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YIELD, YIELD COMPONENTS, QUALITY ASSESSMENT AND YIELD ANALYSIS FOR SOME LOCAL AND INTRODUCED FLAX VARIETES UNDER TWO DIFFERENT RETTING METHODS

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ABSTRACT: Two field experiments carried out at the Experimental Farm of EL-Gemmiza Agricultural Research Station in EL-Gharbia Governorate, Agricultural Research Center (ARC), Egypt, during the successive winter seasons of 2019/2020 and 2020/2021. The objective was to evaluate yield, yield components, quality, and yield analysis of several local and introduced flax varieties, specifically Sakha 1, Sakha 2, Sakha 3, Giza 9, Giza 10, Giza 11, and Giza 12 (local varieties), as well as Evona, Lezeta, and Ariane (introduced varieties), utilizing two retting methods: still water retting (traditional method) and running water retting. The experimental design employed a randomized complete block design with four replicates in the field experiment. Following harvest, twenty combinations of ten tested flax varieties and two retting methods were arranged in a split plot design, with the retting methods assigned to the main plots and the flax varieties distributed in the subplots. The simple correlation coefficient and path coefficient analysis among straw, seed, and fiber yields, along with several of their contributing traits, were evaluated. The principal findings, averaged over the two seasons, can be encapsulated as follows:

1- Significant varietal differences were observed for all studied traits whereas Giza 9 cv. followed by Giza 12 cv. exceeded the other tested flax varieties in straw yield traits *i.e.*, total length/plant, straw yield/plant, and straw yield/fed. On the other hand, Sakha 3 cv. and Giza 10 gave the tallest technical length with no significant difference between them. Moreover, Giza 11 cv. ranked first for main stem diameter, followed by Giza 12 cv. with no significant differences between them. Giza 11 cv. was superior in all seed yield traits *i.e.* number of capsules/plants, number of seeds/plants, seed index, seed yield/plant, seed yield/fed, seed oil %, and oil yield/fed. However, imported flax varieties *i.e.*, Evona, Lezeta, and Ariane cvs. gave the lowest seed yield traits. Giza 9 cv. followed by Sakha 3 and Giza 10 cv. recorded higher estimates for fiber yield and its technological traits *i.e.*, fiber yield/plant, fiber yield/fed, total fiber %, fiber length, and fiber fineness.

2- The retting methods detected significant differences in fiber yield and its technological traits *i.e.*, fiber yield/plant, fiber yield/fed, total fiber %, fiber length, and fiber fineness, whereas running water retting recorded higher values of the previous fiber traits as compared with still water retting (traditional retting method).

3- A significant interaction effect was observed between the ten tested flax varieties and the two retting methods for fiber yield and its technological traits *i.e.*, fiber yield/plant, fiber yield/fed, fiber length, and fiber fineness.

4- The results indicated that straw, seed, and fiber yields, as well as the majority of their contributions, were positively and highly significant.

5- Path coefficient analysis indicated that straw yield/plant, main stem diameter and the interaction between each of straw yield/plant and total length/plant, and the interaction between total length/plant and main stem diameter are considered the main sources of straw yield/fed variation, having the relative contribution of 6.20, 46.45, 29.84, and 10.16 % respectively. At the same time seed yield/plant, number of capsules/plant, number of seeds/plant, and the interaction between seed yield/plant and number of capsules/plant are considered the main sources of seed yield/fed variation, having the relative contribution of 304.31, 15.69, 134.31, and 136.13 % respectively. Also, fiber

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yield/plant, total fiber %, and the interaction between them are considered the main sources of fiber yield/fed variation having relative contributions of 29.15, 31.47, and 19.17 % respectively.

Keywords: Flax varieties, retting methods, yield, yield components, fiber and its technological traits, correlation and path analysis.

INTRODUCTION

Flax (*Linum usitatissimum* L.) was sown in Egypt as one of the oldest crops since the beginning of civilization till nowadays (Goyal *et al.,* 2014). It is the second most important fiber crop after cotton, which played an important role in the national economy owing to export beside local industry. Flax is grown in Egypt as a dual-purpose crop for fiber and oil production. The long fiber which is characterized by high quality used for making flax cloth, while the shorter and coarse fiber is used for manufacturing sail, ropes, twine, and banknote paper (Jhala and Hall 2010). The sheaves (woody part of flax stems) were used for making boards. Moreover, fresh linseed oil is used as an edible for human beings' food, and for some medical purposes, and the residual materials from flax seeds, namely cake, are used for dairy cattle feeding (Charlton and Ehrensing 2001). But after boiling this oil is treated chemically and used in making paints, varnishes, and printing ink.

Retting is a process to dissolve and eliminate the pectin that binds the fibers to the woody parts of the stems and to eliminate the thin wall tissues surrounding the fibers by damping or soaking the stems in water in retting tanks. The retting process is the most important operation in the production of flax. If the retting is not completed successfully, the fiber may be damaged or quality reduced. It is well known that retting cannot improve the fiber; however, proper retting can ensure that the fiber's original properties are maintained rather than diminished. So great efforts were made to choose the best method of retting and proper technique for retting to obtain good fiber with high quality and this intern encouraged us to introduce the high commercial trade of textiles to the external world. In this respect, Radesh *et al.* (1999) compared different retting methods such as controlled tank retting, retting in free-flowing water, spraying water, and covering with polyethylene sheets and concluded that controlled tank retting method gave the maximum values of fiber yield, fiber length, and fiber fineness as compared with the other retting methods. Abd EL-Fatah and EL-Deeb (2006) investigated the effect of flax retting methods (streaming water, still water and water changed every 48 hours) on fiber quality of two flax cultivars and concluded that retting with water changed every 48 hours gave the highest values of fiber length, while the best values of fiber yield/fed, fiber fineness, fiber strength, and fiber % were obtained from retting in streaming water as compared with still water or water changes every 48 hours, respectively. EL-Deeb (2007) compared flax cultivars Sakha 3 and Sakha 4 under different retting methods and observed significant differences between cultivars and retting methods concerning fiber yield and its quality traits, whereas the highest values of fiber %, fiber yield/fed, and fiber fineness were obtained from retting without water change while water change every 24 hours gave the best values of fiber strength. On the other hand, water changes every 72 hours gave intermediate estimates for fiber %, fiber yield/fed, fiber strength, and fiber fineness. EL-Refaey *et al.* (2010) mentioned that retting straw of Blenika and Ilona flax varieties with water change every 48 hours gave the maximum values for fiber yield/fed, fiber %, and fiber fineness as compared with the other tested flax genotypes. EL-Borhamy *et al.* (2015) retted straw of three flax genotypes (Sakha 3, Ilona, and S.541/D/10) under two retting methods (retting in water change every 24 hours and still water retting) and reported that the retting methods recorded significant differences in fiber length, fiber strength, fiber yield/plant and fiber yield/fed in the second season only. While fiber fineness and fiber percentage differed significantly between seasons, the retting method with a 24-hour water change produced the most significant values for fiber length, fiber strength, fiber fineness, fiber percentage, fiber yield/plant, and fiber yield/fed. Several investigators recorded significant varietal differences in yield and quality of flax among them EL-Kady, Eman and Abd EL-Fatah (2009) observed significant differences among twelve flax genotypes regarding yield and its components. EL-Refaey *et al.* (2010) found that the Giza 10 cultivar (fiber type) gave the highest values for plant height, technical length, fiber fineness, fiber length, total fiber %, and fiber yield/fed as compared with other dual purpose and oil type cultivars. EL-Seidy *et al.* (2010) mentioned that line 22 (oil type) gave the highest values of the number of fruiting branches/plant, number of capsules/plant, number of seeds/capsule, seed yield/fed, oil %, and oil yield/fed as compared with the other dual purpose and fiber type cultivars. Hussein (2012) assessed eight flax varieties in terms of seed and fiber yields and components, seed and fiber qualities, and fiber chemical composition, and found significant varietal differences for all traits studied. EL-Borhamy *et al.* (2015) studied the effect of four harvesting dates (120, 130, 140, and 150 DAS) and two retting methods (retting in water change every 24 hours and still water retting) on yield and its quality, yield components of three flax genotypes (Sakha 3, Ilona, and Strain 541/D/10) and observed high significant differences among the tested flax genotypes. EL-Shimy *et al.* (2015) studied the mean performance of sixteen flax genotypes under different environmental conditions concerning straw and seed yield and some of their attributed traits and showed highly significant differences among the tested flax genotypes. Rashwan *et al.* (2016) evaluated the effect of irrigation intervals (25, 35, and 45) on straw, seed, oil, fiber yields and quality of flax cultivars (Sakha 1, Giza9, and Giza 10) and found significant differences in most yield and quality character. EL-Borhamy *et al.,* (2017) compared yield, its components, and the chemical composition of twelve flax genotypes concerning straw and seed yields and their related characters and observed highly significant differences among the tested flax genotypes. EL-Sorady *et al.* (2022) studied yield, yield components, and chemical composition of six flax genotypes regarding straw and seed yields and their components. They observed significant differences among the tested flax genotypes.

The correlation coefficient is a crucial metric for assessing the degree of association between two traits, making it applicable in plant breeding programs. Path coefficient analysis was conducted to assess the relative contributions of yield components to yield variation in flax.

Numerous researchers have examined correlation and path analysis, including Momtaze *et al.* (1977), Aly and Awaad (1997), AL-Kaddoussi and Moawed (2001), Mostafa and Ashmawy (2003), Hussein (2007), Hussein (2012) and EL-Shimy *et al.* (2015).

Therefore, the main objective of the present study was to evaluate some quantity and quality traits as well as yield analysis for some local and introduced flax varieties under two different retting methods at middle of the Nile Delta.

MATERIALS AND METHODS

This study was conducted at the Experimental Farm of EL-Gemmeiza Agriculture Research Station in Gharbia Governorate, located in the central Nile Delta, Egypt, over two consecutive winter seasons, 2019/2020 and 2020/2021. The objective was to evaluate yield, yield components, fiber yield, and associated technological traits of ten local and introduced flax varieties: Sakha 1, Sakha 2, Giza 11, and Giza 12 (local dual-purpose types); Sakha 3, Giza 9, and Giza 10 (local fiber types); and Evona, Lezeta, and Ariane (introduced fiber types), utilizing two retting methods: Still water retting (traditional method) and Running water retting. The ten tested flax varieties were arranged in a randomized complete block design with four replicates for straw yield and its components and seed yield and its related traits. The experimental unit was (2 m X 3 m) 6 m^2 in both seasons, while after harvesting the twenty combinations between the ten flax varieties, the two retting methods were designed in a split plots design with four replications, whereas the retting methods were arranged in main plots and the tested flax varieties were allocated in sub plots. The pedigree of the ten tested flax varieties is presented in Table 1 as shown:

Table 1: Pedigree and origin of the ten local and introduced flax varieties under study.

No.	Varieties	Pedigree	Type	Origin
1	Sakha 1	Bombay (USA) X I. 1485 (USA)	Dual	Local
2	Sakha 2	I. 2348 (Hungar) X I. Hera (India)	Dual	Local
3	Sakha 3	Belinka X I. 2569	Fiber	Local
4	Giza 9	S. 420 X Bombay	Fiber	Local
5	Giza 10	S. 420 X Bombay	Fiber	Local
6	Giza 11	Giza 8 X S. 2419/1 (New variety)	Dual	Local
7	Giza 12	S. 2419 X S. 148/6/1 (New variety)	Dual	Local
8	Evona	Imported from Belgium	Fiber	Introduced
9	Lezeta	Imported from Belgium	Fiber	Introduced
10	Ariane	Imported from Holland	Fiber	Introduced

Mean climatic records (temperature and relative humidity) are presented in Table 2.

The soil texture was clay loam. Before sowing, the physical and chemical properties of the experimental soil sites were analyzed mechanically following the method described by Piper (1950) and chemically according to Black *et al.* (1965). The soil characteristics in the experimental soil sites are given in Table 3.

Table 2: Mean climatic records for EL-Gemmeiza Gharbia Governorate during the retting period in the 2019/2020 and 2020/2021 seasons.

Seasonal month	2019/2020 season				2020/2021 season			
	Temperature			relative	Temperature			relative
	Max.	Min.	Mean	humidity %	Max.	Min.	Mean	humidity %
May	35	22	28.5	47	36	24	30	48
June	37	24	30.5	54	37	25	31	55
July	36	27	31.5	59	38	26	32	60

Table 3: Some physical and chemical properties of the experimental soil sites at EL-Gemmeiza Agriculture Research Station before sowing (0-30 cm depth).

Soil analysis	physical properties					chemical properties				
Variable	Sand %	Silt %	Clay %	O.M	Total $CaCO_3$ %	pH 1:2.5 susp.	EC dsm^{-1}	Available N.P.K (PPM)		
								N	P	K
2019/2020 season	15.21	45.28	39.51	2.49	2.59	7.75	0.99	64.55	10.85	485.22
2020/2021 season	15.64	44.82	39.54	2.52	2.65	7.83	0.95	69.36	11.22	512.88

Seeds of the ten tested flax varieties were shown on 5th and 7th of November in the first and second seasons, respectively. Seeds were hand drilled into rows 15 cm apart at the recommended seeding rate of each variety which gives 2500 plant/m^2. Seeds of the ten tested flax varieties were obtained from Fiber Crops Research Department, Field Crops Research

Institute Agricultural Research Center (ARC), Egypt. Recommended p and k fertilizers were added pre-sowing fully at the rate of 100 Kg/fed calcium super phosphate (15.5 % P_2O_5) and 24 Kg/fed potassium sulfate (48.5 K_2O) in one dose. Recommended N fertilizer was applied at the rate of 45 Kg N/fed in the form of ammonium nitrate (33.5 % N) in two equal doses, the first half was added before the first irrigation and the second one was applied before the second irrigation. Weeds were chemically controlled. Irrigation was carried out using surface irrigation. The preceding crop was Maize (*Zea mays* L.) in the two seasons. All other recommended agronomic practices of flax growing were followed for the region. At harvesting time (full maturity), a sample of ten guarded plants from each experiment unit (subplot) in four replicated were hand-pulled carefully at random and left for one week for complete air drying to determine yield components. Seed, straw, and fiber yields/fed were estimated from an area of 2 m^2 from each experiment unit, which was estimated in Kg/m^2 and then converted to (Kg/fed).

Data recorded included:

A- Yield and yield components:

1- Straw yield and its related traits:

Total length/plant (cm), technical length/plant (cm), main stem diameter, straw yield/plant (g), and straw yield/fed (ton).

2- Seed yield and its related traits:

Number of capsules/plant, number of seeds/plant, seed index (1000 seed weight in g), seed yield/plant (g), seed oil % (was determined by Soxhelt apparatus and using pure petroleum ether with a boiling range of 60 - 80 C° as a solvent for six hour, the oil % was calculated on dry weight basis according to A.O.A.C method (1995), and oil yield/fed (Kg) calculated by multiplying (seed oil % X seed yield/fed).

3- Fiber yield and its technological traits:

Retting process:

In both seasons the retting process was carried out in August in tubes retting in the still water method takes seven days to reach the end point of retting, while in the running water method, it takes twelve days to reach the end point of retting. The endpoint of the retting process was obtained when fibers were easily separated from the internal cortex of flax plants. Controlling the retting temperature was achieved by using a temperature thermostat put in every retting basin. The retting process could be explained as follows:

The harvested straw of each subplot was arranged into bundles which were maintained in retting basins. The estimated temperature of retting water ranged between 28 C° - 37 C° whereas pH value reaches up to 6 - 7 and the volume of retting water reaches up to 1013 m^3. The traditional retting rooms were uncovered places, whereas the treatment places were covered with enclosed plastic tanks. The tested bundles were divided into three equal parts for activation with the previous treatments. A split plot design with four replications was implemented, with retting methods assigned to the main plots and ten flax varieties designated as subplots. Subsequently, fiber yield and its technological characteristics were documented as follows: Fiber yield per plant (g) and fiber yield per fed (ton) were estimated from an area of 2 m^2 for each subplot (kg) and subsequently converted to ton/fed. Total fiber percentage was estimated as follows:

$$\text{Total fiber \%} = \frac{\text{Total fiber yield/fed X 100}}{\text{The retted straw yield}}$$

Fiber length (cm): it was measured as the average of ten fiber ribbons (bundles) from each subplot area, and fiber fineness (*N.m*): was determined according to Radwan and Momtaz (1966) as follows:

$$N.m = \frac{N \times L}{G}$$

Where *N.m* = metrical number, N = the number of 20 fibers of 10 cm in length, L = length of fibers in mm (2000), and G = weight of fiber in mg.

B- Yield analysis:

1- Correlation coefficient analysis

The association between straw, seed, and fiber yields/fed and their related traits as an average of the two seasons were subjected to a simple correlation coefficient according to Svab (1973) using the following equation:

$$r = \frac{SPxy}{\sqrt{SSx \cdot SSy}}$$

Where $SP = \Sigma\, xy - (\Sigma\, x \cdot \Sigma\, y) / n$, $SSx = \Sigma\, x^2 - (\Sigma\, x)^2 / n$, $SSy = \Sigma\, y^2 - (\Sigma\, y)^2 / n$, SPxy is the phenotypic covariance between the two traits, SSx is the phenotypic standard deviation of the first trait and SSy is the phenotypic standard deviation of the second trait. The r test was used for the significance of the r value.

2- Path coefficient analysis:

The path coefficient study was computed by using the method described by Li (1975).

Statistical analysis:

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for randomized complete block design for straw and seed yields and their yield components and split plot design for fiber yield and its related traits as published by Gomez and Gomez (1984) by using Michigan State University Computer Statistical package (MSTATC). The analysis of variance was used for two experiments according to Snedecor and Cochran (1982). The data was statistically analyzed for each season and the homogeneity of experimental error in both seasons was tested by using the Bartlett test, the combined analysis of data was performed for the traits over two seasons (Le Clerg *et al.*, 1966). The least significant differences (L.S.D) test at 5% and 1% levels of significance were used to indicate mean comparison.

RESULTS AND DISCUSSION

1- Yield and yield components:

A- Straw yield and its related traits:

The analysis of variance for the combined data regarding straw yield traits *i.e.* total length/plant, technical length/plant, main stem diameter, straw yield/plant, and straw yield/fed showed significant and highly significant differences among the ten tested flax varieties as presented in Table 4. It was observed that the Giza 12 variety ranked first and exceeded the other tested flax varieties for the previous characters, with no significant difference between this variety and the Giza 11 variety for total length/plant and main stem diameter. However, the lowest values of these characters were recorded with the imported variety Ariane. Moreover, other tested flax varieties recorded intermediate estimates for the straw studied characters as the average of the two seasons. Giza 9 variety followed by the Sakha 3 variety produced the highest values for technical length, without significant differences between them. It was observed that the Giza 12 variety followed by the Giza 11 variety recorded the highest values of total length/plant. However, the Giza 9 variety followed by each of the Sakha 3 variety, Giza 10 variety and Giza 12 variety recorded the highest values of technical length/plant.

In this study, the analysis of variance for the combined data showed that the local flax varieties were superior in straw yield traits as compared with the imported ones whereas the Giza 12 variety exceeded the imported Aiane variety by 14.81, 62.34, and 30.62 % for total length/plant, straw yield/plant, and straw yield/fed as average of the two seasons, respectively. The present results are mainly due to the genetic differences and potential between the local flax varieties and the imported ones. These results are in good agreement with those obtained by Abd EL-Fattah and EL-Deeb (2006), EL-Deeb (2007), EL-Kady Eman and Abd EL-Fattah (2009), EL-Refaey *et al.* (2010), EL-Seidy *et al.* (2010), Hussein (2012), EL-Borhamy *et al.* (2015), EL-Shimy *et al.* (2015), Rashwan *et al.* (2016), EL-Borhamy *et al.* (2017) and Shahein *et al.* (2021).

Table 4: Means of straw yield and its related traits for ten tested local and introduced flax varieties in 2019/2020 and 2020/2021 and their combined analysis.

Character	Total length (cm)			Technical length (cm)			Main stem diameter (mm)		
Season / Variety	1st	2nd	Comb.	1st	2nd	Comb.	1st	2nd	Comb.
V_1: Sakha 1	112.48	109.17	110.82	95.99	93.53	94.76	2.49	2.03	2.26
V_2: Sakha 2	110.05	106.88	108.45	94.75	92.29	93.52	2.58	2.12	2.35
V_3: Sakha 3	112.99	109.58	111.29	99.91	97.45	98.68	2.03	1.56	1.80
V_4: Giza 9	113.03	111.70	112.36	101.13	98.66	99.90	2.08	1.62	1.85
V_5: Giza 10	112.61	109.38	110.99	100.61	98.15	98.38	1.96	1.50	1.73
V_6: Giza 11	119.42	117.36	118.54	98.47	96.01	97.24	3.19	2.73	2.96
V_7: Giza 12	120.51	118.59	119.55	99.38	96.92	98.15	3.09	2.63	2.86
V_8: Evona	107.60	105.45	106.52	98.05	95.59	96.82	1.64	1.17	1.40
V_9: Lezeta	106.43	104.20	105.31	97.71	95.25	96.48	1.55	1.08	1.31
V_{10}: Ariane	105.26	103.00	104.13	96.78	94.32	95.55	1.50	1.05	1.27
F. test	*	**	**	*	**	**	*	**	**
L.S.D at 5 %	3.81	3.53	2.46	2.93	2.75	1.88	0.28	0.22	0.18
L.S.D at 1 %	-	4.16	3.05	-	3.22	2.33	-	0.35	0.25

Table 4: cont.

Character	Straw yield/plant (g)			Straw yield/fed (ton)		
Season / Variety	1st	2nd	Comb.	1st	2nd	Comb.
V_1: Sakha 1	2.001	1.532	1.766	3.804	3.336	3.570
V_2: Sakha 2	1.889	1.421	1.655	3.704	3.236	3.470
V_3: Sakha 3	2.116	1.648	1.882	3.945	3.477	3.711
V_4: Giza 9	2.220	1.752	1.986	4.111	3.643	3.877
V_5: Giza 10	1.975	1.507	1.741	3.747	3.279	3.513
V_6: Giza 11	2.356	1.888	2.122	4.175	3.706	3.941
V_7: Giza 12	2.622	2.154	2.388	4.479	4.011	4.245
V_8: Evona	1.873	1.405	1.639	3.594	3.126	3.360
V_9: Lezeta	1.747	1.279	1.513	3.544	3.076	3.310
V_{10}: Ariane	1.705	1.237	1.471	3.485	3.016	3.250
F. test	**	*	**	**	**	**
L.S.D at 5 %	0.198	0.175	0.165	0.305	0.255	0.185
L.S.D at 1 %	0.232	-	0.182	0.416	0.364	0.212

B- Seed yield and its related traits:

Combined analysis for seed yield traits *i.e.* number of capsules/plant, number of seeds/plant, seed index, seed yield/plant, seed yield/fed, seed oil %, and oil yield/fed showed highly significant differences among the ten tested flax varieties Table 5. Giza 11 variety as a dual-purpose type ranked first and produced the highest values for all studied seed yield traits. On the contrary, the imported varieties, namely Evona, Lezeta, and Ariane gave the lowest value for the abovementioned traits as an average of the two seasons. In this respect, the Giza 11 variety outyielded the Ariane variety by 76.66, 128.72, 158.39, 173.33, 132.94, 42.36, and 231.61 % for the number of capsules/plant, number of seeds/plant, seed index, seed yield/plant, seed oil %, and oil yield/fed traits as average of the two seasons, respectively. On the other hand, other tested flax varieties recorded intermediate estimates for the previous traits as average of the two seasons. The differences between the tested flax varieties could be attributed to the differences in their genetic constitution and their response to environmental conditions. These results are in harmony with those obtained by Abd EL-Fattah and EL-Deeb (2006), EL-Deeb (2007), EL-Kady, Eman and Abd EL-Fattah (2009), EL-Seidy *et al.* (2010), Hussein (2012), EL-Borhamy *et al.* (2015), EL-Shimy *et al.* (2015), Rashwan *et al.* (2016), EL-Borhamy *et al.* (2017), Shahein *et al.* (2021) and EL-Sorady *et al.* (2022).

Table 5: Means of seed yield and its related traits for ten tested local and introduced flax varieties in 2019/2020 and 2020/2021 seasons and their combined analysis.

Character	No. of capsules/plant			No. of seeds/plant			Seed index (g)			Seed yield/plant (g)		
Season / Variety(v)	1st	2nd	Comb.	1st	2nd	Comb.	1st	2nd	Comb.	1st	2nd	Comb.
V_1: Sakha 1	13.34	12.88	13.11	104.12	101.66	102.89	9.68	9.22	9.45	1.612	1.144	1.378
V_2: Sakha 2	15.47	15.01	15.24	140.15	137.61	138.92	10.40	9.94	10.17	1.961	1.493	1.727
V_3: Sakha 3	10.55	10.09	10.32	72.28	69.82	71.05	5.52	5.06	5.29	1.098	0.630	0.864
V_4: Giza 9	10.75	10.29	10.52	73.91	71.45	72.68	5.61	5.15	5.38	1.149	0.681	0.915
V_5: Giza 10	11.98	11.52	11.75	78.78	76.32	77.55	6.51	6.05	6.28	1.199	0.731	0.965
V_6: Giza 11	16.20	15.74	15.97	143.61	141.15	142.38	10.85	10.39	10.62	2.079	1.611	1.845
V_7: Giza 12	14.05	13.59	13.82	107.55	105.09	106.32	10.11	9.65	9.88	1.650	1.182	1.416
V_8: Evona	10.64	10.18	10.41	66.19	63.73	64.96	4.88	4.42	4.65	0.756	0.688	0.722
V_9: Lezeta	9.53	9.07	9.30	64.75	62.31	63.54	4.52	4.05	4.29	0.739	0.671	0.705
V_{10}: Ariane	9.27	8.81	9.04	63.48	61.02	62.25	4.34	3.88	4.11	0.709	0.641	0.675
F. test	*	*	*	*	**	**	*	**	**	*	**	**
L.S.D at 5 %	0.65	0.54	0.48	1.85	2.05	1.08	0.42	0.37	0.22	0.092	0.078	0.058
L.S.D at 1 %	-	-	0.62	-	2.66	1.65	-	0.58	0.46	-	0.099	0.075

Table 5: cont.

Character	Seed yield/fed (kg)			Seed oil %			Oil yield/fed (kg)		
Season / Variety(v)	1st	2nd	Comb.	1st	2nd	Comb.	1st	2nd	Comb.
V_1: Sakha 1	675.93	673.47	674.70	38.45	37.99	38.22	259.89	255.85	257.87
V_2: Sakha 2	769.48	767.02	768.25	42.17	41.71	41.94	324.45	319.92	322.20
V_3: Sakha 3	458.57	456.11	457.34	33.75	33.29	33.52	154.77	151.84	153.30
V_4: Giza 9	496.86	494.40	495.63	35.11	34.65	34.88	174.45	171.31	172.87
V_5: Giza 10	536.15	533.69	534.92	38.35	37.88	38.12	205.61	202.62	203.91
V_6: Giza 11	792.11	789.65	790.88	43.26	43.49	43.49	346.31	340.81	343.95
V_7: Giza 12	689.74	687.28	688.51	39.68	39.22	39.45	273.69	269.55	271.62
V_8: Evona	391.56	389.10	390.33	32.37	31.91	32.14	126.75	124.16	125.45
V_9: Lezeta	370.32	367.86	369.09	32.11	31.65	31.88	118.91	116.43	117.67
V_{10}: Ariane	340.75	338.29	339.52	30.78	30.32	30.55	104.88	102.57	103.72
F. test	**	**	**	**	*	**	**	**	**
L.S.D at 5 %	21.63	19.98	15.45	0.85	0.79	0.64	19.88	14.16	10.22
L.S.D at 1 %	47.26	38.55	26.18	1.02	-	0.88	24.12	20.45	16.66

C- Fiber yield and its technological traits:

Results of fiber yield and its technological traits *i.e.* fiber yield/plant, fiber yield/fed, total fiber %, fiber length, and fiber fineness as affected by the tested flax varieties and the two studied retting methods in the two seasons and their combined are presented in Table 6.

1- Effect of retting methods:

Analysis of variance for data presented in Table 6 revealed that the two retting methods had significant differences in fiber yield and its technological traits *i.e.* fiber yield/plant, fiber yield/fed, total fiber %, fiber length, and fiber fineness. In contrast, the retted straw of ten tested flax varieties by running water recorded higher values for the abovementioned characters than retted straw of these varieties by using still water retting. In contrast, the running water retting exceeded still water retting by 21.15, 10.03, 11.09, 2.68, and 9.20 % for fiber yield/plant, fiber yield/fed, total fiber % fiber length, and fiber fineness as an average of the two seasons, respectively. These results could explain the favorable effect of microorganisms on fiber quality. These results were in harmony with those reported by Radesh *et al.* (1999), Sharma and Foughey (1999), Abd El-Fattah and EL-Deeb (2006), EL-Deeb (2007), EL-Refaey *et al.* (2010) and EL-Borhamy *et al.* (2015).

2- Varietal performance:

The analysis of variance for the combined data regarding fiber yield and its technological characteristics showed highly significant differences among the ten tested flax varieties. The Giza 9 variety followed by the Sakha 3 variety recorded the highest values for fiber yield/plant, fiber yield/fed, fiber length, and fiber fineness without significant differences between them. While the lowest values of these traits were recorded with Sakha 2 and Sakha 1 varieties. As shown in Table 6, the Giza 12 variety ranked second for fiber yield, and its technological traits had higher total and technical length/plant. The difference between Sakha 3 and Giza 9 did not reach the level of significance. On the other hand, the Evona variety followed by Lezeta variety recorded higher total fiber % and medium values for fiber yield/plant, fiber yield/fed fiber length, and fiber fineness as compared with the Giza 9 variety. In this respect, the superiority ratio between the new local flax variety Giza 9 and the imported Ariane was 31.80, 23.53, 3.55, 3.77, and 8.46 % for fiber yield per plant, and per feddan total fiber %, fiber length, and fiber fineness at the combined analysis. Such differences could be attributed to the genetic constituents of flax varieties. These results agree with those obtained by Abd EL-Fattah and EL-Deeb (2006), EL-Deeb (2007), EL-Refaey *et al.* (2010), Hussein (2012), EL-Borhamy *et al.* (2015), EL-Shimy *et al.* (2015), Rashwan *et al.* (2016) and EL-Borhamy *et al.* (2017).

Table 6: Means of fiber yield and its technological traits for ten tested local and introduced flax varieties as affected by two retting methods and their interaction in 2019/2020 and 2020/2021 seasons and their combined analysis.

Character	Fiber yield/plant (g)			Fiber yield/fed (ton)			Total fiber (%)		
Season / A- Retting method	1st	2nd	Comb.	1st	2nd	Comb.	1st	2nd	Comb.
Still water retting	0.377	0.285	0.331	0.759	0.638	0.698	19.45	19.16	19.30
Running water retting	0.451	0.351	0.401	0.826	0.729	0.778	21.76	21.12	21.44
F. test	**	*	**	**	**	**	**	*	**
L.S.D at 5 %	0.064	0.052	0.045	0.043	0.066	0.068	1.75	1.66	1.45
L.S.D at 1 %	0.082	-	0.066	0.055	0.085	0.095	2.22	-	1.88
C- Interaction (A x B) F. test	*	*	*	*	*	*	*	*N.S*	*N.S*
B-Variety (v)									
V_1: Sakha 1	0.378	0.269	0.323	0.677	0.578	0.627	17.79	17.33	17.56
V_2: Sakha 2	0.348	0.267	0.307	0.609	0.517	0.563	16.45	15.99	16.22
V_3: Sakha 3	0.450	0.353	0.402	0.921	0.795	0.858	23.35	22.88	22.12
V_4: Giza 9	0.510	0.409	0.460	0.924	0.838	0.882	22.47	23.01	22.74
V_5: Giza 10	0.402	0.314	0.358	0.795b	0.680	0.737	21.21	20.75	20.98
V_6: Giza 11	0.398	0.285	0.341	0.713	0.616	0.665	17.08	16.62	16.85
V_7: Giza 12	0.441	0.325	0.383	0.872	0.762	0.816	19.46	18.99	19.23
V_8: Evona	0.435	0.320	0.377	0.835	0.712	0.773	23.24	22.78	23.01
V_9: Lezeta	0.419	0.312	0.365	0.807	0.687	0.746	22.78	22.32	22.55
V_{10}: Ariane	0.355	0.304	0.349	0.773	0.655	0.714	22.19	21.73	21.96
F. test	*	**	**	**	**	**	*	**	**
L.S.D at 5 %	0.042	0.036	0.028	0.085	0.076	0.058	0.96	0.88	0.65
L.S.D at 1 %	-	0.055	0.036	0.105	0.095	0.085	-	1.05	0.76

Table 6: cont.

Character	Fiber length (cm)			Fiber fineness (N.m)		
Season / A- Retting method	1st	2nd	Comb.	1st	2nd	Comb.
Still water retting	100.32	98.41	99.36	307.45	304.99	306.22
Running water retting	103.52	100.66	102.02	335.63	333.17	334.40
F. test	**	*	**	**	**	**
L.S.D at 5 %	2.88	2.12	2.15	17.72	16.55	15.56
L.S.D at 1 %	3.66	-	2.44	25.33	23.22	18.95
C- Interaction (A x B) F. test	*	*	*	*	*	*
B-Variety (v)						
V_1: Sakha 1	100.39	97.93	99.16	278.59	276.13	277.36
V_2: Sakha 2	98.85	96.39	97.62	277.18	274.72	275.95
V_3: Sakha 3	104.52	102.06	103.29	341.78	339.32	340.55
V_4: Giza 9	104.64	102.18	103.41	348.69	346.23	347.46
V_5: Giza 10	104.37	101.91	103.14	336.83	334.37	335.60
V_6: Giza 11	102.70	100.24	101.47	316.63	314.17	315.40
V_7: Giza 12	103.35	100.89	102.12	333.45	330.99	332.22
V_8: Evona	101.92	99.46	100.69	330.86	328.40	329.63
V_9: Lezeta	101.57	99.11	100.34	329.78	327.32	328.55
V_{10}: Ariane	100.88	98.92	99.65	321.59	319.13	320.36
F. test	*	**	**	**	**	**
L.S.D at 5 %	2.73	2.16	1.48	15.66	12.55	11.22
L.S.D at 1 %	-	3.32	2.25	20.24	18.78	13.85

3- Interaction effect:

Regarding the interaction effect between the ten tested flax varieties and the two retting methods on fiber yield and its technological traits *i.e.* fiber yield/plant, fiber yield/fed, fiber length, and fiber fineness combined analysis for data presented in Table 7 showed that the four fiber traits affected significantly by the two studied factors, whereas the highest fiber yield/plant, fiber yield/fed, the longest fiber, and the finest fiber were obtained from Giza 9 variety when retted straw of the tested variety using running water retting method, followed by Sakha 3 cv. with no significant differences between them. However, the lowest values of these traits were given with the retted straw of the Sakha 2 variety using the still water retting method (the traditional retting method). On the other hand, the total fiber % trait was not affected by flax varieties and retting method interaction. This indicates that the two studied factors affected this trait independently. Similar results were reported by Abd El-Fattah and EL-Deeb (2006), EL-Deeb (2007), EL-Refaey *et al.* (2010) and EL-Borhamy *et al.* (2015).

Table 7: Significant interaction effect between the ten tested flax varieties and the two retting methods on fiber yield and its technological traits (combined analysis for 2019/2020 and 2020/2021 seasons).

Retting method	Sakha 1	Sakha 2	Sakha 3	Giza 9	Giza 10	Giza 11	Giza 12	Evona	Lezeta	Ariana
	Flax variety									
Fiber yield/plant (g)										
Still water retting	0.265	0.255	0.380	0.415	0.306	0.288	0.365	0.356	0.313	0.295
Running water retting	0.355	0.349	0.452	0.488	0.375	0.348	0.438	0.432	0.378	0.365
L.S.D at 5 %	0.066									
Fiber yield/fed (ton)										
Still water retting	0.618	0.615	0.795	0.815	0.688	0.650	0.750	0.715	0.725	0.672
Running water retting	0.711	0.682	0.883	0.908	0.768	0.728	0.835	0.812	0.788	0.735
L.S.D at 5 %	0.085									
Fiber length (cm)										
Still water retting	96.44	96.27	101.45	102.35	100.36	99.34	99.45	99.12	98.23	97.39
Running water retting	100.08	99.88	105.56	105.82	104.05	102.35	103.68	102.25	101.18	100.19
L.S.D at 5 %	2.95									
Fiber fineness (N.n)										
Still water retting	308.20	303.71	321.04	327.40	316.23	308.33	314.31	313.12	311.44	309.03
Running water retting	320.03	319.35	335.05	340.96	332.18	320.05	331.63	328.84	323.55	321.44
L.S.D at 5 %	12.55									

Correlation coefficient analysis:

Data of simple correlation coefficient between straw yield/fed and some of its associated traits for ten tested flax varieties in the combined analysis of 2019/2020 and 2020/2021 seasons are presented in Table 8. Results revealed that straw yield/fed was positive and highly significantly correlated with each of straw yield/plant (r = 0.912), total length/plant (r = 0.918), and main stem diameter (r = 0.975), but positive and insignificant associated with technical length/plant. A positive and highly significant correlation was found between straw yield/plant and each total length/plant (r = 0.812) and main stem diameter (r = 0.879), but negative and insignificant associated with technical length/plant (r = - 0.053). Also, total length/plant was positive and highly significantly correlated with main stem diameter (r = 0.933), but positive and insignificant associated with technical length/plant (r = 0.334). Moreover, a positive and insignificant association was found between technical length/plant and main stem diameter with an r value of 0.140. These results indicate that straw yield/plant, total length/plant, and main stem diameter are the main components to improve straw yield/fed. Similar results agree with those obtained by Aly and Awaad (1997), AL-Kaddoussi and Moawed (2001), Mostafa and Ashmawy (2003), Hussein (2007), Hussein (2012) and EL-Shimy *et al.* (2015).

Table 8: Simple correlation coefficient among straw yield and its related traits as affected by ten local and introduced flax varieties (combined analysis for 2019/2020 and 2020/2021 seasons).

Variables	1	2	3	4	5
1- Straw yield/fed	-	0.912^{**}	0.918^{**}	0.068	0.975^{**}
2- Straw yield/plant		-	0.812^{**}	- 0.053	0.879^{**}
3- Total length/plant			-	0.334	0.933^{**}
4- Technical length				-	0.140
5- Main stem diameter					-

The combined analysis of the data presented in Table 9 reveals a clear and simple correlation between seed yield/fed and some of its related traits. The results showed a positive and highly significant correlation between seed yield/fed and seed yield/plant (r = 0.985), number of capsules/plant (r = 0.981), number of seeds/plant (r = 0.959), seed index (r = 0.985), seed oil% (r = 0.977), and oil yield/fed (r = 0.996). Furthermore, a positive and highly significant relationship was discovered between seed yield/plant and each of the following variables: number of capsules/plant (r = 0.985), number of seeds/plant (r = 0.992), seed index (r = 0.975), seed oil% (r = 0.960), and oil yield/fed (r = 0.991). A positive and highly significant association was found between the number of capsules/plant and each of the number of seeds/plant (r = 0.978), seed index (r = 0.971), and oil yield/fed (r = 0.989). However, the association between the number of capsules/plant and seed oil % was positive, but insignificant (r = 0.462). The number of seeds/plant was positive and highly significant correlated with each of seed index (r = 0.949), seed oil % (r = 0.940), and oil yield/fed (r = 0.974). These associations could be employed through the selection both of higher seed yield/plant, a higher number of capsules and seeds/plant, and higher 1000 seed weight, higher oil content, and higher oil yield/fed. These results indicated that the previously studied seed traits are the main components to improve seed yield/fed. These results are following those obtained by Momtaz *et al.* (1977), Aly and Awaad (1997), AL-Kaddoussi and Moawed (2001), Mostafa and Ashmawy (2003), Hussein (2007), Hussein (2012) and EL-Shimy *et al.* (2015).

Table 9: Simple correlation coefficient among seed yield and its related traits as affected by ten local and introduced flax varieties (combined analysis for 2019/2020 and 2020/2021 seasons).

Variables	1	2	3	4	5	6	7
1- Seed yield/fed	-	0.985^{**}	0.981^{**}	0.959^{**}	0.985^{**}	0.977^{**}	0.996^{**}
2- Seed yield/plant		-	0.985^{**}	0.992^{**}	0.975^{**}	0.960^{**}	0.991^{**}
3- *No*. of capsules/plant			-	0.978^{**}	0.971^{**}	0.462	0.989^{**}
4- *No*. of seeds/plant				-	0.949^{**}	0.940^{**}	0.974^{**}
5- Seed index					-	0.943^{**}	0.977^{**}
6- Seed oil %						-	0.987^{**}
7- Oil yield/fed							-

A simple correlation coefficient between fiber yield and some of its technological traits is presented in Table 10. Relevant results showed that fiber yield/fed was positive and highly significantly associated with each fiber yield/plant (r = 0.735), total length/plant (r = 0.764), and fiber fineness (r = 0.751), but negative and insignificant correlated with total fiber % (r = -0.083). However, fiber yield/plant was positive and insignificant associated with each of total fiber % (r = 0.314), fiber length (r = 0.316), and fiber fineness (r = 0.485). Also, total fiber % was positive and highly correlated with fiber fineness (r = 0.801), but negative and insignificant associated with fiber length (r = -0.621). On the other hand, fiber length recorded a negative and insignificant correlation with fiber fineness (r = -0.331). These results indicated that each fiber yield/plant, total fiber %, and fiber fineness are the main technological traits for improving fiber yield/fed. Similar results were obtained by Aly and Awaad (1997), AL-Kaddoussi and Moawed (2001), Mostafa and Ashmawy (2003), Hussein (2007), Hussein (2012) and EL-Shimy *et al.* (2015).

Table 10: Simple correlation coefficient among fiber yield and its technological traits as affected by the ten local and introduced flax varieties and the two retting methods (combined analysis for 2019/2020 and 2020/2021 seasons).

Variables	1	2	3	4	5
1- Fiber yield/fed	-	0.735^{**}	0.764^{**}	$- 0.083^{**}$	0.751^{**}
2- Fiber yield/plant		-	0.314	0.316	0.485
3- Total fiber %			-	0.621	0.801^{**}
4- Fiber length				-	0.331
5- Fiber fineness					-

Path coefficient study:

The path coefficient procedure was used to analyze the final flax yield components to explore the relative importance of such components to the final flax yield (straw, seed, and fiber) per unit area of the land.

1- Path coefficient analysis related to straw yield and its components:

The results of partitioning simple correlation coefficient among straw yield and its components as affected by the ten tested flax varieties are presented in Table 11 and illustrated in Figure 1. The highest direct effect was obtained for the main stem diameter (0.636) and for straw yield/plant indirect effect via the main stem diameter (0.599). These results showed the important role of these components in increasing straw yield.

Table 11: Partitioning of simple correlation coefficients among straw yield and its components of the tested flax varieties (combined analysis for 2019/2020 and 2020/2021 seasons).

Source		Coefficient
Straw yield/plant via straw yield/fed		
Direct effect	Py_1	= 0.2490445
Indirect effect via total length/plant	$r_{12}Py_2$	= 0.0648542
Indirect effect via main stem diameter	$r_{13}Py_3$	= 0.5990992
Total	ry_1	= 0.9121998
Total length/plant via straw yield/fed		
Direct effect	Py_2	= 0.0798697
Indirect effect via straw yield /plant	$r_{12}Py_1$	= 0.2022241
Indirect effect via main stem diameter	$r_{23}Py_3$	= 0.6359039
Total	ry_2	= 0.9179977
main stem diameter via straw yield/fed		
Direct effect	Py_3	= 0.6815691
Indirect effect via straw yield/plant	$r_{13}Py_1$	= 0.2189101
Indirect effect via total length/plant	$r_{23}Py_2$	= 0.0745184
Total	ry_3	= 0.9749758

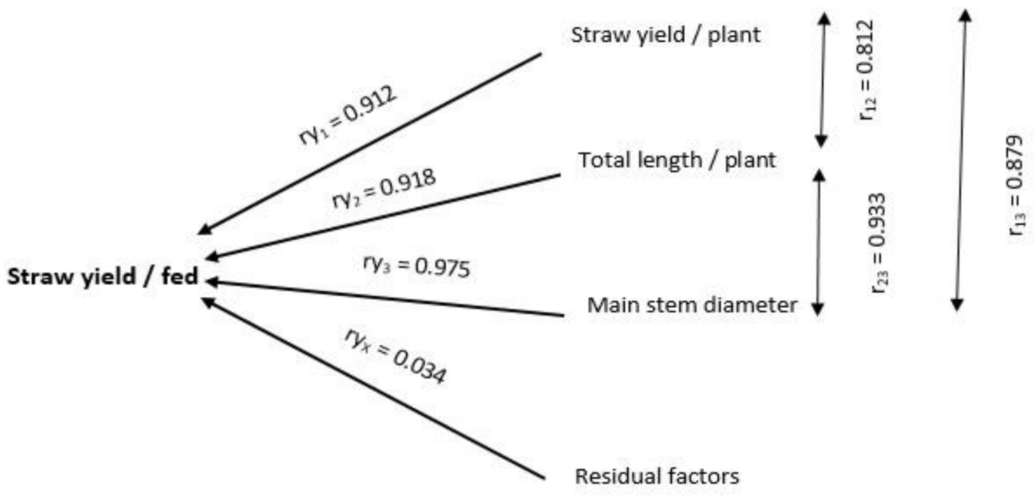

Fig 1: A path coefficient diagram of factors affecting straw yield (ton/fed) of the tested flax varieties (combined analysis for 2019/2020 and 2020/2021 seasons).

The direct and joint effects of straw yield components, presented as a percentage of straw yield/fed variation as affected by ten tested flax varieties are presented in Table 12. Results showed that straw yield/plant, main stem diameter, the interaction between straw yield/plant and main stem diameter, as well as the interaction between total length/plant and main stem diameter are considered the main sources of straw yield/fed variation, having the relative contribution of 6.20, 46.45, 29.84, and 10.16 % respectively. R^2 recorded herein 96.52 % of the total variation. However, the residual effect of the other straw yield components included in the present study was 3.48 %. This residual variation could be attributed to other yield-contributing traits. Finally, according to relative importance, the traits studied could be arranged as follows: main stem diameter (56.61), total length/plant (30.48), and straw yield/plant (9.43) (Table 13). These results are in harmony with those reported by Aly and Awaad (1997), AL-Kaddousi and Moawed (2001), Hussein (2007), Hussein (2012) and EL-Shimy *et al.*, (2015).

Table 12: Direct and joint effect of straw yield/plant, total length/plant and main stem diameter as well as their interaction at % of straw yield/fed variation for the tested flax varieties (combined analysis for 2019/2020 and 2020/2021 seasons).

Source of variation	**C.D**	**%**
Straw yield/plant	0.0620232	6.20232
Total length/plant	0.0063792	0.63792
Main stem diameter	0.4645364	46.45364
Straw yield/plant x total length/plant	0.0323032	3.23032
Straw yield/plant x main stem diameter	0.2984047	29.84047
Total length/plant x main stem diameter	0.1015789	10.15789
R^2	0.9652278	96.52278
R^2F	0.0347722	3.47722
Total	1.0000000	100.00000

Table 13: Total contribution of straw yield components.

Source	Direct	Indirect	Total
Straw yield/plant	6.20232	3.23032	9.43264
Total length/plant	0.63792	29.84047	30.47839
Main stem diameter	46.45364	10.15789	56.61153
Total	53.29388	43.22868	96.52256

2- Path coefficient analysis related to seed yield and its components.

The results of partitioning simple correlation coefficient among seed yield and its components of ten flax varieties are given in Table 14 and illustrated in Figure 2. The highest direct effect was obtained from seed yield/plant followed by the number of capsules/plant with mean values of 1.744 and 0.396, respectively. Meanwhile, the number of seeds/plant was negative (-1.159). The highest indirect effect was noticed for the number of seeds/plant was through indirect effect via seed yield/plant (1.718). These results showed that increasing alleles played a great role in increasing these traits through seed yield. The other indirect effects were negative, revealing that the decreasing alleles played a great role in these interactions to decrease seed yield. Direct and joint effects of seed yield/plant, number of capsules/plant, and number of seeds/plant as well as their interaction as % of seed yield/fed variation of the tested flax varieties as combined data are presented in Table 15. Results revealed that seed yield/plant, number of seeds/plant, and the interaction between seed yield/plant and number of capsules/plant were the main sources of flax seed/fed variation having relative contributions of 304.31, 134.31, 136.13, and 15.69 % respectively.

Table 14: Partitioning of simple correlation coefficients among seed yield and its components of the tested flax varieties (combined data of 2019/2020 and 2020/2021 seasons).

Source		Coefficient
Seed yield/plant via seed yield/fed		
Direct effect	Py_1	= 1.7444609
Indirect effect via no. of capsules/plant	$r_{12}Py_2$	= 0.3901907
Indirect effect via no. of seeds/plant	$r_{13}Py_3$	= - 1.1496516
Total	ry_1	= 0.9850000
No. of capsules/plant via seed yield/fed		
Direct effect	Py_2	= 0.3961327
Indirect effect via seed yield /plant	$r_{12}Py_1$	= 1.7182939
Indirect effect via no. of seeds/plant	$r_{23}Py_3$	= - 1.1334267
Total	ry_2	= 0.9810000
No. of seeds/plant via seed yield/fed		
Direct effect	Py_3	= - 1.1589229
Indirect effect via seed yield/plant	$r_{13}Py_1$	= 1.7305052
Indirect effect via no. of capsules/plant	$r_{23}Py_2$	= 0.38741782
Total	ry_3	= 0.95900000

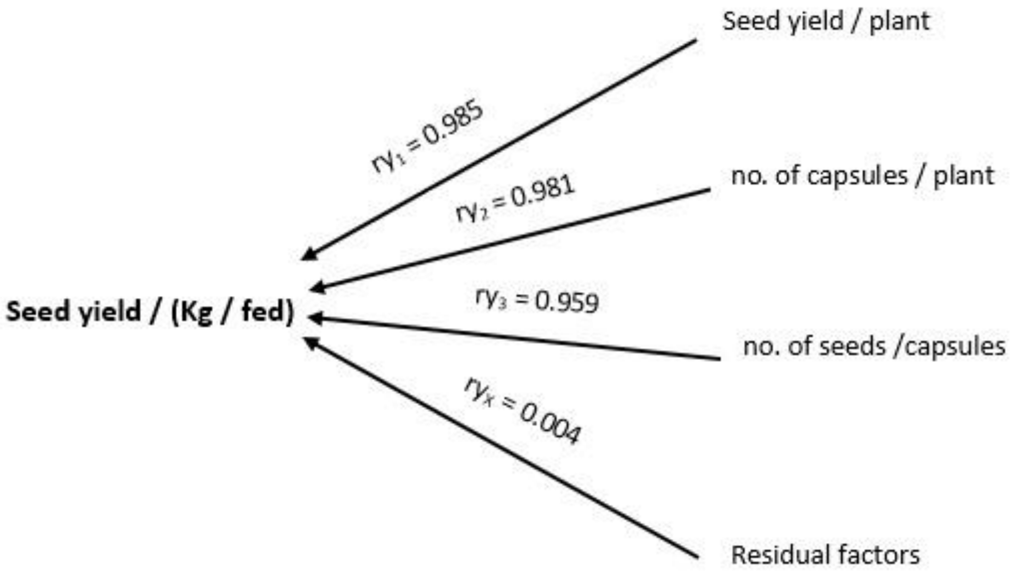

Fig 2: A path coefficient diagram of factors affecting seed yield (Kg/fed) of the tested flax varieties (combined analysis of 2019/2020 and 2020/2021 seasons).

Table 15: Direct and joint effect of seed yield/plant, no. of capsules/plant and no. of seeds/plant as well as their interaction as % of seed yield/fed variation of the tested flax varieties (combined data of 2019/2020 and 2020/2021 seasons).

Source of variation	**C.D**	**%**
Seed yield/plant	3.0431437	304.31437
*N*o. of capsules/plant	0.1569211	15.69211
*N*o. of seeds/plant	1.3431025	134.31025
Seed yield/plant x no. of capsules/plant	1.3613450	136.13450
Seed yield/plant x no. of seeds/plant	-4.0110442	-401.10442
*N*o. of capsules/plant x no. of seeds/plant	-0.8979748	-89.79748
R^2	0.9954933	99.54933
R^2F	0.0045067	0.45067
Total	1.0000000	100.00000

These results revealed that seed yield/plant, number of seeds/plant, number of capsules/plant, and the interaction between seed yield/plant and number of capsules/plant played a great role in flax seed yield/fed estimation since they made the most notable direct or indirect effects estimated by 99.54 % of seed yield variation. Therefore, the plant breeder could focus his attention on seed yield/plant, number of seeds/plant, and number of capsules/plant traits to maximize the final flax seed yield per unit area of the land. On the other hand, the residual effects of other seed yield attributes were 0.45 % of the total seed yield variation indicating that the most effective traits that contributed appreciably to the final seed yield diversity were examined in this study. In general, according to the relative importance the studied traits could be arranged as follows: seed yield/plant (440.45) and number of seeds/plant (44.51) (Table 16). The same trend was obtained by Aly and Awaad (1997), AL-Kaddousi and Moawed (2001), Hussein (2007), Hussein (2012) and EL-Shimy *et al.* (2015).

Table 16: Total contribution of seed yield components.

Source	Direct	Indirect	Total
Seed yield/plant	304.31437	136.13450	440.44887
No. of capsules/plant	15.69211	-401.10442	-385.41231
No. of seeds/plant	134.31025	-89.79748	44.51277
Total	454.31673	-354.7674	99.54933

3- Path coefficient analysis related to fiber yield and its technological traits.

Direct and indirect effects of fiber yield/plant, total fiber %, and fiber fineness on fiber yield/fed as affected by flax varieties and retting methods are given in Table 17 and illustrated in Figure 3. Results revealed that each of fiber yield/plant and total fiber % reflected the highest direct effects on fiber yield/fed with mean values of (0.539) and total fiber % (0.565). Meanwhile, the lowest direct effect on fiber yield/fed was fiber fineness (0.036). These results indicated that each fiber yield/plant and total fiber % played an important role in increasing fiber yield/fed. On the other hand, the indirect effect of fiber yield/plant through total fiber % and the indirect effect of total fiber % through fiber yield/plant on fiber yield/fed variation produced considerable values (0.177) and (0.169), respectively. The relative importance contributed to fiber yield/plant, total fiber %, fiber fineness and their interaction are given in Table 18. The obtained results showed that fiber yield/plant, total fiber %, and the interaction between them were the main sources of flax fiber yield/fed variation having the relative contribution of 29.14, 31.97, and 19.17 % respectively. It could be concluded that fiber yield/plant, total fiber %, and their interaction played a great role in flax yield determination. Since they made the most notable direct or indirect effect estimated by 85.60 % of the total fiber yield/fed variation, therefore the plant breeder could focus his attention on fiber yield/plant and total fiber % to maximize the final flax fiber yield per unit area of the land. In addition, the residual effects of other fiber attributes not encompassed in the present study were 14.39 % of the total fiber yield/fed variation indicating that the most effective traits that contributed appreciably to the final fiber yield diversity were examined in this study. Finally, according to the relative importance, the studied traits could be arranged as follows: fiber yield/plant (48.32) and total fiber % (33.87) (Table 19). The same conclusion was reported by Aly and Awaad (1997), AL-Kaddoussi and Moawed (2001), Hussein (2012) and EL-Shimy *et al.*, (2015).

Table 17: Partitioning of simple correlation coefficients among fiber yield/fed and its components of the tested flax varieties as affected by retting methods (combined data of 2019/2020 and 2020/2021 seasons).

Source		Coefficient
Fiber yield/plant via fiber yield/fed		
Direct effect	Py_1	= 0.5398759
Indirect effect via total fiber %	$r_{12}Py_2$	= 0.1775556
Indirect effect via fiber fineness	$r_{13}Py_3$	= 0.0175685
Total	ry_1	= 0.7349999
Total fiber % via fiber yield/fed		
Direct effect	Py_2	= 0.5654638
Indirect effect via fiber yield /plant	$r_{12}Py_1$	= 0.1695210
Indirect effect via fiber fineness	$r_{23}Py_3$	= 0.0290152
Total	ry_2	= 0.7639999
Fiber fineness via fiber yield/fed		
Direct effect	Py_3	= 0.0362237
Indirect effect via fiber yield/plant	$r_{13}Py_1$	= 0.0261839
Indirect effect via total fiber %	$r_{23}Py_2$	= 0.4529365
Total	ry_3	= 0.7639999

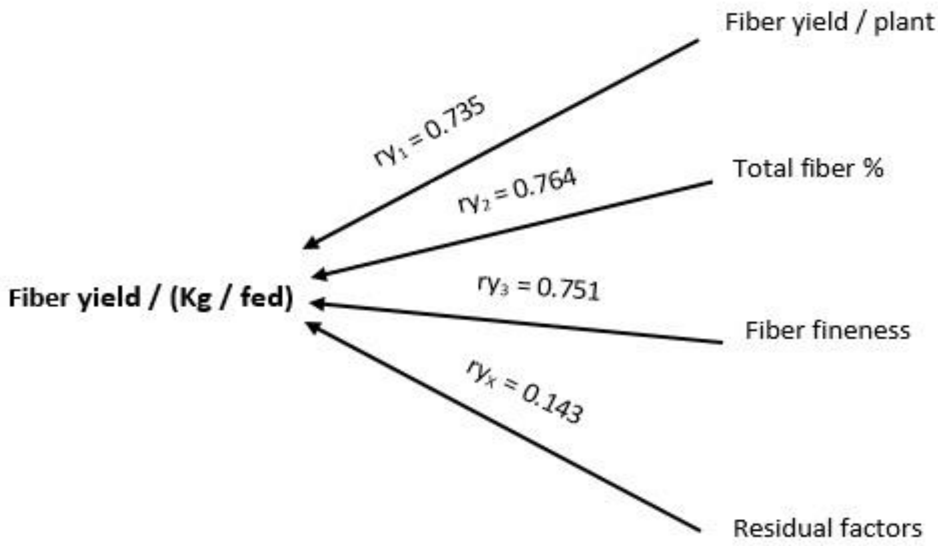

Fig 3: A path coefficient diagram of factors affecting fiber yield (ton/fed) of the tested flax varieties (combined analysis of 2019/2020 and 2020/2021 seasons).

Table 18: Direct and joint effects of fiber yield/plant, total fiber %, and fiber fineness as well as their interaction at % of fiber yield/fed variation for the tested flax varieties as affected by retting methods (combined data of 2019/2020 and 2020/2021 seasons).

Source of variation	C.D	%
Fiber yield/plant	0.2914659	29.14659
Total fiber %	0.3197493	31.97493
Fiber fineness	0.0013122	0.13122
Fiber yield/plant x total fiber %	0.1917159	19.17159
Fiber yield/plant x fiber fineness	0.0189696	1.89696
Total fiber % x fiber fineness	0.0328141	3.28141
R^2	0.8560271	85.60271
R^2F	0.1439729	14.39729
Total	1.0000000	100.00000

Table 19: Total contribution of fiber yield components.

Source	Direct	Indirect	Total
Fiber yield/plant	29.14659	19.17159	48.31818
Total fiber %	31.97493	1.89696	33.87189
Fiber fineness	0.13122	3.28141	3.41263
Total	62.25274	24.34996	85.6070

Conclusion

From the present study, it can be concluded that:

- Among the tested flax varieties Giza 9 cv. followed by Giza 12 exceeded the other tested flax varieties concerning straw yield traits, while Giza 11 cv. followed by Sakha 2 cv. outyielded the other tested flax varieties. Moreover, the three imported flax varieties, *i.e.*, Evona, Lezeta, and Ariane recorded intermediate estimates for straw traits and lowest estimates for seed traits. Giza 9 followed by Sakha 3 gave higher fiber yield and its technological traits.

- Retting methods had a significant effect on fiber yield and its technological traits, whereas the highest records for fiber yield/plant, fiber yield/fed, fiber length, and fiber fineness were obtained by using running water retting as compared with the still water retting method (traditional retting method).
- Furthermore, improving and maximizing the productivity and quality for the abovementioned new flax varieties (Giza 9, Giza 10, Giza 11, Giza 12, and Sakha 3) whereas the plant breeder could be focusing his attention on improving and maximizing straw, seed, and fiber yields per plant in turn the final straw and seed yields per unit area of land.
- From the previous results it could be concluded that the new flax varieties *i.e.* Giza 9, Giza 10, Giza 11, Giza 12, and Sakha 3 which released by Fiber Crop Research Department exceeded the introduced flax varieties *i.e.* Evona, Lezeta, and Ariane in straw and seed yields traits as well as fiber yield and its technological traits under these conditions. So, it may be recommended to encourage the expansion of these new varieties in the Middle Nile Delta and retted their straw using the running water retting method for extracting high fiber yield with best quality.

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تقدير المحصول ومكوناته وجودته وتحليل المحصول لبعض اصناف الكتان المحلية والمستورده تحت طريقتين مختلفتين من التعطين

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الملخص العربى

أجريت تجربتان حقليتان بالمزرعة البحثية بمحطة البحوث الزراعية بالجميزة محافظة الغربية – خلال الموسمين الزراعيين ٢٠١٩/٢٠٢٠، ٢٠٢٠/٢٠٢١. تهدف هذه الدراسة لتقييم تأثير طريقتى التعطين (التعطين بالماء الراكد – التعطين بالماء الجارى) على محصول القش والبذرة والصفات المرتبطة بهما وكذلك محصول الألياف والصفات التكنولوجية المرتبطة به لأصناف الكتان سخا ١، سخا ٢، سخا ٣، جيزة ٩، جيزة ١٠، جيزة ١١، جيزة ١٢ (أصناف محلية)، ايڤونا، ليزيتا و اريتا (أصناف مستورده) وقد استخدم تصميم القطاعات الكاملة العشوائية ذات الأربعة مكررات فى التجربتين الحقليتين خلال الموسمين الزراعيين. بينما بعد الحصاد فإن التوافيق مابين العشرة أصناف المختبرة وطريقتى التعطين قد اتبع فيها تصميم القطع المنشقة مرة واحده حيث وضعت طريقتى التعطين فى القطع الرئيسية بينما وزعت الأصناف العشرة المختبرة فى القطع الشقية. من ناحية أخرى تم دراسة معاملى الارتباط البسيط وكذلك معامل المرور بين محاصيل القش والبذرة والألياف وبعض الصفات المساهمة فيها. وتم تلخيص القيم والنتائج المتحصل عليها كمتوسط للموسمين الزراعيين على النحو التالى:

١- أظهرت الأصناف اختلافات معنوية فيما بينها لكل الصفات المدروسة حيث تفوق صنف الكتان جيزة ٩ متبوعا بالصنف جيزة ١٢ على بقية الأصناف الأخرى فى صفات محصول القش متمثلة فى الطول الكلى/نبات، محصول القش/نبات، محصول القش/فدان. من ناحية أخرى احتل صنف الكتان سخا ٣ متبوعا بالصنف جيزة ١٠ المركز الثانى لصفة الطول الفعال، بينما احتل الصنف جيزة ١١ متبوعا بالصنف جيزة ١٢ المركز الأول لصفة سمك ساق النبات بدون فروق معنوية بينهما. من ناحية أخرى تفوق صنف الكتان جيزة ١١ على بقية الأصناف الأخرى فى صفات محصول البذرة متمثلة فى عدد كبسولات النبات وعدد بذور النبات ودليل البذرة ومحصول البذرة للنبات والفدان، النسبة المئوية للزيت بالبذرة ومحصول الزيت للفدان، بينما سجلت الأصناف المستوردة متمثلة فى ايڤونا، ليزيتا و اريتا أقل القيم لصفات محصولى البذرة. من ناحية أخرى سجل صنف الكتان جيزة ٩ متبوعا بالصنف سخا ٣ وكذلك الصنف جيزة ١٠ على التوالى أعلى القيم لصفات محصول الألياف والصفات التكنولوجية المرتبطة به والمتمثله فى محصول الألياف/نبات، محصول الألياف/فدان، النسبة المئوية للألياف، طول الألياف ونعومتها.

٢- أظهرت طريقتى التعطين فروقاً معنوية فيما بينهما فيما يتعلق بمحصول الألياف والصفات التكنولوجية الخاصة به حيث سجلت طريقة التعطين بالماء الجارى أعلى القيم لهذه الصفات مقارنة بطريقة التعطين بالماء الراكد أو الطريقة التقليدية.

٣- أظهر التفاعل مابين الأصناف وطريقة التعطين فروق معنوية لصفات الألياف متمثلة فى محصول الألياف للنبات والفدان وطول الألياف ونعومتها.

٤- أظهرت النتائج ارتباط موجب وعالى المعنوية لمحاصيل القش والبذرة والألياف ومعظم الصفات المساهمة فيهم.

٥- أظهرت نتائج تحليل معامل المرور أن كل من محصول القش للنبات، وسمك ساق النبات والتفاعل مابين محصول القش للنبات والطول الكلى وكذلك التفاعل مابين الطول الكلى وسمك ساق النبات انها المصادر الرئيسية لاختلاف محصول القش القش للفدان بمساهمة نسبه تقدر بــ ٢٦,٢٠، ٤٦,٤٥، ٢٩,٨٤، ١٠,١٦ % على التوالى. أيضا يعتبر كل من محصول البذرة للنبات، عدد كبسولات النبات وعدد بذور الكبسولة والتفاعل ما بين محصول البذرة للنبات وعدد كبسولات النبات المصادر الرئيسية لاختلافات محصول البذرة للفدان بمساهمة نسبة تقدر بــ ٣٠٤,٣١، ١٥,٦٩، ١٣٤,٣١، ١٣٦,١٣ %على التوالى. وفيما يتعلق بمحصول الألياف والصفات التكنولوجية الخاصة به فقد أوضحت نتائج معامل المرور أن كل من محصول الألياف للنبات ونسبة الألياف الكلية والتفاعل بينهم المصادر الرئيسية فى اختلاف محصول الألياف بمساهمة نسبة تقدر بـ ٢٩,١٥%، ٣١,٩٧% وكذلك ١٩,١٧% للصفات المذكورة على التوالى.

- يمكن التوصية تحت ظروف هذه الدراسة بالتوسع فى زراعة أصناف الكتان المحلية المستنبطة حديثا مثل جيزة ٩، جيزة ١٠، جيزة ١١، جيزة ١٢ وسخا ٣ على التوالى مع استخلاص الألياف منها بطريقة التعطين بالماء الجارى وذلك لزيادة إنتاجية هذه الأصناف من الألياف كما ونوعا تحت ظروف منطقة وسط الدلتا.

الكلمات المفتاحية: أصناف الكتان، طرق التعطين، المحصول، الألياف وصفاتها التكنولوجية، تحليل الارتباط والمسار.