J. Agric. Sci. Mansoura Univ., 27(11): 7323 - 7333, 2002

EVALUATION OF SOME FLAX GENOTYPES FOR POWDERY MILDEW RESISTANCE UNDER GREENHOUSE AND FIELD CONDITIONS

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ABSTRACT

A two-year greenhouse and field study was conducted at Giza and El-Kanater Agricultural Research Stations to (1) estimate heritability of powdery mildew resistance when disease incidence and disease severity were used as criteria to evaluate resistance, (2) assess resistance to powdery mildew of 19 flax genotypes, and (3) quantify the relationship between disease intensity ratings and agronomic traits. Genotype component of variance of disease incidence was highly significant ($p \leq 0.01$) in two tests, while that of disease severity was highly significant ($P \leq 0.01$) in one test and significant ($P \leq 0.05$) in two tests. In addition, the highly significant and the significant genotype components of variance of disease incidence and disease severity were associated with high heritability and with high genetic advance expected from selection. Significant differences in the disease level occurred between the 19 genotypes; however, some of these differences were inconsistent from one test to another, which may indicate the occurrence of genotype x environment interaction. Most of the tested genotypes did not have satisfactory levels of powdery mildew resistance. Moreover, the powdery mildew resistance, which was expressed by few of the genotypes, was environmentally sensitive. Most of the significant correlation coefficients between disease intensity variables and agronomic traits were negative, which implies that selection for powdery mildew resistance would necessarily lead to an improvement in agronomic traits and vice versa.

INTRODUCTION

Flax (*Linum usitatissumum* L.) is considered as the most important bast fiber crop, it ranks second after cotton (Seedy fiber) in relation to economic importance and production. Powdery mildew (PM), casued by *Oidium lini* Škoric, is currently the most common, conspicuous widespread and easily recognized foliar disease of flax in Egypt. Over the last decade, 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). In India, Pandey and Misra (1993) reported that as the disease increased, yield losses increased ranging from 11.8 to 38.9%, yield losses were greater when the disease appears earlier in the season. Accurate assessment of losses due to the disease in Egypt has

not been reported. However, Aly *et al.* (1994) found significant negative correlations between disease intensity ratings and agronomic traits (yield and yield components).

Currently, resistance is not available in commercially grown flax cultivars in Egypt. 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 the disease (Aly *et al.*, 1994). However, complete dependence on fungicides for the disease control carries risks for the producers, in that accurate coverage and distribution of fungicides may not be achieved and there are potential problems with correct timing of applications. Furthermore, increasing concern for the environment will likely mean greater regulation of fungicide usage (Pearce *et al.*, 1996).

Use of cultivars with PM resistance can resolve all these problems. Therefore, there is a need to improve PM resistance in flax cultivars through the introgression of resistance genes. The emphasis in flax breeding programs for PM resistance should placed on adult plant resistance in the hope that it will be durable and effective against wide range of pathogen phenotypes (Leath *et al.*, 1991).

Extensive gnetic variation for PM resistance has been identified in some flax populations. For example, Prasad *et al.* (1988) evaluated 2822 linseed varieties for rust and PM resistance. The germplasm was classified depending on percentage of leaf area infected/plant. Only 24 lines were free from both rust and PM, and 17 showed multiple resistance (1-10% leaf area infected/plant). In addition, 38 genotypes were free from rust and resistant to PM, and 3 were free from PM and resistant to rust.

Sinha *et al.* (1993) evaluated 313 flax lines for their reaction to rust and PM over three years. Twenty two showed resistance towards rust and one line showed resistance to rust and PM. Basandrai *et al.* (1994) evaluated 200 indigenous and exotic flax genotypes for resistance to PM under field conditions. Twenty-four genotypes were free of infection, and 12 genotypes were resistant to PM and also possessed desirable plant height for fiber flax. Mahto *et al.* (1995) found a significant variability among 26 flax genotypes in resistance to pM. Eleven had above average stability and 7 of these had high yields. Tomas *et al.* (1999) found that PM occurred in linseed cultivar trials every year from 1993 to 1998 in either the south or east of the UK, but not in the central areas. Significant differences in the level of disease occurred between 19 cultivars. These differences were consistent from year to year, and from site to site. No cultivar was immune to PM infection, but high levels of partial resistance were recorded.

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 resistance to PM of 19 flax genotypes, and (3) quantify the relationship between disease intensity (DI and DS) ratings and agronomic traits.

MATERIALS AND METHODS

Greenhouse tests

Seeds of flax genotypes were planted on 15 November 1998 and on 20 November 1999 in a natural soil dispensed in 25-cm diameter clay pots (20 seeds/pot). The pots were distributed on greenhouse benches in a randomized complete block design of three replications. PM was allowed to develop naturally. DI and DS (Nutter *et al.*, 1991) were rated visually on 25 April 1999 and on 19 April 2000. DI was measured as percentage of infected plants/pot. DS was measured as percentage of infected leaves/plant in a random sample of 10 plants/pot.

Field tests

Experiments were conducted over two successive growing seasons at Giza and El-Kanater Agricultural Research Stations, beginning in the fall of 1998. Experiments consisted of a randomized complete block design of 3 replications (blocks). Plots were 2x3 m (6 m^2) and consisted of 10 rows spaced 20 cm apart. Seeds of each genotype were sown by hand at a rate of 70 g/plot. Planting dates were from 10 to 15 November each year. DI and DS were rated visually on 15 to 25 April each year. DI was measured as percentage of infected plants in a random sample of 100 plants/plot. DS was measured as percentage of infected leaves/plant in a random sample of 10 plants/plot.

Agronomic traits (yield and yield components)

At harvest, a random sample of 10 plants was taken from each replication (pot in greenhouse tests or plot in field tests) and observations were recorded for each of the following agronomic traits:

1. Total length (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/plant (g): weight of the mature air-dried straw per plant after removing the capsules.
4. Straw yield/feddan (ton): estimated based on the area of the whole plot.
5. Number of capsules per plant: number of harvested capsules per plant.
6. Number of seeds per capsule: number of harvested seeds per capsule.
7. Number of seeds per plant: number of harvested seeds per plant.
8. Apical branching (flowering) zone length (cm): The length from the first or lowest branching point to the top of the plant.
9. Seed yield/plant (g): weight of harvested seeds per plant.
10. Seed yield/feddan (kg): estimated based on the area of the whole plot.
11. Seed index (g): weight of 1000 seeds.
12. No. of apical branches: total number of apical branches of the plant.

Genetic parameters:

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

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

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 (GA) was calculated according to the following formula: $(\sigma^2 g/ \sigma^2 ph)\ K \times (s^2 ph)^{1/2}$, where K = 2.06 at 5% selection intensity (Miller *et al.*, 1958).

Statistical analysis of the data

Analysis of variance (ANOVA) was performed on agronomic traits and disease intensity variables to determine genotype effects. Mean comparisons for variables were made among genotypes by using least significant difference (LSD). The degree of association between disease intensity variables and agronomic traits was evaluated by calculating Pearson's correlation coefficient (r). ANOVA and correlation analysis were performed by computerized programs.

RESULTS AND DISCUSSION

The present study was conducted in 1998/1999 and 1999/2000 growing seasons (hereafter referred to as years 1998 and 1999, respectively) to evaluate the relative resistance of 19 flax genotypes to PM. The precision of field evaluation for genetic resistance is adversely affected by environmental variation and heterogeneous levels of natural inoculum. In addition, field evaluation is expensive. Thus, screening of genotypes for disease resistance under greenhouse conditions would overcome these difficulties and improve the selection process. Therefore, the tested genotypes were screened for PM resistance under both greenhouse and field conditions.

Genotype component of variance of DI was highly significant ($P \leq 0.01$) in two tests, while that of DS was highly significant ($P \leq 0.01$) in one test and significant ($P \leq 0.05$) in two tests (Table 1). In addition, the highly significant and the significant genotype component of variance of DI and DS was associated with high heritability and with high genetic advance expected from selection (Table 2). Taken together, these results suggest that considerable progress in breeding for PM resistance could be expected in current breeding programs if DI or DS is used as criteria for evaluating resistance. However, from practical point of view, DI is more appropriate than DS for evaluating resistance because it is more precise and more easily acquired (Rouse *et al.*, 1981), which would greatly facilitate the selection process.

Natural conditions and levels of inoculum of all the tests resulted in high levels of flax PM, and all the 19 genotypes under evaluation were symptomatic (Table 3). Significant differences in the disease level occurred between the 19 genotypes; however, some of these differences were inconsistent from one test to another, which may indicate the occurrence of genotype x environment interaction. For example, cultivar Ariana sustained statistically significant higher DS than cultivar Bleinka under Giza field

conditions in 1998; however, the difference in DS between the two cultivars was nonsignificant under Giza greenhouse conditions in 1999. Cultivar Wiera expressed statistically significant higher DI than line 2465/1/13 under Giza field conditions in 1998; however, DI on Wiera was statistically less than DI on line 2465/1/3 under Giza greenhouse conditions in 1999. Line 2465/1/3 and line 282/98/16 showed highly significant difference in DI under Giza field conditions in 1998, while the difference in DI between the two lines was nonsignificant in the same site in 1999. This extreme variation in PM resistance could be due to environmental conditions and the physiological races of the pathogen, which may differ from one test to another (Leath *et al.*, 1991). The results of greenhouse and field tests led us to conclude that most of the tested genotypes did not have satisfactory levels of PM resistance. Moreover, the PM resistance, which was expressed by few of the genotypes, was environmentally sensitive. For example, line 282/98/10 was highly resistant under Giza field conditions in 1998, highly susceptible in the same site in 1999, and moderately resistant under El-Kanater field conditions in 1999. Line 2465/1/3 was moderately resistant under El-Kanater field conditions in 1999, while it was highly susceptible under Giza greenhouse conditions in the same year. Cultivar Sakha I, which was resistant under El-kanater field conditions in 1999, showed high susceptibility under Giza greenhouse conditions in the same year.

It is well known that the type and degree of correlation between characters may facilitate or complicate selection process in breeding programs. Selection for a character may result in an improvement or deterioration in other characters according to the type and degree of correlation. Hence, it was desirable to assess the type and degree of association between disease intensity variables (DI and DS) and agronomic traits.

Most of the significant correlation coefficient between disease intensity variables and agronomic traits were negative (Table 4), which implies that selection for PM resistant would necessarily lead to an improvement in agronomic traits and vice versa. This negative correlation between disease intensity variables and agronomic traits was also observed by Aly *et al.* (1994).

Table 1: Form and expected mean squares for analysis of variance of powdery mildew intensity data from flax genotypes screened for relative resistance under greenhouse and field conditions.

Year	Location	Conditions	Source of variation	D.F.	Disease icnidence		Disease severity		Expected mean square [b]
					M.S.	F. value [a]	M.S.	F. value	
1998/1999	Giza	Greenhouse	Replications	2	1315.56	4.95*	1816.36	9.95**	$s^2e + gs^2r$
			Genotypes	14	297.46	1.12	153.36	0.84	$s^2e + rs^2g$
			Error	28	265.56		182.46		s^2e
		Field	Replications	2	281.69	2.32	615.20	1.44	$s^2e + gs^2r$
			Genotypes	14	742.95	6.12**	1085.36	2.54*	$s^2e + rs^2g$
			Error	28	121.31		427.66		s^2e
1999/2000	Giza	Greenhouse	Replications	2	38.44	0.46	281.78	2.99	$s^2e + gs^2r$
			Genotypes	18	817.44	9.71**	939.70	9.96**	$s^2e + rs^2g$
			Error	36	84.20		94.31		s^2e
		Field	Replications	2	241.95	5.12*	132.22	0.63	$s^2e + gs^2r$
			Genotypes	12	54.56	1.15	510.42	2.42*	$s^2e + rs^2g$
			Error	24	47.28		210.81		s^2e
	El-Kanater	Field	Replications	2	1373.83	4.46*	1530.91	2.11	$s^2e + gs^2r$
			Genotypes	12	454.91	1.48	757.43	1.04	$s^2e + rs^2g$
			Error	24	308.13		726.70		s^2e

[a] F. value is significant at $P \leq 0.05$ (*) or $P \leq 0.01$ (**).

[b] s^2e, s^2r, and s^2g are variances due to experimental error, replications, and genotypes, respectively; g and r, respectively, are no. of genotypes and no. of replications.

Table 2: Genetic variance (GV), phenotypic variance (PV), heritability (h^2), and genetic advance expected from selection (GA) for powdery mildew intensity variables of flax genotypes screened for relative resistance under greenhouse and field conditions.

Year	Location	Conditions	Disease icnidence				Disease severity			
			GV	PV	h^2 [a]	GA	GV	PV	h^2	GA
1998/1999	Giza	Greenhouse	10.64	99.15	10.73	2.20	... [b]	51.12	...	...
		Field	207.21	247.65	83.67	27.12	219.23	361.79	60.60	23.74
1999/2000	Giza	Greenhouse	244.41	272.48	89.70	30.50	281.80	313.23	89.96	32.80
		Field	2.43	18.19	13.35	1.17	99.87	170.14	58.70	15.77
	El-Kanater	Field	48.93	151.64	32.27	8.18	10.24	252.48	4.06	1.33

[a] Heritability (h^2) in the broad sense..
[b] The parameter was not calculated because of the lack of genetic variation among the tested genotypes..

Table 3:Powdery mildew intensity variables of flax genotypes udner greenhouse and field conditions.

Genotype	Giza (1998/1999) (Greenhouse)		Giza(1998/1999) (Field)		Giza (1999/2000) (Greenhouse)		Giza (1999/2000) (Field)		El-Kanater (1999/2000) (Field)	
	Disease incidence [a] %	Disease severity [b] %	Disease incidence [c] %	Disease severity [d] %	Disease incidence %	Disease severity %	Disease incidence %	Disease severity %	Disease incidence %	Disease severity %
Alba	83.33 [e]	89.58	82.00	67.49	98.33	94.49	90.67	84.58	86.67	68.59
Ariana	96.67	89.48	100.00	92.68	99.00	95.44	...	...	...	...
Bleinka	96.67	80.77	88.00	41.34	93.33	89.18	...	...	...	...
Bombay	70.00	66.76	80.00	60.90	47.67	81.29	76.00	45.53	70.67	71.13
Jitka	93.33	88.11	89.33	77.15	95.33	93.97	86.67	77.37	73.33	58.18
Midin	70.00	85.67	92.00	80.63	59.67	61.16	...	...	...	...
Gentiana	83.33	74.08	80.00	91.43	89.00	89.14	...	...	...	...
Istru	86.67	79.80	94.67	87.40	60.00	44.34	82.67	83.94	81.33	77.17
Daniela	73.33	82.29	88.67	73.17	62.33	39.82	85.33	86.50	64.00	62.80
Texa	93.33	92.00	80.00	88.76	100.00	99.51	...	...	...	...
Vaiking	96.67	79.42	90.00	73.42	86.67	92.65	88.00	75.35	68.00	56.67
Wiera	83.33	78.09	100.00	73.21	82.33	86.48	...	...	...	...
2465/1/3	100.00	93.31	64.67	37.69	100.00	100.00	85.33	87.17	50.96	47.14
282/98/16	90.00	86.89	37.33	39.07	75.33	88.50	86.67	90.42	53.33	46.97
Jawhar	80.00	82.76	88.00	89.14	80.00	92.07	88.00	62.54	64.00	57.44
Sakha 1	... [f]	...	...	...	89.00	93.40	80.00	86.82	49.33	32.79
Sakha 2	...	...	...	...	99.33	98.68	87.33	80.80	80.00	74.14
Giza 7	...	...	...	...	98.33	93.65	84.00	87.26	80.00	79.64
Giza 8	...	...	...	...	98.67	98.11	92.00	93.48	78.15	58.43
LSD ($P \leq 0.05$)	N.S	N.S	18.42	34.58	15.14	16.02	N.S.	24.47	N.S.	N.S.
LSD ($P \leq 0.01$)	N.S	N.S	24.85	46.65	20.26	21.44	N.S.	33.16	N.S.	N.S.

[a] Disease icnidence is the percentage of infected plants/pot
[b] Disease severity is the percentage of infected leaves/plant in a random sample of 10 plants/pot.
[c] Disease icnidence is treh percentage of infected plants a random sample of 100 plants/plot
[d] Disease severity is the percentage of infected leaves/plant in a random sample of 10 plants/plot.
[e] Mean of three replications. [f] The genotype was not tested.

Table 4: Correlation coefficients for powdery mildew intensity variables (disease incidence and disease severity) and agronomic traits of flax genotypes infected with powdery mildew udner greenhouse and field conditions.

Agronomic trait	Giza (1998/1999) (Greenhouse)		Giza (1998/1999) (Field)		Giza (1999/2000) (Greenhouse)		Giza (1999/2000) (Field)		El-Kanater (1999/2000) (Field)	
	Disease incidence % (n = 15)	Disease severity % (n = 15)	Disease incidence % (n = 10)	Disease severity % (n = 10)	Disease incidence % (n = 16)	Disease severity % (n = 16)	Disease incidence % (n = 13)	Disease severity % (n = 13)	Disease incidence % (n = 13)	Disease severity % (n = 13)
Total length (cm)	-0.048 [a]	-0.168	-0.129	-0.362	-0.006	0.173	-0.288	0.606*	0.065	-0.121
Technical length (cm)	-0.069	-0.263	0.195	0.175	-0.046	0.151	-0.168	0.653*	0.100	0.039
Flowering zone length (cm)... [b]	...		-0.395	-0.607x	0.082	0.068	-0.148	-0.479x	0.024	-0.532x
Straw yield/plant (g)	-0.039	-0.307	-0.342	-0.281	0.225	0.381	-0.075	0.052	-0.430	-0.548x
No. of capsules/plant	-0.037	-0.424	...	...	-0.208	-0.260	0.127	-0.346	-0.277	-0.669*
No. of seeds/capsules	-0.292	-0.500 x	0.442	0.392	-0.493	-0.365	-0.444	-0.521x	-0.360	-0.261
No. of seeds/plant	...	...	-0.170	0.145	...	...	...	...	...	...
Seed yield/plant	-0.374	-0.369	-0.473	-0.323	-0.149	0.012	0.081	-0.039	-0.313	-0.575*
No. of apical branches	-0.228	-0.493 x	-0.630x	-0.514	-0.413	-0.334	0.281	0.090	-0.447	-0.658*
Seed index (g)	...	...	-0.610x	-0.510	...	...	0.119	0.276	-0.319	-0.271
Straw yield/fed. (ton)	...	...	...	...	...	...	-0.075	0.414	0.096	0.071
Seed yield/fed. (kg)	...	...	...	...	...	...	-0.15	0.129	-0.433	-0.499x

[a] Pearson's correlation coefficient (r) is significant at $P \leq 0.10$ (x) or $P \leq 0.05$ (*). [b] The trait was not evaluated.

ACKNOWLEDGEMENT

This study was supported in part by the Commission of the European Community through the Research Project No. E.U. 13.74.96 (Integrated Control of Principal Flax Diseases in Egypt).

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J. Agric. Sci. Mansoura Univ., 27(11), November, 2002

تقييم بعض التراكيب الوراثية للكتان من حيث المقاومة لمرض البياض الدقيقى تحت ظروف الصوبة والحقل

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أجريت الدراسة الحالية لمدة عامين تحت ظروف الصوبة والحقل فى محطتى بحوث الجيزة والقناطر وكانت أهداف الدراسة هى على النحو التالى: (١) تقدير معامل التوريث لصفة مقاومة مرض البياض الدقيقى فى الكتان عند استعمال حدوث المرض وشدة المرض كمعايير لتقييم صفة المقاومة. (٢) تقييم ١٩ تركيب وراثى من حيث المقاومة لمرض البياض الدقيقى. (٣) التقدير الكمى للعلاقة بين المتغيرات الدالة على كثافة المرض والصفات المحصولية. أظهرت الدراسة أن التراكيب الوراثية المختبرة كانت مصدراً عالى المعنوية للتباين فى حدوث المرض فى اختبارين، كما كانت التراكيب الوراثية مصدراً عالى المعنوية للتباين فى شدة المرض فى إختبار واحد فى حين كانت مصدراً معنوياً للتباين فى شدة المرض فى إختبارين. إن المعنوية أو المعنوية العالية للتراكيب الوراثية كمصدر للتباين فى حدوث وشدة المرض ارتبطت بمستوى مرتفع لمعامل التوريث وكذلك بمستوى مرتفع للتحسين الوراثى المتوقع من الإنتخاب. وجدت فروق معنوية فى مستوى الإصابة بالمرض بين التراكيب الوراثية، إلا أن هذه الفروق كانت تتغير من إختبار إلى آخر، مما يدل على احتمال وجود تفاعل بين التراكيب الوراثية والظروف البيئية. أغلب التراكيب الوراثية كانت قابلة للإصابة بالمرض، أما صفة المقاومة - التى لوحظت على القليل من التراكيب الوراثية - فكانت حساسة للتغيرات فى الظروف البيئية. أغلب معاملات الارتباط المعنوية - بين المتغيرات الدالة على كثافة المرض والصفات المحصولية - كانت سالبة مما يدل على أن الإنتخاب لصفة المقاومة للمرض سيؤدى بالضرورة إلى تحسين فى الصفات المحصولية والعكس صحيح.