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

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ABSTRACT

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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 that time (8,10–15). The paper by Caldwell et al (5) and several subsequent reports (8–14) imply that "slow-rusting resistance" is nonspecific to parasite genotype. Other reports (11–13,15) do not necessarily support this concept.

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 seedling 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 Soltrol 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

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recorded in the system 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 decreased 30–60 days after inoculaton.

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

TABLE 1. Infection-type data obtained from *Triticum aestivum* cultivars Suwon 85 (S85) and Thatcher (TC) inoculated with four cultures of *Puccinia recondita* and exposed to four latent period temperatures for specified number of days after inoculation

	Infection types[y] produced with environment and cultivar							
	5 C, 35 days		12 C, 17 days		19 C, 9 days		26 C, 8 days	
Culture	S85	TC	S85	TC	S85	TC	S85	TC
PRTUS1	01C–23C[z]	99P	23X–56X[z]	88P	78X–88P[z]	88P	88P	88P
PRTUS4	01C–23C	99P	23X–56X	88P	78X–88P	88P	88P	88P
PRTUS5	01C	99P	23X	88P	78X–88P	88P	88P	88P
PRTUS6	01C	99P	23X	88P	78X–88P	88P	88P	88P

[y]In 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).

[z]Results were variable between different replications of the experiment from one time to another.

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 at 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

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

1. Browder, L. E. 1973. Specificity of the *Puccinia recondita:Triticum aestivum* 'Bulgaria 88' relationship. Phytopathology 63:524-528.
2. Browder, L. E. 1985. Parasite:host:environment specificity in the cereal rusts. Annu. Rev. Phytopathol. 23:201-222.
3. Browder, L. E., and Eversmeyer, M. G. 1986. Interactions of temperature and time with some *Puccinia recondita:Triticum* corresponding gene pairs. Phytopathology 76:1286-1288.
4. Browder, L. E., and Young, H. C., Jr. 1975. Further development of an infection-type coding system for the cereal rusts. Plant Dis. Rep. 59:964-965.
5. Caldwell, R. M., Roberts, J. J., and Eyal, Z. 1970. General resistance ("slow rusting") to *Puccinia recondita* f. sp. *tritici* in winter and spring wheats. (Abstr.) Phytopathology 60:1287.
6. Johnson, D. A. 1980. Effect of low temperature on the latent period of slow and fast rusting winter wheat genotypes. Plant Dis. 64:1006-1008.
7. Johnson, R. 1981. Durable resistance: Definition of, genetic control, and attainment in plant breeding. Phytopathology 71:567-568.
8. Kuhn, R. C., Ohm, H. W., and Shaner, G. E. 1978. Slow leaf-rusting resistance in wheat against twenty-two isolates of *Puccinia recondita*. Phytopathology 68:651-656.
9. Kuhn, R. C., Ohm, H. W., and Shaner, G. E. 1980. Inheritance of slow leaf-rusting resistance in Suwon 85 wheat. Crop Sci. 20:655-659.
10. Ohm, H. W., and Shaner, G. E. 1976. Three components of slow leaf rusting at different growth stages in wheat. Phytopathology 66:1356-1360.
11. Parlevliet, J. E. 1979. Components of resistance that reduce the rate of epidemic development. Annu. Rev. Phytopathol. 17:203-222.
12. Rowell, J. B. 1981. The relationship between slow-rusting and a specific resistance gene for wheat stem rust. Phytopathology 71:1184-1186.
13. Rowell, J. B. 1982. Control of wheat stem rust by low receptivity to infection conditioned by a single dominant gene. Phytopathology 72:297-299.
14. Shaner, G. E., and Finney, R. E. 1980. New sources of slow-leaf rusting resistance in wheat. Phytopathology 70:1183-1186.
15. Skovmand, B., Roelfs, A. P., and Wilcoxson, R. D. 1978. The relationship between slow-rusting and some genes specific for stem rust resistance in wheat. Phytopathology 68:491-499.
16. Vanderplank, J. E. 1963. Plant Diseases: Epidemics and Control. Academic Press, New York. 349 pp.