USE OF FUNGICIDES, BICARBONATE SALTS, AND FILM-FORMING POLYMERS TO SUPPRESS POWDERY MILDEW OF FLAX.
Aly, A.A.; M.T.M. Mansour; M.S.A. Felaifel; S.M.E. Zayed and A.M. El-Kafrawy

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 sulphur 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 performing 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 usitatissimum* 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 pumpkin 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 sulphur 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.

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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 \[ \frac{\text{DIC} - \text{DIT}}{\text{DIC}} \times 1000 \], 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.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Rate per 100 liter of water</th>
<th>Active ingredient b</th>
<th>Formulation c</th>
</tr>
</thead>
<tbody>
<tr>
<td>That flowable sulphur</td>
<td>250 g</td>
<td>52% Sulphur</td>
<td>WP</td>
</tr>
<tr>
<td>Bayfidan</td>
<td>15 ml</td>
<td>15% Triadimenol</td>
<td>EC</td>
</tr>
<tr>
<td>Bayleton</td>
<td>25 ml</td>
<td>25% Triadimefon</td>
<td>EC</td>
</tr>
<tr>
<td>Rubigan</td>
<td>30 ml</td>
<td>12% Fenorimol</td>
<td>EC</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>1000 g</td>
<td>NaHCO₃</td>
<td>SP</td>
</tr>
<tr>
<td>Potassium bicarbonate 1000 g</td>
<td>KHCO₃</td>
<td>SP</td>
<td></td>
</tr>
<tr>
<td>Ammonium bicarbonate 1000 g</td>
<td>NHHCO₃</td>
<td>SP</td>
<td></td>
</tr>
<tr>
<td>Nu-Film-17</td>
<td>600 ml</td>
<td></td>
<td>EC</td>
</tr>
<tr>
<td>Super-Film</td>
<td>600 ml</td>
<td></td>
<td>EC</td>
</tr>
</tbody>
</table>

*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.

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

<table>
<thead>
<tr>
<th>Source</th>
<th>PMI on 15/4/1999</th>
<th>PMI on 30/4/1999</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M.S.</td>
<td>F-value</td>
</tr>
<tr>
<td>Replication</td>
<td>4</td>
<td>21.095</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td>2</td>
<td>119.283</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>9</td>
<td>2667.489</td>
</tr>
<tr>
<td>C x T</td>
<td>18</td>
<td>149.023</td>
</tr>
<tr>
<td>Error</td>
<td>116</td>
<td>47.607</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>PMI on 15/4/1999</th>
<th>PMI on 30/4/1999</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Giza 5</td>
<td>Giza 6</td>
</tr>
<tr>
<td>That flowable sulphur%*</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>90.000</td>
<td>90.000</td>
</tr>
<tr>
<td>Bayfidan %</td>
<td>77.75</td>
<td>50.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>55.754</td>
<td>45.000</td>
</tr>
<tr>
<td>Bayleton %</td>
<td>76.00</td>
<td>78.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>60.906</td>
<td>67.706</td>
</tr>
<tr>
<td>Rubigan %</td>
<td>94.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>81.000</td>
<td>90.000</td>
</tr>
<tr>
<td>Sodium bicarbonate%</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Potassium bicarbonate%</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Ammonium bicarbonate%</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Nu-Film %</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Super-Film %</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>None %</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Mean</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>d.f.</td>
<td>M.S.</td>
</tr>
<tr>
<td>Replication</td>
<td>4</td>
<td>7656.449</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td>2</td>
<td>11556.659</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>9</td>
<td>3171.127</td>
</tr>
<tr>
<td>C x T</td>
<td>18</td>
<td>306.797</td>
</tr>
<tr>
<td>Error</td>
<td>116</td>
<td>205.777</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Giza 5</td>
<td>Giza 6</td>
</tr>
<tr>
<td>That flowable sulphur%</td>
<td>52.00</td>
<td>44.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>46.204</td>
<td>45.000</td>
</tr>
<tr>
<td>Bayfidan</td>
<td>6.00</td>
<td>32.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>9.00</td>
<td>30.688</td>
</tr>
<tr>
<td>Bayleton</td>
<td>30.00</td>
<td>30.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>29.358</td>
<td>27.000</td>
</tr>
<tr>
<td>Rubigan</td>
<td>32.00</td>
<td>52.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>24.222</td>
<td>45.734</td>
</tr>
<tr>
<td>Sodium bicarbonate %</td>
<td>42.00</td>
<td>64.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>36.734</td>
<td>57.004</td>
</tr>
<tr>
<td>Potassium bicarbonate%</td>
<td>68.00</td>
<td>80.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>58.766</td>
<td>69.046</td>
</tr>
<tr>
<td>Ammonium bicarbonate%</td>
<td>64.00</td>
<td>82.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>56.534</td>
<td>70.376</td>
</tr>
<tr>
<td>Nu-Film</td>
<td>58.00</td>
<td>82.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>50.534</td>
<td>73.330</td>
</tr>
<tr>
<td>Super-Film</td>
<td>54.00</td>
<td>66.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>50.312</td>
<td>55.330</td>
</tr>
<tr>
<td>None</td>
<td>68.00</td>
<td>92.00</td>
</tr>
<tr>
<td>Arc sine</td>
<td>59.312</td>
<td>79.670</td>
</tr>
<tr>
<td>Mean %</td>
<td>47.40</td>
<td>62.40</td>
</tr>
<tr>
<td>Arc sine</td>
<td>42.058</td>
<td>55.318</td>
</tr>
</tbody>
</table>

LSD (transformed data) for Cultivar

<table>
<thead>
<tr>
<th></th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>5.682</td>
<td>1.754</td>
</tr>
<tr>
<td></td>
<td>10.370</td>
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<tr>
<td>Cultivar x treatment interaction</td>
<td>NS</td>
<td>11.620</td>
</tr>
<tr>
<td></td>
<td>15.370</td>
<td>5.370</td>
</tr>
</tbody>
</table>

* 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 Baylidan 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.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>PMS on 15/4/1999</th>
<th>PMS on 30/4/1999</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>d.f.</td>
<td>M.S.</td>
</tr>
<tr>
<td>Replications</td>
<td>4</td>
<td>49.218</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td>2</td>
<td>103.005</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>9</td>
<td>7911.358</td>
</tr>
<tr>
<td>C x T</td>
<td>18</td>
<td>77.309</td>
</tr>
<tr>
<td>Error</td>
<td>116</td>
<td>76.498</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>PMS on 15/4/1999</th>
<th>PMS on 30/4/1999</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Giza 5</td>
<td>Giza 6</td>
</tr>
<tr>
<td>That flowable sulphur</td>
<td></td>
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</tr>
<tr>
<td>91.58</td>
<td>66.94</td>
<td>73.14</td>
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<tr>
<td>Bayldan</td>
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</tr>
<tr>
<td>Arc sine 55.054</td>
<td>58.930</td>
<td>57.856</td>
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<tr>
<td>%</td>
<td>28.21</td>
<td>7.90</td>
</tr>
<tr>
<td>Bayleton</td>
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<td></td>
</tr>
<tr>
<td>Arc sine 30.478</td>
<td>15.952</td>
<td>15.240</td>
</tr>
<tr>
<td>%</td>
<td>24.74</td>
<td>22.41</td>
</tr>
<tr>
<td>Rubigan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>36.24</td>
<td>44.52</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
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<td></td>
</tr>
<tr>
<td>%</td>
<td>69.99</td>
<td>75.23</td>
</tr>
<tr>
<td>Arc sine 58.318</td>
<td>60.164</td>
<td>60.568</td>
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<tr>
<td>Potassium bicarbonate</td>
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<tr>
<td>%</td>
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<td></td>
</tr>
<tr>
<td>%</td>
<td>92.69</td>
<td>97.14</td>
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<tr>
<td>Arc sine 74.386</td>
<td>80.110</td>
<td>78.256</td>
</tr>
<tr>
<td>Nu-Film</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>94.01</td>
<td>95.04</td>
</tr>
<tr>
<td>Arc sine 77.636</td>
<td>77.190</td>
<td>66.442</td>
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<tr>
<td>Super-Film</td>
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<td></td>
</tr>
<tr>
<td>%</td>
<td>97.75</td>
<td>97.34</td>
</tr>
<tr>
<td>Arc sine 81.776</td>
<td>80.588</td>
<td>75.686</td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>98.94</td>
<td>98.34</td>
</tr>
<tr>
<td>Arc sine 83.924</td>
<td>82.678</td>
<td>81.926</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>70.20</td>
<td>70.27</td>
</tr>
<tr>
<td>Arc sine 60.125</td>
<td>59.306</td>
<td>57.333</td>
</tr>
</tbody>
</table>

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

* 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. Bayldan 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.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M.S.</td>
<td>F-value</td>
</tr>
<tr>
<td>Replications</td>
<td>4</td>
<td>5698.746</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td>2</td>
<td>4190.701</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>9</td>
<td>580.431</td>
</tr>
<tr>
<td>C x T</td>
<td>18</td>
<td>96.396</td>
</tr>
<tr>
<td>Error</td>
<td>116</td>
<td>165.879</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Giza 5</td>
<td>Giza 6</td>
</tr>
<tr>
<td>That flowable sulphur%*</td>
<td>54.64</td>
<td>64.60</td>
</tr>
<tr>
<td>Bayifan (arc sine)</td>
<td>26.42</td>
<td>59.32</td>
</tr>
<tr>
<td>Bayleton (arc sine)</td>
<td>42.18</td>
<td>68.13</td>
</tr>
<tr>
<td>Rubigan (arc sine)</td>
<td>37.87</td>
<td>76.14</td>
</tr>
<tr>
<td>Sodium bicarbonate%</td>
<td>60.37</td>
<td>80.63</td>
</tr>
<tr>
<td>Nitrofilm (arc sine)</td>
<td>54.63</td>
<td>75.99</td>
</tr>
<tr>
<td>Superfilm (arc sine)</td>
<td>51.11</td>
<td>76.53</td>
</tr>
<tr>
<td>None (arc sine)</td>
<td>66.40</td>
<td>72.90</td>
</tr>
<tr>
<td>Mean</td>
<td>49.35</td>
<td>71.38</td>
</tr>
<tr>
<td>LSD (transformed data) for Cultivar</td>
<td>5%</td>
<td>5.102</td>
</tr>
<tr>
<td>Treatment</td>
<td>1%</td>
<td>6.746</td>
</tr>
<tr>
<td>Cultivar x treatment interaction</td>
<td>5%</td>
<td>NS</td>
</tr>
</tbody>
</table>

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

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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.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Straw weight</th>
<th>Seed weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>d.f.</td>
<td>M.S.</td>
</tr>
<tr>
<td>Replication</td>
<td>4</td>
<td>0.013</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td>2</td>
<td>0.031</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>9</td>
<td>0.029</td>
</tr>
<tr>
<td>C x T</td>
<td>18</td>
<td>0.007</td>
</tr>
<tr>
<td>Error</td>
<td>116</td>
<td>0.007</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Straw weight</th>
<th>Seed weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Giza 5</td>
<td>Giza 6</td>
</tr>
<tr>
<td>That flowable sulphur</td>
<td>0.307</td>
<td>0.366</td>
</tr>
<tr>
<td>Bayfidan</td>
<td>0.399</td>
<td>0.339</td>
</tr>
<tr>
<td>Bayleton</td>
<td>0.327</td>
<td>0.297</td>
</tr>
<tr>
<td>Rubigan</td>
<td>0.233</td>
<td>0.270</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>0.256</td>
<td>0.309</td>
</tr>
<tr>
<td>Potassium bicarbonate</td>
<td>0.291</td>
<td>0.295</td>
</tr>
<tr>
<td>Ammonium bicarbonate</td>
<td>0.289</td>
<td>0.315</td>
</tr>
<tr>
<td>Nu-Film</td>
<td>0.300</td>
<td>0.202</td>
</tr>
<tr>
<td>Super-Film</td>
<td>0.291</td>
<td>0.277</td>
</tr>
<tr>
<td>None</td>
<td>0.272</td>
<td>0.311</td>
</tr>
<tr>
<td>Mean</td>
<td>0.297</td>
<td>0.298</td>
</tr>
</tbody>
</table>

LSD (transformed data) for Cultivar

| Cultivar x treatment interaction | 5% NS | NS |
| Treatment                        | 5% 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.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Straw weight</th>
<th>Seed weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>d.f.</td>
<td>M.S.</td>
</tr>
<tr>
<td>Replication</td>
<td>4</td>
<td>0.012</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td>2</td>
<td>0.042</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>9</td>
<td>0.038</td>
</tr>
<tr>
<td>C x T</td>
<td>18</td>
<td>0.015</td>
</tr>
<tr>
<td>Error</td>
<td>116</td>
<td>0.009</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Straw weight</th>
<th>Seed weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Giza 5</td>
<td>Giza 6</td>
</tr>
<tr>
<td>That flowable sulphur</td>
<td>0.445</td>
<td>0.522</td>
</tr>
<tr>
<td>Bayfidan</td>
<td>0.433</td>
<td>0.540</td>
</tr>
<tr>
<td>Bayleton</td>
<td>0.457</td>
<td>0.548</td>
</tr>
<tr>
<td>Rubigan</td>
<td>0.361</td>
<td>0.502</td>
</tr>
<tr>
<td>Sodium Bicarbonate</td>
<td>0.368</td>
<td>0.422</td>
</tr>
<tr>
<td>Potassium Bicarbonate</td>
<td>0.377</td>
<td>0.360</td>
</tr>
<tr>
<td>Ammonium Bicarbonate</td>
<td>0.397</td>
<td>0.401</td>
</tr>
<tr>
<td>Nu-Film</td>
<td>0.453</td>
<td>0.398</td>
</tr>
<tr>
<td>Super-film</td>
<td>0.437</td>
<td>0.323</td>
</tr>
<tr>
<td>None</td>
<td>0.435</td>
<td>0.419</td>
</tr>
<tr>
<td>Mean</td>
<td>0.416</td>
<td>0.443</td>
</tr>
</tbody>
</table>

LSD (transformed data) for Cultivar x 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 cultivar, treatment, and their interaction to variation in powdery mildew intensity variables and yield of flax in 1999.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Disease incidence</th>
<th>Relative contribution to variation in *</th>
<th>Disease severity</th>
<th>Straw weight (g/plant)</th>
<th>Seed weight (g/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivar (C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment (T)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C x T</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Disease incidence</th>
<th>Disease severity</th>
<th>Straw weight (g/plant)</th>
<th>Seed weight (g/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivar (C)</td>
<td>26.3245</td>
<td>8.7619</td>
<td>21.9780</td>
<td>8.4456</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>32.5053</td>
<td>68.3443</td>
<td>13.6982</td>
<td>74.7956</td>
</tr>
<tr>
<td>C x T</td>
<td>6.2896</td>
<td>20.9823</td>
<td>4.5499</td>
<td>15.3186</td>
</tr>
</tbody>
</table>

* 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 < 0.0001), 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 * (combined data of 1999 and 2000)

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

* 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)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>M.S.</th>
<th>F-value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year (Y)</td>
<td>1</td>
<td>6475.316</td>
<td>76.0710</td>
<td>0.0000</td>
</tr>
<tr>
<td>Block (Y)</td>
<td>8</td>
<td>85.122</td>
<td>0.8666</td>
<td>N.S.</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td>2</td>
<td>1597.518</td>
<td>0.4116</td>
<td>N.S.</td>
</tr>
<tr>
<td>Y x C</td>
<td>2</td>
<td>3881.546</td>
<td>39.5169</td>
<td>0.0000</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>9</td>
<td>5865.559</td>
<td>4.4791</td>
<td>0.025</td>
</tr>
<tr>
<td>Y x T</td>
<td>18</td>
<td>301.635</td>
<td>3.0709</td>
<td>0.0000</td>
</tr>
<tr>
<td>C x T</td>
<td>18</td>
<td>298.859</td>
<td>3.0426</td>
<td>0.0001</td>
</tr>
<tr>
<td>Error</td>
<td>232</td>
<td>98.225</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) 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)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>M.S.</th>
<th>F-value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year (Y)</td>
<td>1</td>
<td>1.310</td>
<td>109.1667</td>
<td>0.0000</td>
</tr>
<tr>
<td>Block (Y)</td>
<td>8</td>
<td>0.012</td>
<td>8.8969</td>
<td>0.1389</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td>2</td>
<td>0.069</td>
<td>17.2500</td>
<td>0.0100</td>
</tr>
<tr>
<td>Y x C</td>
<td>2</td>
<td>0.004</td>
<td>0.5294</td>
<td>N.S.</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>9</td>
<td>0.006</td>
<td>10.1667</td>
<td>0.0050</td>
</tr>
<tr>
<td>Y x T</td>
<td>9</td>
<td>0.013</td>
<td>1.6873</td>
<td>0.0425</td>
</tr>
<tr>
<td>C x T</td>
<td>18</td>
<td>0.009</td>
<td>1.1106</td>
<td>0.3425</td>
</tr>
<tr>
<td>Error</td>
<td>232</td>
<td>0.008</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) 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)

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

\(^a\) 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).

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Second DI</th>
<th>Second DS</th>
<th>Straw weight (g/plant)</th>
<th>Seed weight (g/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year (Y)</td>
<td>1.62490</td>
<td>6.92553</td>
<td>51.231912</td>
<td>1.92308</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td>1.75055</td>
<td>3.41718</td>
<td>5.396950</td>
<td>3.84615</td>
</tr>
<tr>
<td>Y x C</td>
<td>8.15021</td>
<td>0.30284</td>
<td>0.00313</td>
<td>0.04808</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>49.65490</td>
<td>56.46041</td>
<td>21.5487</td>
<td>31.2500</td>
</tr>
<tr>
<td>Y x T</td>
<td>3.19650</td>
<td>12.60529</td>
<td>2.1509</td>
<td>1.92308</td>
</tr>
<tr>
<td>C x T</td>
<td>10.90291</td>
<td>5.80693</td>
<td>9.34689</td>
<td>21.15385</td>
</tr>
<tr>
<td>Y x C x T</td>
<td>21.81667</td>
<td>5.75349</td>
<td>6.17912</td>
<td>8.65385</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Variable</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giza 5</td>
<td>1 DI (15 April)</td>
<td>0.8551**</td>
<td>0.7401*</td>
<td>-0.6967*</td>
<td>-0.0587</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 DI (30 April)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 DS (15 April)</td>
<td></td>
<td>0.8448**</td>
<td>-0.4255</td>
<td>-0.3494</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 DS (30 April)</td>
<td></td>
<td>-0.0922</td>
<td>-0.2691</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Straw weight (g/plant)</td>
<td>-0.1560</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Seed weight (g/plant)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giza 6</td>
<td>1 DI (15 April)</td>
<td>0.6565**</td>
<td>0.6915**</td>
<td>0.7406**</td>
<td>-0.0015</td>
<td>-0.3543</td>
</tr>
<tr>
<td></td>
<td>2 DI (30 April)</td>
<td>0.9239**</td>
<td>0.9622**</td>
<td>0.1229</td>
<td>-0.5664x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 DS (15 April)</td>
<td>0.9573**</td>
<td>-0.1025</td>
<td>-0.7718**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 DS (30 April)</td>
<td>0.0777</td>
<td>-0.0872</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Straw weight (g/plant)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Seed weight (g/plant)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giza 7</td>
<td>1 DI (15 April)</td>
<td>0.8403**</td>
<td>0.6407**</td>
<td>0.6134x</td>
<td>-0.08184**</td>
<td>-0.0522</td>
</tr>
<tr>
<td></td>
<td>2 DI (30 April)</td>
<td>0.8431**</td>
<td>0.8253**</td>
<td>-0.7570*</td>
<td>-0.1229</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 DS (15 April)</td>
<td>0.9866**</td>
<td>-0.6363*</td>
<td>-0.5184</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 DS (30 April)</td>
<td>-0.8129x</td>
<td>-0.5384</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Straw weight (g/plant)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Seed weight (g/plant)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Variable</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giza 5</td>
<td>DI (4 April)</td>
<td>0.8122**</td>
<td>0.8245**</td>
<td>0.7724**</td>
<td>-0.0566</td>
<td>-0.3213</td>
</tr>
<tr>
<td></td>
<td>DI (19 April)</td>
<td>0.8269**</td>
<td>0.8899**</td>
<td>0.0011</td>
<td>0.1805</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DS (4 April)</td>
<td>0.8453**</td>
<td>-0.1108</td>
<td>-0.0398</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DS (19 April)</td>
<td>0.0013</td>
<td>0.1915</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Straw weight (plant)</td>
<td>0.1413</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seed weight (plant)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giza 6</td>
<td>DI (4 April)</td>
<td>0.7257**</td>
<td>0.6391*</td>
<td>0.7937**</td>
<td>-0.7499**</td>
<td>-0.4022</td>
</tr>
<tr>
<td></td>
<td>DI (19 April)</td>
<td>0.6212*</td>
<td>0.8021**</td>
<td>-0.5144</td>
<td>-0.2449</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DS (4 April)</td>
<td>0.7424*</td>
<td>-0.2263</td>
<td>-0.3470</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DS (19 April)</td>
<td>-0.4830</td>
<td>-0.1716</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Straw weight (plant)</td>
<td>0.3808</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seed weight (plant)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giza 7</td>
<td>DI (4 April)</td>
<td>0.7108**</td>
<td>0.6833*</td>
<td>0.5297</td>
<td>-0.8351**</td>
<td>-0.5660x</td>
</tr>
<tr>
<td></td>
<td>DI (19 April)</td>
<td>0.7356*</td>
<td>0.7502*</td>
<td>-0.6220x</td>
<td>-0.7022*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DS (4 April)</td>
<td>0.9278**</td>
<td>-0.7896**</td>
<td>-0.5189</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DS (19 April)</td>
<td>-0.7083*</td>
<td>-0.4516</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Straw weight (plant)</td>
<td>0.6718</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seed weight (plant)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Linear correlation coefficient (r) is significant at P < 0.10 (x), P < 0.05 (*), or P < 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). R² 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.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cultivar</th>
<th>Dependent variable (Y)</th>
<th>Regression equation</th>
<th>R²</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Giza 5</td>
<td>Straw yield *</td>
<td>Y = 0.5684016 − 0.0066628X₁ + 0.00390376X₄</td>
<td>88.18*</td>
<td>26.10**</td>
</tr>
<tr>
<td></td>
<td>Giza 6</td>
<td>Straw yield</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Giza 7</td>
<td>Straw yield</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>Giza 5</td>
<td>Straw yield *</td>
<td>Y = 0.8750393 – 0.00112493X₁ + 0.0008565002X₂</td>
<td>74.28*</td>
<td>10.11**</td>
</tr>
<tr>
<td></td>
<td>Giza 6</td>
<td>Straw yield</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Giza 7</td>
<td>Straw yield</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Straw yield in g/plant.

a Contribution of the predictors X₁ (DI on 15 April) and X₄ (DS on 30 April) to R² are 48.54% and 39.64%, respectively.

b Seed yield in g/plant.

No regression equation could be constructed.

a Contribution of the predictors, X₁ (DS on 15 April) and X₄ (DI on 30 April) to R² are 59.57 and 14.70, respectively.

a X₁ is the disease incidence on 15 April.

a X₄ is the disease incidence on 4 April.

a Contribution of the predictors X₁ (DI on 4 April) and X₄ (DS on 19 April) to R² are 69.74% and 9.83%, respectively.

X₁ 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 were 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 (R²). 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 R² 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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REFERENCES


استخدام المبيدات ببتوية وأملاح البيكرونات والبوليميرات المكونة للأغشية في مقاومة مرض البياض الدقيق على الكتان على عدل الهادي علي ، محمد توفيق ممدوه صموئيل ، محمد صلاح الدين عبد العزيز ملقي ، شوقى محمد المشتي زايد ، على محمد الكفاوي معهد بحوث أمراض النبات - مركز البحوث الزراعية - الجيزة - مصر

أجريت تجربة لأصحاب صح مراض الصوبة - خلال موسمي 1999 و 2000 - لتقسيم إمكانية مقاومة مرض البياض الدقيق على الكتان عن طريق علاج المجموع الحمضي بجامعة متنوعة من المركبات هي على النحو التالي: مبيد كيرتي (ذات قوانين سلفر) وثلاثة مبيدات جهادية (بيكرونات بيديلت وروبيجان) وثلاثة أصالا البيكرونات (بيكرونات سوديو بوتاسيموم وامتيوموم) ومركب من البوليميرات المكونة (بيكرونات وسودوم تيم). استخدمت المبيدات التالية على كافية المرض (جودة المرض وضغط المرض) والمتصور (النقي والبتر) معاً لتقييم فعالية المركبات المختبرة في مقاومة المرض. أظهرت النتائج أن أفضل المركبات أدأ في مقاومة المرض هي مجموعة المبيدات الجزءية خاصة البليدين. وفي هذا التحقيق، إلى ضرع هذه المبيدات في الوضع المرتادي: (1) هذه المجموعة هي الأوصف التي أحدثت نماً مرتادي في حدوث المرض بعد الرشة الثانية عام 1999. (2) كانت أكثر المركبات فعالية في القليل من حدوث المرض بعد الرشة الثانية عام 2000. (3) كانت أكثر المركبات فعالية في القليل من حدوث المرض بعد الرشة الثانية عام 1999. (4) أظهرت كفاءة عالية في القليل من حدث المرض بعد الرشة الثانية عام 2000. (5) أعطت زيادات ملونة في محصول القمح والبتر في كل عام. أصالا البيكرونات والبوليميرات المكونة للأغشية - أحياء - كانت تعادل أو حتى تفوق على النباتات من حيث الفعالية في مقاومة المرض وزيادة محصول القمح. لذا، إذا دراسة أظهرت أن هذه المركبات تساهم في زراعة المبيدات (البيكرونات والبوليميرات) جيروم (1) أثناء هذه المركبات في مقاومة المرض، كافئ إلى النباتات بقادة المبيدات (2). عندما أظهرت هذه المركبات فعالية في مقاومة المرض، فإنها كانت هذه الفعالية منخفضة وملتزم مقتربة. يمكن الكشف عن عدد من الربطات المعنوية بين المبيدات المستخدمة على كافة المرض. يمكن في كل من نما الدراسة - من طريق تحليل النباتات باستخدام الإحصاءات المتبعد المراحل وصول إلى ثلاث مراحل لوصف العلاقة بين محصول القمح وفروع البيضة بتركيا ونهاية النباتات على كافة القمح. يمكن في المعالجات أن نسبة تراوح بين 87.8 – 88.1% من العينات إلى 94.5% من العينات في محصول القمح من الممكن أن تعود إلى الإصابات ببياض الدقيق، كما يعود نسبة تراوح مابين 52.03% إلى 88.98% مابين العينات إلى 84.08% لفروع البيضة. يمكن أن تعود إلى الإصابات ببياض الدقيق. هذا المرض.