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EFFECT OF CULTIVAR ON THE EFFICIENCY OF FUNGICIDES IN CONTROLLING POWDERY MILDEW OF FLAX AND RELATIONSHIP OF AGRONOMIC AND TECHNOLOGICAL TRAITS TO DISEASE SEVERITY

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ABSTRACT

A two-year field study was conducted at El-Ismailiya, Egypt, to evaluate the fungicides Bellis and Sulphurs applied as a foliar sprays for controlling powdery mildew on six flax cultivars. Disease severity, straw yield, and seed yield were used as criteria for evaluating the performance of fungicide on the tested cultivars. Analysis of variance (ANOVA) showed that each of the fungicides and cultivar was highly significant source of variation ($p = 0.000$), in disease severity, strae yield, and seed yieled. ANOVA also showed that fungicide x cultivars interaction was a highly significant source of variation ($p = 0.000$) in disease severity, while it was insignificant in straw and seed yields. Both fungicides were effective in reducing disease severity; however, sulphur surpassed Bellis in increasing straw yield and seed yield. Therefore, linear regression analysis was used to determine the relationship between agronomic or technological traits and powdery mildew severity (PMS). All traits showed significant negative correlations with PMS after the appliction of fungicides, which suggest that control of late-season powdery mildew could be economically important when PMS on flax cultivars is high.

Keywords: Flax, *Odium line*, fungicides, agronomic traits

INTRODUCTION

Flax (*Linum usitatissimum* L.) powdery mildew caused by *Oidium lini*, Skoric, which is now identified as a synonym of *Podosphaera lini* (**Preston and Cook 2019; Braun et al., 2019**). Flax is a dual-use plant that has been grown for oil and fiber and for many medical and industrial uses for more than 8,000 years (Emam, 2019). Flax is one of the most important multipurpose plants for oil and fiber production in Egypt and throughout the world and is rich in oil (41%), protein (20%) and dietary fiber (28%) (Barkyet al., 2014). The land area in Egypt is relatively small and has declined dramatically in the last ten years. There was a significant decrease in areas planted with hemp, which reached around 16345 Feddan (Feddan = 4200 m2) in the winter of 2005/2006 (AERMAE, 2007). In the past two years, flax growing areas can grow slowly and reach 25,000 Feddan in the winter of 2019/2020. Flaxseed seedlings blight are caused by various fungi that spread in the soil (Ashour et al., 2019). The most important are *Rhizoctonia solani* and *Fusarium* spp. Specifically, *F. oxysporum* (Aly et al., 2014). Powdery mildew (PM) is currently considered the most common conspicuous widespread and easily recognized foliar disease on flax in Egypt. Flax is grown for both seeds and fibres in the Nile Delta, in particular, the northern governorates. This area is characterized by the prevalence of warm, wet weather during the late period of flax growing season. Such weather favours the epiphytotic spread of the disease when virulent isolate of *O. lini* occurs **Mansour (1998)**. However, yield losses and disease intensity vary from year to year depending on location, fertilization, weather conditions, and cultivar **Mansour (1998)**.
Currently, resistance to powdery mildew is not available in commercially grown flax cultivars in Egypt. Therefore, in years when environmental conditions favour the development of the disease, foliar application of fungicides has become the only commercially available management practice for the disease control. These fungicides include sulphur and sterol biosynthesis inhibitors, such as Bayleton, Bayfidan, and Rubigan **Khalil *et al.* (1987), Aly *et al.* (1994), Mansour (1998), Mansour *et al.* (1999) and Aly *et al.* (2000)**. However, field evaluation of the effect of flax cultivar on the efficiency of fungicides used to suppress the disease has not been determined. Therefore, the present study was conducted in the 2014/2015 and 2015/2016 growing seasons (hereafter referred to as years 2015 and 2016 respectively) to explore the possible effects of six flax cultivars, with varying levels of susceptibility to powdery mildew, on the efficiency of Bellis and Sulphur in controlling the disease under field conditions.

MATERIAL AND METHODS

Field trials

Experiments were conducted over two successive growing seasons at El-Ismailiya Agricultural Research Station, beginning in the fall of 2014. Experiments consisted of a randomized complete block design with three replications (blocks). The plot was 2x3 m (6 m²) and consisted of 20 rows spaced 10 cm apart. Plots were manually planted with the tested cultivars (Table 1) at a rate of 50 kg/ feddan on 20 November 2014 and on 25 November 2015. All the agricultural practices for growing flax were conducted according to the recommendations. Powdery mildew was allowed to develop naturally, and the initial fungicide application to cultivars coincided with the first sign of the disease. Foliar sprays were applied at the recommended rates (Table 2) on 10 and 24 April 2015 and on 25 April and 10 May 2016. Disease severity Nutter et al. (1991) was rated visually on 10 May 2015 and on 25 May 2016. Disease severity was measured as the percentage of infected leaves/plant in a random sample of 10 plants/plot. Fungicidal efficiency was calculated based on disease severity according to the following formula [(DSC-DSF)/DSC] x 100, where DSC is disease severity of the control and DSF is disease severity of fungicide.

Table 1 Origin, type, and pedigree of flax cultivars used in the present study.

No.	Cultivar	Origin	Type	Pedigree
1	Giza 9	Local cultivar	Fiber	L. 420 x Bombay
2	Giza 10	Local cultivar	Fiber	L. 420 x Bombay
3	Sakha 3	Local cultivar	Fiber	Bleinka (2E) x 1.2096
4	Sakha 4	Local cultivar	Fiber	Bleinka (R3) x 1.2096
5	Istro	Introduced from Romania	Fiber	Unidentified
6	Jiteka	Introduced from Czech	Fiber	Unidentified

Table 2 Fungicides used for control of powdery mildew of flax under field conditions in El-Ismailiya in 2014/2015 and 2015/2016 growing seasons

Fungicides[a]	Rate (per 100 liters of water)	Active ingredient[b]	Formulation
Bellis	50 ml	25.2% w/w boscalid (protectant) + 12.8% w/w pyraclostrobin (systemic)	A water dispersible granule
Micronized Sulphur	250 g	80% Sulphur	Wettable granules

[a] Trade name [b] Common name

Agronomic and technological traits

At harvest, a random sample of 10 plants was taken from each plot and observations were recorded on individual plants for each of the following agronomic and technological traits:

Straw yield and its related characters

Total plant height (cm): Plant height from the cotyledonary node to the apical bud of each plant.
Technical stem length (cm): The length of the main stem from the cotyledonary node to the first or lowest branching point.
Straw yield/plant (g): Weight of the mature air-dried straw per plant after removing the capsule.
Straw yield/ feddan (ton): Estimated based on the area of the whole plot.
Fiber yield/feddan (ton): Estimated based on the area of the whole plot after retting.

Seed yield and its related characters

Number of apical branches: Total number of apical branches of plant.
A number of capsules per plant: Number of harvested capsules per plant.
A number of seeds per capsules: Number of harvested seeds per capsule.
Seed index (g): the weight of 1000 seeds.
Seed yield/plant (g): Weight of harvested seeds per plant.
Seed yield/feddan (kg): Estimated based on the area of the whole plot.

Technological traits

Fiber length (cm): Estimated as the mean length of 10 fiber ribbons (bundles) from each plot.
Long fiber percentage: calculated according to the following formula:

$$\text{Long fiber \%} = \frac{\text{Long fiber yield/fed}}{3!Straw\ yield/fed} \text{x } 100$$

Fiber fineness in metrical number (Nm): Calculated according to the following formula:

$$N_m = \frac{N \times L}{G}$$

Fiber Fitness (Nm) Radwan and Momtaz (1966)

Where N = Number of fibers (20 fiber, each was10 cm tall),
L = Length of fibers in cm.
G = Weight of fibers in mg.

Oil percentage: Determined by Soxhlet apparatus according to Horwitz et al. (1965).
Oil yield/fed. (kg): Oil (%) x seed yield/fed. (kg).

Statistical analysis of the data

ANOVA
Analysis of variance (ANOVA) was performed on disease severity, straw yield, and seed yield to determine treatment effects. Mean comparisons of variables were made among treatments by the least significant difference (LSD). ANOVA was performed with the MSTAT-C Statistical Package (Michigan State University, USA).

Regression analysis

Linear regression analysis was used to determine the relationships between agronomic or technological traits and disease severity. Critical-point regression models were developed of the formula $Y=b_0-b_1X_1$ in which Y is agronomic or technological trait, X, is disease severity, and b_0 and b_1 are parameters: The Y-intercept parameter (b_0) represents agronomic or technological trait when disease severity is o (X_1=o), and the slope (b_1) represents the change in agronomic or technological traits with a unit change in disease severity. The equation was fitted to data from each cultivar and fungicide according to Lipps and Madden, (1989). Linear regression analysis was performed with the software package SPSS (IBM, USA).

RESULTS AND DISSCUSSION

Powdery mildew severity

ANOVA (Table 3) for powdery mildew severity (PMS) indicated highly significant effects (*P*=0.0000) of fungicide, cultivar, and their interaction each year. Fungicide was the most important source of variation as it accounted for 54.22 and 90.24% of the explained (model) variation in PMS in 2015 and 2016, respectively. The cultivar was more important than the interaction in 2015 while they almost were equally important in 2016.

Table 3 Analysis of variance of the effect of foliar application of fungicides on powdery mildew severity (PMS) on flax cultivars under field conditions

Source of variation[a]	DF	PMS							
		In 10/5/2015				In 25/5/2016			
		M.S.	F.value	P>F	Contribution[b]	M.S.	F.value	P>F	Contribution
Replication	2	6.171	0.3263			14.845	1.7694	0.1858	
Fungicide (F)	2	14179.76	749.6955	0.000	54.22	22717.04	2707.63	0.000	90.24
Cultivar (C)	5	3347.35	176.9771	0.000	32.00	505.03	60.19	0.000	5.02
F X C	10	719.28	38.0289	0.000	13.75	236.10	28.14	0.000	4.69
Error	34	18.91				8.39			

[a] Replication is random, while fungicide and cultivar are fixed.
[b] Relative contribution to variation in PMS, calculated as a percentage of sum squares of the explained (model) variation.

Due to the highly significant interaction (*P*=0.0000) between fungicide and cultivar, an interaction least significant difference (LSD) was calculated to compare fungicide means within each cultivar (Table 4). These comparisons showed that the differences in PMS between fungicides and control were not the same for each cultivar, that is, cultivars responded differently to the application of fungicides. For example, in 2015, the application of Bellis on Giza 9, Giza 10, Sakha3, Sakha4, and Istro significantly reduced PMS by 77.02, 65.28, 67.61, 95.80, and 59.23%, respectively while it reduced it only by 25.08% on Jiteka. In other words, Jiteka was the least responsive cultivar to the application of Bellis. The comparisons also showed that the differences in efficiency (magnitude of reduction in PMS) between fungicides differed from one cultivar to another. For instance, the efficiencies of Bellis and sulphur were 59.73 and 25.64% respectively, on Istro while they were 25.08 and 49.67 %, respectively, on Jiteka, that is, Bellis and sulphur showed reciprocal performance in controlling the disease on the two cultivars. The efficiencies of fungicides also varied from year to year on the same cultivar. For example, the efficiency of sulphur in controlling the disease on sakha3 increased from 31.16 in 2015 to 70.25% in 2016. On Jiteka, the efficiency of Bellis increased from 25.08 in 2015 to 55.02% in 2016.

Table 4 Effect of foliar application of fungicides on powdery mildew severity (PMS) on flax cultivars under field conditions.

Cultivar	PMS[a]							
	In 10 /5/2015				In 25/5/2016			
	Control	Bellis	Sulphur	Mean	Control	Bellis	Sulphur	Mean
Giza 9	87.93	20.18	43.92	50.64	100.00	43.23	29.25	57.49
Giza10	79.44	27.58	16.22	41.08	68.03	15.92	33.30	39.08
Sakha3	41.37	13.40	28.48	27.75	100.00	32.47	29.75	59.07
Sakha 4	85.67	3.60	19.13	36.13	100.00	30.33	33.25	54.53
Istro	100.00	40.27	74.36	71.59	93.75	18.02	38.73	50.17
Jiteka	100.00	74.92	50.33	75.08	100.00	44.93	36.50	60.48
Mean	82.39	29.99	38.74		93.63	30.82	33.46	
[b]LSD (p<0.05)	7.22				4.81			
LSD (p<0.01)	9.69				6.45			

[a]Percentage of infected leaves/plant in a random sample of 10 plants/plot. [b]LSD = LCD value for fungicide x cultivar interaction

The resistance of powdery mildew fungi to fungicides is well documented in the literature (Dhirhi et al., 2017). Therefore, a successful fungicide program to control powdery mildew on flax should include at least two fungicides with different modes of action to reduce the risk of fungicide resistance and improve control of resistant isolates (Keinath and DuBose, 2004; Keinath, 2015;Barickman et al. 2017).

In the current study, protective fungicides sulphur and boscalid and systemic fungicide pyraclostrobin were used to suppress powdery mildew in flax. In general, protective fungicides are surface protectants that suppress fungal growth and sporulation either by direct contact or vapour phase activity. Most of the systemic fungicides inhibit hyphae and haustoria growth and sporulation, and some also exhibited vapour phase activity Seem et al. (1981).

In general, the mean disease severity in the control treatments of the tested cultivars was 82.39 % in 2015 and 93.63% in 2016. The number of highly susceptible cultivars (100% disease severity) increased from two in 2015 to four in 2016. These results indicated that 2016 was more favorable for the occurrence of flax powdery mildew (FPM) than 2015. The results also indicated that the fungicides were tested under high disease pressure each year. This high disease pressure is considered a prerequisite condition for any meaningful field evaluation of fungicides.

The effects of cultivar and year (environmental conditions) on the efficiency of fungicides in controlling FPM, as we have demonstrated herein, have been previously reported by Aly et al. (2000). These results suggest that efficiency of fungicides in controlling FPM should be evaluated in as many years as possible by using as many cultivars as possible because this will improve the chance of identifying fungicides effectiveness in controlling the disease on many cultivars under different environments.

Straw yield and Seed yield

ANOVA (Table 5) for straw yield showed very highly significant effects of the cultivar (p=0.0000) and fungicide (p=0.0000) in both years. However, the interaction of fungicide x cultivar was a nonsignificant source of variation each year. Fungicide was more important than cultivar as a source of variation in straw yield in both years. The insignificant interaction of fungicide X cultivar indicated that fungicides and cultivars under consideration acted independently of each other, that is, fungicide efficiency in increasing straw yield was not affected by the sprayed cultivar. Due to the lack of a significant interaction, LSD was calculated to compare the general means of fungicides and cultivars (Table 6). These comparisons showed that Bellis, regardless of the tested cultivar, was ineffective in increasing straw yield in 2015 while it increased it by 21.48% in 2016. Sulphur was effective in increasing straw yields by 39.31 and 44.97% in 2015 and 2016, respectively. Giza 9 showed the highest yielding ability while Jiteka showed the lowest yielding ability each year.

Table 5 Analysis of variance of the effect of foliar application of fungicides on straw yield (ton/ feddan[a]) of flax cultivars under field conditions

Source of variation[b]	DF	Straw yield							
		In 2015				In 2016			
		M.S.	F.value	P>F	Contribution[c]	M.S.	F.value	P>F	Contribution
Replication	2	1.398	17.9182	0.000		0.221	2.7614	0.0774	
Fungicide (F)	2	7.017	89.9516	0.000	48.92	8.085	101.1895	0.000	55.04
Cultivar (C)	5	2.281	29.2345	0.000	39.84	2.492	31.1860	0.000	42.41
F X C	10	0.039	0.4938		2.28	0.031	0.3829		1.04
Error	34	0.078				0.080			

[a]One Feddan=4200m[2] [b] Replication is random, while fungicide and cultivar are fixed.
[c]Relatives contribution to variation in PMS, calculated as a percentage of sum squares of the explained (model) variation.

Table 6 Effect of Foliar application of fungicides on straw yield (ton/ Feddan[a]) of flax cultivars under field conditions.

Cultivar	**Straw Yield**							
	In 2015				**In 2016**			
	Control	Bellis	Sulphur	Mean	Control	Bellis	Sulphur	Mean
Giza 9	3.68	4.42	5.27	4.46	3.57	4.28	5.01	4.29
Giza10	3.53	4.23	4.94	4.23	3.49	4.18	4.86	4.12
Sakha3	3.17	3.68	4.39	3.75	3.02	3.92	4.28	3.79
Sakha 4	3.16	3.80	4.37	3.78	2.80	3.35	4.19	3.45
Istro	3.03	3.63	4.09	3.58	2.65	3.18	3.96	3.26
Jiteka	2.52	3.03	3.53	3.03	2.36	2.83	3.63	2.94
Mean	3.18	3.80	4.43		2.98	3.62	4.32	
LSD for fungicides	(P< 0.05)	= 0.67			= 0.19			
	(P< 0.01)	= 0.90			= 026			
LSD for cultivars	(P< 0.05)	= 0.95			= 0.27			
	(P< 0.01)	= 1.27			= 0.36			

[a]One Feddan=4200m[2]. LSD for fungicide x cultivar interaction was insignificant in both seasons

ANOVA (Table 7) for seed yield showed very high significant effects of cultivar (p=0.0000) and fungicide (p=0.0000) in both years. However, the interaction of fungicide x cultivar was a nonsignificant source of variation each year. Fungicide was less important than cultivar as a source of variation in seed yield in both years. The insignificant interaction of fungicide X cultivar indicated that fungicides and cultivars under consideration acted independently of each other, that is, fungicide efficiency in increasing seed yield was not affected by the sprayed cultivar. Due to the lack of a significant interaction, LSD was calculated to compare the general means of fungicides and cultivars (Table 8). These comparisons showed that Bellis, regardless of the tested cultivar, was effective in increasing seed yield by 19.89 and 19.92% in 2015 and 2016, respectively. Sulphur was more effective in increasing seed yield as it increased it by 40.37 and 40.26 in 2015 and 2016, respectively. Giza 9 showed the highest yielding ability while Istro and Jiteka showed the lowest yielding ability each year.

Table 7 Analysis of variance of the effect of fungicides application on flax seed yield (Kg/Feddan[a]) under field conditions.

Source of variation	DF	Seed yield							
		In 2015				In 2016			
		M.S.	F.value	P>F	Contribution[c]	M.S.	F.value	P>F	Contribution
Replication[b]	2	29900.96	25.8054	0.000		542.15	0.4353		
Fungicide (F)	2	78371.83	67.6371	0.000	32.76	60173.111	48.3088	0.000	39.45
Cultivar (C)	5	50881.93	43.9125	0.000	53.17	35577.258	28.5625	0.000	58.32
F X C	10	750.145	0.6474		1.57	570.520	0.4580		1.87
Error	34	1158.711				1245.594			

[a]One Feddan =4200m^2 [b] Replication is random, while fungicide and cultivar are fixed.
[c] Relatives contribution to variation on seed yield, calculated as percentage of sum squares of the explained (model) variation.

Table 8 Effect of foliar application of fungicides on seed yield (kg/Faddan) of flax cultivars under field conditions.

Cultivar	Seed yield							
	In 2015				In 2016			
	Control	Bellis	Sulphur	Mean	Control	Bellis	Sulphur	Mean
Giza 9	416.57	499.49	585.92	500.66	385.46	462.51	518.33	455.93
Giza10	357.55	428.72	505.87	430.71	302.55	362.77	428.53	364.62
Sakha3	349.02	418.49	506.61	424.71	277.39	332.59	388.43	332.80
Sakha 4	326.40	391.16	425.38	380.98	280.96	336.88	416.27	344.70
Istro	258.43	309.87	371.69	313.33	229.63	275.33	348.55	284.50
Jiteka	253.34	303.78	357.63	304.92	247.26	296.48	316.95	286.90
Mean	326.89	391.92	458.85		287.21	344.42	402.85	
LSD for fungicides	P< 0.05	= 23.06			= 23.91			
	P< 0.01	= 30.96			= 32.10			
LSD for cultivars	P< 0.05	= 32.61			= 33.081			
	P< 0.01	= 43.78			= 45.39			

[a]One feddan =4200m^2. LSD for fungicide x cultivar interaction was insignificant in both years.

Bellis did not contribute to a significant increase in straw yield in 2015 regardless of the tested cultivar. This may be surprising because Bellis significantly reduced disease severity on all tested cultivars in 2015. However, these findings are inconsistent with the results of others (Frank and Ayers 1986; Kema 1995; Lipps and Madden, 1988), who showed that a reduction in powdery mildew, due to fungicide treatments, was not always associated with a comparable increase in yield. This could be attributed to inter plot interference, which obscured the yield response of cultivars to some fungicide treatments tested (Frank and Ayers 1986; Lipps and Madden, 1988). The experimental design of the present study was a completely randomized block of three replications. In each block (replication), plots of the different treatments were adjacent to one another, inoculums from heavily infected plants in the control plots would have had an effect on those in the other plots. The ultimate influence would be higher than normal levels of disease and lower yield response in treated plots, thus, leading to the apparent loss of efficacy. In commercial-sized fields, foliar sprays of Bellis would be expected to control powdery mildew and increase yield to a greater extent than observed in the present study (Lipps and Madden, 1988).

Sulphur is a constituent of the amino acids cysteine and methionine. Cysteine is important in regulating the structure and function of protein. Sulphur is also a component of several coenzymes and plant hormones, a constituent of many active groups involved in oxidation- reduction reactions and components of sulfolipids, which are structural constituents of all biological membranes (Kirkpatrick and Rothrock, 2001). Therefore, it was not surprising to find significant increases in straw yield and seed yield each year, regardless of the tested cultivar, by the foliar application of sulphur. Our results are in agreement with those of Chourasia et al. (1992) who reported the beneficial effects of sulphur on growth, yield, and quality of linseed. Three fungicides including Propiconazole (0.1%), Difenconazole (0.05%) and wetable sulphur (0.25%) applied twice were also highly effective for controlloing the flax powdery mildew, resulting in higher seed yield of both (9.53 q/ha) followed by wettable sulphur (8.77q/ha) (Gohokar et al., 2016). The plot were also treated with hexaconazole and sulphur, which recorded the highest yields of (588 kg/ha and 542 kg/ha, respectively) (Arshiya et al., 2017). Both Bellis and sulphur were effective in reducing disease severity; however, sulphur surpassed Bellis in increasing straw yield and seed yield. These results suggest that sulphur was a better choice than Bellis for controlling FPM.

Relationship between agronomic or technological traits and PMS

Linear regression analysis was used to determine the relationship between agronomic or technological traits and PMS (Tables 9 and 10). All traits showed a significant negative correlation with PMS. R^2 values of the obtained regression models ranged from 0.355to 0.642 in 2015 (Table 9) and from 0.181 to 0.799 in 2016 (Table 10). Regression equations with coefficient of determination (R2) above 0.50 were considered adequate for trait estimates (Lipps and Madden, 1989). With this as a guide, six equations in 2015 and five equations in 2016 were adequate for trait estimate. Four of these equations were adequate in both years, which were equations for oil percentage, technical length, fiber length and fiber finenness.

Table 9 Regression equations that describe the effects of powdery mildew severity (X) on agronomic and technological traits of flax (Y_S) after foliar application of fungicides in EL- Ismailiya in 2014 /2015 growing seasons.

Agronomic or technological trait (Y)	Regression equation	r[a]	R^2[b]	F. value	P>F
Seed yield /plant (Y_1)	Y1 = 0.489- 0.00196 X	-0.608	0.370	9.380	0.007
Seed yield /feddan(Y_2)	Y2 = 482.315 – 1.782 X	-0.630	0.397	10.518	0.005
Straw yield / plant (Y_3)	Y3 = 1.181 – 0.0043 X	-0.596	0.355	8.817	0.009
Straw yield / feddan (Y_4)	Y4 = 4.605 – 0.01487X	-0.642	0.412	11.209	0.004
Oil percentage (Y_5)	Y5 = 37.699 – 0.07940 X	-0.750	0.562	20.559	0.000
Oil yield/ feddan in kg (Y_6)	Y6 = 179.558 – 0.895 X	-0.673	0.454	13.277	0.002
No. of fruiting branches (Y_7)	Y7 = 10.568 – 0.03938 X	-0.683	0.433	13.981	0.002
No. of capsules / plant (Y_8)	Y8 =11.770 – 0.04973 X	-0.715	0.511	16.753	0.001
No. of seeds /capsule(Y_9)	Y9 = 9.139- 0.02883 X	-0.801	0.642	28.716	0.000
1000 seed weight in g (Y_{10})	Y10 = 6.701 – 0.01861 X	-0.677	0.458	13.544	0.002
Total length / plant in cm (Y_{11})	Y11 = 108.384- 0.160 X	-0.654	0.427	11.946	0.002
Technical length /plant in cm (Y_{12})	Y12 = 97.326 – 0.176 X	-0.725	0.526	17.767	0.001
Fiber yield / feddan[c] in ton (Y_{13})	Y13 = 0.789 – 0.004030X	-0.637	0.406	10.928	0.004
Fiber percentage (Y_{14})	Y14 = 17.621 – 0.05413X	-0.692	0.479	14.708	0.001
Fiber length in cm (Y_{15})	Y15 = 102.931 – 0.259 X	-0.769	0.592	23.187	0.000
Fiber fineness in Nim (Y_{16})	Y16 = 283.007 – 0.600 X	-0.741	0.549	19.509	0.000

[a] Linear correlation coefficient. [b]Coefficient of determination. [c]One feddan= 4200m^2.

Table 10 Regression equations that describe the effects of powdery mildew severity (X)on agronomic and technological traits of flax (Y_S) after foliar application of fungicides in EL- Ismailiya in 2015 /2016 growing seasons.

Agronomic or technological trait (Y)	Regression equation	r[a]	R^{2b}	F. value	P>F
Seed yield /plant (Y_1)	Y1 = 0.448 – 0.001402 X	-0.426	0.181	3.547	0.028
Seed yield /feddan (Y_2)	Y2 = 471.319 – 1.496 X	-0.519	0.269	5.889	0.027
Straw yield / plant (Y_3)	Y3 = 1.053 – 0.003646 X	-0.488	0.238	4.991	0.040
Straw yield / feddan (Y_4)	Y4 = 4.472 – 0.01577 X	-0.657	0.432	12.182	0.003
Oil percentage (Y_5)	Y5 = 37.996 – 0.0912 X	-0.894	0.799	63.574	0.000
Oil yield feddan in kg (Y_6)	Y6 = 151.702 – 0.692 X	-0.641	0.410	11.133	0.004
No. of fruiting branches (Y_7)	Y7 = 9.562 – 0.02594 X	-0.452	0.205	4.116	0.059
No. of capsules / plant (Y_8)	Y8 = 9.816 – 0.03033 X	-0.503	0.253	5.421	0.033
No. of seeds /capsule (Y_9)	Y9 = 8.695 – 0.02383 X	-0.616	0.380	9.809	0.006
1000 seed weight in g (Y_{10})	Y10 = 6.628 – 0.01847 X	-0.685	0.470	14.171	0.002
Total length / plant in cm (Y_{11})	Y11 =109.251 – 0.252 X	-0.809	0.655	30.332	0.000
Technical length /plant in cm (Y_{12})	Y12 = 96.173 – 0.181 X	-0.725	0.526	17.723	0.001
Fiber yield / feddan[c] in tons (Y_{13})	Y13 = 0.737 – 0.003930 X	-0.627	0.393	10.341	0.005
Fiber percentage (Y_{14})	Y14 = 16.697 – 0.04985 X	-0.630	0.397	10.530	0.005
Fiber length in cm (Y_{15})	Y15 = 101.251 – 0.271 X	-0.760	0.578	21.893	0.000
Fiber fineness in (Nim) (Y_{16})	Y16 = 280.953 – 0.624 X	-0.773	0.597	23.742	0.000

[a] Linear correlation coefficient. [b] Coefficient of determination [c] One feddan= 4200m²

Model predictions that accurately predict yield (or loss) would be useful in making economically sound disease management decisions. It is often assumed that the area under the disease progress curve (AUDPC) and multiple-point models provide more precise estimates of yield (or less) than critical-point models because information on a larger part of the epidemic is used in the former models (Lipps and Madden, 1989). Multiple-point and AUDPC models are limited in practice by the large amount of data that must be collected, especially late in the epidemic. Attempts to develop a multiple-point model generally resulted in disease severity at only one assessment time being significant; probably because of the high correlation between disease ratings at different times. Likewise, equations based on AUDPC, in most cases, were no more precise than equations using a single assessment time; Possibly this was because AUDPC gives equal weight to disease levels from all assessment times when predicting yield (Lipps and Madden, 1989).

In the present study, significant negative correlations were obtained between agronomic or technological traits and disease severity by using one-time disease assessment (critical-point model). This disease assessment system required a few trips to the field and simple enough to be used by those with little or no specific training. As suggested by many researchers, the simplest disease assessment method is usually the one least prone to error. The observed negative correlations and the significant reduction in PMS with foliar application of fungicides suggest that control of late-season powdery mildew could be economically important when PMS on flax cultivars is high.

CONCLUSION

Each of fungicide and cultivar was a highly significant source of variation in disease severity, straw yield, and seed yield. Fungicide x cultivar interaction was a highly a highly significant source of variation in disease severity while it was a non significant in each of straw yield, and seed yield. Bellis and sulphar were effective the disease severity, however, suppressed Bellis in increasing straw yield, and seed yield. Therefore, sulphar was abetter choice than Bellis for controlling the disease. All agronomic and technological traits showed significant and linear negative correlations and the significant reduction in disease severity after folir applications of fungicides suggest that control of the late season powdery mildew could be economically important when the severity of the disease on flax cultivars is high.

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