Crop Protection 115 (2019) 122–129

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Identification of known leaf rust resistance genes in common wheat cultivars from Sichuan province in China

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ARTICLE INFO

Keywords:
Wheat leaf rust
Gene postulation
Slow-rusting resistance
Molecular marker

ABSTRACT

Leaf rust, caused by *Puccinia triticina* (*Pt*), is one of the most important wheat diseases of common wheat (*Triticum aestivum* L.). Using resistant cultivars is the most economical and efficient way to control the disease. A total of 86 wheat cultivars from Sichuan province in China were inoculated with 14 *Pt* races for postulating seedling leaf rust resistance (*Lr*) gene(s) in the greenhouse. Meanwhile, these cultivars were also planted in Baoding and Zhoukou trial fields for identifying slow leaf rusting genes during the 2014–2015 and 2015–2016 cropping seasons. Twelve specific markers for ten known *Lr* genes (*Lr1*, *Lr9*, *Lr10*, *Lr19*, *Lr20*, *Lr24*, *Lr26*, *Lr34*, *Lr37* and *Lr46*) were also used for molecular marker detection. Based on the results from the gene postulation and molecular marker detection, nine *Lr* genes (*Lr1*, *Lr2a*, *Lr26*, *Lr3ka*, *Lr30*, *Lr36*, *Lr15*, *Lr37*, and *Lr46*) were identified in 45 cultivars either singly or in combination. Most frequently identified *Lr* genes were *Lr26* in 25 cultivars and *Lr37* in 21 cultivars. Less frequently detected genes were *Lr1* and *Lr46* each in nine cultivars, *Lr3ka* in five cultivars, *Lr30* in three cultivars and *Lr36* in two cultivars. *Lr2a* and *Lr15* were found in Chuannong 16 and Chuanmai 1, respectively. Twenty-nine cultivars were found to have slow rusting resistance during the two growing seasons. The results should be useful for selecting cultivars with combinations of genes for effective resistance to grow and in breeding new cultivars with improved resistance to leaf rust.

1. Introduction

Wheat leaf rust caused by *Puccinia tirticina* (*Pt*) is one of the most important wheat diseases that pose a huge threat to wheat production worldwide. It arises in a wide array of climates wherever wheat is grown causing substantial yield and economic losses. It causes more than 40% production losses when the disease is severe on susceptible cultivars (Khan et al., 2013). In China, more than 15 million hectares of wheat is affected annually. Regular wheat leaf rust epidemics occur in the southwest and northwest, the middle and lower Yangtze River Valley and the southern Huang-Huai-Hai region of China (Huerta-Espino et al., 2011). Significant yield losses were documented in Gansu, Sichuan, Shanxi, Henan, and Anhui provinces of China in 2012 (Li et al., 2014; Zhou et al., 2013). Although the disease can be controlled by using fungicides, the fungus may become resistance to fungicides (Luo, 2009). Moreover, chemical residues in wheat may harm the consumers. Therefore, using resistant wheat cultivars is the most effective, economic, and environmentally safe way to control the disease.

So far, 78 *Lr* genes have been catalogued in wheat (McIntosh et al., 2017). Most of these are major or seedling resistance genes and can be overcome by virulence variations (And and Linde, 2003). However, four *Lr* genes, namely *Lr34*, *Lr46*, *Lr67* and *Lr68* confer slow rusting resistance despite a compatible host reaction (Caldwell, 1968; Herrera-Foessel et al., 2011; Hiebert et al., 2010; Singh et al., 2011). Slow rusting genes or minor genes provide more durable resistance than major genes. Wheat cultivars with slow rusting resistance genes displayed longer latent periods, low infection frequencies, smaller pustule size and less spore production (Caldwell, 1968; Zhang et al., 2017). Identifying *Lr* genes present in wheat cultivars helps to control the disease. Gene postulation and molecular marker detection can be used to identify *Lr* genes carried by wheat cultivars. Gene postulation based on the gene-for-gene hypothesis (Flor, 1956), has been widely used to

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https://doi.org/10.1016/j.cropro.2018.09.012
Received 19 January 2018; Received in revised form 16 September 2018; Accepted 17 September 2018
Available online 03 October 2018
0261-2194/

identify *Lr* genes in wheat cultivars. For example, Gebrewahid et al. (2017) identified 12 *Lr* genes (*Lr1*, *Lr26, Lr3ka, Lr11, Lr10, Lr2b*, *Lr13*, *Lr21, Lr34, Lr37, Lr44* and *Lr46*) in 83 Chinese wheat cultivars using 18 *Pt* races. Pathan and Park (2006) reported 10 *Lr* genes, *Lr1, Lr3a, Lr10, Lr13, Lr17*b, *Lr20, Lr26, Lr37, Lr3ka* and *Lr14a* in 105 European wheat cultivars using five *Pt* races. Eight *Lr* genes (*Lr1, Lr3, Lr10, Lr13, Lr16, Lr17, Lr23* and *Lr26*) were postulated in 22 Iraqi bread wheat cultivars with 13 *Pt* races (Al-Maaroof et al., 2005). Li et al. (2010) identified 14 *Lr* genes, namely *Lr1*, *Lr2a*, *Lr3bg*, *Lr3ka*, *Lr14a*, *Lr16*, *Lr17a*, *Lr18*, *Lr20*, *Lr23*, *Lr24*, *Lr26*, *Lr34* and *LrZH84* in 102 Chinese winter wheat cultivars using 24 *Pt* races.

In China, the information of *Lr* genes present in the released wheat cultivars is limited, which has made it difficult to utilize resistant cultivars for managing leaf rust. Sichuan province is a hot spot for wheat rusts including leaf rust. Therefore, characterizing *Lr* genes in the currently grown Sichuan wheat cultivars is extremely useful for breeding new resistant cultivars and for controlling leaf rust using gene deployment schemes. Therefore, the objective of this research was to identify *Lr* genes in 86 common wheat cultivars from Sichuan province.

2. Materials and methods

2.1. Plant materials

A total of 86 wheat cultivars (Table 1) from Sichuan province were used to test their seedling responses with 14 *Pt* races. Thirty-six differential lines, most of which are near isogenic lines (NILs) in the background of Thatcher with known *Lr* genes, *viz. Lr1, Lr2a, Lr2c, Lr3, Lr9, Lr16, Lr24, Lr26, Lr3ka, Lr11, Lr17, Lr30, LrB, Lr10, Lr14a, Lr18, Lr2b, Lr3bg, Lr13, Lr14*b, *Lr15, Lr19, Lr20, Lr21, Lr23, Lr28, Lr29, Lr33, Lr36, Lr39, Lr42, Lr44, Lr45, Lr47, Lr51* and *Lr53*, provided by USDA-ARS Cereal Disease Laboratory, University of Minnesota, St Paul, USA were included as references. All 88 wheat cultivars, including susceptible check Zhengzhou 5389 and slow rusting resistance check Saar (Lillemo et al., 2008; Zhang et al., 2009), were evaluated in the field tests.

2.2. *Pt* races

Through single spore separating and pure culturing, 14 *Pt* races were used to inoculate the 86 wheat cultivars from Sichuan and 36 differentials with known *Lr* genes. The *Pt* races were named using the *Pt* code system (Long and Kolmer, 1989), with adding the forth letter for the reactions to the fourth set of differentials (https://www.ars.usda.gov/ARSUserFiles/50620500/Cerealrusts/pt_nomen.pdf).

Table 1
The Pedigree of 86 wheat cultivars tested for leaf rust response from Sichuan provinces in China.

Line No.	Genotype	Pedigree	Line No.	Genotype	Pedigree
1	Chengdianmai 1	MY92-8/91S-5-4	44	Chuannong 24	Baili 3/Yunfan 52894-2
2	Chuan 77-1293	NA	45	Chuannong 27	Chuannong 19/R3301
3	Chuanfu 5	Mianyang 88–334/88-11525	46	Chuannong 7	Mianyang 11/84-2014
4	Chuanmai 1	NA	47	Chuanyu 12	80-9418/83-4516
5	Chuanmai 8	NA	48	Chuanyu 14	79-2812/1900
6	Chuanmai 21	76-3/79 Zhong2882	49	Chuanyu 16	30020/8619-10/Jinmai 30
7	Chuanmai 22	76-3/1900	50	Chuanyu 17	Mianyang 26/G295-4
8	Chuanmai 24	78 Zhong 5594/Chuan 230//Mianyang 19	51	Chuanyu 19	Chuanyu 5/Mo 460/mian yang 26
9	Chuanmai 25	1414/Chuanyu 5	52	Chuanyu 20	SW3243//35050/21530
10	Chuanmai 26	8282-15/12391//Mianyang 11	53	Chuanyu 21	Zhou 88114/G159
11	Chuanmai 27	1900/1190	54	Chuanyu 23	R59//Zheng 9023/H435
12	Chuanmai 28	Wanya2/2874//Caucasus/2874/3/Mianyang 19	55	Chuanyu 9	Chuanyu 5/NPFP
13	Chuanmai 29	Tai2874/7781-1-2-K4//305	56	Jinfeng 626	9481/93N1001
14	Chuanmai 32	1900″S″/Ning8439/1900	57	Kechengmai 1	Guinong 22/Chuanyu12
15	Chuanmai 33	2469/80-28-7	58	Lemai 3	Mianyang 89–224/7705
16	Chuanmai 35	SW1862/2469	59	Liangmai 2	Mianyang 26/Yiyuan 2
17	Chuanmai 36	SW5193/Milan	60	Liangmai 3	N711/M301-1-1
18	Chuanmai 37	88 Fan/88-309	61	Liangmai 4	N1491/N1071
19	Chuanmai 38	Syn-CD769/SW89-3243//Chuan 6415	62	Mianmai 1403	Mianyang 04854/Guinong 21-1
20	Chuanmai 39	Mo 444/90-7	63	Mianmai 185	Mianyang 96-5/Liaochun 10
21	Chuanmai 42	SynCD768/SW3243//Chuan 6415	64	Mianmai 38	07146-12-1/Guinong 19-4
22	Chuanmai 43	SynCD768/SW3243//Chuan 6415	65	Mianmai 40	Mianyang 01821/Guinong 19-4
23	Chuanmai 44	97 Xia 440/Guinong 21	66	Mianmai 43	07146-12-1/Guinong 19-4
24	Chuanmai 45	GH430/SW1862	67	Mianmai 46	07242-3-1-1/Guinong 21
25	Chuanmai 46	Ta193-6280/96-5429	68	Miannong 7	85-42/Bamai 18
26	Chuanmai 47	Syn-CD786/Mianyang 26//Mianyang 26	69	Mianyang 12	Fan 6/406
27	Chuanmai 48	SW8188/SW8688	70	Mianyang 15	Mianyang11
28	Chuanmai 49	Guinong 21/Hesheng 3295	71	Mianyang 20	70-5858/fan 6
29	Chuanmai 50	Guinong 21/3295	72	Mianyang 26	Chuanyu 9/Mianyang 20
30	Chuanmai 51	174/183//99-1572	73	Mianyang 30	Mianyang 01821/83xuan 13028//Mianyang 0552014
31	Chuanmai 52	Chuanmai 36/SW1862	74	Mianyang 32	C49S—89/J17
32	Chuanmai 56	Chuanmai 30/Chuanmai 42	75	Mianyang 33	1294/Mianyang 23
33	Chuanmai 58	Chuanmai 42/03 Jian 3//Chuanmai 42	76	Mianyang 35	05363-8-1mian you 2
34	Chuanmai 107	2469 × 80-28-7	77	Neimai 9	Mianyang 26/92R178
35	Chuannong 11	78-5038/85-D·H·5075	78	Rongmai 3	96-2547/133-3
36	Chuannong 12	91S-23/A302	79	Rongmai 4	96-2547/133-3
37	Chuannong 16	87-429/chuan yu 12	80	Shumai 375	(Mianyang 93-7/92R141)F_2/Mianyang 96-32
38	Chuannong 17	91S-23/A302	81	Shumai 482	(Mianyang 93-7/92R141)F2/Mianyang96-324
39	Chuannong 18	Chuan yu 12/87-429	82	Xikemai 1	Mianyang88-304/Mexico M-212
40	Chuannong 19	Qian 1104A/R935	83	Xikemai 3	Guinong 21/5575
41	Chuannong 20	Qian 1104A/R935	84	Xikemai 4	Mo 460/9601-3
42	Chuannong 21	R841/Qianhui 3	85	Xikemai 6	Mianyang 95–325/92R-135
43	Chuannong 23	R1685/MY26	86	Xingmai 2	Mianyang 26/92R178

NA = Not available.