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USE OF FUNGICIDES, BICARBONATE SALTS, AND FILM-FORMING POLYMERS TO SUPPRESS POWDERY MILDEW OF FLAX.

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ABSTRACT

An outdoor pot experiment was conducted in 1999 and 2000 growing seasons to evaluate foliar application of a diverse group of compounds for control of flax powdery mildew. The tested compounds were a sulpher fungicide (That Flowable Sulphur), three ergosterol biosynthesis inhibitors (Bayfidan, Bayleton, and Rubigan), three bicarbonate salts (salts of sodium, potassium, and ammonium), and two film-farming polymers (Nu-Film and Super-Film). Disease intensity variable (disease incidence and disease severity) and yield (straw and seed) were used as criteria for judging efficiencies of the compounds in controlling the disease. The findings of the present study demonstrate that sterol biosynthesis inhibitors in particular Bayfidan were the best performaring compounds in controlling the disease. This superiority was attributed to the following reasons: first, they were the only compounds, which significantly reduced disease incidence after the second spray in 1999. Second, they were the most effective compounds in reducing disease incidence after the second spray in 2000. Third, they were the most effective compounds in reducing disease severity after the second spray in 1999. Fourth, they showed high efficiencies in reducing disease severity after the second spray in 2000. Fifth, they gave considerable increases in straw and seed yield each year. In some cases, bicarbonates and film-forming polymers were as effective as or even more effective than fungicidal chemicals in controlling the disease and increasing yield; however, bicarbonates and film-forming polymers had two drawbacks: first, they showed inconsistent performance in controlling the disease compared to the fungicidal chemicals. Second, when they were effective, they mostly showed lower efficiencies in reducing disease incidence and disease severity. Significant negative correlations between powdery mildew intensity variables and yield were observed each year particularly in case of cultivar Giza 7. Three regression models, derived from stepwise multiple regression analysis, were constructed for each year to predict straw and seed yield. These models showed that yield differences observed were due largely to the disease which accounted for 56.23 to 88.18% and 49.31 to 74.28% of the explained (model) variation in straw and seed yield, respectively.

INTRODUCTION

Powdery mildew, caused by *Oidium lini* Škoric, is widely distributed and destructive disease of flax (*Linum usitatissumum* L.) in Egypt. Disease control is generally achieved by the use of fungicidal chemicals, including sulphur and sterol biosynthesis inhibitors, such as Bayleton, Bayfidan, and Rubigan (Khalil *et al.*, 1987; Aly *et al.*, 1994; Mansour *et al.*, 1999). The requirement to reduce fungicide usage in plant disease control, concern for a healthy environment, and the unavailability of resistant flax cultivars emphasize the need for alternative method for powdery mildew control of flax. One of the potential methods is the foliar application of inorganic salts, such as bicarbonates, as “biocompatible” fungicides (Horst *et al.*, 1992; Ziv and Zitter, 1992) or the use of film-forming polymers, which are nonphytotoxic, permeable to gases, resistant to changing environmental conditions and penetration of solar irradiation, and biodegradable (Zekaria-Oren *et al.*, 1991). For example, McKee (1968) reported the control of rose powdery mildew caused by *Sphaerotheca pannosa* var. *rosa* by spraying sodium bicarbonate mixed with an unspecified summer petroleum oil on infected leaves. The mixture was twice as effective as either material alone. Homma *et al.* (1981a) reported on the use of sodium bicarbonate and emulsifiers and surfactants to control cucumber powdery mildew and described the inhibitory effect of sodium bicarbonate on the life cycle of *S. fuliginea* (Homma *et al.*, 1981b). Ziv and Frederiksen (1983) found that some film-forming polymers were as effective as the fungicide Benomyl in reducing powdery mildew severity on wheat seedlings. Zekaria-Oren *et al.* (1991) reported that development of leaf rust on wheat seedlings was markedly suppressed by preinoculation application of some film-forming polymers. The results suggested that film-forming polymers altered the topography of the leaf surface, thus interfering with adhesion of the germ tube and recognition of penetration sites. Weekly sprays of aqueous solution of sodium bicarbonate significantly controlled powdery mildew of roses; however, a combination of sodium bicarbonate and oil was more effective (Horst *et al.*, 1992). Ziv and Zitter (1992) found that sodium and potassium bicarbonate combined with oil, both at 0.5%, were more effective treatments for controlling powdery mildew on pumkin than either of the materials used alone.

The objective of this investigation was to determine the effectiveness of bicarbonates and film-forming polymers in controlling powdery mildew on flax compared to fungicidal chemicals, such as sulpher and sterol biosynthesis inhibitors.

MATERIALS AND METHODS

Seeds of flax cultivars Giza 5, Giza 6, and Giza 7 were planted on 15 November 1998 and on 20 November 1999 in autoclaved soil dispensed in 25-cm-diameter clay pots (20 seeds/pot). The pots were distributed outdoors in a randomized complete block design of five replications. Powdery mildew was allowed to develop naturally, and the initial application of treatments to plants coincided with the first sign of the disease. Foliar sprays were applied at the recommended rates (Table 1) on 30 March and 16 April 1999 and on 20 March and 5 April 2000. Disease incidence and disease severity (Nutter, 1991) were rated visually on 15 and 30 April 1999 and on 4 and 19 April 2000. Disease incidence was measured as percentage of infected plants/pot. Disease severity was measured as percentage of infected leaves/plant in a random sample of 10 plants/pot. Disease incidence and disease severity data were transformed into arc sine angles before carrying out the analysis of variance to produce approximately constant variance. At harvest, straw and seed weight were recorded for each plant.

Statistical analysis of data

Analysis of variance (ANOVA) was performed on transformed data of disease intensity variables (disease incidence and disease severity) and on agronomic traits (Straw and seed weight) to determine treatment effects. Means comparisons for variables were made among treatments by using least significant difference (LSD). Treatment efficiency was calculated based on the percentage data according to the following formula [(DIC-DIT)/DIC]x1000, where DIC is disease intensity (disease incidence or disease severity) of the control and DIT is disease intensity of treatment. ANOVA of the data was performed with the MSTAT-C Statistical Package (A Microcomputer Program for the Design, Management, and Analysis of Agronomic Research Experiments, Michigan State Univ., USA). Correlation analysis and stepwise regression technique were used to determine the relationship between disease intensity variables (disease incidence and disease severity) and agronomic traits. Correlation and regression analyses were performed with a computerized program.

Table 1:Compounds used for control of powdery mildew of flax under outdoor conditions in 1999 and 2000.

Compound [a]	Rate per 100 liter of water	Active ingredient [b]	Formulation [c]
That flowable sulphur	250 g	52% Sulphur	WP
Bayfidan	15 ml	15% Triadimenol	EC
Bayleton	25 ml	25% Triadimefon	EC
Rubigan	30 ml	12% Fenorimol	EC
Sodium bicarbonate	1000 g	$NaHCO_3$	SP
Potassium bicarbonate	1000 g	$KHCO_3$	SP
Ammonium bicarbonate	1000 g	$NHHCO_3$	SP
Nu-Film-17	600 ml		EC
Super-Film	600 ml		EC

[a] **Trade names.**
[b] **Common names.**
[c] **WP = Wettable powder.**
EC = Emulsifiable concentrate.
SP = Soluble powder.

EXPERIMENTAL RESULTS

Effects of treatments on powdery mildew incidence

ANOVA (Table 2) for disease incidence (DI) in the first assessment date (AD) in 1999 indicated nonsignificant effects of cultivars (P = 0.09) and very highly significant effects of treatments (P = 0.0000). Due to the very highly significant interaction between cultivars and treatments (P = 0.0001), an interaction least significant difference (LSD) was calculated to compare treatment means within each cultivar (Table 3). These comparisons showed that the differences in DI between sterol biosynthesis inhibitors and control were not the same for each cultivar-that is, cultivars responded differently to the foliar application of these fungicides. For example, foliar application of Bayfidan on Giza 6 and Giza 7 significantly reduced DI by 50.00 and 47.20%, respectively, while it reduced it only by 22.25% on Giza 5. In other words, Giza 5 was the least responsive cultivar to the foliar application of Bayfidan.

Table 2. Analysis of variance of effect of foliar application of different treatments on powdery mildew incidence (PMI) on flax cultivars under outdoor conditions.

Source Of variation[a]	d.f.	PMI on 15/4/1999 M.S.	F-value	P > F	PMI on 30/4/1999 M.S.	F-value	P > F
Replication	4	21.095	0.4431		65.897	0.7003	
Cultivar (C)	2	119.283	2.5056	0.0860	2246.758	23.8781	0.0000
Treatment (T)	9	2667.489	56.0314	0.0000	1707.141	18.1432	0.0000
C x T	18	149.023	3.1303	0.0001	737.038	7.8331	0.0000
Error	116	47.607			94.093		

[a] Replications are random, while cultivars and treatments are fixed.

Table 3: Effect of foliar application of different treatments on powdery mildew incidence on flax cultivars under outdoor conditions in 1999.

Treatments		PMI on 15/4/1999 Giza 5	Giza 6	Giza 7	Mean	PMI on 30/4/1999 Giza 5	Giza 6	Giza 7	Mean
That flowable sulphur	%[a]	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Arc sine	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000
Bayfidan	%	77.75	50.00	52.80	60.18	100.00	55.20	63.00	72.73
	Arc sine	55.754	45.000	46.594	49.133	90.000	51.002	53.438	64.813
Bayleton	%	76.00	78.00	100.00	84.67	100.00	50.80	77.60	76.13
	Arc sine	60.906	67.706	90.000	72.871	90.000	40.798	67.406	66.068
Rubigan	%	94.00	100.00	100.00	98.00	100.00	49.40	100.00	83.13
	Arc sine	81.000	90.000	90.000	87.000	90.000	44.430	90.000	74.810
Sodium bicarbonate	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Arc sine	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000
Potassium bicarbonate	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Arc sine	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000
Ammonium bicarbonate	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Arc sine	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000
Nu-Film	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Arc sine	90.000	90.000	90.000	90.000	90.000	90.000	90.00	90.000
Super-Film	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Arc sine	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000
None	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Arc sine	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000
Mean	%	94.78	92.80	95.28	94.29	100.00	85.54	94.06	91.22
	Arc sine	80.760	88.275	85.659	83.90	90.000	76.623	84.084	83.569
LSD (transformed data) for cultivar x treatment interaction at									
				5%	8.643				12.15
				1%	11.43				16.07

[a] Percentage data were transformed into arc sine angles before carrying out the analysis of variance.

While Bayleton significantly reduced DI on Giza 5 and Giza 6 by 24.00 and 22.00%, respectively, it was ineffective in reducing DI on Giza 7. Rubigan significantly reduced DI on Giza 5 by only 6.00%, while it was ineffective on both Giza 6 and Giza 7. On the other hand, That Flowable Sulphur (TFS), bicarbonates, and film-forming polymers were all ineffective in reducing DI on all the tested cultivars. ANOVA (Table 2) for DI in the second AD in 1999 showed that cultivar (P = 0.0000), treatment (P = 0.0000), and cultivar x treatment interaction (P = 0.0000) were all very highly significant sources of variation in DI. When an interaction LSD was used to compare between treatment means within cultivars, it was found that Bayfidan lost its efficiency in reducing DI on Giza 5, while this efficiency was slightly decreased to 44.80, and 37.00% on Giza 6 and Giza 7, respectively. Efficiency of Bayleton to reduce DI on Giza 5 was lost, while it was increased to 49.20 and 22.40% on Giza 6 and Giza 7, respectively. Rubigan was effective in reducing DI by 50.60% on Giza 6, while it was ineffective on Giza 5 and Giza 7. The second spray did not improve the efficiencies of TFS, bicarbonates, and Film-forming polymers, thus, they remained ineffective in the second AD.

ANOVA (Table 4) for DI in the first AD in 2000 showed very highly significant effects on cultivars (P = 0.0000) and treatments (P = 0.0000). However, the interaction of cultivar x treatment was a nonsignificant source of variation (P = 0.11). The nonsignificant of this interaction indicated that cultivars and treatments under consideration acted independently of each other-that is, treatment efficiency was not affected by the tested cultivar. Due to the lack of a significant interaction between cultivars and treatments, a LSD was calculated to compare between the general means of treatments (Table 5). These comparisons showed that Bayfidan and Bayleton were the best performing treatments in reducing DI regardless of the tested cultivar. Thus, they reduced DI by 60.47 and 50.38%, respectively. TFS and Rubigan were almost equally effective because they reduced DI by 37.21 and 30.10%, respectively. Sodium bicarbonate and Super-Film were the least effective treatments because they reduced DI only by 22.48 and 17.83%, respectively. Potassium bicarbonate, ammonium bicarbonate, and Nu-Film were ineffective in reducing DI. ANOVA (Table 4) for DI in the second AD in 2000 indicated very highly significant effects of cultivars (P = 0.0002), treatments (P = 0.0000), and their interaction (0.0029).

Table 4: Analysis of variance of effect of foliar application of different treatments on powdery mildew incidence (PMI) on flax cultivars under outdoor conditions.

Source of variation[a]	Powdery mildew incidence						
	PMI on 4/4/2000				PMI on 19/4/2000		
	d.f.	M.S.	F-value	P > F	M.S.	F-value	P > F
Replication	4	7656.449	37.2075	0.0000	83.258	0.9670	
Cultivar (C)	2	11556.659	56.1610	0.0000	773.138	8.9800	0.0002
Treatment (T)	9	3171.127	15.4105	0.0000	1337.078	15.5301	0.0000
C x T	18	306.797	1.4909	0.1055	205.248	2.3839	0.0029
Error	116	205.777			86.096		

[a] **Replications are random, while cultivars and treatments are fixed.**

Table 5: Effect of foliar application of different treatments on powdery mildew incidence on flax cultivars under outdoor conditions in 2000.

Treatments		PMI on 4/4/2000 Giza 5	Giza 6	Giza 7	Mean	PMI on 19/4/2000 Giza 5	Giza 6	Giza 7	Mean
That flowable sulphur	%[a]	52.00	44.00	66.00	54.00	92.00	98.00	92.00	94.00
	Arc sine	46.204	45.000	54.508	48.571	79.670	86.312	77.312	81.098
Bayfidan	%	6.00	32.00	64.00	34.00	64.00	88.00	60.00	70.67
	Arc sine	9.000	30.688	54.000	31.229	53.178	74.064	50.870	59.371
Bayleton	%	30.00	30.00	68.00	42.67	96.00	92.00	78.00	88.67
	Arc sine	29.358	27.000	58.842	38.400	82.624	77.312	64.762	74.899
Rubigan	%	32.00	52.00	86.00	56.67	84.00	96.00	74.00	84.67
	Arc sine	24.222	45.734	72.734	47.563	66.688	84.688	59.576	70.317
Sodium bicarbonate	%	42.00	64.00	94.00	66.67	100.00	94.00	92.00	95.33
	Arc sine	36.734	57.004	81.000	58.246	90.000	81.000	77.312	82.771
Potassium bicarbonate	%	68.00	80.00	96.00	81.33	96.00	96.00	98.00	96.67
	Arc sine	58.766	69.046	82.624	70.129	86.312	82.624	86.312	85.083
Ammonium bicarbonate	%	64.00	82.00	90.00	78.67	98.00	98.00	92.00	96.00
	Arc sine	56.534	70.376	75.982	67.631	86.312	86.312	79.670	84.098
Nu-Film	%	58.00	82.00	90.00	76.67	100.00	98.00	96.00	98.00
	Arc sine	50.534	73.330	75.688	66.401	90.000	86.312	84.688	87.000
Super-Film	%	54.00	66.00	92.00	70.67	96.00	100.00	100.00	98.67
	Arc sine	50.312	55.330	82.154	62.599	82.624	90.00	90.000	87.541
None	%	68.00	92.00	98.00	86.00	100.00	100.00	100.00	100.00
	Arc sine	59.312	79.670	86.312	75.098	90.000	90.00	90.000	90.000
Mean	%	47.40	62.40	84.40	64.73	92.60	96.00	88.20	92.27
	Arc sine	42.058	55.318	72.384	56.587	80.741	83.862	76.050	80.218

LSD (transformed data)	Level	4/4/2000	19/4/2000
for Cultivar	5%	5.682	
	1%	7.514	
Treatment	5%	10.370	
	1%	13.720	
Cultivar x treatment interaction	5%	NS	11.620
	1%	NS	15.370

[b] **Percentage data were transformed into arc sine angles before carrying out the analysis of variance.**

Comparisons between treatment means within cultivars (Table 5) revealed that DI on Giza 5 was effectively reduced by 36.00 and 16.00% by the application of Bayfidan and Rubigan, respectively. Foliar application of Bayfidan and Bayleton on Giza 6 significantly reduced DI by 12.00 and 8.00%, respectively. Giza 7 was the most responsive cultivar to the application of the different treatments. Thus, TFS, Bayfidan, Bayleton, Rubigan, and Sodium bicarbonate were all effective in reducing DI by 8.00, 40.00, 22.00, 26.00, and 8.00%, respectively. On the other hand, potassium bicarbonate, ammonium bicarbonate, Nu-Film, and Super-Film were not effective in reducing DI on any of the tested cultivars

Effects of treatments on powdery mildew severity

ANOVA (Table 6) for disease severity (DS) in the first AD in 1999 showed that treatments (P = 0.0000) was the only significant source of variation in DS. Due to the nonsignificance of cultivar treatment interaction,/ a LSD was calculated to compare between the general means of treatments (Table 7). These comparisons showed that Bayfidan, Bayleton, and Rubigan were the best performing treatments in reducing DS regardless of the tested cultivar. Thus, they significantly reduced DS by 85.44, 77.17, and 59.93%, respectively. TFS and sodium bicarbonate were almost equally effective in reducing DS because they significantly reduced it by 28.39 and 25.25%, respectively. Potassium bicarbonate and NU-Film showed the lowest efficiency because they significantly reduced DS by 6.95 and 7.64%, respectively. Ammonium bicarbonate and Super-Film were ineffective in reducing DS. ANOVA (Table 6) for DS in the second AD in 1999 showed that cultivars (P = 0.0000), treatments (P = 0.0000), and cultivar x treatment interaction (P = 0.0000) were all very highly significant sources of variation. When an interaction LSD was used to compare between treatment means within cultivars (Table 7), it was found that the differences in DS between the tested compounds and control were not the same for each cultivar-that is, cultivars responded differently to the foliar application of compounds. For example, Giza 5 was the least responsive cultivar to the application of sterol biosynthesis inhibitors compared to Giza 6 or Giza 7. Thus, the application of Bayfidan, Bayleton, and Rubigan on Giza 5 significantly reduced DS by 9.44, 35.54, and 22.72%, respectively. On the other hand, the application of the same fungicides reduced DS by 69.59, 78.71, and 74.69%, respectively on Giza 6, or by 79.43, 70.31, and 54.76%, respectively on Giza 7. TFS was effective only on Giza 7 where it significantly reduced DS by 20.22%. Sodium bicarbonate was ineffective in reducing DS on Giza 6, while it was effective in reducing DS by 8.17 and 30.34% on Giza 5 and Giza 7, respectively. Giza 7 was the only responsive cultivar to the application of potassium bicarbonate, ammonium bicarbonate, and Nu-Film where they reduced DS by 10.94, 6.29, and 21.75%, respectively. Super-Film was ineffective in reducing DS on all cultivars.

Table 6: Analysis of variance of effect of foliar application of different treatments on powdery mildew severity (PMS) on flax cultivars under outdoor conditions.

Source of variation[a]	Powdery mildew severity						
		PMS on 15/4/1999			PMS on 30/4/1999		
	d.f.	M.S.	F-value	P > F	M.S.	F-value	P > F
Replications	4	49.218	0.6434		81.944	0.8706	
Cultivar (C)	2	103.005	1.3465	0.2642	4443.413	47.2068	0.0000
Treatment (T)	9	7911.358	103.4198	0.0000	5136.890	54.5743	0.0000
C x T	18	77.309	1.0106	0.4534	391.776	4.1622	0.0000
Error	116	76.498			94.127		

[a] Replications are random, while cultivars and treatments are fixed.

Table 7:Effect of foliar application of different treatments on powdery mildew severity on flax cultivars under outdoor conditions in 1999.

Treatment		Powdery mildew severity							
		PMS on 15/4/1999				PMS on 30/4/1999			
		Giza 5	**Giza 6**	**Giza 7**	**Mean**	**Giza 5**	**Giza 6**	**Giza 7**	**Mean**
That flowable sulphur		%[a]	66.94	73.14	71.65	70.58	98.29	97.14	79.30
	91.58								
	Arc sine	55.054	58.930	57.856	57.28	85.396	80.398	63.908	76.567
Bayfidan	%	28.21	7.90	6.94	14.35	90.50	30.37	20.42	47.10
	Arc sine	30.478	15.952	15.240	20.557	72.332	33.458	26.552	44.114
Bayleton	%	24.74	22.41	20.35	22.50	67.41	21.26	29.47	39.38
	Arc sine	28.558	22.360	26.884	25.934	55.826	27.428	31.724	38.326
Rubigan	%	36.24	44.52	37.72	39.49	77.23	25.28	44.91	49.14
	Arc sine	36.204	41.876	37.876	38.652	62.182	30.196	42.002	44.793
Sodium bicarbonate	%	69.99	75.23	75.78	73.67	91.77	95.92	69.15	85.61
	Arc sine	58.318	60.164	60.568	59.683	75.088	78.396	56.710	70.065
Potassium bicarbonate	%	92.48	91.61	91.04	91.71	97.97	99.45	88.41	95.28
	Arc sine	74.918	73.214	72.596	73.576	83.746	85.772	70.330	79.949
Ammonium bicarbonate	%	92.69	97.14	95.83	95.22	99.31	97.75	92.40	96.49
	Arc sine	74.386	80.110	78.256	77.584	86.418	81.428	74.404	80.750
Nu-Film	%	94.01	95.04	84.05	91.03	97.97	95.24	77.68	90.30
	Arc sine	77.636	77.190	66.442	73.756	83.304	77.140	65.228	75.224
Super-Film	%	97.75	97.34	92.08	95.72	99.78	99.46	92.20	97.15
	Arc sine	81.776	80.588	75.686	79.350	88.796	85.808	77.634	84.093
None	%	98.94	98.34	98.41	98.56	99.93	99.83	99.27	99.68
	Arc sine	83.924	82.678	81.926	82.843	89.302	87.682	86.916	87.967
Mean	%	70.20	70.27	67.39	69.29	92.02	76.17	69.32	71.17
	Arc sine	60.125	59.306	57.333	58.920	78.239	66.771	59.545	68.185
LSD (transformed data) for Cultivar					5%	NS			
					1%	NS			
Treatment					5%	6.326			
					1%	8.364			
Cultivar x treatment interaction					5%	NS			12.15
					1%	NS			16.07

[a] **Percentage data were transformed into arc sine before carrying out the analysis of variance.**

ANOVA (Table 8) for DS in the first AD in 2000 showed that cultivars (0.0000) and treatments (0.0007) were very highly significant sources of variation. However, cultivar x treatment interaction was a nonsignificant source of variation. Due to the nonsignificance of this interaction, a LSD was calculated to compare between the general means of treatments (Table 9). These comparisons showed that all the tested compounds were effective, with varying degrees, in reducing DS with the exception of sodium bicarbonate, ammonium bicarbonate, and Super-Film. Bayfidan was the best performing compound because it significantly reduced DS by 43.77%. It is noteworthy that Bayleton and Nu-Film significantly reduced DS by 16.06 and 15.83%, respectively – that is, Nu-Film was almost as effective as Bayleton in reducing DS regardless of the tested cultivar. On the other hand, Nu-Film was slightly superior to TFS and Rubigan, which significantly reduced DS by

13.71 and 14.72%, respectively. Potassium bicarbonate was the least effective compound because it significantly reduced DS only by 11.88%.

Table 8: Analysis of variance of effect of foliar application of different treatments on powdery mildew severity (PMS) on flax cultivars under outdoor conditions.

Source of variation[a]		Powdery mildew severity					
		PMS on 4/4/2000			PMS on 19/4/2000		
	d.f.	M.S.	F-value	P > F	M.S.	F-value	P > F
Replications	4	5698.746	34.3548	0.0000	88.299	0.8629	
Cultivar (C)	2	4190.701	25.2636	0.0000	1035.651	10.1213	0.0001
Treatment (T)	9	580.431	3.4991	0.0001	2038.207	19.9193	0.0000
C x T	18	96.396	0.5811		208.719	2.0398	0.0125
Error	116	165.879			102.323		

[a] Replications are random, while cultivars and treatments are fixed.

Table 9:Effect of foliar application of different treatments on powdery mildew severity on flax cultivars under outdoor conditions in 2000.

Treatments		Powdery mildew severity							
		PMS on 4/4/2000				PMS on 19/4/2000			
		Giza 5	Giza 6	Giza 7	Mean	Giza 5	Giza 6	Giza 7	Mean
That flowable sulphur	%[a]	54.64	66.40	75.97	65.67	58.39	82.49	84.74	75.21
	Arc sine	48.838	55.748	62.358	55.648	50.484	66.374	68.132	61.663
Bayfidan	%	26.42	59.32	42.64	42.79	21.95	53.86	18.54	31.45
	Arc sine	24.936	50.434	41.254	38.875	26.492	47.198	17.760	30.483
Bayleton	%	42.18	68.13	67.98	59.43	59.99	68.42	68.09	65.50
	Arc sine	40.164	57.222	56.936	51.441	50.866	56.450	56.026	54.447
Rubigan	%	37.87	76.14	80.69	64.90	54.46	70.55	81.21	68.74
	Arc sine	36.990	50.166	64.562	50.573	47.566	57.560	65.046	56.724
Sodium bicarbonate	%	60.37	80.63	73.52	71.51	78.85	84.96	66.70	76.84
	Arc sine	51.182	65.370	60.822	59.125	63.030	67.408	55.424	61.954
Potassium bicarbonate	%	52.69	66.39	82.11	67.06	67.70	81.66	74.77	74.71
	Arc sine	46.016	55.718	65.510	55.748	55.792	65.732	60.204	60.576
Ammonium bicarbonate	%	55.49	71.35	79.86	68.90	59.55	84.16	82.87	75.53
	Arc sine	47.990	59.884	63.600	57.158	51.306	66.716	65.702	61.241
Nu-Film	%	46.33	75.99	69.82	64.05	79.60	79.90	78.86	79.45
	Arc sine	42.586	62.816	59.344	54.915	63.600	65.238	64.666	65.501
Super-Film	%	51.11	76.53	73.56	67.07	69.97	77.44	74.47	73.96
	Arc sine	46.294	62.214	60.466	56.325	57.116	63.662	59.834	60.204
None	%	66.40	72.90	89.00	76.10	95.44	97.08	87.97	93.50
	Arc sine	51.552	60.206	72.094	61.284	79.788	80.336	71.284	77.135
Mean	%	49.35	71.38	73.52	64.75	64.59	78.05	71.82	71.49
	Arc sine	43.655	57.978	60.695	54.109	54.604	63.667	58.408	58.893
LSD (transformed data) for Cultivar		5%		5.102					
		1%		6.746					
Treatment		5%		9.315					
		1%		12.320					
Cultivar x treatment interaction		5%		NS					12.670
		1%		NS					16.740

[a] Percentage data were transformed into arc sine angle before carrying out the analysis of variance.

ANOVA (Table 8) for DS in the first AD in 2000 showed that cultivars (0.0000) and treatments (P = 0.0007) were very highly significant sources of variation. However, cultivar x treatment interaction was a nonsignificant source of variation. Due to the nonsignificance of this interaction, a LSD was calculated to compare between the general means of treatments (Table 9). These comparisons showed that Bayfidan was the best performing compound in controlling the disease because it reduced DS by 43.77% regardless of the tested cultivar. Bayleton and Nu-Film were almost equally effective in controlling the disease because they significantly reduced DS by 16.06 and 15.83%, respectively. On the other hand, Nu-Film was slightly more effective than Rubigan, which reduced DS by 14.72%. TFS and potassium bicarbonate were the least effective compounds in controlling the disease because the reduced DS by 13.71 and 11.88%, respectively. ANOVA (Table 8) for DS in the second AD in 2000 indicated significant effects of cultivars (0.0001), treatment (0.0000), and cultivar x treatment interaction (0.0125). Due to the significance of cultivar x treatment interaction, an interaction LSD was calculated to compare between treatment means within each cultivar (Table 9). These comparisons showed that the differences in DS between treatments and control were not the same for each cultivar-that is, cultivars responded differently to the foliar application of treatments. For example, foliar application of Bayfidan reduced DS by 77.00 and 78.92% on Giza 5 and Giza 7, respectively, while it reduced it only by 44.52% on Giza 6. In other words, Giza 6 was the least responsive cultivar to the application of Bayfidan. While Bayleton reduced DS by 37.14% on Giza 5, it reduced it only by 29.52 and 22.60% on Giza 6 and Giza 7, respectively. Sodium bicarbonate showed the highest level of efficiency (24.18%) on Giza 7 while its efficiency decreased to 17.38% on Giza 5 and 12.48% on Giza 6. TFS, Rubigan, potassium bicarbonate, ammonium bicarbonate, Nu-film, and Super-Film were ineffective in reducing DS on Giza 7; however, the application of these compounds significantly reduced DS, with varying degrees, on Giza 5 and Giza 6.

Effects of treatments on straw and seed yield

ANOVA (Table 10) for straw yield (g/plant) in 1999 showed highly significant effects of cultivars (P = 0.01) and very highly significant effects of treatments (P 0.0000). However, the interaction of cultivar x treatment was a nonsignificant source of variation (P = 0.38). The nonsignificance of this interaction indicated that treatments under consideration acted independently of the tested cultivars-that is, treatment effects on straw yield was not affected by the tested cultivar. Due to the lack of a significant interaction between cultivars and treatments, a LSD was calculated to compare between the general means of treatments (Table 11). These comparisons showed that application of TFS, Bayfidan, and Bayleton significantly increased straw yield by 23.95, 46.01, and 12.17%, respectively, while the application of any of the other compounds did not result in significant increase in straw yield.

Table 10: Analysis of variance of effect of foliar application of different treatments on straw weight (g/plant) and seed weight (g/plant) of flax cultivars under outdoor conditions in 1999.

Source of variation [a]		Yield					
		Straw weight			Seed weight		
	d.f.	M.S.	F-value	P > F	M.S.	F-value	P > F
Replication	4	0.013	1.9675	0.1040	0.003	3.8514	0.0056
Cultivar (C)	2	0.031	4.7646	0.0103	0.003	3.1916	0.0447
Treatment (T)	9	0.029	4.4878	0.0000	0.005	6.1637	0.0000
C x T	18	0.007	1.0826	0.3782	0.001	1.4348	0.1283
Error	116	0.007			0.001		

[a] **Replications are random, while cultivars and treatments are fixed.**

Table 11: Effect of foliar application of different treatments on yield (g/plant) of flax cultivars under outdoor conditions in 1999.

Treatments	Yield (g/plant)							
	Straw weight				Seed weight			
	Giza 5	Giza 6	Giza 7	Mean	Giza 5	Giza 6	Giza 7	Mean
That flowable sulphur	0.307	0.366	0.306	0.326	0.090	0.091	0.103	0.093
Bayfidan	0.399	0.339	0.415	0.384	0.100	0.090	0.085	0.092
Bayleton	0.327	0.297	0.261	0.295	0.089	0.111	0.108	0.103
Rubigan	0.233	0.270	0.206	0.236	0.109	0.093	0.123	0.108
Sodium bicarbonate	0.256	0.309	0.251	0.272	0.122	0.101	0.095	0.106
Potassium bicarbonate	0.291	0.295	0.243	0.276	0.075	0.075	0.071	0.074
Ammonium bicarbonate	0.289	0.315	0.236	0.280	0.082	0.074	0.094	0.083
Nu-Film	0.300	0.202	0.257	0.253	0.104	0.082	0.072	0.086
Super-Film	0.291	0.277	0.157	0.242	0.083	0.048	0.049	0.060
None	0.272	0.311	0.207	0.263	0.092	0.053	0.024	0.056
Mean	0.297	0.298	0.254	0.283	0.095	0.082	0.082	0.086
LSD (transformed data) for Cultivar			5%	0.033				0.013
			1%	0.044				NS
Treatment			5%	0.061				0.023
			1%	0.080				0.030
Cultivar x treatment interaction			5%	NS				NS
			1%	NS				NS

ANOVA (Table 10) for seed yield (g/plant) in 1999 showed significant effects of cultivars (0.04) and very highly significant effects of treatments (0.0000). However, the interaction of cultivar x treatment was a nonsignificant source of variation (P = 0.13). The comparisons between the general means of treatments revealed that all treatments, except-Super-Film, caused significant increases in seed yield (Table 11). These increases ranged from 32.14%, in case of potassium bicarbonate to 92.86% in case of Rubigan.

ANOVA (Table 12) for straw weight (g/plant) in 2000 showed significant effects of cultivars (P 0.01) and very highly significant effects of treatments (P 0.0001). Due to the significant interaction between cultivars and treatments (P = 0.06), an interaction LSD was calculated to compare between treatment means within each cultivar (Table 13). These comparisons showed that none of the tested compounds caused significant increase in straw weight of Giza 5-that is, Giza 5 was nonresponsive to the application of the tested compounds in terms of straw weight. Bayfidan and Bayleton significantly increased straw weight of Giza 6 by 28.88 and 30.79%, respectively, while all the other compounds were ineffective in increasing straw weight of this cultivar. TFS, Bayfidan, Bayleton, Super-Film significantly increased straw weight of Giza 7 by 74.73, 97.44, 47.99, and 48.35%, respectively. Super-Film was surprisingly as effective as Bayleton in increasing straw weight of Giza 7.

Table 12: Analysis of variance of effect of foliar application of different treatments on straw weight (g/plant) and seed weight (g/plant) of flax cultivars under outdoor conditions in 2000.

Source of variation [a]		Yield					
		Straw weight			Seed weight		
	d.f.	M.S.	F-value	P > F	M.S.	F-value	P > F
Replication	4	0.012	1.2634	0.2884	0.013	13.0638	0.0000
Cultivar (C)	2	0.042	4.5393	0.0126	0.001	1.4330	0.2428
Treatment (T)	9	0.038	4.1202	0.0001	0.003	2.7490	0.0060
C x T	18	0.015	1.6248	0.0648	0.002	2.3393	0.0035
Error	116	0.009			0.001		

[a] **Replications are random, while cultivars and treatments are fixed.**

Table 13: Effect of foliar application of different treatments on yield (g/plant) of flax cultivars under outdoor conditions in 2000.

Treatments	Yield (g/plant)							
	Straw weight				Seed weight			
	Giza 5	Giza 6	Giza 7	Mean	Giza 5	Giza 6	Giza 7	Mean
That flowable sulphur	0.445	0.522	0.477	0.481	0.093	0.110	0.101	0.101
Bayfidan	0.433	0.540	0.539	0.504	0.097	0.079	0.129	0.102
Bayleton	0.457	0.548	0.404	0.470	0.129	0.108	0.085	0.107
Rubigan	0.361	0.502	0.345	0.403	0.093	0.104	0.124	0.107
Sodium Bicarbonate	0.368	0.422	0.372	0.387	0.136	0.092	0.066	0.098
Potassium Bicarbonate	0.377	0.360	0.340	0.359	0.080	0.096	0.088	0.088
Ammonium Bicarbonate	0.397	0.401	0.380	0.392	0.081	0.078	0.109	0.089
Nu-Film	0.453	0.398	0.322	0.391	0.124	0.102	0.078	0.101
Super-film	0.437	0.323	0.405	0.388	0.075	0.062	0.093	0.077
None	0.435	0.419	0.273	0.376	0.090	0.070	0.042	0.067
Mean	0.416	0.443	0.386	0.415	0.100	0.090	0.092	0.094
LSD (transformed data) for Cultivarx treatment interaction			5%	0.119				0.040
			1%	NS				0.052

ANOVA (Table 12) for seed weight (g/plant) in 2000 showed nonsignificant effects of cultivars (P = 0.24), very highly significant effects of treatments (0.006). Due to the highly significant interaction between cultivars and treatments (P = 0.004), an interaction LSD was used to compare between treatment means within each cultivar (Table 13). These comparisons showed that Bayleton and Sodium bicarbonate significantly increased seed weight of Giza 5 by 43.33 and 51.11%, respectively, while TFS significantly increased seed weight of Giza 6 by 57.14%. However, none of the other compounds was effective in increasing seed weight of Giza 5 or Giza 6. On the contrary, all the tested compounds, except sodium bicarbonate and Nu-Film, caused considerable increases in seed weight of Giza 7. These increases ranged from 207.14% in case of Bayfidan to 102.38% in case of Bayleton.

Relative contribution of cultivar, treatment, and their interaction to variation in disease and yield

In 1999, treatment was the most important source of variation in DI and DS particularly in the first AD when it accounted for 88.87 and 97.54% of their explained (model) variation, respectively (Table 14). Also, most of the variation in straw and seed yield was attributed to treatment. The relative contribution of cultivar to variation in DI and DS was greater in the second AD. Cultivar accounted for 12.40% of the explained (model) variation in straw weight; however, its contribution to variation in seed weight decreased to 5.95%. The relative contribution of cultivar x treatment interaction to variation in DI and DS was strikingly greater in the second AD particularly in case of DS.

Table 14: Relative contribution of cltivar, treatment, and their interaction to variation in powdery mildew intensity variables and yield of flax in 1999.

Source of variation	Relative contribution to variation in [a]					
	Disease incidence		Disease severity		Straw weight (g/plant)	Seed weight (g/plant)
	15/4/1999	30/4/1999	15/4/1999	30/4/1999		
Cultivar (C)	0.883	13.458	0.282	14.219	12.402	5.952
Treatment (T)	88.874	46.017	97.542	73.973	52.165	53.571
C x T	9.930	39.735	1.906	11.283	25.197	25.000

[a] Calculated as percentage of sum of squares of the explained (model) variation.

In 2000, treatment was the first in importance as a source of variation in DI regardless of AD (Table 15). However, in case of DS, it was the most important source of variation only in the second AD. Also, treatment was the most important source of variation in straw yield where it accounted for 46.08% of the explained (model) variation. Cultivar was the most important source of variation only in the first DS. Cultivar x treatment interaction was the first in importance as a source of variation only in case of seed weight.

Table 15: Relative contribution of cultivar, treatment, and their interaction to variation in powdery mildew intensity variables and yield of flax in 2000.

Source of variation	Relative contribution to variation in [a]					
	Disease incidence		Disease severity		Straw weight (g/plant)	Seed weight (g/plant)
	4/4/2000	19/4/2000	4/4/2000	19/4/2000		
Cultivar (C)	26.3245	8.7819	21.9780	8.4456	11.2162	2.5000
Treatment (T)	32.5053	68.3443	13.6982	74.7956	46.0810	20.0000
C x T	6.2896	20.9823	4.5499	15.3186	36.3514	34.1667

[a] **Calculated as percentage of sum of squares of the explained (model) variation.**

Combined ANOVA

Combined ANOVA of the effect of year, cultivar, and their interactions on disease intensity variables after the second spray and yield is shown in Tables 16-19. Year was a highly significant source of variation in DI (P 0.01) and a very highly significant source of variation in DS and straw yield (P = 0.0000), while it was a nonsignificant source of variation in seed weight. Cultivar was a nonsignificant source of variation in DI and DS, while it was a highly significant source of variation in straw weight (P = 0.01) and a significant source of variation in seed weight (P = 0.03). Treatment was a significant source of variation in DS (P 0.03), while it was a very highly significant source of variation in all other variables (P = 0.005). Each of year x cultivar interaction, year x treatment interaction, and year x cultivar x treatment interaction was a significant source of variation in DI and DS and a nonsignificant source of variation in yield. Cultivar x treatment interaction was either a significant or a very highly significant source of variation in all the tested variables.

Table 16: Analysis of variance of effect of year, cultivar. treatment, and their interactions on disease incidence [a] (combined data of 1999 and 2000)

Source of variation	d.f.	M.S.	F-value	P > F
Year (Y)	1	842.358	11.2950	N.S.
Block(Y)	8	74.578	0.8278	0.0100
Cultivar (C)	2	907.449	0.4296	N.S.
Y x C	2	2112.447	23.4471	0.0000
Treatment (T)	9	2860.008	15.5258	0.005
Y x T	9	184.210	2.0446	0.0355
C x T	18	313.991	3.4851	0.0000
Y x C x T	18	628.295	6.9737	0.0000
Error	232	90.094		

[a] **Second disease incidence.**

Table 17. Analysis of variance of effect of year, cultivar, treatment, and their interactions on disease severity [a] (combined data of 1999 and 2000)

Source of variation	d.f.	M.S.	F-value	P > F
Year (Y)	1	6475.316	76.0710	0.0000
Block (Y)	8	85.122	0.8666	N.S.
Cultivar (C)	2	1597.518	0.4116	N.S.
Y x C	2	3881.546	39.5169	0.0000
Treatment (T)	9	5865.559	4.4791	0.025
Y x T	9	1309.538	13.3320	0.0000
C x T	18	301.635	3.0709	0.0000
Y x C x T	18	298.859	3.0426	0.0001
Error	232	98.225		

[a] Second disease severity.

The assessment of the relative contribution of each source of variation to the explained (model) variation of the tested variables (DI, DS, and yield) is shown in Table (20). Treatment was the most important source of variation in all the tested variables with the exception of straw yield where year was the most important source of variation. The contributions of the other sources of variation to the explained (model) variation were highly variables depending on the variable under consideration.

Table 18: Analysis of variance of effect of year, cultivar, treatment, and their interactions on straw weight [a] (combined data of 1999 and 2000)

Source of variation	d.f.	M.S.	F-value	P > F
Year (Y)	1	1.310	109.1667	0.0000
Block (Y)	8	0.012	1.5567	0.1389
Cultivar (C)	2	0.069	17.2500	0.0100
Y x C	2	0.004	0.5294	N.S.
Treatment (T)	9	0.061	10.1667	0.0050
Y x T	9	0.006	0.7811	N.S.
C x T	18	0.013	1.6873	0.0425
Y x C x T	18	0.009	1.1106	0.3425
Error	232	0.008		

[a] Straw weight (g/plant).

Table 19: Analysis of variance of effect of year, cultivar, treatment, and their interactions on seed weight [a] (combined data of 1999 and 2000)

Source of variation	d.f.	M.S.	F-value	P > F
Year (Y)	1	0.0040	0.5000	N.S.
Block (Y)	8	0.0080	8.8969	0.0000
Cultivar (C)	2	0.0040	40.0000	0.0250
Y x C	2	0.0001	0.1097	N.S.
Treatment (T)	9	0.0070	14.0000	0.0050
Y x T	9	0.0005	0.5048	N.S.
C x T	18	0.0020	2.7198	0.0003
Y x C x T	18	0.0010	1.1406	0.3139
Error	232	0.0010		

[a] Seed weight (g/plant).

Table 20: Relative contribution of year, cultivar, treatment, and their interactions to variation in powdery mildew intensity variables and yield (combined data of 1999 and 2000).

Source of variation	Relative contribution to variation in[a] Second DI	Second DS	Straw weight (g/plant)	Seed weight (g/plant)
Year (Y)	1.62490	6.92553	51.231912	1.92308
Cultivar (C)	1.75055	3.41718	5.396950	3.84615
Y x C	8.15021	0.30284	0.00313	0.04808
Treatment (T)	49.65490	56.46041	21.5487	31.2500
Y x T	3.19650	12.60529	2.1509	1.92308
C x T	10.90291	5.80693	9.34689	21.15385
Y x C x T	21.81667	5.75349	6.17912	8.65385

[a] **Calculated a sum of squares of the explained (model) variation.**

Correlation between powdery mildew and yield

Some significant negative correlations between yield and powdery mildew intensity variables (PMIV) were observed each year particularly in case of Giza 7 (Tables 21 and 22).

Table 21: Correlation coefficients among powdery mildew intensity and yield variables of flax under the effect of foliar application of different compounds in an outdoor experiment in 1999.

Cultivar		Variable	Variable 2	3	4	5	6
Giza 5	1	DI (15 April)	… [a]	0.8551** [b]	0.7401*	-0.6967*	-0.0587
	2	DI (30 April)		…	…	…	…
	3	DS (15 April)			0.8448**	-0.4255	-0.3494
	4	DS (30 April)				-0.0922	-0.2691
	5	Straw weight (g/plant)					-0.1560
	6	Seed weight (g/plant)					
Giza 6	1	DI (15 April)	0.6565*	0.6915*	0.7406*	-0.0015	-0.3543
	2	DI (30 April)		0.9239**	0.9622**	0.1229	-0.5664x
	3	DS (15 April)			0.9573**	-0.1025	-0.7718**
	4	DS (30 April)				0.0777	-0.6873*
	5	Straw weight (g/plant)					0.0872
	6	Seed weight (g/plant)					
Giza 7	1	DI (15 April)	0.8403**	0.6407*	0.6134x	-0.08184**	-0.0522
	2	DI (30 April)		0.8431**	0.8253**	-0.7570*	-0.1229
	3	DS (15 April)			0.9866**	-0.6363*	-0.5184
	4	DS (30 April)				-0.6129x	-0.5394
	5	Straw weight (g/plant)					0.3088
	6	Seed weight (g/plant)					

[a] **DI on 30 April was not included in statistical analysis because its mean was 100% for any of the tested compounds on Giza 5.**
[b] **Linear correlation coefficient (r) is significant at P ≤ 0.10 (x), P ≤ 0.05 (*), or P ≤ 0.01 (**)..**

Table 22: Correlation coefficients among powdery mildew intensity and yield variables of flax under the effect of foliar application of different compounds in an outdoor experiment in 2000.

Cultivar		Variable	Variable 2	3	4	5	6
Giza 5	1	DI (4 April)	0.8122** [a]	0.8245**	0.7724**	-0.0566	-0.3213
	2	DI (19 April)		0.8269**	0.8889**	0.0011	0.1805
	3	DS (4 April)			0.8453**	-0.1108	-0.0398
	4	DS (19 April)				0.0013	0.1915
	5	Straw weight (g/plant)					0.1413
	6	Seed weight (g/plant)					
Giza 6	1	DI (4 April)	0.7257*	0.6391*	0.7937**	-0.7499*	-0.4022
	2	DI (19 April)		0.6211x	0.8021**	-0.5144	-0.2449
	3	DS (4 April)			0.7424*	-0.2263	-0.3470
	4	DS (19 April)				-0.4830	-0.1716
	5	Straw weight (g/plant)					0.3808
	6	Seed weight (g/plant)					
Giza 7	1	DI (4 April)	0.7108*	0.6833*	0.5297	-0.8351**	-0.5650x
	2	DI (19 April)		0.7356*	0.7502*	-0.6220x	-0.7022*
	3	DS (4 April)			0.9278**	-0.7896**	-0.5189
	4	DS (19 April)				-0.7083*	-0.4516
	5	Straw weight (g/plant)					0.6718
	6	Seed weight (g/plant)					

[a] **Linear correlation coefficient (r) is significant at $P \leq 0.10$ (x), $P \leq 0.05$ (*), or $P \leq 0.01$ (**).**

Six regression equations were obtained to describe the effects of PMIV on yield of the three flax cultivars after foliar application of the different compounds (Table 23). R^2 values of the equations ranged from 49.31 to 88.18%.

Table 23: Regression equations that describe the effect of powdery mildew intensity variables (X) on yield (Y) of flax after foliar application of different compounds.

Year	Cultivar	Dependent variable (Y)	Regression equation	R^2	F-value
1999	Giza 5	Straw yield [a]	$Y = 0.5684016 - 0.00669280X_1 + 0.00390376X_4$	88.18 [b]	26.10**
		Seed yield [c]	… … … … … … … … … … … … [d]	…	…
	Giza 6	Straw yield	… … … … … … … … … … … …	…	…
		Seed yield	$Y = 0.8750393 - 0.00112493X_3 + 0.0008565002X_2$	74.28 [e]	10.11**
	Giza 7	Straw yield	$Y = 0.6152373 - 0.003792373X_1$ [f]	66.97	16.22**
		Seed yield	… … … … … … … … … … … …	…	…
2000	Giza 5	Straw yield	… … … … … … … … … … … …	…	…
		Seed yield	… … … … … … … … … … … …	…	…
	Giza 6	Straw yield	$Y = 0.6431735 - 0.003395408X_1$ [g]	56.23	10.28*
		Seed yield	… … … … … … … … … … … …	…	…
	Giza 7	Straw yield	$Y = 0.8035384 - 0.00373779X_1 - 0.001425315X_4$	79.57 [h]	13.63**
		Seed yield	$Y = 0.213394 - 0.001386553X_2$ [i]	49.31	7.78*

[a] **Straw yield in g/plant.**
[b] **Contribution of the predictors X_1 (DI on 15 April) and X_4 (DS on 30 April) to R^2 are 48.54% and 39.64%, respectively.**
[c] **Seed yield in g/plant.**
[d] **No regression equation could be constructed.**
[e] **Contribution of the predictors, X_3 (DS on 15 April) and X_2 (DI on 30 April) to R^2 are 59.57 and 14.70, respectively.**
[f] **X_1 is the disease incidence on 15 April.**
[g] **X_1 is the disease incidence on 4 April.**
[h] **Contribution of the predictors X_1 (DI on 4 April) and X_4 (DS on 19 April) to R^2 are 69.74% and 9.83%, respectively.**
[i] **X_2 is the DI on 19 April.**

DISCUSSION

The present study was conducted in 1999 and 2000 growing seasons to explore the possible utilization of foliar application of a diverse group of compounds for control of flax powdery mildew (FPM) under natural infection conditions. Disease intensity variables (DI and DS) and yield were used as criteria for evaluating the tested compounds.

The tested compounds vary in modes of action. TFS is surface protectant that suppresses fungal growth and sporulation either by direct contact or vapor phase activity (Seem *et al.*, 1981). Bayfidan, Bayleton, and Rubigan are ergosterol biosynthesis inhibitors (Siegel, 1981). Film-forming polymers (Nu-Film and Super-Film) may form physical barrier on leaf surface against germ tube penetration by conidia (Horst *et al.*, 1992). They may also alter the topography of the leaf surface, thus, interfering with adhesion of the germ tube and recognition of penetration sites (Zekaria-Oren *et al.*, 1991). Bicarbonate inhibits conidial formation and germination (Horst *et al.*, 1992).

Environmental conditions in 1999 and 2000 were favourable for epiphytotic spread of the disease. This was apparent as these environmental conditions resulted in high levels of DI and DS in the control pots, which did not receive treatments. These high levels of DI and DS in the control pots indicate that compounds were tested under high disease pressure. This high disease pressure is considered as a prerequisite condition for any meaningful evaluation of fungicides.

The finding of the present study demonstrated that sterol biosynthesis inhibitors in particular Bayfidan were the best performing compounds in controlling FPM. This superiority was attributed to the following reasons: first, they were the only compounds, which significantly reduced DI after the second spray in 1999. Second, they were the most effective compounds in reducing DI after the second spray in 2000. Third, they were the most effective compounds in reducing DS after the second spray in 1999. Fourth, they showed high efficiencies in reducing DS after the second spray in 2000. Fifth, they gave considerable increases in straw and seed yield. These findings are in agreement with previous studies. For example, Khalil *et al.* (1987) found that out of ten fungicides tested under greenhouse conditions, only Bayfidan and Bayleton appeared to posses protective and eradicative properties on FPM. Aly *et al.* (1994) and Mansour (1998) found that Bayfidan and Rubigan were effective in controlling FPM under field conditions.

The present study indicate that, in some cases, bicarbonates and film-forming polymers were as effective as or even more effective than fungicidal chemicals in controlling FPM and increasing yield. For example, each of TFS and sodium bicarbonate reduced DI by 8% after the second spray in 2000. In 1999, TFS and sodium bicarbonate significantly reduced DS after the first spray by 28.39 and 25.25%, respectively, regardless of the tested cultivar. In 1999, Bayfidan reduced DS on Giza 5 by 9.44% after the second spray, while sodium bicarbonate reduced it by 8.17%. TFS reduced DS on Giza 7 by 20.22% after the second spray, while sodium bicarbonate and Nu-Film reduced it by 30.34 and 21.75%, respectively. In 2000, Bayleton reduced DS by 16.06% after the first spray regardless of the tested cultivar, while Nu-Film reduced it by 15.83%. In 2000, Bayleton and ammonium bicarbonate reduced DS on Giza 5 after the second spray by 37.17 and 37.60%, respectively. In 1999, the application of Bayfidan increased seed yield by 64.29% regardless of the tested cultivar, while sodium bicarbonate increased it by 89.29%. In 2000, Bayleton and Super-Film increased straw yield of Giza 7 by 47.99 and 48.55%. On the other hand, the present study shows that bicarbonates and film-forming polymers had two drawbacks: first, they showed inconsistent performance in controlling the disease compared to the fungicidal chemicals. Second, when they were effective, they mostly showed lower efficiencies in reducing DI and DS. These compounds exhibit low mammalian and environmental toxicities-that is, they are biocompatible fungicides (Horst *et al.*, 1992). This advantage may justify the need of additional research to maximize their efficiencies in controlling FPM. This may be achieved by more application frequency and earlier application of the compounds before the first sign of the disease.

Combined ANOVA revealed that treatment x year interaction was a significant ($P = 0.04$) source of variation in DI and a very highly significant ($P = 0.0000$) source of variation in DS. Treatment x cultivar was also a very highly significant ($P = 0.0000$) source of variation in DI and DS. Taken together, these interactions imply that a single compound can be highly effective in controlling the disease on a given cultivar, but may have only a minimal effect on the disease on another cultivar. Similarly, a single compound may be highly effective in controlling the disease in one year, but may have only a minimal effect on the disease in another year. These findings have an important bearing on fungicide testing methods for controlling FPM. Fungicides should be tested against the disease by using as many cultivars as possible, over as many years as possible, as this will improve the chance of identifying fungicides effective in controlling the disease on several cultivars, under a wide range of environmental conditions. Our results are in accordance with those of Jones *et al.* (1987) who reported a highly significant ($P = 0.001$) interaction between oat cultivars and fungicides used for controlling powdery mildew.

Significant negative correlations between powdery mildew intensity variables (PMIV) and yield were observed each year particularly in case of cultivar Giza 7. These negative correlations between PMIV and yield, and the significant reduction in PMIV with some compounds suggest that the control of late-season powdery mildew could increase yields of cultivars in particular cultivar Giza 7.

Data for PMIV and yield wee entered into a computerized stepwise multiple regression analysis. The analysis constructed a predictive model by adding predictors, in this case PMIV, to the model in order of their contribution to coefficient of determination (R^2). The analysis was effective in eliminating those variables with little or no predictive value by incorporating into the model only those variables that made a statistically significant contribution to the R^2 value of the model (Podleckis *et al.*, 1984). Using the predictors supplied by stepwise regression, three models were constructed for each year to predict straw and seed yield. These models showed that yield differences observed were due largely to the disease, which accounted for 56.23 to 88.18% and 49.31 to 74.28% of the explained (model) variation in straw and seed yield, respectively. Thus, the application of appropriate compound for controlling the disease would be an important determinant of straw and seed yield under Egyptian conditions.

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إستعمال المبيدات الفطرية وأملاح البيكربونات والبوليمرات المكونة للأغشية فى مقاومة مرض البياض الدقيقى على الكتان

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أجريت تجربة أصص خارج الصوبة – خلال موسمى ١٩٩٩ و ٢٠٠٠ – لتقييم إمكانية مقاومة مرض البياض الدقيقي على الكتان عن طريق رش المجموع الخضرى بمجموعة متنوعة من المركبات هى على النحو التالى: مبيد كبريتى (ذات فلوابل سلفر) وثلاثة مبيدات جهازية (بايفيدان وبايليتون وروبيجان) وثلاثة أملاح بيكربونات (بيكربونات صوديوم وبوتاسيوم وأمونيوم) ومركبان من البوليمرات المكونة للأغشية (نيوفيلم وسوبر فيلم). أستعملت المتغيرات الدالة على كثافة المرض (حدوث المرض وشدة المرض) والمحصول (القش والبذرة) كمعايير لتقييم فعالية المركبات المختبرة فى مقاومة المرض. أظهرت الدراسة أن أفضل المركبات أداءً فى مقاومة المرض هى مجموعة المبيدات الجهازية خاصة البايفيدان ويعزى هذا التفوق إلى تفرد هذه المبيدات بمجموعة من المزايا هى: (١) هذه المجموعة هى الوحيدة التى أحدثت نقصاً معنوياً فى حدوث المرض بعد الرشة الثانية عام ١٩٩٩. (٢) كانت أكثر المركبات فعالية فى التقليل من حدوث المرض بعد الرشة الثانية عام ٢٠٠٠. (٣) كانت أكثر المركبات فعالية فى التقليل من شدة المرض بعد الرشة الثانية عام ١٩٩٩. (٤) أظهرت كفاءة عالية فى التقليل من شدة المرض بعد الرشة الثانية عام ٢٠٠٠. (٥) أعطت زيادات ملموسة فى محصول القش والبذرة فى كل عام. أملاح البيكربونات والبوليمرات المكونة للأغشية – أحياناً – كانت تعادل أو حتى تتفوق على المبيدات من حيث الفعالية فى مقاومة المرض وزيادة المحصول ، إلا أن الدراسة أظهرت أن لهذه المركبات (الأملاح والبوليمرات) عيبان هما: (١) أداء هذه المركبات فى مقاومة المرض كان يفتقر إلى الثبات مقارنة بأداء المبيدات. (٢) عندما أظهرت هذه المركبات فعالية فى مقاومة المرض فغالباً ما كانت هذه الفعالية منخفضة مقارنة بالفعالية التى أظهرت المبيدات. أمكن الكشف عن العديد من الإرتباطات المعنوية السالبة بين المحصول والمتغيرات الدالة على كثافة المرض. أمكن فى كل عام من عامى الدراسة – عن طريق تحليل البيانات بإستخدام الإنحدار المتعدد المرحلى – التوصل إلى ثلاث معادلات لوصف العلاقة بين محصول القش أو البذرة والمتغيرات الدالة على كثافة المرض. أظهرت هذه المعادلات أن نسبة تتراوح مابين ٥٦,٢٣ إلى ٨٨,١٨% من التباين فى كمية محصول القش من الممكن أن تعزى إلى الإصابة بالبياض الدقيقى ، كما أن نسبة تتراوح مابين ٤٩,٣١ إلى ٧٤,٢٨% من التباين فى محصول البذرة من الممكن أن تعزى إلى الإصابة بهذا المرض.