Influence of Temperature on Development of *Puccinia recondita* with *Triticum aestivum* ‘Suwon 85’

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**ABSTRACT**


*Triticum aestivum* ‘Suwon 85’ and ‘Thatcher’ seedlings were inoculated with four uredial cultures of *Puccinia recondita* and grown at 5, 12, 19, and 26 C. No classifiable differences in infection type were observed between Suwon 85 and Thatcher with any of the four cultures at 26 or 19 C. In some replications, small differences in infection type occurred between the cultivars at 19 C, regardless of culture. At 12 C, each of the cultures consistently produced an intermediate infection type with Suwon 85. In some replications at 12 C, some of the cultures produced more sporulation with Suwon 85 than did other cultures. Much greater differences in infection type between Suwon 85 and Thatcher with each of the cultures occurred at 5 C. Each culture with Suwon 85 produced nonsporulating infection types in the time required for the same culture and Thatcher to produce profuse sporulation. Testing at low temperature may provide an efficient means of selecting slow-rusting lines. Differences in infection type between different cultures with Suwon 85 suggest specificity of the slow-rusting character of Suwon 85 with *P. recondita*.

Additional key words: environment, parasite:host interaction, resistance.

Vanderplank’s proposal (16) that there are two kinds of resistance to plant disease, “vertical” and “horizontal,” led to great interest in the concept of horizontal resistance. Caldwell et al (5) reported resistance in wheat cultivars to leaf rust that appeared to be different from the commonly used resistance brought about by specific interactions. This resistance was termed “slow rusting,” and the concept has been widely used in cereal rust research since slow-rusting cultivar Suwon 85 (8,9).

Slow rusting was originally described from sequential observations of disease development on one cultivar relative to another under field conditions (5). Since that time, differences in latent period, precisely measured sporulation, number of pustules from similar inoculations, and length of sporulation period have been used to experimentally detect slow rusting. These components have been studied both in flag leaves (8–10,14) and in seedling leaves (6,10). The evaluation of each of these components is laborious and not well suited for detecting resistance in large numbers of wheat lines within a breeding program. An easily observed and recorded parameter from seedling tests would be very useful if the results were related to slow rusting in the field.

Johnson (6) observed greater differences in latent period between cultivars at 4 and 10 C than at 16, 21, or 27 C. We (3) observed that the function of certain corresponding gene pairs in *Puccinia recondita*: *Triticum* depended on temperature. Function of some sets of corresponding gene pairs was negated by low temperature. Function of other sets of corresponding gene pairs is known to be negated by high temperatures (2). Within the premise that restriction of fungal development is the result of parasite:host:environment interaction (2), it follows that an increased latent period of *P. recondita* with the wheat cultivar Suwon 85 may be greater at some temperatures than others. This could be used to develop an easy test for the host genotype related to slow rusting.

This paper reports results of experiments designed to explore the possibility of detecting slow rusting in a seedling test, using the slow-rusting cultivar Suwon 85 (8,9).

**MATERIALS AND METHODS**

Seeds of *Triticum aestivum* L. ‘Suwon 85’ (PI 157600) were obtained from the U.S. Department of Agriculture Small Grains Collection, Beltsville, MD 20705. Seeds of the cultivar Thatcher (CI 10003) were available from previous studies. *Puccinia recondita* Rob. ex Desm. cultures PRTUS1, PRTUS4, PRTUS5, and PRTUS6 are available from the American Type Culture Collection and from the senior author. All experiments were conducted using seedlings plants. Plant growing and inoculating procedures have been previously described (1). Four plantings of each cultivar were made for each culture/temperature treatment in each of five replications conducted in different time periods. Fully expanded primary leaves were inoculated with urediniospores suspended in Soltron 170 oil. Inoculated plants were misted with tap water and placed in a moist chamber overnight at 16 ± 2 C. Inoculated plants were removed from the moist chamber after 16 hr, and four randomly preselected subsets were moved into growth chambers held at 5, 12, 19, or 26 C and a 12-hr photoperiod. Temperature control in these treatments was ±3 C.

In addition to comparing relative differences at the four temperatures, experiments were conducted using a larger sample of cultures to ascertain the range of pathogenicity in *P. recondita* to Suwon 85 at 12 C. This experiment was repeated once.

Observations of materials in different temperature treatments were made at varying times after inoculation because of the overall effect of temperature on the growth rate of *P. recondita* and wheat. Observations in all experiments were made when sporulation of *P. recondita* with Thatcher was judged to be at its peak for the various temperature treatments. Observations of infection type were
recorded in the study of Browder and Young (4). Three
characteristics of the phenotype in each parasite:host:temperature
treatment were coded. Visual estimates of relative sporulation were
made in a 0–9 scale, using 0 as none and 9 as the maximum amount
observed; these estimates were recorded as the first character in the
coding system. Visual estimates of lesion size were made in a 0–9
scale and recorded as a second character in the coding system. A
descriptor of tissue damage within or around the lesions or as an
indicator of the uniformity of different lesions on the same leaf
produced by a pure culture was recorded as a third character in the
code. P, C, N, and X were used to represent pale, chlorotic,
necrotic, and mesothetic, respectively; X-infection types were
characterized by visually assessed reduced sporulation and a
mosaic pattern of different sized lesions with different sporulation
amounts on the same leaf.

RESULTS

Influence of temperature on relative differences in infection
type. Results of exposing Suwon 85 and Thatcher infected with
different cultures of *P. recondita* to 5, 12, 19, or 26 C are shown in
Table 1. Differences in infection type between Suwon 85 and the
different cultures relative to Thatcher with the same cultures were
not consistent between different replications at 19, 12, or 5 C. At
19 C, differences of infection type were observed between Suwon
85 with all cultures relative to Thatcher with the same cultures in
some tests but not in others. At 5 and 12 C, however, differences
between Suwon 85 and Thatcher with the same cultures were much
greater and more consistent.

In the 12 C treatment, each culture with Suwon 85 consistently
produced an X-infection type in the same time the same culture
with Thatcher produced an 88P infection type, about 17–20 days.
After 20 days, each culture with Suwon 85 continued to grow.
Sporulation differences of each culture with Suwon 85 relative to
the same culture with Thatcher decreased. Classifiable differences
were observed between the two cultivars with any of the cultures
even after 30 days at 12 C. Differences between cultures in
pathogenicity to Suwon 85 could not be consistently classified at
12 C by infection-type evaluation.

Differences in infection type were very large in the 5 C treatment.
After 30–35 days, each culture with Thatcher produced as much, or
more, sporulation at 5 C as the same culture with Thatcher
produced at 12 C after 15–17 days. Some of the cultures growing
with Suwon 85 had not sporulated after 30 days at 5 C, whereas
others had sporulated slightly (Table 1). As in the 12 C treatment,
all cultures of *P. recondita* continued growth and produced spores
with Suwon 85 at 5 C. Sporulation differences of each culture with
Suwon 85 relative to that of the same culture with Thatcher
declined 30–60 days after inoculation.

Infection types produced at 12 C by Suwon 85 and by Thatcher
with a larger sample of *P. recondita* cultures. Suwon 85 and

### Table 1. Infection-type data obtained from *Triticum aestivum* cultivars

<table>
<thead>
<tr>
<th>Infection types produced with environment and cultivar</th>
<th>5 C, 35 days</th>
<th>12 C, 17 days</th>
<th>19 C, 9 days</th>
<th>26 C, 8 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culture</td>
<td>S85 TC</td>
<td>S85 TC</td>
<td>S85 TC</td>
<td>S85 TC</td>
</tr>
<tr>
<td>PRTUS1</td>
<td>01C–23C° 99P</td>
<td>23X–56X° 88P</td>
<td>78X–88P° 88P</td>
<td>88P 88P</td>
</tr>
<tr>
<td>PRTUS5</td>
<td>01C 99P</td>
<td>23X 88P</td>
<td>78X–88P° 88P</td>
<td>88P 88P</td>
</tr>
<tr>
<td>PRTUS6</td>
<td>01C 99P</td>
<td>23X 88P</td>
<td>78X–88P° 88P</td>
<td>88P 88P</td>
</tr>
</tbody>
</table>

1 Coding system, first character is relative sporulation in a 0–9 scale (0 = no sporulation, 9 = maximum sporulation), second character is relative lesion size in a 0–9 scale, and third character is descriptor of tissue within or around sporulating area (C = chlorosis, P = pale, X = mosaic pattern of varying sized lesions).

2 Differences were variable between different replications of the experiment from one time to another.

Suwon 85 and Thatcher were inoculated with 24 cultures of *P. recondita* obtained
from pathogenicity survey collections from the United States. All
except one with Suwon 85 produced a variable X-infection type
very similar to that of Suwon 85 with the cultures used in the
temperature study. Culture 3215 produced a much different, 03C
infection type with Suwon 85 after 17 days and an 88P infection
type with Thatcher. Culture 3215 continued growth and produced
slight sporulation with Suwon 85 after 20–25 days. Infection-type
differences remained very large between Suwon 85 with culture
3215 and Thatcher with culture 3215 until the infected leaves of
Thatcher died.

DISCUSSION

Two effects of reducing temperature on growth of *P. recondita*
with *Triticum* occur. Reducing temperature, within the range used
in our study, generally slows the rate of *P. recondita* development
regardless of the cultivar with which it is growing. Johnson’s results
(6), our previous results (3), and our current results show, however,
that the effect of reducing temperature differs according to host
genotype. The differential effect is the more important effect when
disease resistance is being considered. Differences in the effect of
reducing temperature also depend, in some cases, on parasite
genotype. The relative effect of reducing temperature may be
reversed in some cases (1,3).

Our present results indicate that differences in development of *P.
recondita* with Suwon 85 relative to *P. recondita* with Thatcher are
much greater at 5 and 12 C than at 19 and 26 C. This result is
similar to Johnson’s results (6), although he used latent period in days as
a measurement criterion and we used visual assessment of infection
type at one time as our criterion. Differences in latent period imply
that differences in rust development are visually assessable at some
point. Our objective was to determine if slow rusting could be
detected with one observation at one point in time. The results
indicate that slow rusting, at least in the case of Suwon 85, probably
can be detected with a seedling test at 12 or 5 C. This facilitates
testing for slow rusting.

Others (8–10) who have reported Suwon 85 to be a slow-rusting
cultivar have studied rust development in infected flag leaves at one
temperature and have used latent period, pustule size, and
numbers of pustules as measurement criteria. We do not have
unequivocal evidence that slow rusting detected by differences in
flag leaf tests and the differences in rust development that we
observed in seedlings at 12 and 5 C are due to the same genetic
mechanisms. Johnson (6) studied latent period at both different
temperatures and different growth stages, although not in all
combinations. His results indicated that latent period differences
were greater at lower temperatures and that similar differences
between cultivar groups were observed in different growth stages.
His results lend some support to the view that the differences we
observed are related to slow rusting as reported by others.

Our data are consistent with, but not sufficient to unequivocally
support, the premise that the restricted rust development in Suwon
85 relative to that in Thatcher is the result of parasite:host:
environment specificity (2). Under this premise,
restricted rust development is the result of corresponding
genotypes in parasite and host functioning in a specific
environment. The corresponding genotypes do not function, or
function to a lesser extent, in other environments. If so, Suwon 85
has a genotype that corresponds to *P. recondita* genotypes for
avirulence and the corresponding genotypes function optimally at
low temperatures to cause slower growth of the fungus with Suwon
85 than with Thatcher. When growing at higher temperatures, the
corresponding genotypes function less and bring about smaller
differences in growth rate.

We believe that our observation of slight differences in
sporulation of different *P. recondita* cultures with Suwon 85 at 12
and 5 C also indicate parasite:host specificity. All of the cultures
we used sporulated profusely with Thatcher at 12 and 5 C (Table 1).
Our observation of a culture that produced a 03C infection type
with Suwon 85 but an 88P infection type with Thatcher also
indicates specificity, although the relationship of this infection type

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to slow rusting is not known (9).

The question of specificity or nonspecificity of the slow-rusting character of Suwon 85 is important only in predicting long-term usefulness of the character in disease control. Johnson (7) suggested the concept of durable resistance based on long-term observation of resistance in a cultivar widely exposed to a pathogen. Whereas long-term usefulness is certainly an important means of discerning resistance of cultivars, knowing details of the genetics of these characters and how this relates to parasite genetics and to environment is also important when the character is to be transferred to new cultivars.

Whether or not restricted development of *P. recondita* with Suwon 85 is due to specificity, it can be readily detected at low temperatures. Further, the resistance mechanism would have greatest effect early in leaf rust epidemic development in the winter wheat areas at temperatures that are low relative to those occurring later in the rust development season (6). If the slow-rusting character is, in fact, due to specificity, decrease in slow rusting at higher temperatures may enhance the long-term usefulness of the resistance. The selective effect of Suwon 85 on avirulent and virulent parasites would be reduced at higher temperatures. The genes for resistance in Suwon 85 should not be deployed alone if they are specific to parasite genotype. Deploying them in combination with genes that function optimally at higher temperatures would probably maximize the usefulness of both.

Kuhn et al (9) found that slow rusting of Suwon 85 was simply inherited. The seedling test reported here should make the slow-rusting character of Suwon 85 easy to transfer in breeding programs.

**LITERATURE CITED**


