Effect of Temperature and Host:Parasite Combination on the Latent Period of *Puccinia recondita* in Seedling Wheat Plants

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ABSTRACT

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Increasing the ambient temperature from minimum (10 C) to optimum (26.5 C) decreased the latent period, while raising the temperature from optimum to maximum (32.2 C) increased the latent period. Temperature developmental curves for latent period were skewed to the left, with an optimum at 80% of the temperature range (10.0 – 32.2 C). Significant differences were measured in the effects of temperature, host:parasite combination, and their interactions on latent period. Presence of a gene or genes for resistance in the host line generally was associated with significant differences in the host line effects and host line interaction with temperature and parasite culture. Latent period means for the various culture:temperature combinations show that significant differences occur at temperatures near the minimum for fungal development, but no significant differences in latent period occur near optimum temperatures.

Additional key words: leaf rust, *Triticum aestivum.*

Reasonable success has been achieved in developing models based on biometeorological variables that predict the final severity of either leaf rust or stem rust of wheat (3,8,9). Some of the biometeorological variables also have been used to predict the damage resulting from a wheat leaf rust epidemic (4). Latent period is one of the important parameters characterizing the course of rust epidemics (3,6). Cammack (5), Chester (6), Parlevliet (11), Melander (10), and Saari and Moore (12) have examined the influence of temperature, light, uredial density, and virulence of various pathogen populations on latent period. In an attempt to improve prediction of the course of wheat leaf rust epidemics, we initiated a study to determine the effect of temperature and host:parasite interaction on the length of the latent period in seedling wheat. Latent period is used in this paper as the time between inoculation and initial spore release from the first uredium formed on the apical two-thirds of the primary leaf. In the early phases of the study we attempted to determine whether various host:parasite combinations subjected to various temperature regimes would show a difference in the length of the latent period.

MATERIALS AND METHODS

Nine wheat cultivars were selected for study on the basis of the infection type resulting from inoculation with 12 cultures of *Puccinia recondita* Rob. ex Desm. f. sp. *tritici.* Infection types ranged from 1 C to 89 C depending on the host:parasite and

temperature combination used. The infection types were rated in a system (2) where the first code depicts relative sporulation and the second code depicts relative lesion size, each on a 0 to 9 scale. The C code indicates chlorosis around the sporulating area.

Seeds of the seven *Triticum aestivum* L. cultivars, Morroco, Parker, Triumph, Trison, Sage, Satanta, Thatcher (TC), and two monogenic lines with LR16(TC) (Thatcher 6*/Exchange, RL 6005) (1) and LR18(TC) (Africa 43/7* Thatcher, RL 6009) (7) in a Thatcher background were planted in a 9-cm square pot. Wheat plants were grown in the greenhouse for 10 days after emergence, then plants in each pot were inoculated with one of the following *P. recondita* cultures:UN2-70-22 (ATCC PR77), UN02-64A (ATCC PR3), UN01-68A (ATCC PR 67), UN01-68B (ATCC PR51), 6B-NA65-9 (ATCC PR76), 66-763 (ATCC PR60), 65359-01, PRE1 WQL (ATCC PR69), 66-36-03 (ATCC PR61), 0967-1, UN09-66A (ATCC PR66), or UN17-68A (ATCC PR62). The inoculated plants were randomly arranged in a moist chamber for 18 hr and then placed in environmental chambers at different temperatures. Inoculum level was adjusted to provide one-to-three urediospores per square centimeter on the primary leaf.

During each experiment, one environmental chamber was maintained at 21.1 C. Temperatures in three additional environmental chambers were varied. Constant temperatures used were 10, 15.6, 26.7, and 32.2 C with approximately 26,910 lux light intensity for 12 hr and darkness for 12 hr. Various temperature regimes were programmed in the growth chambers by varying the minimum temperature for 12 hr with no light and the maximum temperature for 12 hr with 26,910 lux of light. The minimum-maximum temperatures used were 7–14, 12–24, and 18–29 C. One environmental chamber had a cam-operated temperature control which was programmed to raise the temperature at an hourly rate. The temperature regime used in that chamber included a 4 hr minimum temperature period followed by a period of 10 hr during which the temperature was raised 2–4 C/hr to the maximum temperature for a 4-hr period and then decreased 3–5 C/hr to the minimum temperature. This program approximated temperature curves that occur at Manhattan, Kansas, during May and October. The minimum temperature used in these experiments was either 10 or 13 C and the maximum temperature was 26.7, 29.0, or 32.2 C.

A ×10 hand lens was used to determine the time the uredium first released urediospores. We were able to correlate urediospore release (which was determined by using volumetric airspora samplers) with visual observation of urediospore release. The first urediospores always were trapped by the volumetric traps within ± 4 hr of the time urediospore release was observed with the ×10 hand lens.

Because frequent removal of plants from the environmental chamber to observe stage of uredial development during the latent period would expose plants to temperatures differing from the experimental temperature, observations were made once a day until uredial break. Occasionally an additional observation was needed during uredial break to determine the time of initial urediospore release.

RESULTS

Table 1 shows the mean number of hours from inoculation to urediospore release for all combinations of cultures UN02-64A, UN01-68B, UN01-68A, UN2-70-22, and 6B-NA65-9 with host lines Thatcher, LR16(TC), and LR18(TC), measured under the various temperature regimes used in the environmental chambers. These host:parasite combinations had temperature development curves for latent period that are representative of host lines used in this experiment.

At 10 C, the infection of Thatcher monogenic line carrying *Lr18* and inoculated with *P. recondita* culture UN02-64A did not develop to the point of urediospore release during the experiment, which was more than 500 hr. In all replications the LR18(TC) plants inoculated with urediospores of culture UN02-64A senesced before the fungus developed to the urediospore formation stage. At 10 C, sporulation on LR18(TC) inoculated with *P. recondita* culture UN2-70-22 began after 444 hr and sporulation on LR16(TC) inoculated with UN2-70-22 began after 396 hr. The other host:parasite combinations sporulated after 372 hr at 10 C. Raising the temperature in the environmental chamber to 15.6 C decreased the latent period to 236 hr for all combinations except the LR18(TC): and LR16(TC):UN2-70-22 combinations, which sporulated 228 hr after inoculation. Raising the temperature to 21.1 C decreased the latent period by 24 – 36 hr. Generally at 21.1 C the host:culture combination that produced the lower infection type also required the longest time to sporulate. When the temperature was raised to 26.7 C, the Thatcher:UN2-70-22 combination sporulated at the end of 168 hr. There were no significant differences in the latent periods among the other host:parasite combinations at 26.7 C. In all replications at 32.2 C the plants senesced before the fungus developed to the urediospore formation

TABLE 1. Mean latent periods for various host:parasite combinations resulting from inoculation of seedling wheat plants with *Puccinia recondita* cultures

Culture	Cultivar latent period[x]			Culture means
	LR18(TC)	LR16(TC)	Thatcher	
UN02-64A	271 a	216 bcdef	215 cdef	234 g
UN01-68B	224 bc	224 bc	221 bcd	223 h
UN01-68A	225 b	222 bcd	216 bcdef	221 h
UN2-70-22	219 bcde	213 def	207 f	213 i
6B-NA65-9	216 bcdef	207 f	210 ef	211 i
Cultivar means	231 j	216 k	214 l	

[x]Latent periods are expressed as number of hours from inoculation to initial urediospore release. Data are mean latent periods of constant temperatures of 10, 15.6, 21.1, and 26.7 C in environmental chambers. Means followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

TABLE 2. Effect of temperature on mean latent periods for *Puccinia recondita* on seedlings of various wheat cultivars

Cultivar	Temperature C[x]				Cultivar means
	10	15.6	21.1	26.7	
LR18 (TC)	330 a	242 d	192 e	158 f	231 g
LR16(TC)	276 b	240 d	193 e	156 f	216 h
Thatcher	266 c	238 d	194 e	156 f	214 i
Temperature means	291 j	240 k	193 l	157 m	

[x]Latent periods are expressed as number of hours from inoculation to initial urediospore release. Data are mean latent periods of the five *P. recondita* cultures used in the experiment. Means followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

TABLE 3. Effect of temperature on mean latent periods of *Puccinia recondita* cultures on wheat seedlings

Culture	Temperature C[x]				Culture means
	10	15.6	21.1	26.7	
UN02-64A	351 a	228 f	200 g	156 i	234 j
UN01-68B	276 bc	256 e	202 g	156 i	223 k
UN01-68A	268 cd	260 de	196 g	160 i	221 k
UN2-70-22	276 bc	228 f	192 g	156 i	213 l
6B-NA65-9	284 b	228 f	176 g	156 i	211 l
Temperature means	291 m	240 n	193 o	157 p	

[x]Latent periods are expressed as number of hours from inoculation to initial urediospore release. Data are means of latent period for Thatcher, LR16(TC), and LR18(TC), the host lines used in the experiment. Means followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

stage. No attempt was made to determine if the high temperature killed the fungus prior to leaf senescence.

The mean effect of temperature on the length of the latent periods on host lines Thatcher, LR16(TC), and LR18(TC) inoculated with the five *P. recondita* cultures is shown in Table 2. The effect of temperature on the length of latent periods of the five *P. recondita* cultures on Thatcher, LR16(TC), and LR18(TC) is shown in Table 3.

Other host:parasite combinations showed the same general trends in the effect of temperature on latent period as the combinations shown in Fig. 1. The presence or absence of a gene for resistance in the host line did not change the asymmetric form of the temperature development curves for latent period. Generally, the presence of a gene for resistance shifted the curve to the right on the X-axis but did not affect its asymmetric form.

The average length of the latent period for all nine host line and 12 parasite combinations measured under all the temperature regimes used in the experiment is shown in Fig. 2. Temperatures are expressed as the mean hourly temperature for a 24-hr period.

DISCUSSION

Light, temperature, and virulence of various pathogen populations have been shown to affect latent period in several host:parasite systems (5,6,10,11). We found temperature and host:parasite combinations significantly affected the length of latent period in wheat seedlings in the *P. recondita:T. aestivum* system.

Analyses of variance of the latent period data for host lines LR16(TC), LR18(TC), and Thatcher with parasite cultures UN02 -64A, UN01-68A, UN01-68B, UN2-70-22, and 6B-NA65-9 that had no missing values indicate significant differences caused by the effects of temperature, host line, parasite culture, and their interactions on length of latent period ($P = 0.05$).

Generally, those cultures producing a higher infection type on a particular host line caused the latent period to decrease significantly from that for cultures giving a lower infection type on the same host line under the same temperature regimes (Table 1). The range of variation around the latent period means varied from 12–76 hr depending on the specific host:parasite and temperature combination used.

Near the minimum temperature for *P. recondita* development there were significant differences in the length of the latent periods measured for the different host lines inoculated with the five cultures. Increasing the temperatures to near the optimum (15.6, 21.1, 26.7) resulted in no significant differences in the latent periods within a specific temperature regime (Table 2).

Although constant 24-hr temperatures between the optimum and maximum for fungal development were not included in this experiment, we believe the same phenomenon will occur near maximum temperature.

A possible reason for the erratic results for temperatures ranging 18–25 C shown in Fig. 2 is that the minimum temperature was 10 C or the maximum temperature was 29.0-32.2 C for several of the temperature regimes used and, therefore, the temperature was above or below the threshold for mycelial and uredial development for much of the growth period during each day. Fungal growth in the leaf is greatly affected by these low or high temperatures because a relatively long time is required after temperatures above or below the threshold temperature for fungal growth to overcome the adverse effects of that temperature.

Near optimum temperature there was no significant difference in the interaction of temperature on latent period for the various host:parasite combinations. Temperature effects on latent period for host:parasite combinations became significant near the maximum or minimum temperature for fungal development. The range of variation around the latent period means at optimum temperatures varied less than 12 hr. The range of variation around the latent period means at temperatures near either the maximum or minimum temperature threshold was 12–42 hr.

Presence of a gene or genes for resistance in the host line was

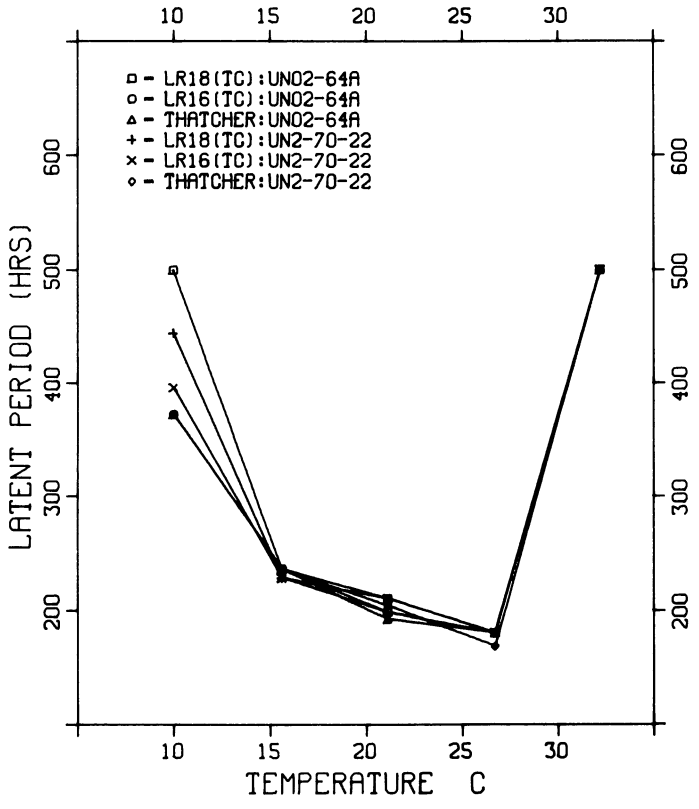

Fig. 1. Temperature developmental curves for the latent period of selected *Puccinia recondita:Triticum aestivum* combinations. Temperatures were held constant during the experiment. Symbols at 500 hr indicate that no sporulation had occurred before the leaves senesced.

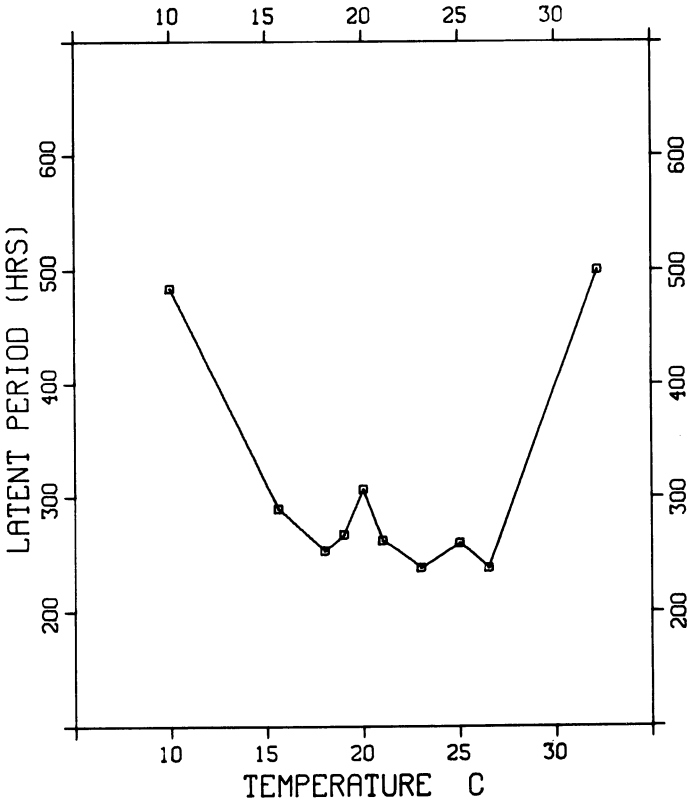

Fig. 2. Temperature developmental curves for the mean latent period of all *Puccinia recondita:Triticum aestivum* combinations under varying temperature regimes. Temperature is the mean hourly temperature during the experiment. Symbols at 500 hr indicate that no sporulation had occurred before the leaves senesced.

associated with significant differences in the host line effects and the host line interactions with temperature and parasite culture. Latent period means varied from 24 to 76 hr for the various lines both with and without genes for resistance.

Mean latent periods for the various culture:temperature combinations show that significant differences occur at temperatures nearer the minimum for fungal development (10 and 15.6) but no significant differences in latent period occur near optimum temperatures (21.1 and 26.7). (Table 3 and Fig. 1).

Mean latent periods for the three host lines were significantly different at 10 C but not at 15.6, 21.1, or 26.7 C (Table 2). However, when averaged over all four temperatures, the overall cultivar means differed significantly. Mean latent periods for different temperature treatments differed significantly whether averaged over host lines (Table 2) or over rust cultures (Table 3). Some significant differences in mean latent periods occurred among rust cultures, but at 21.1 C and 26.7 C the differences were not significant (Table 3).

The response of *P. recondita* to known temperatures in a constant environment has been studied using juvenile wheat plants; however, the total response can be accurately shown only over the entire range of temperatures and wheat growth stages. Data on the relationship between *P. recondita,* wheat cultivars, and temperature in affecting latent period are largely empirical. If it is assumed that the temperature response curves for the different host:parasite combinations at the various growth stages have basically the same form then average temperature developmental curves for the latent period may be constructed.

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