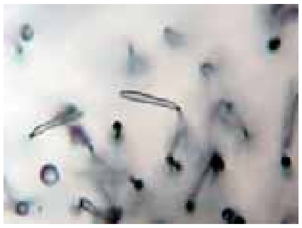
Improving Wheat Resistance to Tan Spot caused by *Pyrenophora tritici-repentis*



Tan spot caused by *Pyrenophora tritici-repentis* (anam. *Drechslera tritici-repentis*) is a foliar disease that has become a major component of the leaf spotting complex in Australia, Canada, the USA and several European countries in recent decades. Tan spot is also found in Argentina, Brazil, Mexico, Nepal, North Africa and Central Asia (Kazakhstan and Tajikistan). Severe tan spot epidemics tend to cause 10-20% yield losses, and may cause losses of over 50% under conditions favorable for disease development. Intensive wheat production, reduced tillage practices, susceptible varieties, and shorter crop rotations have contributed to tan spot epidemics in many regions.

The pathogen propagates both asexually and sexually. Conidia (asexual spores) are disseminated by wind and ascospores (sexual spores) are discharged from pseudothecia, black fruiting bodies that develop on infected crop stubble, where the fungus overwinters. The disease is also seed transmitted. Since disease inoculum survives on crop residues on the soil surface, more resistance to stubble-borne diseases like tan spot is an important priority, given the increased attention to and adoption of conservation agriculture. Typical symptoms consist of necrotic leaf spots with or without chlorotic margins, where conidia develop.

Tan spot can be controlled by crop rotation and destruction of sources of inoculum. Fungicides are effective but raise environmental concerns and may not be cost-effective everywhere. Resistant varieties are therefore the most effective and economical means of controlling the disease.

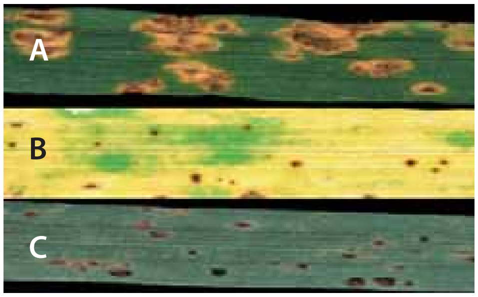
Tan Spot Races and Challenges for Resistance Screening

Worldwide isolates of *P. tritici-repentis* are classified into eight races based on their ability to induce tan necrosis and / or chlorosis in a set of differential wheat genotypes.

Race	Glenlea	6B365	6B662	Salamouni
1	N	C	R	R
2	N	R	R	R
3	R	C	R	R
4	R	R	R	R
5	R	R	C	R
6	R	C	C	R
7	N	R	C	R
8	N	C	C	R

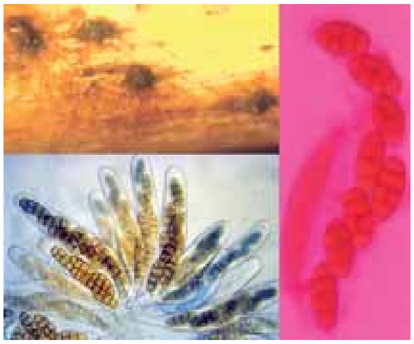
Pyrenophora tritici-repentis **races based on symptoms induced in differential wheat genotypes, established by Lamari et al. (2003); N = necrosis; C = chlorosis; R = resistant**

The fungus produces host-specific toxins (HSTs), which have been associated with the necrosis and chlorosis symptoms induced on susceptible cultivars.



Necrosis (A), chlorosis (B) and resistance (C) symptoms used to assess disease reaction in seedlings

Wheat stubble from the previous season being inspected for tan spot in a standing wheat field in Central Asia



Pseudothecia (fruiting structures) on stubble (top), containing asci (bottom), which contain ascopospores (the sexual spores, right)

The HST Ptr ToxA (produced by races 1, 2, 7, and 8) is the main factor causing necrosis. Two chlorosis-inducing HSTs, Ptr ToxB, isolated from race 5, and Ptr ToxC, isolated from race 1, have been identified. Genetic studies have established that sensitivity to toxins Ptr ToxA, Ptr ToxB, and Ptr ToxC and susceptibility to their producer races are each controlled by the same gene.

Genotype	Races							
	4	2	1	8	7	5	6	3
Glenlea		Ptr ToxA	Ptr ToxA	Ptr ToxA	Ptr ToxA			
6B662				Ptr ToxB	Ptr ToxB	Ptr ToxB	Ptr ToxB	
6B365			Ptr ToxC	Ptr ToxC			Ptr ToxC	Ptr ToxC

Relationship between races and host-specific toxins in *Pyrenophora tritici-repentis*

Resistance to Ptr ToxA is controlled by a single recessive gene, designated *tsn1*. A single dominant gene controls resistance to chlorosis induced by races 1 and 3. The presence of frequent sexual reproduction increases the potential for the development of new races of *P. tritici-repentis*. Race 1 is the most widespread race worldwide and is overwhelmingly the most common in Kazakhstan. Race 2 is also widely distributed. Both races 1 and 2 are found in Mexico and South Asia.

Screening for tan spot resistance in the field is challenging: symptoms are not easily distinguished from other foliar diseases under natural conditions and hot spot locations for tan spot alone are not easy to find; producing large amounts of inoculum is costly and time consuming due to the slow growth of the pathogen and strict light requirements for producing conidia; humidity must be maintained in the field after inoculation for the disease to become established; and the disease progresses slowly in inoculated fields and can be masked by other foliar diseases. Therefore screening for tan spot at the seedling stage is often preferred to allow the most susceptible materials to be discarded before confirmation of field resistance. A consistent and accurate disease evaluation is possible in controlled conditions and a positive correlation has been reported between assessments of resistance at the seedling stage and of adult plants in the field. Toxins or culture filtrates may be used in screening for resistance as a surrogate for conidia inoculation, though direct use of the pathogen is recommended.

Research at CIMMYT

CIMMYT has been working on tan spot for more than two decades. With Belgian collaboration (DGCD-UCL) a worldwide collection of *P. tritici-repentis* strains has been assembled under the MUCL Fungi collection in Belgium. The epidemiology and distribution of the disease has been further understood over the years through work with a network of collaborators in Central and South Asia, North Africa and South America.

A set of resistant wheat materials has also been identified. Both greenhouse and field screening for tan spot resistance are conducted at CIMMYT in Mexico. CIMMYT's studies show that it is more practical to carry out initial evaluations in the greenhouse and follow these with confirmation tests in the field. Both quantitative and qualitative resistance to tan spot have been reported. Preliminary results from association mapping studies reveal that genomic regions on the short arm of chromosomes 1A, 1B, and 6B, and the long arm of chromosomes 4A, 6A, 2B, 3B, 5B, and 7B, play important roles in resistance to tan spot induced by *P. tritici-repentis* race 1. CIMMYT may over the years have accumulated a germplasm base with resistance to tan spot that differs from other resistance sources identified, probably as a result of the extensive use of Veery lines in the 1980s.

Severe tan spot symptoms: leaf lesions harbor conidia (asexual spores) recognizable under the microcope by basal cells in the shape of a snake's head.

Through a collaborative project with the Swedish University of Agricultural Sciences (SLU, Uppsala) supported by SIDA, CIMMYT is continuing to study tan spot distribution and race structure in Mexico, and investigating means to increase its greenhouse screening throughput, in order to enhance its capacity to phenotype mapping populations, and accelerate the selection of resistant materials. Observations of breeding nurseries during field visits in several countries (e.g. Tajikistan) have highlighted the need to broaden the genetic resistance base to tan spot as many entries appeared susceptible. CIMMYT's emphasis on tan spot is also in line with the increased attention being given to conservation agriculture practices.

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