Breeding Adult Plant Resistance to Stripe Rust in Spring Bread Wheat Germplasm Adapted to Sichuan Province of China

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Abstract: Sichuan is an important wheat producing province of China where severe stripe rust epidemics occur annually. Developing high-yielding wheat varieties with good and stable stripe rust resistance is a foremost breeding objective of all breeding programs. Because minor gene based adult-plant resistance (APR) is considered durable, a shuttle breeding program between Sichuan Academy of Agricultural Sciences (SAAS) and CIMMYT was initiated in 2000 to transfer APR identified in CIMMYT wheats to wheat germplasm adapted in Sichuan. During 2007–2009, a total of 669 advanced generation lines obtained from this shuttle breeding effort were provided to the Plant Protection Research Institute, SAAS for official multi-environment stripe rust tests, and 231 elite lines were characterized for yield performance by the agronomists at the Crop Research Institute, SAAS. Between 11–39% lines were highly resistant depending on the year of testing and 17 (7.3%) lines had 5% or higher yields than the check mean. The adapted resistant lines are being used by various breeding programs to enhance resistance diversity, and three lines are being tested in National or Provincial Yield Trials for possible releases.

Keywords: durable resistance; *Puccinia striiformis*; stripe rust; *Triticum aestivum*

Yellow, or stripe rust, caused by the fungus *Puccinia striiformis tritici* is considered to be the most important disease of wheat (*Triticum aestivum*) in China. Sichuan is an important wheat producing province where the wheat crop is annually affected by severe stripe rust epidemics. Several resistant varieties have been released over the years. However the resistance of many varieties was short-lived due to evolution of new races (Wan *et al.* 2007). Race CYR32, identified in the late 1990s, has caused severe epidemics since then in Sichuan and several other provinces, and the use of fungicides has increased in the last decade. Several studies conducted in recent years have shown that varieties that have shown resistance durability carry adult plant resistance (APR) based on combinations of multiple minor genes. Slow rusting genes *Yr18*, *Yr29* and *Yr46* are often involved in a durable adult plant resistance complex (Singh 2007). The objective of this study was to transfer the high level of resistance bred into CIMMYT wheats to wheat germplasm adapted in Sichuan province using a Mexico-Sichuan shuttle-breeding scheme aimed towards the release of wheat varieties with adult plant resistance.

MATERIAL AND METHODS

To implement a shuttle breeding scheme between Mexico and China, 16 high yielding but stripe rust

susceptible (or moderately susceptible) Sichuan wheat varieties and high yielding lines were crossed in Mexico during 2000 in various combinations with 14 CIMMYT wheats that carry high levels of APR. The resulting 143 F_1s were then backcrossed with Sichuan parents and approximately 400 seeds per combination obtained. The BC_1 and BC_1F_2 populations of about 1200 plants were grown and selected in Mexico. About 500 BC_1F_3 bulked seeds from selected plants in each population were grown in Chengdu, Sichuan province, from 2003 onwards for continuing single plant selections under stripe rust pressure created with local predominant races CYR32 and CYR33. During 2007–2009, a total of 669 advanced lines were evaluated by the Plant Protection Research Institute (PPRI), Sichuan Academy of Agricultural Sciences (SAAS) under artificially inoculated, multi-environment stripe rust official trials in Sichuan. Field plots were established on about 10 plants each 1-m row seeded 10 cm apart, with 0.25 m between rows. The spreader cv. Chuanyu 12, sown a row vertically at one end of each plot between columns, was artificially inoculated 2–3 times with predominant races CYR32 and CYR33 at seedling stage in January each year. Stripe rust severity was used to group lines into the following four categories: R or resistant (0–15%), MR or moderately resistant (20–35%), MS or moderately susceptible (40–55%) and S or susceptible (60–100%).

A set of Avocet near-isogenic lines (NILs) and tester varieties were also planted to determine the effectiveness of various resistance genes to the stripe rust races used in the field trials. Yield performance of 231 lines was determined in large plot, two-replicate trials by the agronomists at the Crop Research Institute (CRI), SAAS.

RESULTS AND DISCUSSION

Response of Avocet NILs and other testers to stripe rust. Race analyses conducted in Sichuan and China have shown that races CYR29, CYR30, CYR31 and CYR32 have dominated from the mid 1990s onwards, and CYR32 was has been the most important race in the last decade (Wan *et al.* 2007). In 2008, a new race, CYR33, with additional virulence, was identified. The performance of Avocet NILs and other testers during 2007, 2008 and 2009 is summarized in Table 1. Resistance genes that were not effective in all three years were *Yr1*, *Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr9*, *Yr17*, *Yr31*, *YrA* and *YrSp* (Table 1). Resistance genes such as *Yr18*, *Yr24*, *Yr27*, *Yr28*, *Yr29* and *YrCV* either were ineffective in some years, or did not confer adequate resistance, and were grouped in the MS category. *Yr5*, *Yr10* and *Yr15* were highly effective in all years.

Table 1. Performance of Avocet NILs and other tester varieties in Sichuan for three years

Line	Stripe rust response		
	2007	2008	2009
Avocet	S	S	S
Avocet + *Yr1*	S	S	S
Kalyansona (*Yr2*, *Yr29*)	MS	MS	S
Avocet + *Yr5*	R	R	R
Avocet + *Yr6*	S	S	S
Avocet + *Yr7*	S	S	S
Avocet + *Yr8*	S	MS	MS
Avocet + *Yr9*	S	S	S
Avocet + *Yr10*	R	R	R
Avocet + *Yr15*	R	R	R
Avocet + *Yr17*, *Yr18*	MS	MS	MS
Avocet + *Yr18*	MS	MR	MS
Avocet + *Yr24*	MS	R	MS
Avocet + *Yr26*	MR	R	MR
Avocet + *Yr27*	R	MS	S
Avocet + *Yr28*	S	MR	S
Avocet + *Yr29*	MS	MS	MS
Avocet + *Yr31*	S	S	S
Avocet + *YrA*	S	S	S
Avocet + *YrCV*	S	MR	S
Avocet + *YrSp*	S	MS	S
Opata 85 (*Yr27*, *Yr18*, *Yr30*, +)	R	R	MR
Pavon 76 (*Yr6*, *Yr7*, *Yr29*, *Yr30*, +)	MS	MS	MS
PBW 343 (*Yr9*, *Yr27*, *Yr29*, +)	R	MR	MS
Seri 82 (*Yr2*, *Yr9*, *Yr29*, *Yr30*, +)	R	R	MR
Super Kauz (*Yr9*, *Yr27*, *Yr18*, *Yr30*, +)	R	R	MR
Tatara (*Yr3* + *Yr29*, +)	MR	R	MR

R – resistant; MR – moderately resistant; MS – moderately susceptible; S – susceptible

Table 2. Stripe rust resistance of 89 advanced lines in 2007 and 2008 Disease Identification Nursery in Sichuan Province

Year tested	Response to stripe rust and frequency of advanced lines							
	R		MR		MS		S	
	No.	%	No.	%	No.	%	No.	%
2007	34	38.2	27	30.3	22	24.7	6	6.7
2008	36	40.5	45	50.6	6	6.7	2	2.3

R – resistant; MR – moderately resistant; MS – moderately susceptible; S – susceptible

Stripe rust resistance of advanced breeding lines. Between 11 to 39% of the advanced breeding lines were highly resistant (R), and 26–46% carried moderate resistance (MR) to stripe rust (Table 2). Eighty-nine lines were tested for two years, 2007 and 2008, to determine the stability of their performance. Lines in the R category in 2007 maintained their resistance in 2008. A majority of lines with a MR response were also classified in the same category. In 2008, the frequency of lines with a MR response was much higher and 2 additional lines were grouped in the R category.

Grain yield performance of advanced breeding lines. Seventeen (7.3%) of the 231 lines tested during 2007 and 2009 had a 5% or higher yields than the checks. Five and seven of these 17 lines belonged to R and MR categories, respectively, to stripe rust. A new variety proposed for release in Sichuan Province must have at least a 5% higher yield than the checks mean for 3 years in Provincial Yield Trials. In addition, they must also be classified as R or MR for stripe rust resistance by the PPRI pathologists.

Twelve highly resistant lines with good agronomic traits and adaptation to Sichuan environments were provided to various breeding programs in Sichuan. These lines are being used as resistant parents in our, and other, breeding programs to enhance genetic diversity and durability of resistance to stripe rust. Additional advanced shuttle breeding lines were provided to wheat breeding programs in Beijing and Gansu provinces for utilization in their breeding programs and other studies. One elite line, 08RC2525 (CHUANMAI 32 × 2/CHAPIO), is in National Yield Trials and two lines, 07RC3929 (SW119 × 2/TUKURU) and 07RC3941 (SW119 × 2/TUKURU), in Sichuan Provincial Yield Trials in 2010. The ten best performing entries in the resistant category R from various crosses are listed in Table 3.

Table 3. Ten best yielding entries from different crosses that showed resistant (R) or medium resistant (MR) response to stripe rust

Sichuan designation	Cross	Response to stripe rust	Relative yield (% of the checks)
08RC2525	CHUANMAI 32 × 2/CHAPIO	MR	115.6
07RC3929	SW119 × 2/TUKURU	R	110.5
06RC4117	SW119 × 2/TUKURU	R	107.4
08RC2329	CHUANMAI 32 × 2/CHAPIO	R	106.5
08RC2338	CHUANMAI 32 × 2/CHAPIO	R	104.8
08RC1177	CHUANMAI 32 × 2/CHAPIO	R	104.6
07RC3941	SW119 × 2/TUKURU	R	104.4
08RC1202	CHUANMAI 32 × 2/JARU	R	95.7
08RC1796-1	SW00-60165 × 2/TUKURU	R	94.9
08RC2724	CHUANMAI 32 × 2/JARU	R	94.6

R – resistant; MR – moderately resistant

Selecting complex adult plant resistance has given us good experience and confidence that such resistance can be utilized successfully in developing new wheat varieties that may show resistance durability in the coming years. This will help Sichuan farmers to rely more on genetic resistance than depend on chemical control. We aim to conduct studies such as: (a) resistance tracing – determine the response to a new race to determine durability; (b) methodology to transfer minor gene based resistance to varieties with major genes – several new wheat varieties and elite breeding lines in Sichuan carry a major gene and therefore molecular markers are required for this work; (c) determining the role of known slow rusting resistance genes such as *Yr18* and *Yr29* in the high level of resistance of some lines – *Yr18* and *Yr29* alone are not very effective in Sichuan and our initial molecular marker studies indicate that only some highly resistant APR lines carried *Yr18*, hence some other uncharacterized minor genes are present; and (d) utilization of APR present in land-races – Sichuan Province is rich in land-races and stripe rust resistance in some has survived for a long time, however the genetic basis of resistance is not known.

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