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Mechanism of durable resistance: a new approach

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Summary. Wheat genotypes, including backcross derivatives of 'Thatcher' carrying *Lr*10 and *Lr*23, substitution lines for *Lr*10 and *Lr*23 in Chinese Spring background and Chinese Spring and Thatcher were analysed against 21 pathotypes of leaf rust in seedling tests. Adult plant responses in all these stocks were observed in the field nurseries under exposure to the inoculum of the Indian virulent races of leaf rust. The seedling data demonstrated that both the substitution lines and the backcross derivatives for each gene carry identical pattern of infection for resistance. The high level of adult plant resistance in the substitution lines, in contrast to the backcross derivatives in Thatcher, has been postulated to be due to the combination of resistance contributed by *Lr*10 and adult plant Chinese Spring resistance or to *Lr*23 and Chinese Spring adult plant resistance. It has been suggested that genes *Lr*10 and *Lr*23 added to the Chinese Spring background provide sources for durable resistance, since Chinese Spring has continued to provide a moderate level of adult plant resistance to leaf rust for a very long time.

Key words: *Triticum aestivum* – *Puccinia recondita* – Adult plant resistance – Resistance genes – Durable resistance

Introduction

The most destabilizing factor for wheat yield is the rust incidence. Since all three rust pathogens, namely *Puccinia recondita, P. striiformis* and *P. graminis* (given in order of importance) attack wheat in the Indian subcontinent, wheat breeding programmes require introduction of resistance to all three rusts. Although incorporation of resistance normally controlled by major genes has been achieved, the main problem is the subsequent failure of such resistance due to changes in racial pathogenicity. Hence, durable resistance is the major concern.

The history of resistance to stem rust reveals that resistant varieties that have remained effective for many years have possessed, with a few exceptions, a combination of resistance genes (McIntosh and Watson 1982). Stem rust resistance gene, *Sr*2, operative around boot stage, is still effective (Hare and McIntosh 1979) and has been considered a desirable genetic background into which more effective, but less durable resistance genes can be added for adequate level of durable resistance (McIntosh 1988). The genetic basis of varieties with durable resistance to stripe rust has identified a substantial level of resistance not controlled by recognised race-specific components (Johnson and Lupton 1987).

Leaf rust resistance related to single genes has always been observed to be short-lived. The durable nature of resistance to leaf rust in most of the cultivars has been found to be due to a combination of *Lr*13 (adult plant resistance gene) and *Lr*34 (Roelfs 1988), as in stem rust. Likewise, the high level of lasting resistance to leaf rust in cv Frontana was reported to be controlled by two interacting genes, *Lr* T2 (*Lr*34) and *Lr* T3 (*Lr*33), in combination with *Lr*13 (Dyck and Samborski 1982). The Chinese Spring wheat carries mature plant resistance against *P. recondita* (McIntosh and Baker 1966) and is still effective and probably includes genes *Lr*12 and *Lr*13 (Watson 1970; Watson and Butler 1984). However, this adult plant resistance, which is independent of seedling resistance, conditions inadequate resistance. These examples suggest that the possibility of achieving durable re-

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Table 1. Seedling reactions of various stocks with *Lr*10 and *Lr*23 and their carrier lines when tested against individual pathotypes of leaf rust

Pathotype	Stock			Carrier variety		Stock	
	Tc*6/Exchange (*Lr*10)	CS/KF 1A (*Lr*10)	CS/KF 7D (*Lr*10)	Thatcher	Chinese Spring	Tc*6/Lee 310 (*Lr*23)	CS/KF 2B (*Lr*23)
10	3	3	3	4	3	1−2	0;−1
11	0;−1	1	0;−2	2−3	4	0;−1	0;
12	3	3	x	4	4	0;−2	1
12-1	4	4	4	4	4	2	0;−1
12-2	4	4	4	4	4	2	0;−1
17	3	3	3	4	4	0;−1	0;
20	3	3	3	4	4	0;	0;
63	0;	0;−2	0;−2	3	4	0;−1	0;
77	2	0;	0;	4	4	0;	1
77-1	4	4	4	4	4	1	1
77-2	4	3	4	4	4	4	4
77A	4	4	4	4	4	0;−1	2
77A-1	4	4	4⁻	4	4	0;−2	0;−2
104	1−2	1−2+	2⁺	3−4	4	2+	1−3
104-1	3	4	3	4	4	3	4
104A	2+	3−	2+	4	4	2+	2+
104B	4	4	4	4	4	4	4
106	0;	4	3	0;&4	4	0;	0;−1
107	0;	0;−1	0;−2	4	4	0;−1	0;
162	3	3	3	3	3	3	4
162A	4	3+	4	4	4	3⁻	3⁻

Infection type (IT) 0;, 0;−1, 1, 0;−2, 2, 2+, 1−2+ = resistance; IT 2−3, X, 3⁻ = low reaction. IT 0; &4 = Heterogenous for resistance and susceptible infection; IT 3, 3−4, 4 = Susceptible
Tc – Thatcher
CS – Chinese Spring
KF – Kenya Farmer

sistance is enhanced if adult plant resistance is combined with seedling resistance genes. The report that is being presented using substitution lines has demonstrated that, for resistance to leaf rust, wheat lines carrying adult plant resistance which provides inadequate level of resistance, when combined with seedling major specific genes for resistance, may provide a longer run, with complete protection.

Materials and methods

The studies were carried out on seven wheat genotypes. These included Thatcher (Tc) and backcross derivatives of Thatcher such as Tc*6/Exchange and Tc*6/Lee 310 carrying *Lr*10 and *Lr*23, respectively; substitution lines of Kenya Farmer (KF) stock in the Chinese Spring (CS) background: CS/KF1A(*Lr*10) and CS/KF 2B(*Lr*23). The chromosome substitution lines used in this study were developed by substituting chromosome of Chinese Spring with the corresponding chromosome of Kenya Farmer (McIntosh and Dyck 1975). CS/KF 7D was also included to establish the identity of resistance in this substitution line. Chinese Spring was included as another check.

Seedling tests were conducted against individual races of leaf rust under controlled inoculations in a glasshouse. Adult plant responses were observed in the field under artificial epidemic of leaf rust produced with inoculum of a mixture of important races. The seedling data of infection types were recorded according to standard procedure of Stakman et al. (1962). The tissue affected and type of response at the adult plant stage were recorded according to the scale devised by Loegering (1959).

Results and discussion

The seedling data of various host genotypes when tested against 21 races of leaf rust individually are presented in Table 1. The pathogenicity and non-pathogenicity data against different races were observed to be almost identical on genotypes Tc*6/Exchange (*Lr*10), CS/KF 1A and CS/KF 7D(*Lr*10). Both Thatcher and Chinese Spring exhibited highly compatible reactions, except that Thatcher produced low reaction against races 11 and 106. The low reaction on Tc*6/Exchange, in contrast to Chinese Spring lines with *Lr*10 (CS/KF 1A and CS/KF 7D) to race 106, is probably due to resistance in Thatcher. However, a high level of resistance (Low infection) was observed on CS/KF 1A and CS/KF 7D, known or postulated to carry *Lr*10 in Chinese Spring background, in comparison to an intermediate reaction observed on Thatcher against race 11. In this case, it is not possible to

Table 2. Adult plant response of stocks with *Lr*10 and *Lr*23 and the carrier lines when tested at Delhi under leaf rust epiphytotic conditions 1986–1987, 1987–1988

Crop season	Stock		Carrier variety		Stock	
	Tc*6/Exchange (*Lr*10)	CS/KF 1A (*Lr*10)	Thatcher	Chinese Spring	Tc*6/Lee 310 (*Lr*23)	CS/KF 2B (*Lr*23)
1986–1987	60S	20MR	80S	20MS	50MR	5MR
1987–1988	80S	10MR	90S	40MS	20MR	TR

TR – Trace resistant
MR – Moderately resistant
MS – Moderately susceptible
S – Susceptible

differentiate the contribution of the background effect or the other specific genes for resistance, because a more incompatible interaction masks the effect of a less incompatible interaction. Almost identical patterns of infection on CS/KF 1A and CS/KF 7D (Table 1) suggest that both the substitution lines carry *Lr*10. The presence of *Lr*10 in CS/KF 7D has been postulated (McIntosh and Dyck 1975). An identical pattern of infection produced on lines carrying *Lr*23, Tc*6/Lee 310 and CS/KF 2B also suggests that these lines are the same in their behaviour for seedling resistance. However, lines with *Lr*23 are effective to a large number of races in the seedling stage, though susceptibility to four of the important races (77-2, 104-1, 104B, 162) suggests that *Lr*23 alone may not provide adequate protection to leaf rust.

Table 2 gives leaf rust responses at the adult plant stage for two crop seasons (1986–1987 and 1987–1988) exposed to the important races of leaf rust, resulting in a good epidemic. A comparison of the adult plant response on the Chinese Spring substitution line, CS/KF 1A, and Thatcher backcross line, Tc*6/Exchange, both carrying *Lr*10, identified CS/KF 1A as a highly effective and Tc*6/Exchange as a less effective source. The line carrying *Lr*10 in Thatcher background in multilocation tests was reported to produce a high coefficient of infection (Sawhney et al. 1982).

The resistance reaction on the line carrying *Lr*10 in Chinese Spring background, in contrast to a high degree of susceptible reaction on a line carrying *Lr*10 in Thatcher background, suggests that the resistance in the substitution line is due either to Chinese Spring adult plant resistance or the combined contribution of *Lr*10 and Chinese Spring adult plant resistance. The high level of resistance in the substitution line in comparison to the intermediate level of resistance in cv Chinese Spring supports the observation that enhancement of resistance in the substitution line is due to the combination of resistance contributed by *Lr*10 and Chinese Spring adult plant resistance.

Similarly, a high level of resistance in CS/KF 2B could be explained on account of the combination of *Lr*23 and Chinese Spring adult plant resistance. *Lr*23 in Thatcher background, however, produced low level of resistance with 50% area infected and a moderately resistant (MR) type of rust reaction. An observation that *Lr*23 + Tc confers adult plant resistance against race 77A was also made by Saini et al. (1986). In earlier studies, *Lr*23 in Thatcher background was observed to produce a high average coefficient of infection above the tolerable limit, when tested at a number of locations for a period of 4 years (Swahney et al. 1982). Ineffectiveness of *Lr*23 at the adult plant stage (Sawhney et al. 1982) when tested at multilocation, in contrast to intermediate resistance observed in the present study, could be due to untapped virulences and/or to the influence of different environments and inoculum pressures. However, cultivars PV 18, Gabo, Lee, Esshovskoya 32 and Sasatovskoya, postulated to carry *Lr*23, have continued to provide resistance in the USSR (L.A. Mikhailova, personal communication).

In the present work, leaf rust resistance race-specific genes, *Lr*10 and *Lr*23, when added into the Chinese Spring background, have produced a high degree of protection to *Puccinia recondita*. These resistant genotypes (CS/KF 1A and CS/KF 2B) should serve both as additional sources of resistance and durable ones. Chinese Spring resistance could be considered a desirable background into which other specific genes can be added for enhanced level of durable resistance.

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