0.98
Giza 10	94.59	95.80	95.20	80.54	82.40	81.47	1.05	1.12	1.09
Giza 11	104.10	105.54	104.82	91.96	91.01	91.49	2.03	1.93	1.98
Giza 12	105.28	106.14	105.71	95.54	93.83	94.69	1.92	2.08	2.00
Belinka	86.33	90.13	88.23	83.06	83.50	83.28	0.72	0.70	0.71
Sezier	87.64	88.29	87.97	83.19	83.84	83.52	0.90	0.89	0.90
Sofia	90.96	90.04	90.50	88.72	83.82	86.27	1.52	1.48	1.50
S.2467/	90.68	91.29	90.99	81.14	78.99	80.06	1.41	1.37	1.39
S.2419/	89.26	90.09	89.68	81.84	76.69	79.26	0.79	0.83	0.81
Prhiton	81.31	81.98	81.65	69.88	73.92	71.90	2.00	2.02	2.01
Pilton	88.51	88.30	88.41	72.80	73.24	73.02	1.47	2.12	1.79
LSD5 %	8.77	6.80	7.30	5.78	7.38	4.98	0.41	0.26	0.30
LSD1 %	11.80	9.15	9.82	7.78	9.94	6.70	0.56	0.35	0.40

Continued Table 2

Genotypes	Number of fruiting branches/ plant			Straw yield/ plant (g)			Straw yield / fad (ton)		
	1st	2nd	com	1st	2nd	com	1st	2nd	com
Sakha 1	11.11	11.45	11.28	4.34	3.86	4.10	3.87	3.88	3.88
Sakha 2	15.67	16.01	15.84	3.84	4.04	3.94	4.54	4.21	4.37
Sakha 3	7.94	7.17	7.56	3.82	3.86	3.84	3.99	4.17	4.08
Sakha 4	7.25	8.07	7.66	3.27	3.68	3.48	4.02	4.23	4.13
Sakha 6	6.90	7.67	7.29	4.05	4.13	4.09	4.46	4.24	4.35
Giza 9	8.67	8.22	8.45	3.99	3.97	3.98	4.57	4.32	4.45
Giza 10	9.16	8.82	8.99	3.32	3.68	3.50	4.47	4.31	4.39
Giza 11	20.52	14.11	17.32	4.90	4.06	4.48	5.35	4.75	5.05
Giza 12	21.75	14.72	18.24	4.94	4.12	4.53	5.23	4.81	5.02
Belinka	6.55	6.64	6.59	3.19	3.16	3.18	3.44	3.74	3.59
Sezier	5.45	5.92	5.69	2.47	2.61	2.54	3.74	3.73	3.74
Sofia	6.52	6.14	6.33	2.38	2.41	2.40	3.95	3.61	3.78
S.2467/	10.72	12.19	11.46	3.53	3.28	3.41	4.33	4.12	4.22
S.2419/	11.51	11.48	11.49	3.40	3.11	3.25	4.04	4.19	4.11
Prhiton	19.60	20.53	20.07	3.58	3.52	3.55	3.65	3.69	3.67
Pilton	16.98	19.67	18.33	2.65	2.14	2.39	3.75	3.80	3.77
LSD5 %	2.53	1.97	1.74	0.76	0.46	0.50	0.63	0.25	0.37
LSD1 %	3.41	2.66	2.34	1.03	0.62	0.68	0.85	0.33	0.50

Continued Table 2

Genotypes	Fiber percentage (%)			Number of capsules /plant			Number of seeds /capsule		
	1st	2nd	com	1st	2nd	com	1st	2nd	Com
Sakha 1	15.63	16.70	16.16	23.37	26.35	24.86	6.46	6.87	6.66
Sakha 2	13.91	14.53	14.22	24.03	26.64	25.33	6.91	7.40	7.16
Sakha 3	18.39	20.30	19.35	22.19	22.40	22.29	5.41	5.50	5.45
Sakha 4	18.86	17.72	18.29	19.44	21.05	20.25	5.64	5.27	5.45
Sakha 6	17.56	18.87	18.21	23.92	24.67	24.30	6.27	6.13	6.20
Giza 9	18.15	19.40	18.78	22.06	23.78	22.92	5.95	6.20	6.07
Giza 10	18.74	17.47	18.11	26.89	26.94	26.92	5.83	5.27	5.55
Giza 11	15.61	16.20	15.91	31.29	31.52	31.41	7.67	5.53	6.60
Giza 12	15.36	16.97	16.16	32.74	33.87	33.31	9.13	7.27	8.20
Belinka	18.69	21.75	20.22	17.32	17.91	17.61	5.78	5.03	5.41
Sezier	20.62	21.58	21.10	15.24	15.73	15.49	5.76	5.13	5.45
Sofia	20.52	21.53	21.03	14.38	14.23	14.31	5.60	5.03	5.32
S.2467/	16.17	16.63	16.40	22.12	23.76	22.94	7.57	5.67	6.62
S.2419/	16.21	16.70	16.46	21.70	22.00	21.85	7.31	5.60	6.46
Prhiton	15.09	15.62	15.35	33.07	30.98	32.03	7.70	5.20	6.45
Pilton	17.40	18.66	18.03	28.41	29.00	28.71	7.47	5.17	6.32
LSD5 %	2.20	1.88	1.42	3.76	4.84	4.03	1.17	0.74	0.68
LSD1 %	2.96	2.52	1.91	5.07	6.52	5.43	1.57	1.00	0.91

Ending Table 2

Genotypes	Seed yield /plant (g)			Seed yield / fad (kg)			Oil present age (%)		
	1st	2nd	com	1st	2nd	com	1st	2nd	com
Sakha 1	0.79	0.80	0.80	595.00	547.67	571.33	32.48	32.59	32.54
Sakha 2	0.83	0.97	0.90	661.00	632.00	646.50	32.71	32.22	32.47
Sakha 3	0.67	0.63	0.65	376.00	418.33	397.17	32.22	31.85	32.04
Sakha 4	0.63	0.61	0.62	394.33	392.67	393.50	32.15	31.60	31.88
Sakha 6	0.65	0.62	0.63	653.33	406.00	529.67	33.25	33.37	33.31
Giza 9	0.72	0.68	0.70	411.00	399.33	405.17	32.67	31.55	32.11
Giza 10	0.61	0.57	0.59	436.67	284.00	360.33	31.67	31.88	31.78
Giza 11	0.95	0.81	0.88	730.67	757.00	743.83	33.37	33.37	33.37
Giza 12	0.97	0.48	0.72	786.00	513.00	649.50	32.67	32.34	32.50
Belinka	0.40	0.34	0.37	304.00	255.67	279.83	32.41	32.37	32.39
Sezier	0.44	0.37	0.40	336.33	330.67	333.50	29.18	31.90	30.54
Sofia	0.47	0.42	0.45	327.67	215.33	271.50	32.48	32.30	32.39
S.2467/	0.86	0.62	0.74	499.00	505.33	502.17	35.33	32.71	34.02
S.2419/	0.85	0.68	0.77	492.67	533.00	512.83	35.37	31.18	33.27
Prhiton	0.91	0.93	0.92	661.33	704.67	683.00	35.78	35.86	35.82
Pilton	0.90	0.87	0.88	623.00	551.00	587.00	35.03	35.10	35.06
LSD5 %	0.08	0.13	0.09	91.45	160.40	102.08	2.34	1.35	1.53
LSD1 %	0.11	0.18	0.12	123.15	215.99	137.45	3.15	1.82	2.06

Estimation of genetic parameters. To identify the amount of genetic variability of the tested flax genotypes, the range, mean, phenotypic (PCV) and genotypic (GCV) coefficients of variation, heritability in broad sense (H2b) and genetic advance (GA) were computed for twelve traits (Table 3).

It is apparent from Table 3 that all flax genotypes tested exhibited broad-range values for all traits. Plant height varied from 81.65 to 105.71 with a mean of 95.75 cm; technical stem length from 71.90 to 94.69 with a mean of 84.60 cm, main stem diameter from 0.71 to 2.19 with a mean of 1.37 mm; number of fruiting branches from 5.69 to 20.07 with a mean of 11.41; straw yield per plant from 2.39 to 4.53 with a mean of 3.54 g; fiber percentage from 14.22 to 21.10 with a mean of 17.74; number of capsules per plant from 14.31 to 33.31 with a mean of 24.03; number of seeds per capsule from 5.32 to 8.20 with an average of 6.21; seed yield per plant from 0.37 to 0.92 with an average of 0.69 g and oil percentage from 30.54 to 35.82 with an average of 32.84 kg.

Phenotypic coefficient of variation (PCV) differed from their corresponding genotypic (GCV) one for plant height, technical stem length, number of fruiting branches / plant and number of capsules / plant, whereas phenotypic and genotypic coefficients variation for stem diameter, straw yield / plant, fiber%, number of seeds / capsule, seed yield / plant and oil% had close values.

Genotypic coefficient of variation reached maximum (70.26) for number of fruiting branches, number of capsules per plant (40.78), plant height (18.21) and technical length (14.65).

Heritability in broad sense along with genetic advance are considered as a reliable indices for selecting the effective traits in improvement flax yield as confirmed earlier by [12].

High heritability coupled with high values of genetic advance (as % of mean) for all characters, except plant height and oil% which were moderate as presented in Table 3. This indicates the importance of additive gene action in the inheritance of these traits, thus selecting one or more of these traits would be effective in improving flax yield. Similar results were reported by [1, 3, 6—7, 17—18].

Table 3

Genetic parameters of sixteen flax genotypes for straw, seed yields and their related characters as combined analyses of 2015/16 and 2016/17 seasons

Genotypes		Plant height (cm)	Technical stem length (cm)	Stem diameter (mm)	Number of fruiting branches/plant	Straw yield/ plant (g)
Range	Min	81.65	71.90	0.71	5.69	2.39
	Max	105.71	94.69	2.19	20.07	4.53
Mean		95.75	84.60	1.37	11.41	3.54
VG		52.29	37.18	0.23	24.05	0.42
VP		52.29	37.18	0.23	24.05	0.42
PCV		24.87	18.16	6.41	73.45	4.84
GCV		18.21	14.65	5.62	70.26	3.98
H2		0.73	0.81	0.88	0.96	0.82
GA 5 %		12.76	11.30	0.93	9.90	1.22
GA% of means		13.33	13.36	67.77	86.73	34.37

Ending Table 3

Genotypes		Fiber percentage (%)	Number of capsules /plant	Number of seeds /capsule	Seed yield /plant (g)	Oil (%)
Range	Min	14.22	14.31	5.32	0.37	30.54
	Max	21.10	33.31	8.20	0.92	35.82
Mean		17.74	24.03	6.21	0.69	32.84
VG		3.93	29.40	0.55	0.03	1.40
VP		4.65	35.25	0.72	0.03	2.24
PCV		8.73	48.89	3.86	1.57	2.27
GCV		7.38	40.78	2.98	1.44	1.42
H2		0.84	0.83	0.77	0.92	0.63
GA 5 %		3.76	10.22	1.35	0.34	1.93
GA% of means		21.18	42.51	21.74	49.33	5.88

PCV: phenotypic coefficient of variation, GCV: Genotypic coefficient of variation, H2b: broad sense heritability, GA: Genetic advance, GAM%: Genetic advance as percent of mean

Association of traits. Phenotypic (rp) and genotypic (rg) correlations were estimated between straw/plant, seed yield/plant and its attributes for sixteen flax genotypes based on average of 2015/2016 and 2016/2017 seasons as presented in Table 4. Straw yield per plant was positively and significantly or highly significantly correlated with plant height and technical stem length. Also, high significant positive correlations were observed among seed yield/plant and main stem diameter, number of fruiting branches, number of capsules/plant and number of seeds/capsule, indicating that the breeder can utilize such correlated response to obtain high straw and seed yielding genotypes through selection for one or more of these characters. These results are in harmony with those reported by [6—7, 19—20]. In general, the pattern of association of straw and seed yields with other related traits supports the evidence for the possibility of selecting genotypes characterized with high straw yielding ability and in the same time high seed yield potentialities.

Table 4

Phenotypic and genotypic correlation of sixteen flax genotypes for straw, seed yields and its related characters as combined analyses of 2015/2016 and 2016/2017 seasons

Traits	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	1.000	0.733**	0.200	0.055	0.688**	-0.282	0.242	0.351	0.205	-0.274
X2	0.916**	1.000	-0.018	-0.203	0.522*	0.033	-0.055	0.241	-0.150	-0.456
X3	0.246	0.035	1.000	0.777**	0.234	-0.529*	0.576*	0.523*	0.631**	0.356
X4	0.059	-0.228	0.826**	1.000	0.294	-0.733**	0.792**	0.694**	0.809**	0.595*
X5	0.853**	0.680**	0.277	0.305	1.000	-0.555*	0.524*	0.480	0.419	-0.059
X6	-0.354	-0.001	-0.606*	-0.805**	-0.618*	1.000	-0.665**	-0.653**	-0.806**	-0.394
X7	0.350	-0.011	0.705**	0.907**	0.645**	-0.804**	1.000	0.662**	0.694**	0.499*
X8	0.504*	0.261	0.634**	0.786**	0.646**	-0.871**	0.756**	1.000	0.592*	0.298
X9	0.261	-0.184	0.671**	0.862**	0.439	-0.919**	0.838**	0.700**	1.000	0.558
X10	-0.403	-0.703**	0.558*	0.780**	0.016	-0.595*	0.618*	0.381	0.749	1.000

X1: Total plant height, X2: Technical length, X3: Stem diameter, X4: Number of fruiting branches/plant, X5: straw yield/ plant, X6: Fiber percentage, X7: Number of capsule /plant, X8: Number of seeds /capsule, X9: Seed yield /plant, X10: Oil percentage.

Conclusion

From above mentioned results, it can be concluded that valuable phenotypic and genotypic variability or divergence were detected among tested flax genotypes for the studied characters. Thus, there is a great opportunity in improvement flax yield through direct selection and crossing among tested flax genotypes to create viable and potential segregant populations for the subsequent breeding work.

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Оценка урожайности генотипов льна

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Аннотация. Шестнадцать генотипов льна *Linum usitatissimum* L. исследованы по показателям урожайности на сельскохозяйственной исследовательской станции Геммейза в Центре сельскохозяйственных исследований (Египет, мухафаза Эль-Гарбия) в течение двух вегетационных периодов 2015/2016 и 2016/2017 гг. Блочный рандомизированный эксперимент выполнялся с тремя повторностями. Фенотипические и генотипические коэффициенты вариации для всех изученных признаков имели близкие значения. Высокая наследуемость коррелировала с высоким генетическим прогрессом,% от среднего, для большинства изученных признаков. Высота растения, техническая длина и диаметр стебля служили лучшими критериями для контроля увеличения урожайности. Количество ветвей, коробочек и семян также использовались и были не менее эффективными критериями отбора для повышения урожайности растений льна, что подтвердилось фенотипической и генотипической корреляцией.

Ключевые слова: лен, генетическая изменчивость, корреляция, наследственность, генетический прогресс

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