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Susceptibility of some Flax Lines to Powdery Mildew and Effect of The Disease on Agronomic and Technological Traits.

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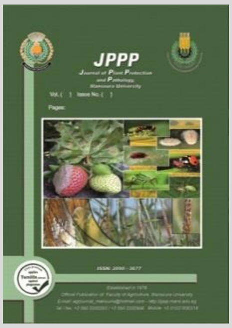

ABSTRACT

A two-year field study was conducted at El-Giza Agricultural Research Station to (1) estimate heritability of powdery mildew (PM) resistance when disease incidence (DI) or disease severity (DS) was used as criterion for evaluating resistance, (2) assess PM resistance of ten flax genotypes (lines), (3) determine relationship between each of DI and DS ratings and agronomic or technological traits. Genotypes component of variance of DI and DS were highly significant each year indicating that extensive genetic variation for DI and DS were present within the tested genotypes. Heritability and genetic advance of DS were greater in both years than those of DI demonstrating that considerable progress in breeding for PM resistance could be expected in current breeding programs when DS is used as criterion for evaluating resistance. Genotype 3 was a promising genotype for commercialization for the following reasons: firstly, it was the least susceptible genotype. Secondly, it showed environmentally stable performance. Thirdly, it showed superiority in some traits compared to some of the tested genotypes. No significant correlations were observed between disease intensity variables (DI and DS) and agronomic or technological traits.

Keywords: flax, powdery mildew, resistance, heritability

INTRODUCTION

Flax (*Linum usitatissimum* L.) 2n=30, is a multipurpose crop grown for the production of stem fiber and seed oil. It is also called linseed or flaxseed. Flax belongs to the genus *Linum* of the family linaceae. The name *Linum* originated from lin or thread and the species name *usitatissimum* means the most useful in latin (Dhirhi *et al*., 2017). There are two flax centers of origin i.e. South West Asia particularly in India and Mediterranean region of Europe (Richharia, 1962).

Almost every part of flax plant is commercially utilized, either directly or after processing. The oil is mainly used in many industries particularly paints. It is a source of complete protein (all 8 essential amino acids), complex carbohydrates, vitamins, minerals and a natural source of Omega 3 (Alfa linolenic acid) and Omega 6 fatty acids (Dayanidhi and Sahoo, 2013). Oil cakes also have very good nutritive feeding value for animals (Singh *et al*., 2016)

Flax has diversified into two main types, namely fiber and oil (linseed) type as well as an intermediate type. These types differ considerably in morphology, growth, habit, and agronomic traits. Fiber-type plants are usually taller and have fewer branches while oil types are often shorter, have more branches and produce more seeds (You *et al*., 2017). The Egyptian flax cultivars are dual purpose cultivars (El-Refaie *et al*., 2011)

Powdery mildew (*Oidium lini* Skoric) of flax is currently considered the most common, conspicuous, widespread, and easily recognized foliar disease of flax in Egypt. Flax is grown for both seeds and fibers in the Nile Delta, particularly in the northern governorates. This area is characterized by the prevalence of warm, wet weather during the late period of flax growing season. Such weather favors epiphytotic spread of powdery mildew (PM) when virulent isolates of the pathogen occur. Currently, the importance of this disease has increased probably due to the appearance and rapid distribution of new races capable of attacking the previously resistant cultivars (Aly *et al*., 1994).

Although the fungus causing PM on flax, in other countries, has been reported as *Erysiphe polygoni* DC, EX Marat (Nyvall, 1981), in Egypt, it has not been observed in its perefect stage. Therefore, in the present work the fungus will be referred to in its imperfect conidial stage, i.e. *Oidium lini* Skoric (Muskett and Colhoun, 1947). Recently, *O. lini* has been reconsidered and is now known as *Podosphaera lini* (Preston and CooK, 2019, Braun *et al*., 2019).

Currently, resistance is not available in the commercially grown flax cultivars in Egypt (Aly *et al*., 2002). Therefore, in years when environmental conditions favor the development of the disease, foliar application of fungicides has become the only commercially available management practice for its control (Aly *et al*., 1994). For instance, these fungicides included sulphur, and sterol biosynthesis inhibitors, such as Bayleton, Bayfidan, and Rubigan (Aly *et al*., 2000). Both Bellis and sulphur were effective in reducing PM severity on flax; however, sulphur surpassed Bellis in improving agronomic and technological traits (Aly *et al*., 2013). In other countries,

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fungicides were also applied for controlling the disease. For example, in Iran, flax PM was completely controlled by spraying with Calixin (Tridemorph) for 3 times at intervals of 15 days (Saeidi and Sharifnabi, 2006). In China, the disease was effectively controlled by the application of 40 % Flusilazole EC, 43 % Tebuconazole SC, and 40 % Myclobutanil WP, control efficiencies by these fungicides were 85.60, 78.29, and 74.06 %, respectively, after 20 days of the application (SuoLao *et al*., 2006).

Admittedly, synthetic fungicides that combat phytopathogenic fungi can increase yield and provide stability of crop production and market quality. On the other hand frequent use of fungicides may result in negative impacts such as the development of fungicide-tolerant pathogenic strains (Staub, 1991) and accumulation of fungicide-residues in the food chain above safe limits (El-Nahhal, 2004).

Use of flax cultivars with PM resistance can resolve all these proplems. Therefore, there is a need to improve PM resistance in flax cultivars through the introgression of resistance genes. There is a good possibility to attain this goal because extensive genetic variation for PM resistance has been identified in some flax populations. For example, Sharan *et al*., (2008) evaluated 120 genotypes of linseed against PM in India. Among the 120 genotypes, 37 were free from the disease, 43 were resistant, 24 were moderately resistant, and 20 were moderately susceptible. Disease severity was high in delayed sowing. Some of the genotypes that were free of the disease during timely sowing exhibited disease symptoms in delayed sowing, 18 genotypes remained free of the disease regardless of the sowing date. When Khare *et al*., (2011) evaluated 70 varieties of linseed under field conditions in India they found that eight varieties were highly resistant (no disease) and 34 were resistant to PM (1-6 % disease). Only five varieties showed susceptibility (more than 75 % of the plant area covered). The disease appeared when the temperature ranged from 16 to 21 ˚C with relative humidity 80-90 % and maximum (16) rainy days. Affected plants did not die, complete defoliation was noticed. Reddy *et al*. (2013) screened linseed genotypes for PM resistance in India. Among the tested genotypes, ten were resistant to PM under field conditions and therefore have the potential to reduce yield losses caused by PM. In India, Dhirhi *et al*. (2017) evaluated a set of one hundered fifty linseed germplasm accessions for PM tolerance. PM score ranged from 0 (free) to 5 (highly susceptible), 21 genotypes were found highly resistant, 44 genotypes showed resistance, 47 genotypes were moderately resistant, 20 genotypes were susceptible and only eight genotypes showed high susceptibility. Despite being highly susceptible some tested entries produced good yield and showed tolerance to PM. In Latvia, Stafecka *et al*. (2019) evaluated a total of 24 flax genotypes for PM resistance. The genotype Rezeknes exhibited higher resistance to PM at the seedling stage and complete resistance at the adult stage compared to all genotypes. In Egypt, Asran *et al*. (2020) conducted an out door pot experiment to evaluate reactions of 15 flax cultivars to PM in 6/4/2017 and 20/4/2017. The tested cultivars showed a wide range of disease severity ranged from 8.84 % on Ottowa 770 B to 78.35 % on Giza 10 in the first evaluation date and from 11.94 on Brasium to 86.72 % on Giza 10 in the second evaluation date.

Some genes for PM resistance have also been identified. For instance, it was postulated that the Chinses flax line 9801-1 carried a single dominant gene for PM resistance (Xue *et al*., 2008). A single dominant gene designated *pm1* was described in the Canadian cultivars, AC Watson, AC Mc Duff, and AC Emerson, and in the Eurpean cultivars Atlanta and Linda. Two additional putative dominant genes was also postulated in cultivar Linda (Asgarinia *et al*., 2013).

The objectives of the present study were to (1) estimate heritability of PM resistance when disease incidence (DI) or disease severity (DS) were used as criteria for evaluating resistance, (2) assess PM resistance of 10 flax genotypes, and (3) determine relationship between each of DI and DS ratings and agronomic or technological traits under field conditions.

MATERIALS AND METHODS

Experiments were conducted over two successive growing seasons at Giza Agricultural Research Station. Experiments consisted of randomized complete block design of three replicates (blocks). Plots were 2×3 m (6 m^2) and consisted of ten rows spaced 20 cm apart. Seeds of each genotype were sown manually at a rate of 70 g/plot. Planting dates were 15 December 2019 and 20 December 2020. Disease incidence (DI) and disease severity (DS) were rated visually on 15 April 2020 and on 20 April 2021. DI was measured as percentage of infected plants in a random sample of 50 plants/plot. DS was measured as percentage of infected leaves/plant in a random sample of ten plants/plot (Nutter *et al*., 1991).

At harvest, a random sample of ten plants were taken from each plot and observations were recorded on individual plants for each of the following agronomic and technological traits:

A. Straw yield and its related traits:

1. Total plant height (cm): Plant height from the cotyledonary node to the apical bud of each plant.
2. Technical stem length (cm): The length of the main stem from the cotyledonary node to the first or lowest branching point.
3. Straw yield/feddan (ton): Estimated based on the area of the whole plot.
4. Fiber yield/feddan (kg): Estimated based on the area of the whole plot.

B. Seed yield and its related traits:

1. Number of capsules per plant: number of harvested capsules per plant.
2. Number of seeds per capsules: number of harvested seeds per capsule.
3. Seed yield/plant (g): Weight of harvested seeds per plant.
4. Seed yield/feddan (kg): Estimated based on the area of whole plot.
5. Seed index (g): weight of 1000 seeds.

C. Technological traits:

1. Long fiber percentage: calculated according to the following formula:

$$\textbf{long fiber}\ (\%) = \frac{\text{long fiber yield/fed}}{\text{straw yield/fed}} \times 100$$

2.Oil percentage was determined by soxhlet apparatus according to Horwitz *et al*. (1965).
3.Oil yield/feddan (Kg): Oil (%) × seed yield/feddan (Kg).

Genetic parameters

1.Heritability in the broad sense (h^2) was calculated according to the following formula:

$$H^2 = \frac{\text{Genotypic variance } (\sigma^2_g)}{\text{phenotypic variance}(\sigma^2_{ph})} \times 100 \qquad \text{(Miller } et\ al., 1958)$$

Where: $\sigma^2_g = ((\sigma^2_e + r\sigma^2_g) - \sigma^2_e)/r$
$\sigma^2_{ph} = (\sigma^2_e + r\sigma^2_g)/r$

2.Genetic advance expected from selection (G. A.) was calculated according to the following formula:

$$(\sigma^2_g/\sigma^2_{ph})\ K \times \sqrt{\sigma^2_{ph}}$$

where k = 2.06 at 5% selection intensity (Miller *et al*., 1958)

Statistical analysis of the data

The experimental design of the present study was a randomized complete block with three replicates. Least significant difference (LSD) was used to compare treatment means. Analysis of variance (ANOVA) was carried out by MSTAT-C statistical package. Correlation analysis was performed with the software package SPSS 10.0.

RESULTS AND DISCUSSION

The present study was conducted in the 2019/2020 and 2020/2021 growing seasons (hereafter referred to as years 2019 and 2020, respectively to evaluate the field performance of ten flax lines (Table 1). Agronomic traits, technological traits, and disease intensity variables (DI and DS) were used as criteria for evaluating the tested lines (genotypes).

Table 1. Types and Pedigrees of flax genotypes screened in the present study.

Genotype no.	Type	Pedigree
1	Dual purpose	886/16/5/8/10/4/3/2465/1/3×Romanian 10
2	Dual purpose	888/15/1/9/9/1/4/5/× Romanian 20/2465/1/3
3	Dual purpose	888/38/4/3/8/2/2× Romanian 20/2465/1/3
4	Dual purpose	889/5/6/1/2465/1/3×L10
5	Dual purpose	889/33/4/4/1/3/4/2465/1/3×L10
6	Dual purpose	889/33/2465/1/3/L10
18	Dual purpose	932/1/9/4/4/1/2419/1×Escalina
809/2	Fiber	Giza 7×Marlin
888/22	Fiber	Romanian 20×2465×1×3
620/3/5	Fiber	L422×Giza 7

Genotypes components of variance of DI and DS were highly significant each year indicating that extensive genetic variation for DI and DS were present within the tested genotypes (Tables 2 and 3).

Table 2. Form and expected mean squares for analysis of variance of powdery mildew intensity data from 10 flax genotypes screened for relative resistance under field conditions at Giza in 2019/2020.

Source of variation	D.F.	Disease incidence			Disease severity			Expected mean square[a]
		M.S.	F.value	P>F	M.S.	F.value	P>F	
Replicates	2	30.48	0.49	0.620	100.51	1.69	0.213	$\sigma_e^2+g\sigma_r^2$
Genotypes	9	232.61	3.74	0.008	429.19	7.20	0.000	$\sigma_e^2+r\sigma_g^2$
Error	18	62.16			59.61			σ_e^2

[a] σ_e^2, σ_r^2 and σ_g^2 are variances due to experimental error, replications, and genotypes repectively, while g and r are no. of genotypes and no. of replications, respectively.

Table 3. Form and expected mean squares for analysis of variance of powdery mildew intensity data from 10 flax genotypes screened for relative resistance under field conditions at Giza in 2020/2021.

Source of variation	D.F.	Disease incidence			Disease severity			Expected mean square[a]
		M.S.	F.value	P>F	M.S.	F.value	P>F	
Replicates	2	57.86	0.74	0.492	137.54	2.22	0.138	$\sigma_e^2+g\sigma_r^2$
Genotypes	9	322.54	4.12	0.005	562.55	9.06	0.000	$\sigma_e^2+r\sigma_g^2$
Error	18	78.39			62.08			σ_e^2

[a] σ_e^2, σ_r^2 and σ_g^2 are variances due to experimental error, replications, and genotypes repectively, while g and r are no. of genotypes and no. of replications, respectively.

Heritable variation is useful for successful improvement and knowledge of heritability is important for selection measures, as it indicates the possibility and extent to which improvement can be brought. Heritability and genetic advance are two complementary concepts and it is necessary to exploit both in combination for selection. Therefore, the estimate of heritability alone without genetic advance, which indicates genetic gain resulting from selection, has little importance (Rastogi and Shukla, 2018). In the present study, values of heritability and genetic advance of DS were greater in both years than those of DI (Table 4) demonstrating that considerable progress in breeding for PM resistance could be expected in current breeding programs when DS is used as criterion for evaluating resistance.

Table 4. Heritability (h^2)[a] and genetic advance expected from selection (GA) for powdery mildew intensity variables of 10 flax genotypes screened for relative resistance under field conditions at Giza in2019/2020 and 2020/2021

	Disease incidence		Disease severity	
year	h^2	GA	h^2	GA
2019/2020	73.28	13.30	86.11	21.22
2020/2021	75.70	16.17	88.96	25.09

[a] Heritability (h^2) in the broad sense.

Natural conditions and inoculum levels in 2019 and 2020 at Giza resulted in high levels of PM and all the genotypes under evaluation were symptomatic. DI ratings ranged from 72 to 100 % in 2019 and from 51 to 93 % in 2020. DS ratings were also high and ranged from 65 to 98 % in 2019 and from 44 to 97 in 2020. None of the tested genotypes was significantly less susceptible than genotype no. 3, but the genotypes were either as susceptible as genotype 3 or significantly more susceptible (Table 5).

Table 5. Powdery mildew intensity variables of of ten flax genotypes tested under field conditions at Giza.

	2019/2020				2020/2021			
	Disease incidence		Disease severity		Disease incidence		Disease severity	
Genotype	%	Trans.[a]	%	Trans.	%	Trans.	%	Trans.
1	97	83.853	91	75.377	93	77.787	97	82.367
2	97	81.813	98	82.983	87	69.927	96	80.833
3	81	64.780	69	56.190	51	45.787	44	41.277
4	93	75.280	72	58.323	71	59.617	63	52.590
5	93	75.550	65	54.020	79	63.007	79	64.187
6	94	78.377	76	60.643	67	55.337	73	59.190
18	100	90.00	98	81.253	92	73.920	93	74.297
888/22	94	76.160	73	77.537	72	58.460	95	77.350
809/2	72	59.517	73	58.503	87	69.340	82	65.497
620/3/5	95	77.837	96	81.143	59	50.407	63	52.960
LSD ($P \leq 0.05$)		12.87		12.61		14.46		12.87

[a] **percentage data were transformed into arc sine angles before carrying out the ANOVA to produce approximately constant variance.**

Ranking of genotypes was determined based on the transformed data. Low ranking indicated resistance while high ranking indicated susceptibility. Small difference of ranking suggested stable performance while large difference suggested unstable performance (Tables 6 and 7) the results of the present study showed that genotype 3 was a promising genotype for commercialization for the following reasons: firstly, it was the least susceptible genotype. Secondly, it showed environmentally stable performance. Thirdly, it showed superiority in some agronomic traits compared to some of the tested genotypes (Tables 8 and 9).

No significant correlations were observed between disease intensity variables (DI and DS) and agronomic or technological traits (Table 10). This lack of correlation could be attributed to the fact that agronomic and technological traits of flax are highly heritable characters (El- Refaie *et al*., 2011; Singh *et al*., 2015; Siddiqui *et al*., 2016; Rajanna et al., 2020), which indicates that they were mainly governed by genetic factors and therefore, slightly affected by biotic stress resulted from infection by PM. This lack of correlation implies that selection for PM resistance would not necessarily lead to an improvement in agronomic traits and vice versa. In other words, this lack of correlation may complicate flax breeding program, which aims to the development of PM-resistant cultivars with superior agronomic traits. This lack of correlation was also reported by Aly *et al*. (2001) and Zayed *et al*. (2008). On other hand, seed yield/plant, seed yield/fed, and oil yield/fed. were notable exceptions because they showed significant and positive correlation with DS in the second season (Table 10). It is unlikely that this correlation indicated a causal relationship between DS and each of these traits. Therefore, the most likely explanation for such a correlation is the presence of another variable, such as nitrogen fertilization, which caused both DS and each of the tested traits to increase simultaneously. The results of Grant *et al*. (2016) lend support to this speculation. According to these results, flaxseed yield increased with increasing nitrogen fertilization. At the same time susceptibility of flax to diseases may also increase with increasing levels of nitrogen fertilization.

Table 6. Ranking of ten flax genotypes based on incidence of powdery mildew on these genotypes.

	2019/2020		2020/2021		Difference
Genotype	Incidence	ranking	Incidence	ranking	of ranking
1	83.85	9	77.79	10	1
2	81.81	8	69.93	8	0
3	64.78	2	45.79	1	1
4	75.28	3	59.62	5	2
5	75.55	4	63.01	6	2
6	78.38	7	55.34	3	4
18	90.00	10	73.92	9	1
888/22	76.16	5	58.46	4	1
809/2	59.52	1	69.34	7	6
620/3/5	77.84	6	50.41	2	4

Table 7. Ranking of ten flax genotypes based on severity of powdery mildew on these genotypes.

	2019/2020		2020/2021		Difference
Genotype	severity	ranking	severity	ranking	of ranking
1	75.38	6	82.37	10	4
2	82.98	10	80.63	9	1
3	56.19	2	41.28	1	1
4	58.32	3	52.59	2	1
5	54.02	1	64.19	5	4
6	60.64	5	59.19	4	1
18	81.25	9	74.30	7	2
888/22	77.54	7	77.35	8	1
809/2	58.50	4	65.50	6	2
620/3/5	81.14	8	52.96	3	5

Table 8. Yield, yield components, and technological traits of 10 flax genotypes infected with powdery mildew at Giza in 2019/2020.

Genotype	Total length (cm)	Technical length (cm)	Straw yield per plant (g)	Straw yield per fed. (Ton)	Long fiber yield per fed. (Kg)	Long fiber (%)	No. of capsules per plant	No. of seeds per capsule	Seed yield per plant (g)	Seed index (g)	Seed yield per fed. (Kg)	Oil (%)	Oil yield per fed. (Kg)
1	108.428	93.143	2.830	3.796	504.157	13.297	14.381	6.929	1.812	8.250	494.428	39.453	195.093
2	115.715	97.857	4.242	4.805	596.023	12.386	18.857	7.667	2.171	8.825	565.283	39.930	225.788
3	109.375	93.375	3.981	5.343	726.197	13.596	15.125	6.334	1.943	9.550	557.629	40.687	226.954
4	107.238	95.143	2.888	3.959	459.600	11.592	10.381	6.333	1.804	9.100	554.568	42.377	235.144
5	125.700	106.267	3.870	4.862	640.666	13.180	12.300	7.883	2.306	9.200	629.362	42.197	265.550
6	118.667	102.433	3.594	4.238	566.396	13.366	14.467	7.533	2.038	9.475	601.625	39.067	234.934
18	131.500	111.500	4.524	4.437	621.042	17.371	9.233	7.333	1.868	11.050	574.136	37.300	214.122
888/22	124.704	103.333	4.383	4.374	850.296	19.446	13.741	7.130	1.925	4.124	570.930	35.700	203.827
809/2	138.400	121.467	3.925	4.559	857.116	18.813	7.533	8.100	1.665	4.675	560.858	35.830	201.025
620/3/5	116.933	101.000	3.824	4.543	821.444	18.118	10.667	7.533	1.790	8.675	558.652	37.567	209.882
LSD ($p \leq 0.05$)	5.119	5.781	0.562	0.483	72.088	0.555	3.423	0.615	0.205	0.202	23.591	0.573	10.617

Table 9. Yield, yield components, and technological traits of 10 flax genotypes infected with powdery mildew at Giza in 2020/2021.

Genotype	Total length (cm)	Technical length (cm)	Straw yield per plant (g)	Straw yield per fed. (Ton)	Long fiber yield per fed. (Kg)	Long fiber (%)	No. of capsules per plant	No. of seeds per capsule	Seed yield per plant (g)	Seed index (g)	Seed yield per fed. (Kg)	Oil (%)	Oil yield per fed. (Kg)
1	118.233	105.233	2.228	3.324	436.030	13.155	6.467	7.500	1.369	8.075	461.655	39.113	180.622
2	103.667	89.667	2.315	3.390	425.101	12.565	10.633	7.317	1.670	8.800	501.222	39.983	200.408
3	103.852	84.630	2.938	3.990	540.425	13.547	14.704	7.055	0.782	9.125	337.144	40.357	136.204
4	100.196	86.810	2.047	3.243	379.724	11.693	7.952	7.000	0.327	9.050	286.067	41.797	119.614
5	108.722	91.556	5.486	5.436	700.017	12.975	25.778	6.722	1.592	9.425	538.074	42.400	228.253
6	119.733	99.400	3.379	4.287	581.330	13.575	14.867	7.217	0.833	9.500	417.258	38.850	162.210
18	93.533	62.700	4.110	4.147	676.020	16.312	19.067	6.067	0.950	10.775	458.805	36.390	166.523
888/22	106.278	78.833	5.369	5.130	983.996	19.223	36.611	5.889	1.750	4.087	581.194	36.377	211.382
809/2	116.278	93.222	4.169	5.001	959.718	19.149	19.500	7.083	1.045	4.025	465.699	35.767	166.268
620/3/5	101.167	85.000	2.735	3.355	605.028	17.998	13.792	8.292	0.606	8.750	409.436	37.370	153.065
LSD ($p \leq 0.05$)	6.310	3.440	0.576	0.605	95.010	0.562	4.400	0.466	0.387	0.123	52.720	0.532	19.577

Table 10. Correlation between powdery mildew intensity variables and each of yield, yield components, and technological traits for 10 flax genotypes tested under field conditions at Giza

Trait	2019/2020		2020/2021	
	Disease incidence (n=10)	Disease severity (n=10)	Disease incidence (n=10)	Disease severity (n=10)
Total length	-0.170[a] (0.639)[b]	0.012 (0.973)	0.140 (0.699)	0.158 (0.663)
Technical length	-0.263 (0.464)	-0.089 (0.807)	0.070 (0.849)	0.029 (0.936)
Straw yield per plant	0.028 (0.940)	0.341 (0.335)	0.004 (0.992)	0.180 (0.619)
Straw yield per fed.	-0.432 (0.212)	-0.216 (0.548)	-0.025 (0.946)	0.088 (0.809)
Long fiber yield per fed.	-0.519 (0.124)	0.099 (0.785)	-0.012 (0.974)	0.159 (0.660)
Long fiber (%)	-0.158 (0.663)	0.355 (0.314)	-0.049 (0.892)	0.128 (0.726)
No. of capsules per plant	0.232 (0.519)	0.217 (0.547)	-0.148 (0.683)	0.171 (0.636)
No. of seeds per capsule	-0.025 (0.945)	0.125 (0.731)	-0.215 (0.550)	-0.313 (0.378)
Seed yield per plant	0.245 (0.495)	-1.18 (0.745)	0.428 (0.217)	0.748* (0.013)
Seed index	0.513 (0.130)	-0.001 (0.998)	-0.063 (0.863)	-0.247 (0.491)
Seed yield per fed.	-0.082 (0.685)	-0.369 (0.294)	0.408 (0.242)	0.739* (0.015)
Oil (%)	0.602 (0.867)	-0.479 (0.161)	-0.188 (0.604)	-0.313 (0.378)
Oil yield per fed.	-0.018 (0.960)	-0.559 (0.093)	0.370 (0.292)	0.670* (0.034)

[a] Linear correlation coefficient.

[b] probability level.

The type and degree of correlation among agronomic and technological traits (Tables 11 and 12) varied from one season to another, indicating that correlation among traits is sensitive to changes in environmental conditions.

Possible mechanisms of resistance to PM in flax need to be explored. However, it has been demonstrated that resistant to PM is associated with energy-requiring biochemical defence reactions, which deprive the host of energy and ultimately led to quantitative and qualitative yield reduction, although no visible symptoms appear (Smedegaard-Peterson and Stolen, 1981). Therefore, it is possible that resistant flax genotypes have the ability to better compensate for the depleted energy in disease reaction than do susceptible genotypes. In *Uncinula necator*-grape pathosystem, it has been found that PM reduce photosynthesis of infected leaves of susceptible but not resistant grape cultivars (Lakso *et al*., 1982). Therefore, another possibility is that photosynthesis of susceptible flax genotypes is adversely affected by infection while that of resistant genotypes is not adversely affected by PM infection.

Table 11. Correlation among yield, yield components, and technological traits of 10 flax genotypes infected with powdery mildew and tested under field conditions at Giza in 2019/2020

Trait	Total length	Technical length	Straw yield per plant	Straw yield per fed.	Long fiber yield per fed.	Long fiber (%)	No. of capsules per plant	No. of seeds per capsule	Seed yield per plant	Seed index	Seed yield per fed.	Oil (%)	Oil yield per fed.
Total length		0.973**[a] (0.000)[b]	0.622 (0.055)	0.163 (0.653)	0.565 (0.088)	0.691* (0.027)	-0.552 (0.098)	0.747* (0.013)	-0.076 (0.834)	-0.381 (0.277)	0.443 (0.200)	-0.634* (0.049)	-0.113 (0.755)
Technical length			0.478 (0.163)	0.090 (0.804)	0.514 (0.128)	0.644* (0.044)	-0.667* (0.035)	0.728* (0.017)	-0.207 (0.566)	-0.368 (0.296)	0.385 (0.272)	-0.593 (0.071)	-0.125 (0.730)
Straw yield per plant				0.621 (0.055)	0.608 (0.062)	0.554 (0.097)	0.039 (0.916)	0.406 (0.244)	0.261 (0.467)	-0.115 (0.752)	0.467 (0.173)	-0.504 (0.138)	-0.019 (0.957)
Straw yield per fed.					0.465 (0.175)	0.041 (0.910)	0.229 (0.524)	0.126 (0.728)	0.419 (0.228)	0.112 (0.758)	0.438 (0.206)	0.101 (0.782)	0.359 (0.308)
Long fiber yield per fed.						0.843** (0.002)	-0.281 (0.432)	0.379 (0.280)	-0.249 (0.489)	-0.634* (0.049)	0.152 (0.676)	-0.708* (0.022)	-0.355 (0.314)
Long fiber (%)							-0.523 (0.121)	0.375 (0.285)	-0.486 (0.154)	-0.585 (0.076)	-0.001 (0.997)	-0.915** (0.000)	-0.594 (0.070)
No. of capsules per plant								-0.178 (0.623)	0.610 (0.061)	0.155 (0.669)	-0.060 (0.869)	0.327 (0.357)	0.169 (0.640)
No. of seeds per capsule									0.230 (0.522)	-0.252 (0.482)	0.451 (0.191)	-0.402 (0.249)	0.047 (0.898)
Seed yield per plant										0.335 (0.343)	0.651* (0.041)	0.515 (0.127)	0.771** (0.009)
Seed index											0.147 (0.685)	0.602 (0.066)	0.484 (0.156)
Seed yield per fed.												0.156 (0.191)	0.764* (0.041)
Oil (%)													0.515* (0.012)

[a] Linear correlation coefficient.

[b] probability level. Correlation is significant at $p \leq 0.01$(**) or $p \leq 0.05$(*).

Table 12. Correlation among yield, yield components, and technological traits of 10 flax genotypes infected with powdery mildew and tested under field conditions at Giza in 2020/2021

Trait	Total length	Technical length	Straw yield per plant	Straw yield per fed.	Long fiber yield per fed.	Long fiber (%)	No. of capsules per plant	No. of seeds per capsule	Seed yield per plant	Seed index	Seed yield per fed.	Oil (%)	Oil yield per fed.
Total length		0.862**[a] (0.001)[b]	0.045 (0.903)	0.249 (0.488)	0.144 (0.692)	-0.031 (0.932)	-0.058 (0.873)	0.250 (0.486)	0.235 (0.513)	-0.383 (0.275)	0.197 (0.585)	-0.025 (0.945)	0.211 (0.559)
Technical length			-0.314 (0.376)	-0.115 (0.752)	-0.274 (0.443)	-0.365 (0.300)	-0.401 (0.251)	0.568 (0.087)	0.105 (0.773)	-0.156 (0.666)	-0.047 (0.898)	0.344 (0.331)	0.078 (0.831)
Straw yield per plant				0.953** (0.000)	0.833** (0.003)	0.497 (0.144)	0.934** (0.000)	-0.666* (0.036)	0.503 (0.138)	-0.364 (0.302)	0.695* (0.026)	-0.258 (0.472)	0.645* (0.044)
Straw yield per fed.					0.831** (0.003)	0.427 (0.218)	0.857** (0.002)	-0.595 (0.070)	0.468 (0.172)	-0.449 (0.193)	0.612 (0.060)	-0.191 (0.597)	0.581 (0.078)
Long fiber yield per fed.						0.848** (0.002)	0.856** (0.002)	-0.492 (0.148)	0.349 (0.323)	-0.725* (0.018)	0.596 (0.069)	-0.656* (0.040)	0.404 (0.247)
Long fiber (%)							0.602 (0.066)	-0.181 (0.616)	0.109 (0.765)	-0.671* (0.034)	0.411 (0.238)	-0.885** (0.001)	0.137 (0.706)
No. of capsules per plant								-0.683* (0.029)	0.513 (0.129)	-0.501 (0.140)	0.686* (0.029)	-0.348 (0.324)	0.592 (0.071)
No. of seeds per capsule									-0.375 (0.286)	0.189 (0.601)	-0.403 (0.248)	0.171 (0.637)	-0.337 (0.341)
Seed yield per plant										-0.354 (0.316)	0.911** (0.000)	-0.062 (0.864)	0.937** (0.000)
Seed index											-0.419 (0.229)	0.521 (0.123)	-0.245 (0.496)
Seed yield per fed.												-0.332 (0.349)	0.947** (0.000)
Oil (%)													-0.018 (0.962)

[a] Linear correlation coefficient.
[b] probability level. Correlation is significant at p≤0.01(**) or p≤0.05(*).

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قابلية بعض سلالات الكتان للإصابة بالبياض الدقيقى و تأثير المرض على الصفات المحصولية و التكنولوجية.

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أجريت دراسة حقلية لمدة عامين بمحطة البحوث الزراعية بالجيزة و كانت أهداف الدراسة هى على النحو التالى: (١) تقييم معامل التوريث لصفة مقاومة مرض البياض الدقيقى فى الكتان عند استعمال حدوث المرض أو شدة المرض كمعيار لقياس مستوى المرض. (٢) تقييم عشرة تراكيب وراثية (سلالات) للكتان من حيث المقاومة لمرض البياض الدقيقى، (٣) تقييم العلاقة بين حدوث أو شدة المرض و الصفات المحصولية أو التكنولوجية للتراكيب الوراثية موضع الدراسة، كانت التراكيب الوراثية مصدرا عالى المعنوية للتباين فى حدوث المرض أو شدة المرض مما يدل على وجود اختلافات وراثية ملموسة بين التراكيب الوراثية لكل من حدوث المرض و شدة المرض. أمكن الحصول على قيم مرتفعة لكل من معامل التوريث و العائد الوراثى من الانتخاب، عند استعمال شدة المرض لتقييم مستوى الاصابة، و على العكس من ذلك، كانت هذة القيم منخفضة عند استعمال حدوث المرض، تراوح حدوث المرض على التراكيب الوراثية المختبرة من ٧٢ إلى ١٠٠ ٪ عام ٢٠١٩ و من٥١ إلى ٩٣ ٪ عام ٢٠٢٠. أما شدة المرض فقد تراوحت ما بين ٦٥ إلى ٩٨ ٪ عام ٢٠١٩ و من ٤٤ إلى ٩٧ ٪ عام ٢٠٢٠. أظهر التركيب الوراثى رقم ٣ أقل مستوى من القابلية للإصابة. يعد هذا التركيب الوراثى مبشرا على المستوى التجارى للأسباب التالية: أولا، هو التركيب الوراثى الأقل قابلية للإصابة. ثانيا، أظهر هذا التركيب الوراثى أداء يتسم بالثبات بيئيا. ثالثا، أظهر تفوقا فى بعض الخواص المحصولية أو التكنولوجية مقارنة ببعض التراكيب الوراثية الأخرى. لم تلاحظ ارتباطات معنوية بين كثافة المرض (حدوث المرض وشدة المرض) و كل من الصفات المحصولية أو التكنولوجية. قيم معامل الارتباط بين الصفات المحصولية أو التكنولوجية أظهرت حساسية للتغير فى الظروف البيئية. نوقشت الآليات المحتملة لمقاومة مرض البياض الدقيقى فى الكتان.