

General Resistance Displayed by Three Hard Red Spring Wheat (*Triticum aestivum*) Cultivars to Leaf Rust

Glen D. Statler, John E. Watkins and John Nordgaard

Associate Professor of Plant Pathology, North Dakota State University, Fargo, ND 58102; Assistant Professor of Plant Pathology, University of Nebraska, Lincoln, NB 68503; Plant Pathologist, Northwood, ND 58267.

Published with approval of the Director of the North Dakota Agricultural Experiment Station as Journal Series Paper No. 751.

Accepted for publication 20 December 1976.

ABSTRACT

STATLER, G. D., J. E. WATKINS, and J. NORDGAARD. 1977. General resistance displayed by three hard red spring wheat (*Triticum aestivum*) cultivars to leaf rust. *Phytopathology* 67: 759-762.

Hard red spring wheat (*Triticum aestivum*) cultivars, Justin, Fortuna, and Tioga with susceptible reaction types to *Puccinia recondita tritici*, which causes leaf rust were evaluated for general resistance. Percentage disease severity and reaction type were evaluated periodically. Logit analyses of disease progress curves were computed to compare the apparent infection rate (AIR) for several cultivars. Cultivars Justin, Fortuna, and Tioga consistently exhibited less leaf rust in the field and slower rates of rust development than Thatcher. Rust increased earlier in the season and more rapidly on Thatcher than on the other cultivars. The high correlation coefficient between AIR and rust severity indicated final rust severity could be used as an indication of

AIR. The high correlation for AIR between the flag, flag-1, and lower leaves indicated that rate of rust development on a given cultivar could be measured on any leaf. Yields of Justin, Fortuna, and Tioga were not increased by controlling leaf rust with systemic fungicide but yields of Thatcher were usually increased significantly. General resistance was indicated for Justin, Fortuna, and Tioga since they always exhibited a slower rate of rust development and lower rust severities at the end of the evaluation period than did Thatcher. The general resistance displayed by these cultivars apparently provides partial protection against leaf rust infection under North Dakota conditions.

Additional key words: Indar, horizontal resistance, slow rusting.

For several years we have been evaluating wheat cultivars that exhibit susceptible reactions to *Puccinia recondita* Rob. ex. Desm. f. sp. *tritici* in the greenhouse and field but which do not develop severe rust symptoms under field conditions.

Low rust severities can be due to a reduced rate of rust development; i.e., slow rusting. MacKenzie (4) described slow rusting as a reduced rate of epidemic acceleration. He reasoned that slow rusters should have a lower apparent infection rate when compared to susceptible cultivars subjected to the same pathogen populations under the same environmental condition. Hooker (3) cited slight differences in incubation time, a slower increase of rust on certain cultivars, small uredia, and reduced sporulation to be characteristic of slow-rusting cultivars.

This study was conducted to compare the rate of rust increase and the rust severity at the final evaluation date with yields of susceptible, resistant, and slow-rusting hard red spring wheats.

MATERIALS AND METHODS

Five cultivars of hard red spring wheat were planted at Casselton, North Dakota each spring from 1972 through 1975 to determine if cultivars with susceptible reaction-types but with lower rust severity than Thatcher would

consistently display a lower rate of rust development and provide adequate protection against the natural leaf rust population. The plots were planted in a randomized block design. Indar [(RH-124) 4-*n*-butyl 1-1, 2, 4-triazole, Rohm and Haas Co., Philadelphia, PA 19105], was used to control *P. recondita tritici* in half the plots. The rate was 0.45 kg active ingredient (a.i.)/hectare (ha) in 1972 and 0.67 kg a.i./ha in 1973, 1974, and 1975. Indar was applied as a foliar spray in 83 liters of water/ha at the three-leaf stage. Each plot was 3.65 m long and 0.91 m wide with a 0.31 m spacing between rows.

Data reported herein are for natural infection. No inoculum was introduced at any time during the 4-yr study. The percentage severity and reaction type of each cultivar was evaluated by the modified Cobb scale (5) every 3 or 4 days after the initial infection occurred. The values reported for five evaluation dates, respectively, are averages of four replications.

Logit analysis of disease progress was used to compare cultivars (6, 8). The apparent infection rates (AIR) were derived from linear regression analysis of logit severity with time. The AIR values are based on a per day increase. Correlation coefficients were computed between AIR and the percentage severity at the final evaluation date for each cultivar. Correlation coefficients among the AIR values also were computed for the top (flag) leaf, leaf below the top leaf (flag-1), and lower leaves. An analysis of variance was used to obtain LSD values for percentage rust severity (Table 1) and for AIR values (Table 2).

Wheat cultivars were harvested separately when

mature and dried to 14% moisture prior to determinations of yield. Yields are averages of four replications.

RESULTS

In previously reported spray trials (7), yields of the susceptible cultivar Thatcher were increased by 954 kg/ha by spraying with Indar. In contrast, yields of the cultivar, Justin, which had a lower severity, and which rusted at a slower rate than Thatcher, were not increased significantly by controlling leaf rust.

Rust developed at a slower rate on Fortuna and Justin than on Thatcher in 1972 and both had lower severities at the last evaluation date than did Thatcher (Table 1). The AIR values based on a per day increase were higher for Thatcher than for Justin, Fortuna, or the resistant cultivar Waldron (Table 2). Yields of Thatcher averaged 584 kg/ha higher where Indar was used to control the rust in 1972. Yields of Fortuna and Justin (which exhibited susceptible reaction types but had lower severities than Thatcher) were not significantly increased by controlling rust with Indar.

The correlation coefficients computed for logits of leaf rust severities plotted against time were high, usually above 0.9. According to Shaner (6) high correlation coefficients indicate that the slopes of the regression lines or the apparent infection rates are useful parameters for comparing cultivars.

Yields were not increased by controlling rust with Indar in 1973. Part of the reason may have been that the

percentage control ranged from 33% for Thatcher to 66% for Justin. We did however, observe slower rates of rust development for Justin, Fortuna, and Tioga than for Thatcher. The AIR values were 0.335 for Justin, 0.314 for Tioga and 0.254 for Fortuna (Table 2). In contrast, Thatcher showed a rather rapid rate of rust development in 1973 and an AIR values of 0.469. Waldron had only a trace of leaf rust throughout the season.

The area under the disease progress curve is a good indication of the amount of rust for the entire season and also for the damage caused by *P. recondita tritici* (1). The area under the disease progress curve is much greater for Thatcher than the other cultivars studied (Fig. 1).

The AIR for the flag-1 leaf was higher for Thatcher than for the slow-rusting cultivars in 1973 (Table 3). The rate of rust development was similar for the two top leaves of Thatcher and Fortuna as well as other cultivars (Fig. 2). The AIR values for the two top leaves were also similar (Table 3). The correlation coefficient between the flag and flag-1 leaf across all cultivars in Table 3 was 0.994. The AIR values for the lower leaves were also higher for Thatcher than for the slow-rusting cultivars (Table 3). However, the AIR values for lower leaves were based on only two evaluation dates. The correlation coefficient between the flag and lower leaves was 0.926 and between flag-1 and lower leaves it was 0.950 across all cultivars in Table 3.

The AIR values were higher for Thatcher in 1974 than for the three cultivars with general resistance (Table 3). Waldron, the previously resistant control had a rating of 6S at the final evaluation. In 1974, yields of Thatcher were

TABLE 1. Percentage severity and reaction types of adult wheat plants infected with *Puccinia recondita tritici* at Casselton, North Dakota

Cultivar	% severity-reaction type per year				\bar{x}
	1972	1973	1974	1975	
Thatcher	77S ^a	70S	80S	47S	68.5S ^c
Justin	40S	36S	50S	18S	36.0S
Fortuna	44S ^b	23S	40S	11S	29.5S
Tioga		30S	50S	26S	37.2S
Waldron	1S	tS	6S	8MS	3.9S
\bar{x}	51.3S	39.9S	56.5S	27.5S	

^aData represent the average of four replications, percentage severity precedes reaction types, S = susceptible, MS = moderately susceptible.

^bCultivar Tioga was not included in 1972 trials; value included in average by missing-plot calculation.

^cLSD ($P = 0.05$) = 12.04; LSD ($P = 0.01$) = 16.85.

TABLE 2. Apparent infection rates (AIR values) for *Puccinia recondita tritici* on five wheat cultivars grown four years at Casselton, North Dakota

Cultivar	AIR value per year				\bar{x}
	1972	1973	1974	1975	
Thatcher	0.256	0.469	0.412	0.327	0.366 ^b
Justin	0.175	0.335	0.345	0.233	0.272
Fortuna	0.183	0.254	0.308	0.224	0.242
Tioga		0.314	0.332	0.298	0.283
Waldron	0.070	0.000	0.198	0.166	0.108
\bar{x}	0.174	1.274	0.319	0.250	

^aCultivar Tioga was not included in 1972 trials; value included in average includes the value that was computed by missing-plot calculation procedures.

^bLSD ($P = 0.05$) = 0.0897.

increased by 268 kg/ha, which was significant only at $P \geq 0.10$ when rust was controlled. Yields of Justin, Tioga, Fortuna, and Waldron were not increased when rust was controlled with Indar.

The results of the 1975 spray trials were similar to those of previous years; the AIR values were higher for Thatcher than for the other cultivars (Table 2). Yields of Thatcher were increased significantly (517.4 kg/ha) ($P \geq 0.05$) with Indar but yields of Justin, Fortuna, Tioga, and Waldron were not significantly increased with Indar. The average percent rust severities at the final evaluation dates for the 4 yr were significantly lower ($P \geq 0.01$) for Justin, Fortuna, and Tioga than for Thatcher. The average percent severity for all cultivars was highest for 1974 and lowest for 1975 (Table 1).

The AIR values for the 4 yr were significantly lower ($P \geq 0.05$) for Justin and Fortuna than Thatcher. Tioga was

significantly lower than Thatcher, but only at $P \geq 0.10$. The average AIR value for all cultivars was greatest in 1974 and least in 1972 (Table 2).

The correlation coefficient for the AIR and the percentage rust severity at the final evaluation date for all years and cultivars was 0.745, significant at $P \geq 0.01$. The correlation coefficients between the AIR values and final rust severity for cultivars within years was 0.997 for 1972, 0.944 for 1973, 0.994 for 1974, and 0.917 for 1975. The correlation coefficients between AIR values and final rust severity across years for each cultivar were 0.140 for Thatcher, 0.406 for Justin, 0.039 for Fortuna, 0.941 for Tioga, and 0.874 for Waldron.

DISCUSSION

Leaf rust severity increased at different rates on different cultivars and in different years. Differences in severity among cultivars became more evident during the season because of different rates of disease development on them. There were ample differences in leaf rust severity between the cultivars to indicate general resistance of the slow-rusting type. Shaner (6) reported similar results with slow-mildewing wheat cultivars.

We have demonstrated that cultivars Justin, Fortuna, and Tioga have susceptible reaction types, but rust at a slower rate and consequently are not so severely rusted as was Thatcher, which is a fast-rusting wheat. We also have demonstrated that yields of these slow-rusting cultivars are not increased by chemically controlling leaf rust and that yields of Thatcher usually were increased. Of the cultivars observed, Fortuna consistently displayed the slowest rate of rust increase except for 1972 when the AIR

TABLE 3. Apparent infection rates (AIR values) for *Puccinia recondita tritici* on the lower, middle, and upper leaves of five wheat cultivars in 1973

Cultivar	AIR values per leaf ^a		
	Flag	Flag-1	Lower
Thatcher	0.469	0.478	0.278
Justin	0.335	0.317	0.124
Fortuna	0.254	0.242	0.156
Tioga	0.314	0.285	0.124
Waldron	0.000	0.008	0.000

^aFlag = upper leaf, Flag-1 = middle leaf; i.e., first leaf below upper leaf.

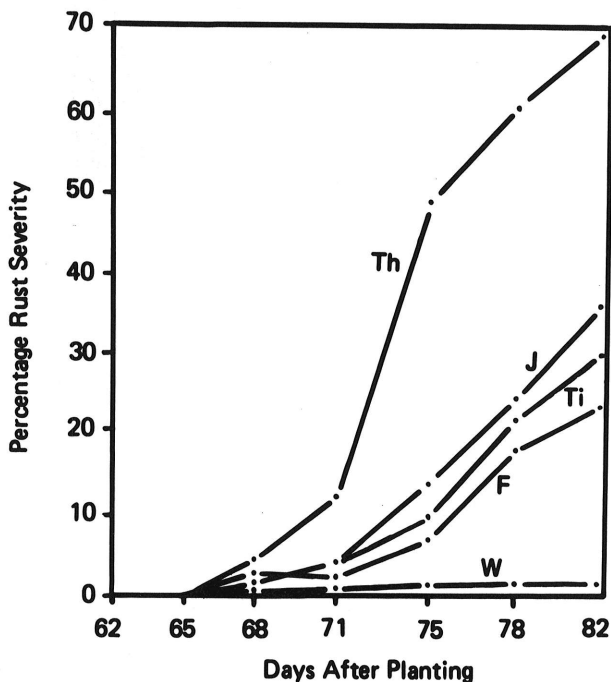


Fig. 1. Disease progress curves for *Puccinia recondita tritici* on wheat cultivars Thatcher (Th), Justin (J), Tioga (Ti), Fortuna (F), and Waldron (W) grown at Casselton, North Dakota in 1973.

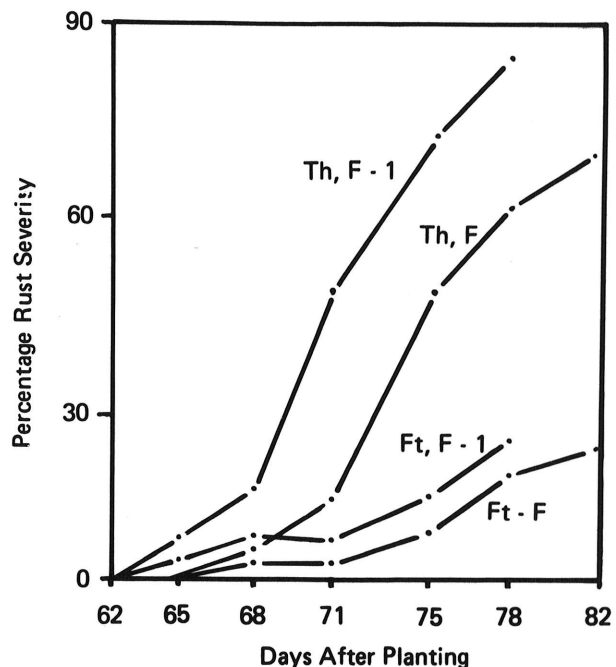


Fig. 2. Disease progress curves for *Puccinia recondita tritici* on flag (F) and flag-1 (F-1) leaves of wheat cultivars Thatcher (Th) and Fortuna (Ft) grown at Casselton, North Dakota in 1973.

value was slightly higher for Fortuna than for Justin.

Thatcher always was characterized by a more rapid increase in rust development earlier in the season than the other cultivars studied. We feel that this has an extremely important effect on yield. The earlier and more rapid rust development on lower and upper leaves alike was responsible for a larger area under the disease progress curve for Thatcher than for Justin, Fortuna, or Tioga.

Wheat leaf rust characteristically begins on the lower leaves and moves to the upper leaves as the season progresses. Leaf rust of susceptible cultivars usually becomes severe on the top leaves later in the season; since the top leaves are important for kernel fill, these are the leaves from which most evaluation samples are taken. In North Dakota the bottom leaves may senesce prior to severe rust development on upper leaves. We believe desiccation of any or all leaves caused by high severity of leaf rust is extremely important in yield reduction.

The high correlation coefficients between AIR values for the flag, flag-1, and lower leaves indicated that rust development on any leaf could be used as an indication of the rate of rust development for a cultivar. The highly significant correlation coefficient for the AIR and the percent rust severity at the final evaluation date indicates that the percent severity at the final evaluation date can be used as an indication of the rate of rust development.

The correlation coefficients for AIR and final rust severity were higher for all cultivars within years than for individual cultivars across years, except for Tioga and Waldron which were high in both cases. This indicates that the percent severity at the final evaluation date would be a better indication of infection rates within years for several cultivars than for individual cultivars across several years.

Cultivars Justin, Fortuna, and Tioga fit MacKenzie's (4) description of slow-rusting types as those cultivars which are characterized by lower r (AIR) values compared to susceptible cultivars. The slower rate of development and lower severities than the susceptible cultivar Thatcher during the 4-yr period also indicates stable protection against the natural *P. recondita tritici* population and fits Caldwell's (2) description of general resistance. This general resistance apparently provides partial protection against yield loss under North Dakota conditions.

LITERATURE CITED

1. BUCHENAU, G. W. 1975. Relationship between yield loss and area under wheat stem rust and leaf rust progress curves. *Phytopathology* 65:1317-1318.
2. CALDWELL, R. M. 1968. Breeding for general and/or specific plant disease resistance. Pages 263-272 in K. W. Finlay and K. W. Shepherd, eds. *Proc. Third Int. Wheat Genet. Sympos.*, 5-9 August, Canberra, Australia. 479 p.
3. HOOKER, A. L. 1967. The genetics and expression of resistance in plants to rusts of the genus *Puccinia*. *Annu. Rev. Phytopathol.* 5:163-182.
4. MAC KENZIE, D. R. 1976. Application of two epidemiological models for the identification of slow stem rusting in wheat. *Phytopathology* 66:55-59.
5. PETERSON, R. F., A. B. CAMPBELL, and A. E. HANNAH. 1948. A diagrammatic scale for estimating rust intensity on leaves and stems of cereals. *Can. J. Res.* 26:496-500.
6. SHANER, G. 1973. Evaluation of slow-mildewing resistance of Knox wheat in the field. *Phytopathology* 63:867-872.
7. STATLER, G. D. 1974. The relationship of leaf rust infections and wheat yields. *N. D. Farm Res.* 31:24-26.
8. VAN DER PLANK, J. E. 1963. *Plant Diseases: epidemics and control*. Academic Press, New York. 349 p.