Evaluation of the Role of Host Resistance and the Physiological Properties of Tubers in Relation to Potato Late Blight Disease Resistance

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Team Leader: William Kirk, MSU Dept. of Plant Pathology

Team Members: Phillip Wharton and Ray Hammerschmidt, MSU Dept. of Plant Pathology, and Dave Douches, MSU Dept. of Crop and Soil Science

Project Justification
Late blight of potato, caused by *Phytophthora infestans*, is a major worldwide threat to the production of high quality potatoes. Late blight is readily transmitted by seed-borne inoculum and consequently immature stems and leaves may be exposed to disease from infected seed pieces. The resistance of tubers to late blight is therefore an important factor in the epidemiology and economics of this disease. MSU has developed a strong breeding program for potatoes which is based on resistance to *P. infestans*. The relation between tuber and foliar late blight is not correlated and therefore the physiology and nature of resistance or susceptibility in tubers needs to be clarified.

Objectives
1. Determine the importance of the tuber skin (periderm) in resistance to infection by *P. infestans*.
2. Determine whether or not resistance in MSU potato varieties identified as tuber late blight resistant, is due to mechanical characteristics of the periderm or biochemical host defense mechanisms that occur in the underlying tissue in a range of cultivars with different levels of foliar and tuber resistance.

Results and Accomplishments
To determine the importance of the tuber periderm in resistance to infection by *P. infestans*, tubers from varieties listed in Table 1 were harvested at three different levels of maturity, a) immature, in which the periderm is still forming, b) mature, in which the periderm is fully formed but the tubers have not gone through skin set, and c) fully-mature, in which the periderm is fully formed and the tubers have undergone skin-set. Tubers at the three levels of maturity were then inoculated by placing a 1.0 cm² piece of filter paper wetted with a 50 µl drop of sporangial suspension over periderm tissue of each tuber. To determine the importance of biochemical host defense mechanisms mature tubers were inoculated by a sub-peridermal injection of a sporangia suspension. Tuber rot severity was expressed relative to the average reflective intensity (ARI) of the non-inoculated treatments for each cv./ABL (Fig. 1). The relative average reflective intensity (RARI) of a treatment was calculated as follows:

\[
\% \text{ RARI} = \left[ 1 - \frac{\text{MeanARI}_{\text{treatment}}}{\text{MeanARI}_{\text{control}}} \right] \times 100
\]

% RARI has a minimum value of zero (no visible symptoms) and maximum value of 100 (tuber surface completely blackened).

In all varieties, no late blight developed in tuber tissue after surface inoculation of the tuber (non-invasive to tuber parenchyma tissue) harvested when tubers were immature or of intermediate (data not presented). Test results also indicated that the inoculation of the tuber surface (non-invasive to tuber parenchyma tissue) in mature tubers did not result in development of tuber blight as no variety had a % RARI value significantly different from the dummy control value (% RARI = 0); (Table 1). Sub-peridermal inoculation of the parenchyma tissue resulted in % RARI values that indicated severe infection of the
tuber tissue. The % RARI values indicated that the varieties fell into their previously assigned resistance/susceptibility classifications (Table 1). It was therefore concluded that the periderm in all potato varieties tested presented an effective barrier to infection even when tubers were immature. Microscopical studies also showed that the fungus was unable to penetrate the periderm and fungal hyphae were never seen growing in tissues below the periderm layer. However, fungal hyphae were often observed growing on the surface of the tuber (Fig. 2). It is likely that *P. infestans* does not have the enzymatic ability to penetrate the layers of the periderm of the potato tuber which are formed from meristematic tissue positioned just below the phellum layer (4 – 5 cells thick) of the tuber. The infection process clearly depends on mechanical damage to the tuber surface either by abrasion or by environmental conditions that expose the parenchyma tissue such as water saturation of the soil. Saturation of the soil with water (rainfall or irrigation) results in the temporary but sustained opening of lenticels (pores in the periderm that allows oxygenation of the tuber tissue). In addition, when soils are wet the presence of inoculum of *P. infestans* may result in successful penetration of the tubers and subsequent development of tuber late blight.

**Table 1. Potato late blight response of mature tubers to inoculation with *Phytophthora infestans* a) by inoculation of the tuber surface (non-invasive to tuber parenchyma tissue) and b) by sub-peridermal inoculation of the parenchyma tissue.**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Tuber/Foliar late blight designationd</th>
<th>Tuber late blight reaction (%RARI)a</th>
<th>Surface inoculation</th>
<th>Sub-periderm inoculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic</td>
<td>S/S</td>
<td>-4.2</td>
<td>c(^b)</td>
<td>32.8</td>
</tr>
<tr>
<td>Defender</td>
<td>R/R</td>
<td>3.3</td>
<td>a</td>
<td>7.5</td>
</tr>
<tr>
<td>J317-1</td>
<td>S/R</td>
<td>1.1</td>
<td>ab</td>
<td>26.2</td>
</tr>
<tr>
<td>LBR-8</td>
<td>R/R</td>
<td>1.5</td>
<td>ab</td>
<td>4.0</td>
</tr>
<tr>
<td>Russet Legend</td>
<td>R/S</td>
<td>4.7</td>
<td>a</td>
<td>11.3</td>
</tr>
<tr>
<td>Snowden</td>
<td>MS/S</td>
<td>0.7</td>
<td>abc</td>
<td>31.6</td>
</tr>
<tr>
<td>Torridon</td>
<td>MS/R</td>
<td>1.1</td>
<td>ab</td>
<td>7.9</td>
</tr>
<tr>
<td>Umatilla Russet</td>
<td>R/S</td>
<td>-1.8</td>
<td>bc</td>
<td>9.0</td>
</tr>
<tr>
<td>Dummy(^c)</td>
<td></td>
<td>0.0</td>
<td>abc</td>
<td>0.0</td>
</tr>
</tbody>
</table>

\(^a\) %RARI has a minimum value of zero (no visible symptoms) and maximum value of 100 (tuber surface completely blackened). Mean ARI of n = 18 tuber pieces.

\(^b\) Values followed by the same letter are not significantly different at P = 0.05 for comparisons of mean RARI values (Tukey Multiple Comparison; HSD).

\(^c\) Dummy value of 0 included to determine if reactions were significantly different from %RARI = 0.

**Impacts**

This study indicates that several varieties have resistance to *P. infestans* in the parenchyma tissue which is of major benefit to potato breeding programs. These qualities could be exploited to produce varieties with both foliar and tuber resistance. Foliar fungicides can cost as much $200-300/A during seasons when conditions are conducive to development of potato late blight and are not 100% effective. Many growers rely not only on foliar fungicides to limit late blight development in tubers but also apply disinfectants to tubers entering storage. Some products such as Phosphonic acid and Hydrogen Peroxide are also applied during storage to prevent tuber blight development. These strategies can cost up to $5.00/ton of stored tubers. Typical production in Michigan results in yields of about 20 ton/A. Therefore total crop protection efforts to prevent tuber late blight could cost as much as $400/A. The development of tubers with both foliar and tuber resistance would enable growers to decrease dependence on crop protection with fungicides applied during the growing season and into tuber storage. The impact of varieties with both foliar and tuber resistance could result in significant reductions in production costs and decrease dependence on fungicides and improve environmental and food quality.
Summary Statement
Late blight is readily transmitted by seed-borne inoculum and consequently immature stems and leaves may be exposed to disease from infected seed pieces. Multiple cycles of sporulation through a growing season can result in production of sporangia and zoospores which can infect potato tubers developing below ground. The resistance of tubers to late blight is therefore an important factor in the epidemiology and economics of this disease. This study indicates that even in immature tubers the periderm plays an important role in protecting the tuber from infection by *P. infestans* as the fungus was unable to infect any of the tubers that were surface inoculated under experimental conditions. In sub-peridermically inoculated tubers, the % RARI values indicated that the varieties fell into their previously assigned resistance/susceptibility classifications (Table 1) suggesting that biochemical host defense plays an important part in resistance to *P. infestans* infection. This study suggests that potato tuber late blight may be minimized through a combination of host plant resistance and careful handling to prevent damage to the periderm.

Funding Partnerships
MPIC $14,000; NPC/ARS $48,000 (2005); IR-4 $11,000 (2005). The results from this study aided in the appropriation of funds from NPC/ARS for Drs. Douches and Kirk for tuber late blight evaluation in germplasm from across the federal state breeding programs. This study also provided the basis for the development of an IR-4 grant investigating the potential use of biofungicides in controlling late blight of tubers in storage.

Figure 1. Scanned images of blighted tubers with typical % RARI values. Lower values indicate more darkening due to greater susceptibility to *Phytophthora infestans*.
Figure 2. Light micrograph showing fungal growth on the tuber surface. Hyphae were never observed growing beneath the periderm.