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Original Research

Genotypic Stability Analysis of Some Flax Genotypes under Different Environmental Conditions

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ABSTRACT: Twelve flax genotypes were evaluated across four locations (Ismailia, Kafr El- Sheikh, El-Beheira, and Eshrkaya) Governorates in two successive seasons 2019/2020 and 2020/2021 in a randomized complete blocks design with three replications. The analysis of variance revealed highly significant differences among genotypes, environments and genotype x environment interactions were recorded for all traits under studied, indicated that genotypes response to different environmental conditions and found a wide range of variation among the environments studied. Mean squares due to years x locations were highly significant for all studied traits, suggested that it may be necessary to increase number of test years and locations in the evaluation of flax genotypes. All studied traits showed high heritability values and low discrepancy between phenotypic (PCV) and genotypic (GCV) coefficients of variability, exhibited the importance of selection for plant height and technical stem length to improve flax straw yield per plant and selection for number of capsules per plant and 1000-seeds weight to improve flax seed yield/plant. Therefore, three strains *i.e.* S. 620/3/5, S.402/1 and S. 894/13/4/3 exhibited superiority and stability (Ysi) for all traits under study except straw yield per hectare, seed yield per plant and 1000-seeds weight for strain 402/1 and plant height, technical stem length, number of seeds per capsule and straw yield per hectare for 894/13/4. Correlation coefficient values among nine traits studied showed that straw yield per plant exhibited significant positive correlation with plant height and number of capsules per plant and the plant height was significant and positive correlated with technical length, thus selection for plant height and technical length maximized straw yield per plant. Seed yield per hectare was significant and positive correlated with seed yield per plant and 1000- seeds weight.

Keywords: Flax (*Linum usitatissimum* L.), genotype X environment interaction, variance, stability, correlation

INTRODUCTION

Flax is one of the oldest and versatile crops under cultivation in Egypt; it is the second important fiber crops following cotton that can be grown in Egypt as a dual purpose crop. Two morphological distinct cultivated species of linseed are recognized namely flax and linseed, is a dicotyledonous and self-pollinated annual crop and has a strong ability to resist adversity (Zhang *et al*., 2020) the flax type is commercially grown for the extraction of fiber, which ranged from 12 to 23% in the straw, this fiber is used for many industrial purposes especially high quality linen. Whereas the linseed type contains about 36 to 45% oil which extracted from seed. Linseed oil is good source of alpha linolenic acid (ALA), an essential omega -3 fatty acid and omega 6 fatty acid (Reddy *et al*., 2013)which increase the body's antioxidant levels (Liu *et al*., 2023), Also it is the richest sources of lignin a group of plant substance, known as phytoestrogen natural anticancer agent. Breeding program that aim to develop genotypes with high environmental productivity often include selection as a key component, however, due to its complexity, selection for high yield is made challenging (Rao *et al*., 2023). Contemporarily the major challenge for the breeder's to select the genotypes which are high yielding across deferent environments (Satasiya and Paul 2022). The final product of multiple characters with polygenic inheritance and strong environmental influence is yield per unit area. In plant breeding programs, selection for high yield and stable genotypes under the new changes of climatic conditions is very important. Genotypes, on the other hand, require a wide range of adaptation to perform consistently across settings. The stable genotype has a minimum interaction with environments and in the same time has a high yield under every change of climatic conditions. Knowledge of genotype x environment interactions (GE) and yield stability are important for breeding new genotypes with improved adaptation across environmental conditions. Many investigator recorded GE interactions and stability under different environments of some flax genotypes, Alem and Dessalegn (2014) showed that year by location and location variability was found to be dominated source of interactions for linseed, Jassim and Aziz (2022) reported that location and year influenced linseed yield more than different environments. The main aim of this investigation was evaluated the yield potential of twelve flax genotypes and theirs stability under different environments (4 locations and 2 years) also to estimate the genotype x environment interaction under the new changes of climatic conditions.

MATERIALS AND METHODS

Eight field experiments were carried out during the two successive seasons (2019/2020 and 2020/2021) to evaluate yield potential of twelve flax genotypes at four locations. Viz: (Ismailia, Sakha, Etay El-baroud and kafr El-hamam) experimental station in (Ismailia, Kafr El-Sheikh, El-Beheira, and Eshrkaya) Governorates, respectively. Soil parameters and the monthly average of weather elements were collected from four experimental locations (Tables 1 and 2) during 2019/2020 and 2020/2021 seasons. The genotypes utilized in this investigation were chosen on the basis of their genetic diversity. The classification (Fiber type (F), dual type (D), oil type (O), origin and pedigree of the twelve flax

Table 1: Soil parameters (type of soil, organic matter, available nitrogen, E.C and pH) across four locations under study.

Governorate	Station	Type of soil	Organic matter	Available nitrogen (ppm)	E.C ds/cm	pH
Ismailia	Ismailia	sandy soil	0.53%	7.11 ppm	0.15	7.39
kafr El. sheikh	kafr El. sheikh	clay soil	2.9%	33.00 ppm	1.88	8.7
El- Beheira	Etay El-baroud	clay soil	3.8%	37.19 ppm	1.46	7.67
El-Shrkaya	Kafr El-hamam	clay soil	1.59%	28.09 ppm	1.23	6.35

E.C (ds/cm) =640 ppm

Table 2: Monthly average of weather factors across (Four Governorates) during 2019/2020 and 2020/2021 seasons.

Season	Month	Ismailia Station					kafr El - Sheikh Station				
		Temperature C°			Relative Humidity %	Wind Speed (m/s)	Temperature C°			Relative Humidity %	Wind Speed (m/s)
		Max.	Min.	Mean			Max.	Min.	Mean		
2019/2020	October	32.49	18.75	25.62	73.25	3.20	30.3	26.7	28.5	70.86	36.6
	November	28.72	15.16	21.94	70.03	1.91	27.9	25.1	26.5	65.6	38.5
	December	21.60	10.08	15.84	68.65	4.26	21.4	13.3	17.35	72.9	30.0
	January	18.47	7.59	13.03	69.45	4.45	18.4	11.8	15.1	74.7	51.0
	February	20.93	8.08	14.51	73.22	3.94	20.4	12.7	16.55	70.6	80.1
	March	24.71	9.80	17.26	76.98	2.20	22.6	15.6	19.1	67.5	98.8
	April	27.23	12.16	19.70	77.77	3.14	26.0	18.9	22.45	62.6	55.83
2020/2021	October	34.24	19.83	27.04	70.43	2.83	30.7	27.7	29.2	71.80	46.9
	November	26.05	14.68	20.36	67.65	3.01	25.0	17.5	21.25	71.7	44.9
	December	23.58	11.08	17.33	65.81	0.99	22.9	13.7	18.3	73.1	39.2
	January	22.16	9.16	15.66	71.18	2.45	21.0	13.5	17.25	71.7	58.3
	February	22.52	8.75	15.64	73.18	3.02	21.5	12.5	17	66.8	83.4
	March	24.06	9.55	16.81	71.61	3.92	23.8	15.2	19.5	60.2	95.0
	April	30.57	11.82	21.20	75.38	2.40	27.6	19.4	23.5	69.22	61.28
		El- Beheira Station					Kafr El-Hamam Station				
2019/2020	October	32.69	19.11	25.9	59.47	4.41	32.99	19.07	26.03	59.44	2.57
	November	28.60	15.27	21.94	58.07	3.30	29.11	15.35	22.23	57.03	2.36
	December	21.51	10.53	16.02	65.22	3.68	21.67	10.16	15.94	65.79	2.84
	January	18.30	8.16	13.23	70.15	3.72	18.51	7.92	13.22	70.53	2.85
	February	20.68	8.46	14.57	67.65	3.73	20.98	8.44	14.71	67.38	2.31
	March	24.58	9.94	17.26	62.49	4.79	24.79	9.99	17.39	63.21	2.87
	April	27.18	12.35	19.76	60.62	4.39	27.54	12.45	20.00	59.41	2.70
2020/2021	October	33.95	19.61	26.78	58.63	4.30	24.83	19.89	22.36	57.79	2.46
	November	24.97	14.63	19.80	64.57	3.65	25.94	14.92	20.43	63.72	2.33
	December	23.03	11.14	17.09	63.80	3.12	23.63	11.25	17.44	61.67	2.09
	January	21.80	9.21	15.51	63.98	3.38	22.29	9.27	15.78	62.66	2.53
	February	22.25	9.11	15.68	64.93	3.56	22.54	9.13	15.84	64.91	2.13
	March	23.45	9.97	16.71	63.22	4.43	23.98	9.87	16.93	63.94	2.60
	April	29.74	11.63	20.69	53.96	4.26	30.72	12.01	21.37	51.84	2.94

Weather data during the growing seasons were obtained from Agriculture Research Meteorological Station near the experimental site.

genotypes presented in (Table 3). Each experiment was designed in randomized complete block design with three replications per each of the eight environments (combination of 4 locations x 2 years). Genotypes seeds were sown during the first week of November for all the trials in two seasons. The experimental plot consisted of ten rows, 3m long and 20cm apart. The other cultural practices of growing flax were applied as recommended in each location. Data at harvest were recorded on the yield of whole plot ($6m^2$) for straw and seed yields per hectare. The other traits were recorded on ten randomly guarded plants from each plot to determine the averages of the individual plant traits. The following criteria were recorded.

Table 3: The classification Fiber type (F); dual type (D); oil type (O), origin and pedigree of the twelve flax genotypes.

Genotypes	Pedigree	Origin	Type
S.934/24/8/8	I. Alba xS.2419/1/3	Local strain	O
S.933/10/2/2	I. Herms x S.2419/1/3	Local strain	D
S.889/50/5/10	S.2465/1/3 x S.10	Local strain	O
S.894/13/4/3	S.10 x Romania 14	Local strain	O
S.402/1	I. 235 x Giza 5	Local strain	O
S. 435/11/10/3	S.162/12 x I. 267/2	Local strain	F
S.413/1/3/2	I.5282/1 x I. 267/2	Local strain	D
S.620/3/5	S.422 x Giza 7	Local strain	D
S.2467/1/2	Selected from I.Hira 7/34-1 India	Local strain	O
S.421/60/14/5	S.162/12 x S. 6/2	Local strain	D
S.889/50/5/9	S.10 x S.2419/1/3	Local strain	D
S.541/C/3/2	I. Iriana x Jowher552	Local strain	O

Straw yield and their related traits

Straw yield/ha (ton), straw yield /plant (g), plant height (cm) and technical length (cm).

Seed yield and their related traits

Seed yield/ha (ton), seed yield /plant (g), number of capsules /plant, number of seeds/capsule and 1000-seed weight (g).

Statistical analysis of variance was carried out for each environment. Means were compared by least significant differences (LSD) at 5% level of probability in both and across seasons after testing the homogeneity of errors according to Bartlett's test (Bartlett, 1937). Therefore, combined analysis was performed for each character across the two seasons as described by Le – Clerg *et al* (1966). Genotype stability was determined according by Kang and Magari (1995) whereas combine yield performance and stability in a single simultaneous selection. The essential step by Kang and Magari (1995) method are the following for each genotype.

1. The first step determines the contribution of each genotype to genotype X environment interaction by calculating δ_i^2 (shukla, 1972).
2. Arrange genotype from highest to lowest yield and then assign yield rank (y\), the genotype which has the lowest yield receiving rank of 1.
3. Calculate protected LSD for yield mean comparisons.
4. Adjust y\ according to LSD and determine adjusted yield rank (y\).
5. Kang determine significance of δ_i^2 using approximate F test and then assign the stability ratings,-8 -4 and -2 for δ_i^2 significant at 0.01,0.05 and 0.10 probability levels and 0 for non - significant δ_i^2
6. Kang Sum adjusted yield rank (y\) and stability rating (s) for each genotype to determine Ysi statistic and finally calculate mean Ysi and identify the stable genotypes with Ysi> mean Ysi.

Correlation coefficient study

Correlation analysis was performed to know the strength of relationship between the examined traits and to calculate their relationship among straw and seed yields with their traits (combined analysis across both seasons) subjected to simple correlation coefficient.

RESULTS AND DISCUSSION

The results of the combined analysis of variance for twelve genotypes under eight environments (2 years X 4 locations) are presented in Table (4). Mean squares due to genotypes were highly significant for all traits, indicated that all genotypes used are differed in their genetic performance which due to differences their origin, pedigree and genetic background. Variability among different genotypes of flax was reported by Abo- Elzahab *et al*., (1994), Abo-Kaied *et al*., (2011).

Abo El-Komsan (2017), El-Hosary *et al*., (2016), Abd El Mohsen and Amein (2016) Jassim and Aziz (2021-2022). Location and year x location interaction differed significantly for straw, seed yields and their related traits, indicated a wide range of variation among the environments studies.

Mean squares due to years x location were highly significant for all traits, suggesting that the highly specific and not forecast stable effects of weather conditions on yielding ability at each location. In such situation it may be necessary to increases number of test years and locations in the evaluation of flax genotypes stability. Potts and Gardiner (1980) showed that years and locations influenced yield more than different production practices.

Table 4: Analysis of variance of years and locations and their interactions on twelve flax genotypes across eight environments.

SOV	d.f	Straw yield and related characters				
		Straw yield/ ha (ton)	**Seed yield/ ha (ton)**	**Straw yield / plant (g)**	**Plant height (cm)**	**Technical length (cm)**
Genotypes (G)	11	4.970**	0.278**	1.251**	423.357**	185.761**
Environmental	7	47.985**	0.765**	14.267**	1787.946**	2013.388**
Interaction	77	1.339**	3.848**	0.349**	56.072**	36.723**
Location (L)	3	106.593**	1.461**	33.070**	325.974**	1498.891**
G x L	33	2.589**	0.061**	0.566**	72.219**	60.554**
Years(Y)	1	2.122**	0.835**	0.392**	10233.319**	7304.376**
G x Y	11	0.730**	0.028**	0.107**	42.469**	24.336**
Y x L	3	4.671**	0.036**	0.083**	434.595**	764.970**
G x L x Y	33	0.292**	0.019**	0.212**	44.305**	16.999**
Heterogeneity	11	2.674	1.331NS	0.382 NS	53.474NS	33.521 NS
Residual	66	1.116	4.268**	0.343**	56.505**	37.257**
Pooled error	176	0.271	0.006	0.056	6.845	4.087

Table 4. Cont.

SOV	d.f	Seed yield and related characters			
		Seed yield /plant (g)	**No. capsules/plant**	**No. seeds/capsule**	**1000-seeds weight (g)**
Genotypes (G)	11	0.449**	132.819**	5.021**	28.371**
Environmental	7	5.259**	1418.285**	6.898**	0.168**
Interaction	77	6.370E-02**	19.413**	0.832**	0.178**
Location (L)	3	11.076**	3159.689**	13.895**	0.250**
G x L	33	0.088**	27.542**	1.157**	0.192**
Years(Y)	1	1.826**	193.717**	0.210**	0.066**
G x Y	11	0.050**	18.263**	0.457**	0.130**
Y x L	3	0.577**	85.169**	2.147**	0.127**
G x L x Y	33	0.045**	11.667**	0.632**	0.181**
Heterogeneity	11	0.124*	44.135**	1.232 NS	0.479**
Residual	66	5.358E-02**	15.293**	0.766**	0.129**
Pooled error	176	0.013	2.61	0.209	0.018

Variance components

Partitioning of phenotypic variance δ^2 ph and variance component calculated from combined ANOVA, phenotypic (PCV), genotypic (GCV) coefficients of variability and heritability (H) for estimate traits of twelve flax genotypes across eight environments were shown in (Table 5).The results illustrated that the phenotypic and interaction variances were higher than the genetic variance, it supported the previously mentioned conclusion, and that all interaction variances in ANOVA were highly significant, therefore it showed certainly be necessary to test genotypes under different locations and multi years. All studied traits revealed high heritability values and low discrepancy between PCV and GCV values for straw yield per hectare (H= 73.06 %, PCV=4.76%, GCV= 4.07%), seed yield per hectare (H= 86.19%, PCV=6.78%, GCV= 6.25%), straw yield

Table 5. Partitioning of phenotypic variance (δ^2_{ph}) and variance component phenotypic (PCV), genotypic (GCV) coefficients of variability and heritability (H) for nine traits of twelve flax genotypes, under eight environments.

Characters	δ^2_{ph}	δ^2_{g}	δ^2_{ge}	δ^2_{e}	H%	PCV%	GCV%
Straw yield/ ha (ton)	0.207	0.151	0.365	0.271	73.064	4.768	4.076
Seed yield/ ha (ton)	0.012	0.010	0.011	0.006	86.19	6.739	6.257
Straw yield/ plant(g)	0.052	0.038	0.098	0.056	72.10	8.992	7.635
Plant height (cm)	17.640	15.304	16.408	6.845	86.76	4.793	4.467
Technical length(cm)	7.740	6.210	10.879	4.087	80.23	4.021	3.602
Seed yield/ plant(g)	0.019	0.016	0.017	0.013	85.81	10.619	9.837
Number of capsules/ plant	5.534	4.725	5.600	2.610	85.39	10.345	9.559
Number of seed /capsule	0.209	0.175	0.208	0.209	83.41	6.105	5.576
1000-seeds weight	1.182	1.175	0.054	0.018	99.37	12.706	12.666

δ^2_{ph} δ^2_{g} δ^2_{ge} δ^2_{e} **are the variance attributed to, phenotypic, genotypic, genotype x environment, interaction and environmental error respectively.**

per plant (H= 72.10%, PCV=8.99%, GCV= 7.63%), plant height (H= 86.76%, PCV=4.79%, GCV= 4.46%), technical length (H= 80.23%, PCV=4.02%, GCV= 3.60%), seed yield per plant (H= 85.81%, PCV=10.62%, GCV= 9.84%), number of capsules per plant (H= 85.39%, PCV=10.34%, GCV=9.56%), number of seeds per capsule (H=83.41%, PCV=6.11%,GCV=5.57%) and 1000-seeds weight (H=99.37%,PCV=12.71%, GCV=12.66%).These results exhibited the importance of selection for plant height and technical length to improve flax straw yield per plant and selection for number of capsules per plant and 1000-seed weight to improve flax seed weight per plant. In this connection, Abo El zahab *et al.,* (1994), Abo Kaied *et al.*, (2008), Abo El Zahab *et al.,* (2010) and Abo Kaied *et al.,* (2011) and found high heritability estimates in all studied traits.

Genotypic stability and mean performance

Mean performance, ranking of genotypes means and yield stability statistic (Ysi) according to Kang and Magari (1995) for straw, seed yield and its related traits for twelve flax genotypes were presented in (Tables 6, 7).In these tables the stable genotype was the one with Ysi> mean Ysi (+), out of twelve flax genotypes six strains exhibited superiority and stability for straw yield per hectare. The strain 620/3/5 gave the highest values (highest ranking) (10.456 ton) followed by S. 933/10/2/2 (10.336 ton), S.435/11/10/3(9.782 ton), S.413/1/3/2(9.499 ton),S.889/50/5/10 (9.489 ton) and strain 421/60/14/5 (9.468 ton). Concerning seed yield per hectare S.889/50/5/10 gave the highest means (1.711 ton) followed by S.933/10/2/2 (1.685 ton), S.894/13/4/3 (1.678 ton), S.620/3/5 (1.655 ton), S.402/1 (1.640 ton) and S. 2467/1/2 (1.638 ton).These six strain also exhibited stability for this traits according to Kang and Magari (1995).For straw yield per plant, five strains exhibited high mean performance (high ranking) and stability, S 421/60/14/5 (2.93 g) followed by S .894/13/4/3 gave (2.87 g), S.620/3/5 (2.71 g), S.2467/1/2 (2.69 g) and S. S.401/1 (2.66 g).Out of twelve flax genotypes five strains exhibited superiority and stability for plant height S.402/1 (92.48 cm) followed by S.620/3/5 (91.70 cm), S.421/60/14/5 (90.74 cm),S.889/50/5/10 (90.04 cm) and S.934/24/8/8(88.94cm).

Table 6: Mean yield, ranking of genotypes and yield stability statistic (Ysi) of straw, seed yield and its related traits for twelve flax genotypes.

Genotypes (G)	Straw yield/ ha (ton)			Seed yield/ ha (ton)			Straw yield / plant (g)			Plant height (cm)			Technical length (cm)		
	Mean	rank	YS_i	Mean	rank	YS_i	Mean	rank	YS_i	Mean	rank	YS_i	Mean	rank	YS_i
S.934/24/8/8	9.173	2	-8	1.577	4	3+	2.31	2	-1	88.94	8	2+	70.53	9	3+
S.933/10/2/2	10.336	11	14+	1.685	11	6+	2.47	7	6+	88.79	7	0	69.65	8	1+
S.889/50/5/10	9.489	8	7+	1.711	12	15+	2.45	6	1+	90.04	9	3+	71.35	10	5+
S.894/13/4/3	8.884	1	-10	1.678	10	5+	2.87	11	6+	87.00	4	-5	69.05	5	-4
S.402/1	9.362	4	-5	1.640	8	2+	2.66	8	2+	92.48	12	11+	71.86	11	6+
S. 435/11/10/3	9.782	10	3+	1.317	1	-10	2.42	4	-6	87.68	5	-2	69.61	7	0
S.413/1/3/2	9.499	9	0	1.545	3	-7	2.43	5	-4	88.67	6	7+	69.23	6	-1
S.620/3/5	10.456	12	15+	1.655	9	3+	2.71	10	4+	91.70	11	12+	74.21	12	7+
S.2467/1/2	9.465	6	-3	1.638	7	9+	2.69	9	3+	86.53	3	-6	66.64	3	-8
S.421/60/14/5	9.468	7	6+	1.605	5	-2	2.93	12	7+	90.74	10	5+	68.06	4	-2
S.889/50/5/9	9.185	3	1	1.491	2	-9	2.32	3	1+	78.85	1	-10	63.76	1	-10
S.541/C/3/2	9.445	5	-4	1.624	6	-1	2.06	1	-10	80.18	2	-9	66.25	2	-9
Mean	9.545		1.33	1.597		1.17	2.54		0.75	87.64		0.67	69.18		-1
LSD (0.05)	0.247			0.003			0.11			1.24			0.96		

Table 6.contd.

Genotypes (G)	Seed yield /plant (g)			No. capsules/plant			No. seeds/capsule			1000-seeds weight (g)		
	Mean	rank	YS_i	Mean	rank	YS_i	Mean	rank	YS_i	Mean	rank	YS_i
S.934/24/8/8	1.27	5	-4	21.62	6	-4	6.99	1	-6	9.50	10	5+
S.933/10/2/2	1.27	6	-3	22.62	7	-2	7.48	7	-2	7.59	3	-8
S.889/50/5/10	1.32	9	2+	20.64	2	-1	7.23	5	3+	9.93	12	11+
S.894/13/4/3	1.48	11	6+	24.91	11	6+	7.49	8	-1	9.45	9	4+
S.402/1	1.21	3	-7	23.27	8	1+	7.74	10	4+	8.14	4	-7
S. 435/11/10/3	0.99	1	-10	20.90	3	-8	8.57	12	7+	6.20	1	-2
S.413/1/3/2	1.27	6	-3	21.24	5	-5	7.57	9	8+	8.15	5	-6
S.620/3/5	1.43	10	5+	27.82	12	7+	8.10	11	6+	8.81	6	9+
S.2467/1/2	1.48	12	7+	24.71	10	5+	7.15	3	1+	9.55	11	6+
S.421/60/14/5	1.24	4	-5	24.34	9	4+	7.24	6	-4	7.46	2	-5
S.889/50/5/9	1.32	8	1+	21.17	4	1+	7.23	4	-6	8.87	7	2+
S.541/C/3/2	1.16	2	-1	19.59	1	-10	7.12	2	-4	9.04	8	3+
Mean	1.29		-1	22.78		-0.5	7.49		0.5	8.56		1
LSD (0.05)	0.005			0.76			0.22			0.006		

Table 7. Ranking of genotypes and yield stability statistic (Ysi) of straw, seed yield and its related traits for twelve flax genotypes.

Genotypes(G)	Straw yield/ ha (ton)	Seed yield/ha (ton)	Straw yield / plant (g)	Plant height (cm)	Technical length (cm)	Seed yield /plant (g)	No. capsules/plant	No.seeds/ capsule	1000-seeds weight (g)
S.934/24/8/8	2	4	2	8	9	5	6	1	10
S.933/10/2/2	11	11	7	7	8	6	7	7	3
S.889/50/5/10	8	12	6	9	10	9	2	5	12
S.894/13/4/3	1	10	11	4	5	11	11	8	9
S.402/1	4	8	8	12	11	3	8	10	4
S. 435/11/10/3	10	1	4	5	7	1	3	12	1
S.413/1/3/2	9	3	5	6	6	6	5	9	5
S.620/3/5	12	9	10	11	12	10	12	11	6
S.2467/1/2	6	7	9	3	3	12	10	3	11
S.421/60/14/5	7	5	12	10	4	4	9	6	2
S.889/50/5/9	3	2	3	1	1	8	4	4	7
S.541/C/3/2	5	6	1	2	2	2	1	2	8

Concerning technical length traits,S.620/3/5 gave the highest value (74.21cm) followed by S.402/1(71.86 cm), S.889/50/5/10 (71.35 cm), S.934/24/8/8 (70.53 cm) and S.933/10/2/2 (69.65 cm), for seed yield per plant, five strains showed high value and stability S.2467/1/2 (1.48 g) followed by S.894/13/4/3 (1.48 g), S.620/3/5 (1.43 g), S.889/50/5/10 (1.32g) and S.889/50/5/9 (1.32g). Five strains gave high number of capsules per plant and stable, S.620/3/5 (27.82) followed by S.894/13/4/3 (24.91), S.2467/1/2 (24.71), S.421/60/14/5 (24.34) and S.402/1 (23.27). Concerning number of seeds per capsule S. 435/11/10/3 followed by S. 620/3/5, 402/1 and S.413/1/3/2 exhibited high ranking and stability for this traits. For 1000-seeds weight S.889/50/5/10 followed by S. 2467/1/2, S.934/24/8/8 and S.894/13/4/3 gave high value of 1000-seeds weight and were stable. In general, the strain S.620/3/5 showed superiority and stability for all traits under study, S.402/1 recorded high mean performance and stability (Ysi) for seed yield per hectare, straw yield per plant, plant height, technical length, number of capsule per plant, and number of seeds per capsules. Also the strain 894/13/4/3 was superior and stable for seed yield per hectare, straw yield per plant, seed yield per plant, No. capsules per plant and1000-seeds weight . These results lead us to conclude that the previous mentioned strains S.620/3/5, S.402/1and S.894/13/4/3 were superiority and stable in a wide range of environments and may be recommended to be included in any breeding program to improving straw, seed yields and its related characters. Data in (Table 7) exhibited the ranked of all strains across all traits under study. These results were agreement with those obtained by Abd Al-Sadek *et al*., (2015), Abd El-Haleem *et al*., (2016), Abd El Mohsen and Amein (2016) and Abo El-Komsan *et al*., (2017).

Correlation (Co - variability)

The possible enhancements of high yield and related traits, as primary target of crop improvement and required understanding the amount of correlations among various yield contributing characters and yield components. The simple correlation coefficients between quantitative traits in this experiment combined for calculated the strength of the relationship between the examined traits. Data in (Table 8) showed that straw yield per plant exhibited significant and positive correlation with plant height (0.594*) and number of capsules per plant (0.808**) and in the same time plant height was significant and positive correlated with technical length (0.855**) thus selection for plant height and technical length maximized straw yield per plant. Seed yield per hectare was significant and positive correlated with seed yield per plant (0.658*), 1000-seed yield (0.632*) and seed yield per plant positive correlated with number of capsules per plant (0.637*), thus using number of capsules per plant and 1000-seeds weight as selection indices for improving seed yield. Also using plant height and technical length as selection indices for improving straw yield per plant. These results were agreement with those obtained by Abo El- Zahab *et al*., (1994), El-Shimy *et al*., (2015) and El-Shimy *et al*., (2019).

Table 8. Correlation coefficients among nine characters in twelve flax genotypes.

	Straw yield/ ha (ton)	Seed yield/ha (ton)	Straw yield / plant (g)	Plant height (cm)	Technical length (cm)	Seed yield /plant (g)	No. capsules/plant	No. seeds/ capsule
Seed yield/ h (ton)	0.055							
Straw yield/plant (g)	0.009	0.298						
Plant height (cm)	0.345	0.278	0.594*					
Technical length(cm)	0.471	0.278	0.301	0.855**				
Seed yield /plant(g)	-0.105	0.658*	0.477	0.061	0.037			
No. capsules/plant	0.320	0.371	0.808**	0.493	0.425	0.637*		
No. seeds/capsule	0.494	-0.514	0.174	0.339	0.471	-.0387	0.231	
1000-seed weight(g)	-0.399	0.632*	0.079	-0.190	-0.048	0.717**	0.082	-0.670**

Conclusion

Genotype X environment interactions (GXE) to be challenging issue among plant breeders and genetics due to a universally acceptable selection criterion that takes GE interaction in consideration does not exist. Whenever an interaction is significant, researchers need statistic that provides to measure the stability or consistency of performance across a range of environments, particularly reflects that contribution of each genotype to the total GE interaction. Data concluded that three strains (S. 620/3/5, S.402/1 and S. 894/13/4/3) exhibited superiority and stability (Ysi) for all traits under study except straw yield per hectare, seed yield per plant and 1000-seeds weight for strain 402/1 and plant height, technical stem length, number of seed per capsules and straw yield/ha for S.894/13/4. The association results in this study helped the flax breeders to the possibility of selection which genotypes superiority in straw and seed yields and related characters. The ability to develop stable and high yield genotype are the main focus of most breeding programs and more important than identifying another unstable genotype.

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