Effect of fungal infection on the composition of acyl lipids in wheat seedlings
A. G. Vereshchagin* and A. V. Zhukov
Laboratory of Lipid Metabolism, Institute of Plant Physiology, Russian Academy of Sciences, 127276 Moscow, Russia

Abstract
Infection of etiolated wheat seedlings with a root rot fungus Bipolaris sorokiniana caused a strong deviation in the fatty acid composition of their total lipids from the control. The deviation occurred at the expense of that lipid group, which predominates in a given plant organ (shoots or roots), and peak deviation coincided with the onset of a severe inhibition of growth.

Introduction
Recently, an increase in the share of cereals in the total cultivated area in Russia caused a widespread propagation of helminthosporic root rot of wheat. Therefore, investigation of the biochemical basis of resistance to this infectional stress is very urgent [1]. The stress-induced metabolic disturbances are known to cause significant changes in the fatty acid (FA) composition of membrane lipids [2]. Therefore, this work was devoted to investigating the effects of root rot infection on the FA composition of total lipids of wheat seedlings.

Experimental
Seeds of a root rot-susceptible cultivar of spring wheat Triticum aestivum L. were treated with a suspension of conidia of pathogenic fungus Bipolaris sorokiniana (Sacch.) Shoemaker [3] or with distilled water (control) and germinated in the dark for 3, 5, 7 and 10 days at 25 °C. Shoots and roots of the seedlings were homogenized in ethanol, homogenate lipids were saponified with NaOH, and FAs obtained were converted into their methyl esters, which were separated by GLC [4]. Infection-induced changes in the composition of major FAs of total lipids were expressed as the weighted average deviation of this composition from the control composition (D), where

\[ D = \left( \sum (d_i - b_i) \times 100^{-1} \right) \]

and where

\[ d_i = \left| 100 - 100b_i \times a_i^{-1} \right| \]

is the individual infection-induced deviation of each ith FA concentration, and \( a_i \) and \( b_i \) are the concentrations of an ith FA, in mol %, in the total lipids of control and infected plants, respectively. The extent of contribution of each ith FA concentration to the D value (\( C_i \)) was determined by the equation:

\[ C_i = 100f_i \times (\sum f_i)^{-1} \]

where

\[ f_i = (d_i \times b_i) + (d_i \times b_i)_a + (d_i \times b_i)_7 + (d_i \times b_i)_10 \]

and 3–10 indicate the age of seedlings, d (days).

Results and discussion
The values of \( a_i \) and \( b_i \) are shown in Table 1. It can be seen that the pattern of their dynamics during germination fails to present a clear picture of infection-induced alterations in FA composition of total lipids in shoots and roots. Therefore, these alterations were assessed using a novel procedure involving the consideration of all individual deviations of \( b_i \) from \( a_i \) regardless of their direction, and subsequent calculation of the overall D value for a given day of germination.

The relationship between D value and seedling age is presented in Figure 1. It is seen that the transition from the fifth day to the seventh day was accompanied by a drastic increase in these values both in shoots (3-fold) and in roots (2.5-fold), and D values peaked on the seventh day. It has been established that this day of germination coincided with the onset of a rapid decrease in the growth rate of both these organs of infected plants (results not shown). Thus, the maximum deviation of FA

Key words: Bipolaris sorokiniana, lipid composition deviation, Triticum aestivum.

Abbreviation used: FA, fatty acid.

*To whom correspondence should be addressed (e-mail ifr@ippras.ru).
Table I

Effect of fungal infection of wheat seedlings on the major FA composition of their total lipids

<table>
<thead>
<tr>
<th>Age of seedlings (days)</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty acid</td>
<td>$a_1$</td>
<td>$b_1$</td>
<td>$a_1$</td>
<td>$b_1$</td>
</tr>
<tr>
<td>Shoots</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_{16:0}$</td>
<td>20.7</td>
<td>24.1</td>
<td>22.4</td>
<td>17.5</td>
</tr>
<tr>
<td>$C_{18:0}$</td>
<td>1.4</td>
<td>0.6</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>$C_{18:1}$</td>
<td>6.1</td>
<td>4.8</td>
<td>4.5</td>
<td>4.4</td>
</tr>
<tr>
<td>$C_{18:2}$</td>
<td>34.2</td>
<td>34.0</td>
<td>29.8</td>
<td>29.3</td>
</tr>
<tr>
<td>$C_{18:3}$</td>
<td>35.8</td>
<td>32.0</td>
<td>36.7</td>
<td>41.4</td>
</tr>
<tr>
<td>$C_{20:0}$-$C_{22}$</td>
<td>0.5</td>
<td>2.2</td>
<td>3.8</td>
<td>3.9</td>
</tr>
<tr>
<td>Roots</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_{16:0}$</td>
<td>17.6</td>
<td>16.4</td>
<td>22.6</td>
<td>19.1</td>
</tr>
<tr>
<td>$C_{18:0}$</td>
<td>1.3</td>
<td>1.9</td>
<td>1.5</td>
<td>2.1</td>
</tr>
<tr>
<td>$C_{18:1}$</td>
<td>9.0</td>
<td>10.4</td>
<td>9.4</td>
<td>9.3</td>
</tr>
<tr>
<td>$C_{18:2}$</td>
<td>52.9</td>
<td>49.9</td>
<td>50.3</td>
<td>48.9</td>
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<tr>
<td>$C_{18:3}$</td>
<td>17.9</td>
<td>17.5</td>
<td>12.5</td>
<td>12.4</td>
</tr>
<tr>
<td>$C_{20:0}$-$C_{22}$</td>
<td>0.0</td>
<td>0.0</td>
<td>0.8</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Composition from the control may be caused by the onset, at this point, of the most severe disturbance of membrane lipid composition resulting in the inhibition of growth.

By the tenth day, the $D$ value in shoots decreased to the initial value due to the adaptation of membranes to the stress. $D$ also decreased in roots, but even on the tenth day its level exceeded the initial value 6-fold because root rot, as a soil pathogen, affects the roots of plants primarily.

$C_i$ values are shown in Table 1. They were compared with $b_m$, the arithmetic mean of four $b$ values for each respective FA species. One can see that, in terms of $C_i$ values of the $C_{16}$-$C_{18}$ FAs of shoots, the $C_{18:2}$ and $C_{16:0}$ acids characteristic of plastid glycolipids [5] exceeded many-fold the $C_{18:2}$ acid typical of extraplastidic membrane phospholipids [5]. In contrast, in roots, the $C_{18:2}$, $C_{18:0}$ and $C_{16:0}$ acids, i.e. the components present in phospholipids, were of similar magnitude, or more, greater in their $C_i$ than the $C_{18:3}$ acid, whose $C_i$ was 8-fold less than its respective $b_m$ value. Thus, it can be suggested that, in shoots, root rot affected for the most part the FA composition of the predominant lipids, i.e. glycolipids of etioplasts, while in roots the infection disturbed mainly the composition of extraplastidic phospholipids prevalent in these organs. It was previously shown that rust fungal infection of leaves resulted in a decrease in the content of chloroplast lipids and a respective increase in the concentration of phospholipids [6,7].

Finally, we must emphasize that, in shoots and roots, $C_i$ of total $C_{20}$-$C_{22}$ acids exceeded by 5- and 8-fold, respectively, the corresponding $b_m$ values (Table 1). Taking into account that these
FAs are typical of epicuticular waxes [8], it can be speculated that the relationship observed was caused by surface wax formation as a protective response to fungal infection, as was the case in wheat leaves, where the powdery mildew infection resulted in doubling of the wax content on their surface [9].

References
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Received 22 June 2000

Sulpholipid reflects plant resistance to stress-factor action
N. Taran', A. Okanenko and N. Musienko
National Taras Shevchenko University, Volodymyrsky st., 64, 01033 Kyiv, Ukraine

Abstract
The results of studying the behaviour of sulphonyuvosyldiaclyglycerol (SQDG) during environmental-factor action are discussed. Low-temperature action caused SQDG accumulation in 1-year-old shoot bark of resistant apple varieties, and was especially striking in the Siberia apple, a variety of extreme hardiness. Another unfavourable factor, high temperature, induced SQDG accumulation in leaves and chloroplasts of drought-resistant plants while in sensitive plants a decrease in its content took place. Water deficit caused the same effect. SQDG increase was also observed in field experiments with artificial irrigation in the drought region of Ukraine, at the stages of stooling and milk ripeness. Besides, SQDG accumulation was observed in wheat plants infected by Puccinia graminis and kidney bean plants infected by tobacco mosaic and potato viruses. But lead supplied at various concentrations caused an SQDG decrease in wheat seedling leaves and roots. The reasons for these phenomena seemed to be mainly the stabilization of the photosynthetic processes, particularly ATP synthesis and light-harvesting complex II functioning, but signal function also cannot be excluded.

For a long time we have been studying environmental-factor action upon the lipid composition of different plants. The results obtained attracted our attention to the behaviour of a sulphur-containing glycerolipid, sulphonyuvosyldiaclyglycerol (SQDG). The point of specificity of plant-adaptive reaction to unfavourable environmental factors is unknown but a main peculiarity of stress metabolism is the intensive formation of active oxygen species like superoxide, hydrogen peroxide and hydroxide radicals. The main targets of these processes are lipids, especially their unsaturated species. But it is interesting that the amount of SQDG was stable while there was a fall in the level of both galactolipids (monogalactosyldiaclyglycerol [MGDG] and digalactosyldiaclyglycerol [DGDG]) during stress exposure in a number of plants, but in broad bean leaves an SQDG increase took place. As a result SQDG content relative to glycolipid quantity increased by 7–45% (depending upon species) [1,2]. Chilling action induced SQDG accumulation in 1-year-old shoot bark of resistant apple varieties, and was especially striking in the Siberia apple (Malus boccata Borkh), a variety of extreme hardiness [3]. Another study [4] showed that a 2-fold increase in the content of SQDG took place in a pine thylakoid preparation during the autumn and the winter.

High-temperature action induced SQDG accumulation in the drought-resistant wheat leaves

Key words: drought resistance, heat resistance, lipid composition, sulphonyuvosyldiaclyglycerol.
Abbreviations used: SQDG, sulphonyuvosyldiaclyglycerol; MGDG, monogalactosyldiaclyglycerol; DGDG, digalactosyldiaclyglycerol.

To whom correspondence should be addressed (e-mail plant@biocc.univ.kiev.ua).