TEMPERATURE ALTERATION OF PHENOTYPIC EXPRESSION OF SPRING WHEAT RESISTANCE TO *STAGONOSPORA NODORUM* SPOT[1]

WILMAR C. DA LUZ[2] and GARY C. BERGSTROM[3]

ABSTRACT - The spring wheat *Triticum aestivum* L. cultivars Fortuna, Newana, and Manitou, previously known as susceptible, moderately resistant, and resistant, respectively, to *Stagonospora nodorum* spot, caused by *Phaeosphaeria nodorum*, were maintained at postinoculation temperatures of 12, 18, 20, 24 or 28°C. At 20°C, reactions were similar to those previously reported for all cultivars with Fortuna being the most severely attacked by the fungus. However, resistance to *Stagonospora nodorum* spot was markedly influenced by temperatures of 24°C; the Manitou reaction changed from resistant to susceptible. The moderately resistant reaction of Newana was unchanged with temperatures of 18 to 28°C. Minimal disease severity occurred at 12°C in all germplasms evaluated. There were no significant differences in percentage of leaf area showing symptoms among cultivars at 28°C. Maximum disease development and the highest number of lesions per cm^2 were observed in plants of Fortuna and Newana kept at 18-24°C and in plants of Manitou kept at 24°C. Incubation period was reduced as the temperature increased from 12 to 24°C in all germplasms tested. These data suggest that temperature might be one factor responsible for contrasting results in resistance tests and for the absence of durable resistance to *Stagonospora nodorum* spot in Brazil.

Index terms: *Triticum aestivum*, *Phaeosphaeria nodorum*, leaf spot disease.

ALTERAÇÃO PELA TEMPERATURA DA EXPRESSÃO FENOTÍPICA DA RESISTÊNCIA DO TRIGO A *STAGONOSPORA NODORUM*

RESUMO - As cultivares de trigo, *Triticum aestivum* L., Fortuna, Newana e Manitou, antes conhecidas respectivamente como cultivares suscetíveis, moderadamente resistente e resistente à mancha-foliar induzida por *Stagonospora nodorum*, foram submetidas a regimes de temperatura pós-inoculação de 12, 18, 20, 24 e 28°C. Em temperaturas de 20°C, a resistência das cultivares foi similar à anteriormente estabelecida. Entretanto, a resistência à *Stagonospora nodorum* foi marcadamente influenciada pela temperatura de 24°C, e a reação da cultivar Manitou mudou de resistente para suscetível. A resistência moderada de Newana não foi modificada com temperatura de 18 a 28°C. O mínimo de severidade da doença ocorreu a 12°C, em todos os germoplasmas avaliados. Não houve diferença na percentagem de sintoma foliar, entre as cultivares mantidas a 28°C. O máximo de desenvolvimento da doença e o máximo número de lesões por cm^2 foram observados em plantas das cultivares Fortuna e Newana mantidas de 18 até 24°C, e em plantas da cultivar Manitou mantidas a 24°C. O período de incubação foi reduzido de acordo com o aumento de temperatura de 12 a 24°C, em todos os germoplasmas avaliados. Estes dados sugerem que a temperatura pode ser um fator responsável por resultados conflitantes em testes para resistência e pela ausência de resistência durável a *Stagonospora nodorum* no Brasil.

Termos para indexação: *Triticum aestivum*, *Phaeosphaeria nodorum*, mancha-foliar.

INTRODUCTION

Stagonospora nodorum spot, induced by *Phaeosphaeria nodorum* (Muller) Hedja. (anam. = = *Stagonospora nodorum* (Berk.) Cast. & Germ.), is an important component of the wheat (*Triticum aestivum* L.) leaf spot syndrome in Brazil (Luz 1981). In Brazil, *Stagonospora nodorum* spot and scab combined reduced yields by an estimated 8% to 10% in Rio Grande do Sul, Brazil, in 1981-1982 (Luz 1984). In Brazil, wheat cultivars regarded as resistant to *Stagonospora nodorum* spot in some years developed severe symptoms under field conditions. Furthermore, glasshouse tests for resistance to *Stagonospora nodorum* spot in Brazil have usually been done at ambient postinoculation temperatures and prolonged wetness with a mixture of several isolates (Fernandes et al. 1980, Picinini et al. 1980) or in controlled envi-

[1] Accepted for publication on December 12, 1985.

[2] Eng. - Agr., EMBRAPA/Centro Nacional de Pesquisa de Trigo (CNPT), Caixa Postal 569, CEP 99100 Passo Fundo, RS, Brazil.

[3] Department of Plant Pathology, Cornell University, Ithaca, NY 14853.

ronment for 72 hours after inoculation followed by transfer to ambient glasshouse environments (Prestes et al. 1982). These tests have produced inconsistent results (Fernandes et al. 1980) and, in some experiments, no resistant cultivars were identified (Picinini et al. 1980). Although wheat cultivar resistance to *P. nodorum* has been reported for many years, the absence of a durable resistance to this microorganism is not well understood. In addition, cultivars reported as resistant to *Stagonospora nodorum* spot in one part of the world may appear susceptible in another (King et al. 1983). It was suggested that variable reaction of a cultivar to *Stagonospora nodorum* spot was due to variability in pathogen isolates, differing environmental conditions during experiments, or different methodologies (Rufty et al. 1981).

A range of variation for virulence in *P. nodorum* has been reported previously (Allingham & Jackson 1981, Thomas 1962). The severity of *Stagonospora nodorum* spot has been shown to be increased by prolonged periods of leaf wetness (Eyal et al. 1977, Holmes & Colhoun 1974, Thomas 1962). The effects of temperature on the causal fungus have been documented. Pycnidiospore germination occurs from 5 to 37°C with an optimum range of 20 to 25°C (Rapilly & Skajenikoff 1974). Fungus growth is optimal at temperatures of 20-24°C with limits near 4 and 32°C (Wiese 1977). Effects of temperature on the compatible host/fungus interaction have also been documented. Disease development was greatest between 20 and 27°C (Wiese 1977). Increases in temperature caused a decrease in latent period (Shearer & Zadoks 1974). High preinoculation temperatures predisposed wheat plants to susceptibility (Rosielle 1968, Thomas 1962).

This paper presents results of a study to evaluate the effect of postinoculation temperature on expression of differential cultivar resistance to *Stagonospora nodorum* spot. Components of disease development assessed were total foliar necrosis, lesion number, and incubation period.

MATERIALS AND METHODS

Seeds of three spring wheat cultivars, Fortuna, Newana and Manitou, previously designated susceptible, moderately resistant, and resistant, respectively, to *Stagonospora nodorum* spot, were obtained from Dr. A.L. Scharen (USDA, Bozeman, MT, USA).

Cultures of a *P. nodorum* isolate, also received from Dr. A.L. Scharen, were maintained at 4°C and the inoculum was increased for ten days on V-8 juice agar at 21 ± 1°C under near UV light with a photoperiod of 12 hr.

Plants (five per pot) of each cultivar were grown in autoclaved soil in 11 cm diameter clay pots in a controlled climate chamber. Plants at growth stage 23 (five leaves unfolded, main shoot and three tillers) (Zadoks et al. 1974) were sprayed with suspensions of 10^6 pycnidiospores/ml using a pressurized sprayer (Model SMC, Sanborn Manufacturing Company). Immediately after inoculation, plants were transferred to a mist chamber for 48 hr of leaf wetness at temperatures of 12, 18, 20, 24 or 28°C. Following this period, plants were transferred to a growth chamber maintained at 80% relative humidity at the respective temperature. The experimental design used was a split plot with temperature treatments as main plots and cultivar treatments as subplots. A single mist chamber and a single postinoculation incubation chamber, each with adjustable temperature, were used for the entire study. Temperature treatments were ordered randomly and were replicated four times temporally. Subplots consisted of single pots of five inoculated plants of each cultivar and were arranged randomly within each main plot. Noninoculated plants were maintained as controls.

Incubation period (time from inoculation to first visible symptoms) was observed on each of the first four leaves for each wheat cultivar at each temperature.

The number of lesions per cm^2 was recorded seven days after inoculation by superimposing a piece of plastic, on which twenty 1 cm^2 areas had been scribed, on the upper surface of each of the four first leaves.

Disease development was estimated ten days after inoculation as percentage of leaf area showing symptoms based on a scale slightly modified from one used in spot blotch evaluation (Luz 1982) as follows: slight, symptomless to 15%; moderate, 16% to 45%; severe, greater than 45% of leaf area showing symptoms.

The data were subjected to analyses of variance and the statistically significant differences among treatments were determined by Fisher's "protected" least significant difference test. Regression analysis was done additionally to determine the relationship between the disease parameters (percentages of leaf area showing symptoms, number of lesions per cm^2 and incubation period) and temperature.

RESULTS AND DISCUSSION

The results of the experiments are shown in Figs. 1, 2, and 3. The regression analyses of various

disease parameters vs. temperature are show in Table 1. Coefficients for terms in equations were significant at P= 0.05. Quadratic models represented most of the relationships between temperature and the parameters measured, indicating curvilinear relationships.

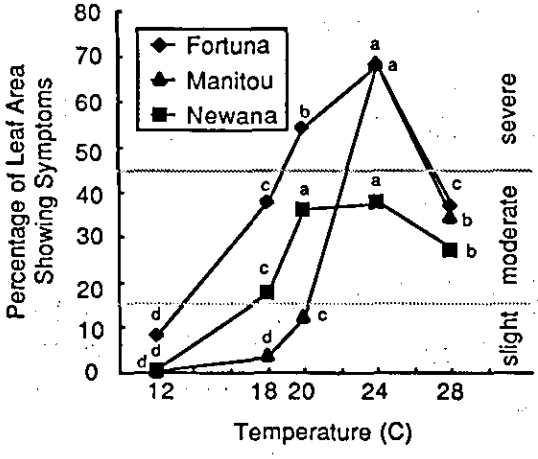

FIG. 1. Effect of temperature on *Stagonospora nodorum* spot development in wheat cultivars differing in resistance. Disease development was estimated as percentage of leaf area showing symptoms ten days after inoculation. Categories of *Stagonospora nodorum* spot severity are separated by dotted lines as follows: slight, symptomless to 15%; moderate, 16 to 45%; severe, greater than 45% of leaf area showing symptoms. Means for an individual cultivar at various temperatures labelled with a common letter are not significantly different by the "protected" LSD test at P= 0.05. CV %= 13.0 and "protected" LSD= 7.8 for main plots, CV %= 13.2 and "protected" LSD= 7.6 for subplots.

An increase in susceptibility of wheat cultivars following exposure to high temperature up to 24°C was observed (Fig. 1). The wheat cultivar Fortuna, designated as susceptible, developed severe symptoms at 20 to 24°C. Manitou, usually reported as resistant to *P. nodorum*, showed slight disease development from 12 to 20°C but was as severely diseased as Fortuna at 24°C. Newana, designated as moderately resistant, developed only moderate symptoms at 24°C, favorable for severe disease development in both Fortuna and Manitou.

There were no significant differences in percentage of leaf area showing symptoms among cultivars at 28°C. The number of lesions per cm^2 increased progressively with increasing temperature from 12-24°C (Fig. 2). Incubation period was reduced as temperature increased from 12 to 24°C (Fig. 3). Minimal disease severity ocurred at 12°C in all cultivars evaluated. The optimum temperature range for disease development was 18 to 24° for cultivar Fortuna and Newana and 24°C for Manitou.

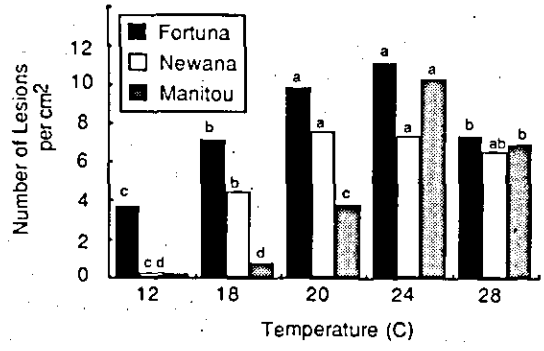

FIG. 2. Effect of temperature on number of lesions per cm^2 induced by *Phaeosphaeria nodorum* seven days after inoculation on leaves of three wheat cultivars. Means for each cultivar at various temperatures labelled with a common letter are not significantly different by the "protected" LSD test at P= 0.05. CV%= 13.7 and "protected" LSD = 4.5 for main plots, CV % = 11.9 and "protected" LSD= 1.9 for subplots.

The results showing 18-24°C as optimum temperatures for disease development support the concept that *Stagonospora nodorum* spot is a disease associated with warm weather, and agrees with the observation that the disease is more severe both in late-sown wheat and late in the wheat growing season (Luz 1986).

These results support in part the reported optimum temperature range for disease development of 20-27°C (Wiese 1977). Our results are also consistent with reports of optimal pycnidiospore germination at 20 to 25°C (Rapilly & Skajenikoff 1974). Alteration of expression of resistance in the cultivar Manitou ocurred at 24°C when this cultivar showed severe disease development.

Thomas (1962) found that *P. nodorum* infection was not affected by temperatures of 18, 24 or 30°C during the mist period. However, high preinoculation temperatures predisposed wheat plants to severe *Stagonospora nodorum* spot development (Rosielle 1968, Thomas 1962). Results presented here definitively indicate that postinoculation temperature is also important for expression of disease symptoms.

Temperature alteration of phenotypic expression of resistance creates problems in testing wheat germplasms for *P. nodorum* resistance. Resistance tests for *Stagonospora nodorum* spot produce variable results (Fernandes et al. 1980, Picinini et al. 1980, Rufty et al. 1981) that may be explained by differences in virulence (Allingham & Jackson 1981, Thomas 1962), long durations of humidity (Eyal et al. 1977, Holmes & Colhoun 1974), preinoculation temperatures (Rosielle 1968, Thomas 1962), or different methodologies (Picinini et al. 1980, Rufty et al. 1981). It is also possible that postinoculation temperature had an effect on those results. Therefore, relative resistance of cultivars to *Stagonospora nodorum* spot may be recorded with less variability if experiments are carried out at standardized temperature regimes. Similarly, postinoculation temperature has also been observed to alter the phenotypic expression of resistance to other wheat leaf spotting fungi (Luz 1986).

Whether wheat plants should be maintained at the optimum temperature for disease development during germplasm screening should be a function of whether or not such environment is commonly found in the target wheat growing area. If it is, characterization of wheat germplasms displaying temperature-sensitive reactions to *Stagonospora nodorum* spot and other leaf spot diseases is strongly recommended.

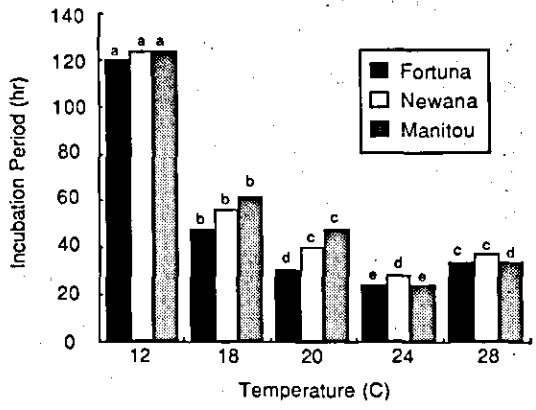

FIG. 3. Effect of temperature on incubation period of *Phaeosphaeria nodorum* on leaves of three wheat cultivars. Means for each cultivar at various temperatures labelled with a common letter are not significantly different by the "protected" LSD test at P = 0.05, CV % = 14.2 and "protected" LSD = 3.9 for main plots, CV % = 13.5 and "protected" LSD = 3.5 for subplots.

TABLE 1. Regression analysis of percentage of leaf area showing *Stagonospora nodorum* spot symptoms, number of lesions per cm^2 and incubation period, vs. temperature in three spring wheat cultivars.

Factors	Regression equations[a]		
	Manitou	Newana	Fortuna
Leaf area (%) Showing symptoms vs. temperature	$y = -44 + 3.34x$	$y = -111.53 + 12.32x - 0.26x^2$	$y = -180.1 + 21.08x - 0.46x^2$
Number of lesions/ cm^2 vs. temperature	$y = -7.45 + 0.58x$	$y = -18.60 + 2.02x - 0.03x^2$	$y = -26.20 + 3.34x + 0.07x^2$
Incubation period vs. temperature	$y = 368.29 - 26.43x + 0.51x^2$	$y = 396.51 - 30.03x + 0.61x^2$	$y = 418.06 - 33.17x + 0.69x^2$

[a] All regressions are represented by quadratic models with the exception of % leaf area showing symptoms vs. temperature and number of lesions/cm^2 vs. temperature for cultivar Manitou. y = disease parameter, x = temperature.

ACKNOWLEDGEMENTS

This research was conducted at Cornell University. The authors gratefully acknowledge the financial support provided by Cornell Agricultural Experiment Station Hatch Project 153-412 and by EMBRAPA (Brazilian Enterprise of Agricultural Research). Appreciation is also extended to Dr. A.L. Scharen tor providing the *P. nodorum* isolate and the differential cultivars.

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