Short Communication

Fungus Spore Germination Inhibited by Blue and Far Red Radiation

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Many fungi respond to light in ways that affect either their growth, reproduction, or both (1, 7, 11). These responses are commonly due to wavelengths in the ultraviolet and blue regions of the spectrum. Fewer cases are known where longer wavelengths in the yellow and red regions affect fungi (6, 9, 10). Rarely (1a, 6a) there are reports of a response to far red radiation among the true fungi, Euomycota. This is in striking contrast to higher green plants in which major morphogenic events are affected by far red radiation (8). We now report a photoresponse to wavelengths in the blue and far red byuredospores of the wheat stem-rust fungus Puccinia graminis f. sp. tritici (Eriks. & Henn.) Guyot.

Germination ofuredospores is inhibited by white light; however, the inhibition is thought to be partial and temporary, lasting only about 6 to 8 hr from the initiation of germination (4, 12, 13). An early worker, using Wratten filters and light of unknown intensities, found uredospore germination inhibited under red, orange, yellow, and purple filters (2). We studied this phenomenon more fully and developed a crude action spectrum.

Uredospores of P. graminis tritici race 56 were collected from wheat seedlings (Triticum aestivum L., "Little Club"), growing in the greenhouse at 18 to 27 C. Freshly collected spores were stored at 5 C in the dark. Just prior to an experiment the spores were exposed to saturated relative humidity for about 15 hr at 21 to 23 C.

At the start of the experiment, two Petri plates containing 1.3% water agar were dusted with spores to achieve a uniform distribution of approximately 25 to 50 spores/mm2 of agar surface. One Petri dish had its outer surfaces covered with black tape, while the other dish had its cover removed and the agar surface exposed to radiation. After irradiation for 2 hr the percentage germination of the spores was measured by examining microscopically at least 100 spores in three randomly selected areas of each plate. The final results are expressed as percentage inhibition (I) in germination of the irradiated spores derived from: I = [1 - (% germination light/ % germination dark)] x 100. The germination on the dark plates was always greater than 50%. The irradiated agar surface showed no signs of dessication. The experiments were done at room temperature, 22 ± 1 C, unless stated otherwise. A thermocouple was placed immediately in front of the irradiated plate in the center of the radiation beam; that temperature never deviated from the prevailing room temperature.

The light source consisted of a photo slide projector, fitted with a 500-w incandescent lamp. A series of Baird-Atomic interference filters which were blocked up to the far infrared regions were used, whose bandwidths at half peak transmittance were either 4 nm (filters in the 400–699 nm range) or 10 nm (filters in the 720–750 nm range). The wavelengths transmitted by each filter were checked by means of an ISCO spectroradiometer. The filter was used in conjunction with a glass bath of running cold water through which the radiation beam passed. Extraneous white light was excluded from this system with the use of black cloth and black masking tape. There were three replicate experiments carried out for each filter tested. The standard intensity at the agar surface was 8,000 ergs cm-2 sec-1 as measured by a YSI Kettering model 65 radiometer.

The averaged results from three experiments are presented in Table I which shows a marked inhibition of germination in two spectral regions, one with a peak in the blue around 419 to 425 nm and the other with a peak in the far red around 720 nm. Most of the intervening spectral region from 450 to 603 nm was virtually without effect on the germination of these fungus spores.

Another group of experiments tested the effect of intensity at the active wavelength of 419 nm. In Table II the inhibitory effect of a 2-hr exposure is clearly evident from 8,000 to 4,000 ergs cm-2 sec-1, but below that intensity the inhibitory effect decreases noticeably.

In further tests, spores were subjected to 5- and 10-min exposures of 720 nm (8,000 ergs cm-2 sec-1) at the start of the experiment and then kept in darkness for the rest of the 2-hr period. These brief exposures to far red light did not inhibit germination.

To test the possibility that small temperature increases in the irradiated spores were causing the inhibitory effects in the far red light, the target and dark plates were placed flat against the metal side of a temperature bath. Trials were carried out with the surface agar temperature (checked by thermocouples) at 14 or 16 C. Percentage inhibition by a 2-hr exposure at 720 nm was 94 and 97, respectively. In two further trials, irradiated plates at 24 C had 17% germination, compared to dark plates at 24 C and 29 C which averaged 81% and 49% germination, respectively. These results suggest that the inhibition of germination of irradiated uredospores at 14 to 24 C was due to far red radiation and not to spurious local heat trapping effects.

Our data with different filters indicate only the major spectral regions of activity and not the precise quantitative relationships between these two regions. This would require a more detailed study resulting in a true action spectrum.

To our knowledge, these data are the first to indicate a photobiological response of a rust fungus to the far red region. Uredospores of other rust species also are reported to be in-

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Table I. Inhibition of Uredospore Germination by Monochromatic Radiation of Different Wavelengths

Two-hour exposure was at 8,000 ergs cm\(^{-2}\) sec\(^{-1}\). Data with different letters are significantly different according to Duncan’s range test. Each datum is the average of three experiments.

<table>
<thead>
<tr>
<th>Peak Wavelength Transmitted by Interference Filter</th>
<th>Inhibition of Germination</th>
</tr>
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<tbody>
<tr>
<td>mm</td>
<td>%</td>
</tr>
<tr>
<td>400</td>
<td>44 a</td>
</tr>
<tr>
<td>419</td>
<td>100 b</td>
</tr>
<tr>
<td>425</td>
<td>99 b</td>
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</tr>
<tr>
<td>510</td>
<td>2 c</td>
</tr>
<tr>
<td>552.5</td>
<td>3 c</td>
</tr>
<tr>
<td>603</td>
<td>1 c</td>
</tr>
<tr>
<td>651</td>
<td>42 a</td>
</tr>
<tr>
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<td>84 b</td>
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<td>96 b</td>
</tr>
<tr>
<td>730</td>
<td>94 b</td>
</tr>
<tr>
<td>750</td>
<td>81 b</td>
</tr>
</tbody>
</table>

Hibited by white light in a manner similar to *P. graminis tritici* (3). Perhaps some or all of these species may respond to the blue and far red regions.

Among higher green plants, there are morphogenic responses called “high energy reactions” which are due to prolonged exposures to high intensities of radiation from the blue or far red regions (4). Some workers ascribe “high energy reactions” to phytochrome, while others do not (5, 14, 15). Although the photoreceptor pigment system remains unknown, there appears to be some resemblance between the events we have studied in a rust fungus and the “high energy reactions” in higher plants.

LITERATURE CITED