

Genetics of Leaf Rust Resistance in Three Western Canada Spring Wheats

J. A. KOLMER, Research Scientist, Agriculture Canada Research Station, 195 Dafoe Road, Winnipeg, Manitoba, R3T 2M9 Canada

ABSTRACT

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The wheat cultivars Laura, Biggar, and Genesis have recently been licensed and released for production in western Canada. These cultivars all have effective resistance to the wheat leaf rust fungus, *Puccinia recondita* f. sp. *tritici*. The objective of this study was to identify the leaf rust resistance genes in these cultivars. The three cultivars were crossed with the leaf rust-susceptible cultivar Thatcher and also with near-isogenic lines of Thatcher with known leaf rust resistance genes. Segregation of F₃ lines in an artificially inoculated rust nursery indicated that Laura has the adult plant gene *Lr34*. The seedling resistance genes *Lr1* and *Lr10* were also identified in Laura. Segregation of F₃ lines indicated that the adult plant gene *Lr13* was in Genesis and Biggar. A second adult plant gene was also identified in Biggar. Genesis and Biggar were determined to have the seedling resistance gene *Lr14a*.

Additional keywords: specific resistance, *Triticum aestivum*

Leaf rust of wheat (*Triticum aestivum* L.), caused by *Puccinia recondita* Roberge ex Desmaz. f. sp. *tritici* occurs in North America wherever wheat is grown (9,16). On a worldwide basis, leaf rust

is one of the most important diseases of wheat (16). Genetic resistance is the most economical means of reducing yield losses to this disease. Effective leaf rust resistance is a requirement for licensing of wheat cultivars developed by Agriculture Canada for Manitoba and Saskatchewan. Knowledge of the identity of the leaf rust resistance genes in released cultivars and germ plasm is essential for

incorporation of new effective resistance genes into breeding programs and maintenance of genetic diversity for resistance genes in commonly grown cultivars.

The objective of this study was to determine the number and identity of leaf rust resistance genes in the recently released western Canadian spring wheat cultivars Laura, Biggar, and Genesis.

MATERIALS AND METHODS

The wheat cultivars Laura, Biggar, and Genesis were developed at the Agriculture Research Station at Swift Current, Saskatchewan. Laura is an awned hard red spring wheat selected from a cross between BW15 and BW517 (3). BW15 was derived from the cross Manitou/Tobari 66, and BW517 was derived from the four-way cross Carazinho/CT 763/Atlas 66/CT 262. Biggar is an awned red Canada Prairie Spring semidwarf wheat that is a reselection of HY320 for kernel hardness (2). Biggar and HY320 were derived from a cross between Tobari 66 and Romany (1). Genesis is an awned white Canada Prairie Spring

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wheat derived from a cross between HY320 and NB402 (4).

Seedlings of Laura, Genesis, and Biggar, the 12 Thatcher near-isogenic lines used as differentials in the *Prt* nomenclature (12), plus the Thatcher lines isogenic for *Lr10* (RL6004), *Lr14a* (RL6013), *Lr18* (RL6009), and *Lr23* (RL6012) were inoculated with selected *P. r. tritici* isolates. Seedlings were grown in a soil-peat moss mixture in 25 × 20 cm fiber flats and fertilized weekly with soluble 20-20-20 N-P-K. Seedlings were inoculated by atomizing a mixture of urediniospores and lightweight mineral oil (2 mg/300 μl) onto fully expanded primary leaves. The inoculated plants were placed in a dew chamber at 14 C for 16 hr and then removed and placed on greenhouse benches at 18–22 C with 8 hr of supplemental fluorescent light. Infection types were rated on a 0–4 scale (12) 12 days after inoculation. Infection types 0;–2+ were considered resistant and types 3–4 were considered susceptible.

Laura, Genesis, and Biggar were used as pollen parents in crosses with the leaf rust-susceptible wheat Thatcher (Tc). Laura was also crossed with the Thatcher lines near-isogenic for *Lr1* (RL6003), *Lr10*, and *Lr34* (RL6058). Genesis and Biggar were also crossed with the Thatcher line near-isogenic for *Lr13* (RL4031). Individual adult plants of each cultivar and F₁ and F₂ generations were grown in 15-cm pots in growth cabinets at 16 C, with 16 hr of fluorescent and incandescent light. In all crosses, F₃ lines were derived from single F₂ plants.

Fifty to 60 seeds of individual F₃ lines were planted in 2-m rows in a field rust nursery artificially inoculated with a mixture of *P. r. tritici* races prevalent in Manitoba and Saskatchewan in 1991 (10). The three cultivars, Thatcher, and the Thatcher backcross lines near-isogenic for leaf rust resistance genes *Lr1*, *Lr10*, *Lr13*, *Lr14a*, and *Lr34* were also evaluated for resistance in the rust nursery. Rust readings were taken when the susceptible check Thatcher had a severity (14) and response (18) rating of 100% susceptible. Readings were taken only on flag leaves. At least 10 plants in each family were examined for severity and response of rust infection. Although the F₃ families varied for relative maturity, they were generally at the early milk stage when the rust readings were taken. The F₃ families were classified as resistant, segregating, or susceptible relative to Thatcher. F₂ seedlings of Tc/Laura, Tc/*Lr1*/Laura, and Tc/*Lr10*/Laura, were planted and inoculated in the same manner as described previously. Goodness of fit to segregation ratios in the individual F₂ plants and F₃ families was determined using chi-square tests (19). F₃ families of Tc/Biggar and Tc/Genesis that were susceptible in the rust nursery were also evaluated for seedling resistance with different *P. r. tritici* isolates.

RESULTS

Leaf rust isolates that had low infection types on seedling plants of Tc/*Lr1* and Tc/*Lr10* also had low infection types on seedlings of Laura (Table 1). The F₂ progeny of Thatcher/Laura segregated 15:1 for resistant and susceptible plants, respectively, when inoculated in the seedling stage with isolate BBB-13 (Table 2). This indicated that two genes conditioned seedling resistance in Laura. The F₂ progenies of Tc/*Lr1*/Laura and Tc/*Lr10*/Laura did not segregate for resistance when inoculated with BBB-13 (Table 2), indicating that Laura has these two seedling resistance genes. The F₃ lines of Thatcher/Laura segregated 1:2:1 when evaluated as adults in the rust nursery (Table 2), indicating that a single gene conditions adult plant leaf rust resistance in Laura. Twenty-seven F₃ families of Tc/*Lr34*/Laura did not segregate for rust resistance when tested as adults in the rust nursery (Table 2). Laura must have *Lr34*, since Laura generally has a field rust reaction similar to that of Tc/*Lr34* and also displays leaf tip necrosis, which is associated with this gene (6). Compared with Thatcher, Tc/*Lr1* and

Tc/*Lr10* did not have effective leaf rust resistance as adult plants in the rust nursery (Table 1).

Biggar and Genesis had very low seedling infection types when tested with leaf rust isolates that were also avirulent to Tc/*Lr14a* (Table 1). Tc/*Lr14a* does not confer resistance to the field mixture of leaf rust races (Table 1). The F₃ families of Thatcher/Biggar and Thatcher/Genesis segregated in 7:8:1 and 1:2:1 ratios, respectively, when tested in the rust nursery (Table 2), indicating that Biggar has two genes and Genesis has one gene that conditions adult plant leaf rust resistance. Genesis has a rust reaction similar to that of Tc/*Lr13* (Table 1), and all F₂ progenies of Tc/*Lr13*/Genesis were resistant to isolate BBB (Table 2), indicating that Genesis has *Lr13*. One of the genes in Biggar is also *Lr13*, since many of the resistant and segregating F₃ families of Thatcher/Biggar had plants with rust reactions very similar to Tc/*Lr13* and all F₂ progenies from Tc/*Lr13*/Biggar were resistant to isolate BBB (Table 2). The F₃ segregation data also indicate that Biggar has a second gene that conditions leaf rust re-

Table 1. Seedling infection types^a to *Puccinia recondita* f. sp. *tritici* isolates and adult plant field reactions^b of Laura, Biggar, Genesis, and Thatcher lines near-isogenic for leaf rust resistance genes

Wheat line	<i>P. r. tritici</i> isolate						
	BBB	CBM	PBL	TBB	MFB	BBB-13	Field
Laura	0;	0;	2+	;	2+	0	TR-5M
Biggar	;2	;	;	23c	3+	;3	10MR-30MR
Genesis	;2	;	;	23c	3+	;3	30MR
Tc/ <i>Lr1</i> RL6003	0;	0;	3+	3+	4	0	100S
Tc/ <i>Lr10</i> RL6004	3+	3+	3+	;	4	;	100S
Tc/ <i>Lr13</i> RL4031	;22+	2+3	3+	3c	3+	33+	50MR-MS
Tc/ <i>Lr14a</i> RL6013	;23	;23	;23	3+	4	3+	100S
Tc/ <i>Lr34</i> RL6058	22+	33+	33+	23c	22+	3	5-20MR
Thatcher	3+	3+	3+	3+	3+	3+	100S

^a Infection types were rated on a scale from 0; (faint hypersensitive flecks) to 4 (large uredinia) as in *Prt* nomenclature (12).

^b Percent rust severity ranging from TR (trace) to 100% on individual plants, with R = resistance (flecks and small uredinia with necrosis), M = mixed infections (flecks and moderate- to large-sized uredinia), MR = moderately resistant (large necrotic flecks and large uredinia), MS = moderately susceptible (moderate to large uredinia with chlorosis), and S = susceptible (large uredinia).

Table 2. Segregation for leaf rust resistance in greenhouse seedling and field rust nursery tests in F₂ and F₃ populations of crosses of Thatcher, and near-isogenic lines of Thatcher, with Laura, Biggar, and Genesis

Cross	Rust isolate	Gen.	Number of plants or families ^a				Ratio	<i>P</i> ^b
			Res.	Seg.	Susc.			
Tc/Laura	BBB-13	F ₂	259	...	23	15:1	0.25–0.10	
Tc/ <i>Lr1</i> RL6003/Laura	BBB-13	F ₂	229	...	0	15:1	0.001	
Tc/ <i>Lr10</i> RL6004/Laura	BBB-13	F ₂	180	...	0	15:1	0.001	
Tc/ <i>Lr13</i> RL4031/Genesis	BBB	F ₂	227	...	0	15:1	0.001	
Tc/ <i>Lr13</i> RL4031/Biggar	BBB	F ₂	216	...	0	15:1	0.001	
Tc/Genesis	PBL	F ₃	7	12	4	1:2:1	0.25–0.10	
Tc/Laura	Field	F ₃	22	55	21	1:2:1	0.25–0.10	
Tc/Biggar	Field	F ₃	57	70	7	7:8:1	0.75–0.50	
Tc/Genesis	Field	F ₃	22	49	23	1:2:1	0.75–0.50	
Tc/ <i>Lr34</i> RL6058/Laura	Field	F ₃	27	0	0	15:1	0.001	

^a Gen. = generation, Res. = resistance, Seg. = segregating, Susc. = susceptible.

^b *P* = probability of a χ² value.

^c No plants or lines expected.

sistance. Progeny lines homozygous for this gene singly had adult plant rust reactions of 30 MS that were distinct from the reactions conditioned by *Lr13* or *Lr34*.

F₃ families of Thatcher/Biggar and Thatcher/Genesis that were susceptible in the rust nursery were inoculated as seedlings with isolate PBL, which is avirulent to gene *Lr14a*. Nineteen of the Thatcher/Genesis F₃ lines were either homozygous resistant or segregated for resistance, whereas four lines were susceptible (Table 2). This indicated that Genesis has a single gene that conditioned seedling resistance to isolate PBL. Progeny lines homozygous for this seedling resistance gene singly had low infection type to all isolates that were avirulent to Tc*Lr14a* (data not shown). This indicated that Genesis has gene *Lr14a*. Susceptible F₃ lines from Thatcher/Biggar that were homozygous for only seedling resistance to isolate PBL were not recovered. However, resistance in the segregating lines was always expressed to rust isolates that had low infection type to *Lr14a*, indicating that Biggar also probably has *Lr14a*. Genesis and Biggar have lower infection types to isolates CBM and PBL than Tc*Lr14a*, since these cultivars also have *Lr13*, which interacted with *Lr14a* to condition a lower than expected infection type (8).

DISCUSSION

Adult plant resistance gene *Lr13* was present in the cultivars Biggar and Genesis and gene *Lr34* was present in Laura. These two genes are present either singly or together in every Canadian spring wheat recommended for Manitoba or Saskatchewan and have provided effective resistance to leaf rust for many years (11). A second effective adult plant gene was found in Biggar. This resistance appeared to be distinct from *Lr13* and *Lr34* and other previously characterized adult plant leaf rust resistance genes. Adult plant gene *Lr12* did not condition

effective resistance to the leaf rust races in the rust nursery. Adult plant genes *Lr22a* and *Lr35* were derived from foreign species, and lines with these genes are not in the pedigree of Biggar. Near-isogenic Thatcher lines with genes *Lr22a* and *Lr35* also had rust nursery reactions distinct from the unknown gene in Biggar.

The seedling resistance genes *Lr1* and *Lr10* were found in Laura and *Lr14a* was found in Genesis and Biggar. All of the races in Manitoba and Saskatchewan have been virulent to *Lr10* and *Lr14a*, and over 50% are virulent to *Lr1* (10). The effective leaf rust resistance present in Laura, Biggar, and Genesis was conditioned by resistance genes that are best expressed in the adult plant stage. Seedling infection-type data of wheat cultivars inoculated with different isolates of leaf rust have been used by a number of workers (13,15,17) to determine which seedling resistance genes may be present. Analysis of seedling infection-type data cannot adequately determine the presence and identity of adult plant resistance genes, which often condition the effective leaf rust resistance in wheat cultivars. Studies examining adult plant leaf rust resistance should employ either F₃ lines as used in this paper or preferably backcross F₂ lines (5).

Laura, Genesis, and Biggar have only moderate levels of resistance to leaf rust. However, the resistance genes *Lr13* and *Lr34* present in these cultivars can be combined with other adult plant genes or with seedling resistance genes that condition effective levels of resistance to develop new cultivars that would be highly resistant to leaf rust (7,8).

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