Leaf Rust Resistance of Spring, Facultative, and Winter Wheat Cultivars from China

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ABSTRACT

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Leaf rust, caused by *Puccinia triticina*, is an important disease of wheat (*Triticum aestivum*) in China. Sixty-one spring and 102 facultative or winter growth habit wheat cultivars from China and a set of testers, carrying named *Lr* genes, were evaluated for resistance at the seedling growth stage with an array of Mexican *Puccinia triticina* races. Variation in seedling infection types of the cultivars was compared with that of the testers, and genes conferring low infection types were postulated. In total, nine named genes, *Lr1* (in 13 cultivars), *Lr3* (12), *Lr3bg* (2), *Lr10* (1), *Lr13* (4), *Lr14a* (1), *Lr16* (49), *Lr23* (9), and *Lr26* (81), were identified. Thirty-one cultivars displayed intermediate reactions to one or more races that could not be attributed to any named gene. Twenty-eight spring cultivars were also evaluated at two field sites in Mexico using two common races. About half of them displayed good to moderate adult resistance that may be partly due to the presence of slow rusting gene *Lr34* in at least seven cultivars. Diversity in adult plant responses of these wheats indicated the presence of additional slow rusting genes. Presence of 1B.1R translocation in 12 wheat cultivars, supposedly derived from intergeneric crosses involving *T. durum*, *Haynaldia villosa*, and *Avena fatua*, indicated that their pedigrees were incorrect.

Wheat (*Triticum aestivum* L.) is grown in China on about 29 million hectares in diverse environments between 25 and 50°N latitudes (5). Using 1988 statistics, spring wheat is the most common wheat type grown (47%), planted mostly in autumn, but also in spring. Facultative wheat contributes about 40% of the wheat area in China, and winter wheat makes up the remaining 13% (4). Among several diseases that constrain production, leaf rust (caused by *Puccinia triticina* Eriks.) is probably the most widely distributed disease, as it affects winter, facultative, and spring wheats. Genetic resistance is the most economical and environmentally benign control measure. Chinese wheats from the Yangtze River Valley are currently being used all over the world as sources of scab (caused by *Fusarium* spp.) resistance (1). Little is known about the leaf rust genes present in these and other Chinese wheats.

The ability to diversify the genetic base for resistance depends on knowledge of resistance genes present in the germ plasm used in a breeding program. Named race-specific genes for resistance to rusts in wheat can be postulated if a wheat line is inoculated with a series of pathogen races that possess diverse combinations of avirulence and virulence genes. This method, which is based on the gene-for-gene relationship, has been described and used by several researchers (2,8,16,17,20,23). Postulations can be further confirmed, if necessary, by genetic analyses.

The objectives of our study were to determine if these Chinese wheats contain previously described genes that confer resistance at the seedling growth stage and to assess the presence of adult resistance in selected spring wheats.

MATERIALS AND METHODS

The 61 spring and 102 facultative or winter wheat cultivars tested are listed in Tables 1 and 2, respectively, along with the province where they originated, pedigree, and area sown during 1995. Seeds of these cultivars were provided by the Chinese Academy of Agricultural Sciences. A set of tester lines, mostly near-isogenic for known single genes in a Thatcher (CI 10003) background, was also included. Seed of the testers, originally provided by

the Cereal Disease Laboratory, St. Paul, Minnesota, and the Plant Breeding Institute of the University of Sydney, Australia, are maintained at CIMMYT.

The nomenclature system for the 14 races of *P. triticina* (Table 3) used in the study follows the system of Long and Kolmer (9), with two additional supplementary sets (14). Vacuum-dried (12) urediniospores of these races are stored at CIMMYT. Fresh inoculum was obtained by multiplying urediniospores on the susceptible cultivar Morocco.

Fully expanded primary leaves of 9-day-old seedlings of cultivars and testers were inoculated by spraying urediniospores suspended in the light-weight mineral oil Soltrol 170 (Phillips 66 Company, Oklahoma) at a concentration of 2 to 3 mg/ml. Different sets of seedlings were used for inoculation with each of the 14 races, and six to eight seedlings planted in a clump were used in each test. In addition to the above tests, two sets of 14-day-old seedlings of cultivars and testers were also inoculated with races LCJ/BN and NCJ/BN. Inoculated plants were placed in a dark dew chamber overnight at 18 to 20°C, dried for an additional 4 h under light, and transferred to a greenhouse maintained at 20 to 25°C. Infection types were recorded after 9 to 12 days using a 0 to 4 scale for leaf rust similar to that described by Stakman et al. (22) for stem rust. Tests were repeated twice during different months. Infection type data from only one test are reported because of the lack of significant variation in infection types in the two tests.

The presence of leaf rust resistance genes (*Lr* genes) in seedlings of the cultivars was postulated by comparing the low and high infection types displayed by the cultivars with the infection type of known *Lr* genes in the testers (20).

Field evaluations of the spring wheat cultivars for resistance to leaf rust were carried out in Mexico at CIMMYT's research stations at Ciudad Obregon (Sonora State) and El Batan (Mexico State) during the 1992-93 and 1993 crop cycles, respectively. Both locations have environments conducive to leaf rust development. Plots consisted of two 1-m rows seeded 20 cm apart, with 70 cm

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between plots and a path of 50 cm. Each plot consisted of approximately 30 to 40 plants. The experiment was planted twice at both locations in isolated areas. In the first experiment, the leaf rust epidemic initiated with race TCB/TD spread in the field from inoculated plants of the sus-

ceptible cultivar Morocco (PI 431591) sown as clumps at one end of each plot in the path. Spreader rows of cultivar Jupateco 73S, inoculated with race TBD/TM, were used in the second experiment. Jupateco 73S is highly susceptible to race TBD/TM but not to

TCB/TD. The two races were common field races in Mexico during the period when the experiments were carried out.

Leaf rust severity and host response data on flag leaves were recorded at growth stages 85 to 87 (soft-dough to hard-dough) on the Zadoks' scale (24). Severity estima-

Table 1. Origin, pedigree, and cultivated area of 61 Chinese spring wheat cultivars tested for resistance to *Puccinia triticina*

No.	Name	Originating province	Pedigree	Cultivated in 1995 (ha) ^a
1	Emai 9	Hubei	Emai 6 Sel.	92,666
2	Huazong 6	Hubei	Mentana/ <i>T. turgidum</i>	... ^b
3	Wannian 2	Jiangxi	Mentana sel.	...
4	Yangmai 3	Jiangsu	Yangmai 1 sel.	...
5	Yangmai 85-128	Jiangsu	Yangmai 3/Chuan 74-4787	Not released
6	Sumai 3	Jiangsu	Funo/Taiwan wheat	...
7	Annong 8903	Anhui	Bainong 3217/Annong 2//St 2422/464	...
8	Mianyang 80-8	Sichuan	Fan 6 sel.	...
9	Chuangyu 5	Sichuan	67-1776/6604	...
10	Chuanmai 22	Sichuan	Mianyang 11/Chuanmai 20	...
11	Guinong 26	Guizhou	<i>Haynaldia villosa</i> / <i>Avena fatua</i> // <i>T. aestivum</i>	...
12	Xuzhou 21	Jiangsu	Punong 3665/UP301	...
13	Ningxia 216	Ningxia	...	...
14	Ningxia 86Y1608	Ningxia	...	...
15	Kefeng 3	Heilongjiang	Ke 71 F4-370-7/Mexipak 66	...
16	Yangmai 4	Jiangsu	Mentana/Triumph/Funo sel.	58,667
17	Yangmai 5	Jiangsu	Mentana/Triumph/Funo/3/St 1472/506	984,000
18	Yangmai 85-46	Jiangsu	Chuan 74-324/Zaohong	Not released
19	Yangmai 85-85	Jiangsu	Fu 728/9-6-1-2	...
20	Yangmai 87-158	Jiangsu	Mentana/Triumph/Funo/3/St 1472/506	405,333
21	Su 8060	Jiangsu	Sufan 411/Wanya 098	...
22	Ning 8675	Jiangsu	80D492/Yangmai 3	...
23	Fan 6	Sichuan	IBO 1828/NP 824/3/Wuyimai//Chengdu Guangtuo/Zhongnong 28/4/Zhongnong 28/ IBO 1828/NP 824/Funo	...
24	Mianyang 11	Sichuan	Airongsui/Ya anza//Fan 6	...
25	Chuanyu 10	Sichuan	Kavkaz/983//980/3130	...
26	Kefeng 5	Heilongjiang	...	...
27	Kehan 10	Heilongjiang	Ke 86-88/Ke 68-585-13//T808/Ke69-513	84,667
28	Shanghai 3	Shanghai	...	...
29	Shanghai 5	Shanghai	...	...
30	Guinong 22	Guizhou	<i>Haynaldia villosa</i> /Sauwene 20	...
31	Wanxie 1128	Anhui	Lumai 1/Xian Aiteza//Guinong 21	...
32	Zhejiang 4	Zhejiang	...	...
33	Yumai 5	Henan	Funo/Zhengzhou 6//Zhengzhou 6609	...
34	Yumai 7	Henan	Predgornaia 2/Yanshi 4	...
35	Yumai 15	Henan	Yanshi 4/Panjiang 3	...
36	Guinong 93-9 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i> // <i>Avena fatua</i>	Not released
37	Chuanyu 11	Sichuan	...	...
38	Guinong 93-3 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i> // <i>Avena fatua</i>	Not released
39	Guinong 93-5 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i> // <i>Avena fatua</i>	Not released
40	Guinong 93-7 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i> // <i>Avena fatua</i>	Not released
41	Chuanmai 18	Sichuan	69-1776/663	...
42	Chuanmai 21	Sichuan	Mianyang 11//983/Kavkaz	...
43	Emai 1	Hubei	Mentana sel.	...
44	Een 1	Hubei	Lovrin 10/Zhengzhou 761//Sumai 3	545,333
45	Fujing 5114	Fujian	...	...
46	Wuhan 3	Wuhan	...	...
47	Zhengzhou 871	Henan	Zhengzhou 761/Wumang 77	...
48	Zhengzhou 872	Henan	Zhengzhou 761/Wumang 77	...
49	10-A	Sichuan	Ya'anza/Oinling Secale//Aurora/3/88-1643	...
50	Mianyang 26	Sichuan	Mianyang 20/Chuanyu 9	...
51	Guinong 20-92004 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i>	Not released
52	Guinong 20-92008 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i>	Not released
53	Guinong 20-92011 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i>	Not released
54	Guinong 20-92013 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i>	Not released
55	Guinong 20-92014 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i>	Not released
56	Guinong 20-92017 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i>	Not released
57	Guinong 20-92019 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i>	Not released
58	Guinong 20-92002 ^c	Guizhou	<i>T. durum</i> / <i>Haynaldia villosa</i>	Not released
59	New Kehan 9	Heilongjiang	Kefeng 2/Ke 74 F3-249-3	464,667
60	Chuanyu 8	Sichuan	Ar'ai/4/Fan 6/3/Fan 6/Yuan 110//170-8	8,000
61	Chuanyu 12	Sichuan	Chuanyu 8/4516	...

^a Source: Ministry of Agriculture, P.R. China.

^b Data on pedigree or cultivated area not available.

^c Pedigree given to authors is incorrect based on the presence of the 1B.1R translocation in the cultivar.

tions were based on the modified Cobb scale (11), and the host response to infection was evaluated following Roelfs et al. (12).

RESULTS AND DISCUSSION

Variation in infection types (ITs) of the known *Lr* gene carrying tester lines, inoculated with 14 *P. triticina* races (Table 3), indicated possibility of the identification of 19 resistance genes (*Lr1*, *2a*, *2b*, *2c*, *3*, *3bg*, *10*, *11*, *13*, *14a*, *15*, *16*, *17*, *19*, *23*, *24*, *26*, *27+31*, and *28*). Resistance genes

Lr3ka, *9*, *21*, *25*, *29*, *30*, *32*, *33*, and *35* displayed low or intermediate ITs with all races. Absence of an *Lr* gene is indicated in a cultivar whenever a high IT is observed with any of the races used in the tests. Postulation of genes *Lr12*, *14b*, *18*, *20*, *22a*, *22b*, and *35* was not possible with these 14 races because high ITs were recorded with each race. Gene *Lr18* can be detected with Mexican races only if tested at temperatures below 18°C (14). Similarly, *Lr34* can give low ITs at low temperatures combined with low light intensi-

ties. Genes *Lr12*, *22a*, *22b*, and *35* are known to be effective only in adult plants (10).

Eleven spring wheat cultivars (numbered 1-11, Table 4) and 18 facultative or winter wheat cultivars (numbered 1-18, Table 5) displayed high ITs with all races; therefore, we could not postulate any known *Lr* gene in these cultivars.

The spring wheat cultivar Xuzhou 21 (numbered 12, Table 4) and four facultative/winter wheat cultivars (numbered 19-22, Table 5) displayed IT 0; with the *Lr1*

Table 2. Origin, pedigree and cultivated area of 102 Chinese facultative or winter wheat cultivars, tested for resistance to *Puccinia triticina*

No.	Name	Originating province	Pedigree	Cultivated in 1995 (ha) ^a
1	Xiaoyan 107	Shaanxi	Mianyang 75-20/Xiaoyan 392	...
2	Shaanmai 897	Shaanxi	Xiaoyanmai (Zhong 4)/3811(2)	94,667
3	Changwu 132	Shaanxi	...	...
4	81168	Shaanxi	...	...
5	Zhongliang 12	Gansu	Chambord/Kangyin 655	...
6	Tianxuan 15	Gansu	Jubileina 2/Abbondanza	...
7	Tianxuan 40	Gansu	Abbondanza/Jaral/691776	...
8	Tianxuan 871	Gansu	...	...
9	Neixiang 5	Henan	Mentana/(Baihuomai+Quality+Baimangmai)	...
10	Pingyuan 50	Henan	Local cultivar	...
11	Youzimai	Henan	Local cultivar	...
12	Zhengzhou 5389	Henan	Local cultivar	...
13	Jinmai 16	Shanxi	Gongnong 12/6014	35,333
14	Jinmai 31	Shanxi	Shaan 6811/Linfen 5610	124,667
15	Ji86-5	Hebei	Lovrin 10/Aiganzao	Not released
16	Yannong 15	Shandong	Youxuan 57/St2422/464	192,667
17	Taigang 113	Shandong	Taishan 2/Yannong 15/Jinghua 1	...
18	Jing 411	Beijing	Fengkang 2/74 Chang 1	197,333
19	Xuzhou 23	Jiangsu	Punong 3665/UP301/Zhengzhou 761	...
20	Wenxian 4	Henan	Wenxian 2540 Sel.	41,333
21	Jimai 31	Hebei	Primepi/Inia 66/Taishan 5	59,333
22	Baiyoubao	Shandong	Youzhimai/Baoda 300 pao	...
23	Bumai 90	Jiangsu	Zhongmai 144 Sel.	...
24	Xian 8	Shaanxi	Aiganzao/St 1472/507	416,000
25	Jing 6226	Beijing	...	...
26	Xiaoyan 6	Shaanxi	St 2422/464/Xiaoyan 96	242,000
27	Shaan 229	Shaanxi	7853/80256	244,000
28	Shaan 611	Shaanxi	(Zhong 3+Zhong 4)/ <i>T. aestivum</i>	...
29	Shaan 861	Shaanxi	1900-5-4-0-9-5/Xiaoyan 6	...
30	N82(2)-10	Shaanxi	9615-11/7014RO	...
31	D10-2	Shaanxi	...	...
32	Tianshui 873	Gansu	...	...
33	Yumai 18	Henan	Zhengzhou 761/Yanshi 4	1,396,667
34	Ji 83-5180-10	Hebei	...	...
35	Jinmai 5	Shanxi	BAU 16/Huabei 187	...
36	Jinmai 21	Shanxi	687-44/Predgornaia 2	...
37	Jinmai 23	Shanxi	68G44F2/Ray	...
38	Jimai 24	Hebei	Anyang 10/Aifeng/Lovrin 10/70114	112,667
39	Jimai 30	Hebei	78-3147/Shi 4414	62,000
40	Ji 8454	Hebei	...	...
41	Ji 87-4314	Hebei	Yun 78-4/78-3662/78-4101	...
42	Ji 874-109	Hebei	Yunzhao 1/4001	Not released
43	Yumai 17	Henan	Yanda 7406/Nanyang 75-6	131,333
44	Yumai 21	Henan	Bainong 791/Yumai 2/Lumai 1/Yanshi 4	90,667
45	Yanshi 86117	Henan	Qianfeng 1/3/Predgornaia 2/Yanshi 4/Xiaoyan 5	...
46	Lumai 1	Shandong	Aifeng 3/Mengxian 201/Neuzucht	406,667
47	Lumai 11	Shandong	...	...
48	Lu 215953	Shandong	Aimengniu/Fu 66	...
49	Lumai 14	Shandong	C149/F4530	1,000,000
50	Yan 7578-128	Shandong	Lovrin 10/3/Virgilio/Rulofen/Youbao	...
51	Jimai 23	Hebei	Anyang 10/Aifeng 1/Lovrin 10/70114	...
52	Fengkang 2	Beijing	Youmangbai 4/Lovrin 10	...
53	Fengkang 8	Beijing	Youmanghong/Lovrin 10	98,667
54	Jingdong 1	Beijing	Jinzhong 849/F49-70/Youmanghong 7	...

(continued on next page)

^a Source: Ministry of Agriculture, P.R. China.

^b Data on pedigree or cultivated area not available.

avirulent races BBB/BN, CBJ/QB, CBJ/QL, CBJ/QQ, and CCJ/SP and high reaction with the remaining nine races. Because this IT pattern matches that of the *Lr1*-carrying tester (Table 3), we postulate the presence of *Lr1* in these cultivars. Indian wheat cultivar UP301, one of the progenitors of Xuzhou 21 and Xuzhou 23, is known to carry gene *Lr1* (17).

Ningxia 216 and Ningxia 86Y1608 are likely to carry gene *Lr3bg* because they displayed low IT; only with the three races avirulent to *Lr3bg*, BBB/BB, LCJ/BN, and NCJ/BN (Table 4). However, it is difficult to be sure because *Lr3* may cause a similar reaction, although the tester line for *Lr3* displayed

intermediate reactions with a few additional races.

Gene *Lr10* may be present in the spring wheat Kefeng 3, seedlings of which displayed low ITs only with the four races that lacked virulence for *Lr10* (Table 4). Similarly, *Lr13* may be present in Bumai 90 and Xian 8 because mesothetic ITs X or XX+ were observed in 9- or 14-day-old seedlings inoculated with *Lr13*-avirulent races BBB/BN, LCJ/BN, and NCJ/BN (Table 5). Gene *Lr14a* could be present in Jing 6226; however, this postulation will require further verification because BBB/BB was the only avirulent race available for testing, and the resistance ITs displayed by the *Lr14a* tester line and Jing 6226 were barely intermediate (Tables 3 and 5).

Gene *Lr16* appears to be present alone in numerous spring (numbered 16-31, Table 4) and facultative or winter wheats (numbered 26-34, Table 5). These wheats displayed ITs ranging from 1 to 3c, similar to the *Lr16* tester, with all races. Similarly, gene *Lr26* was present alone in five spring (numbered 32-36, Table 4) and 27 facultative and winter wheat cultivars (numbered 35-61, Table 5), as evidenced by their low ITs of 0; or ; with races CBJ/QL, CBJ/QQ, TBB/JP, and TBD/TM; ITs ;1⁻ to 13c with BBB/BB and CBJ/QB; and high ITs with the remaining 10 races. Since gene *Lr26* is known to be present in the 1B.1R chromosome translocation (10), the presence of this translocation in these cultivars can be inferred. The origin of this translocation in

Table 2. (continued)

No.	Name	Originating province	Pedigree	Cultivated in 1995 (ha) ^a
55	Dongxie 3	Beijing	Jingshuang 2/Predgornaia 2/Jingshuang 3	...
56	Bau 146	Beijing	...	...
57	Qinmai 6	Shaanxi	...	...
58	6010	Shanxi	Bezostaja 1/72-6051//256-113	...
59	Zhongliang 7553	Gansu	Nongda 181/Lovrin 13	...
60	Huaiyin 9554	Jiangsu	Yumai 13/Yan 1604	...
61	Lifen 7203	Shanxi	Saric/3029/3/74100/Youbao 036/Xiaoyan 759	20,000
62	Tianshui 872	Gansu	...	...
63	Yumai 13	Henan	Bainong 3217/9612-2	44,667
64	Bainong 3217	Henan	Funo/Neixiang 5//Xiannong 39/3/64(4)3/Yanda 24	17,333
65	Bainong 64	Henan	Bainong 8717/3/Yanda 72-629-52/Shi 82-55941 //Bainong 84-4046-1	...
66	Ji 89-6232	Hebei	Bainong 3217/Dongxie 2	...
67	Jinghua 5	Beijing	Aurora/Beijing 15//Youmanghong 7	...
68	Siyang 128	Jiangsu	Siyang 79-23/Siyang 1883	...
69	Kangyin 655	Shanxi	Beijing 8/Suwon 11/Skorospelka 3	...
70	Shaan 213	Shanxi	TJB/7336	13,333
71	Shaan 7852	Shanxi	...	...
72	Shaan 7859	Shanxi	Predgornaia 2/66-46-18/3/Sibley 81// Fengkang 3/62(9)2-1	205,333
73	Xuzhou 174	Jiangsu	Sichuan uni-culm wheat/Predgornaia 2//Punong 3665	...
74	Huaiying 894-2	Jiangsu	Yan C 172/Gao 38 White//Qianfeng 1	...
75	Lumai 15	Shandong	Tal Yangmai 1/757318//104-4	849,333
76	Ji 84-5103	Hebei	Xiaoyan 7014-5-2-14/78-4101	...
77	N82(2)-18	Shanxi	9615-11/7014R0	...
78	Beijing 837	Beijing	Youmanghong 7/Lovrin 10/3/Jingshuang 6/ Predgornaia 2/2/Jingshuang 3	...
79	Beijing 841	Beijing	Beijing 18/Fengkang 4/Nongda 139	34,000
80	BAU 146	Beijing	Chi5021/Rusalka//7201/Lovrin 13	...
81	CA 8646	Beijing	Fengkang 4//Shi 5-061/Youmangbai-Lovrin 10	...
82	Yumai 16	Henan	Zhengzhou 761//Baimian 3/Kavkaz	56,000
83	Lumai 14	Shandong	74(113)/3/Yan 70172/Yan 71152//Yan 71148	855,333
84	Jin 2148	Fujian	Jinjiangchizhi/Huadong 5//Orofen/3/Rieti 11	18,666
85	Wan 8550	Anhui	<i>T. monococtum</i> //Aurora/Ray/3/NPFP 5443/3	...
86	Yan 2419	Shandong	7222-321/74(11)	...
87	Shaan 167-6	Shanxi	TA 174-33/2587	...
88	Zhoumai 10	Henan	Mianyang 81-5/78A	185,333
89	Lantian 1	Gansu	...	...
90	Shaan 7554	Shanxi	...	...
91	Laizhoujian 1-8	Shandong	...	...
92	Laizhou 953	Shandong	Skorospelka 5/Yexun 1//7832110-1	248,000
93	Huaiyin 86220	Jiangsu	Yan C172/Gao 38 White//Qianfeng 1/3/Shaan 7859	...
94	Yumai 2	Henan	65(14)/3/Huixianhong	254,000
95	Zhengzhou 8329	Henan	78(6)9-2/80(6)-6-10	36,000
96	Beijing 10	Beijing	Hubei 672/Xinshi 14//Skorospelka 1B/Huabei 672	...
97	Shaan 897	Shanxi	Xiaoyanmai (Zhong 4)/3811(2)	...
98	Wanmai 19	Anhui	Bao 7422/Yumai 2	...
99	Xiannong 4	Shanxi	Local cultivar	...
100	Mazhamai	Shanxi	Local cultivar	...
101	Zhong 4	Shanxi	Keqiang/Mentana//Ag. <i>intermedium</i>	...
102	Jinmai 33	Shanxi	Naixue/5027//036/3/76-1295/4/ Weidong 7/Xiangyang 4	268,000

Table 3. Seedling infection type responses of testers with known *Lr* genes when inoculated with 14 races of *Puccinia triticina*

Tester	<i>Lr</i> gene	<i>P. triticina</i> race and infection type ^a															
		BBB/ BB	CBJ/ QB	CBJ/ QL	CBJ/ QQ	CBJ/ SP	LCJ/ BN ^b	LCJ/ BN ^c	NCJ/ BN ^b	NCJ/ BN ^c	TBB/ JP	TBD/ TM	TCB/ TB	TCB/ TD	MFB/ SP	MCJ/ QM	MCJ/ SP
RL6003	1	0;	0;	0;	0;	0;	H ^d	H	H	H	H	H	H	H	H	H	H
RL6016	2a	;	;	;	0;	0;	;	;	;	;	H	H	H	H	;	;	;
RL6019	2b	;	;	;	;	0;	;	;	1 ⁺	3c	11 ⁺	1 ⁺ 3c	H	H	;	;	0;
RL6047	2c	1 ⁻	1 ⁺	;	;	0;	3c3	H	H	H	H	H	H	H	;	;	;
RL6002	3	1	23c	3c3	3 ⁻	23c	;	;	;	;	H	H	H	H	;	3c3	3 ⁻ 3
RL6007	3ka	12	12	;	12 ⁻	12	12	12	12	;	12	12 ⁻	12 ⁻	12	12 ⁻	;	12
RL6042	3bg	;	H	H	H	H	;	;	;	;	H	H	H	H	H	H	H
RL6010	9	0;	0;	;	;	;	0;	0;	0;	0;	0;	0;	0;	0;	0;	;	0;
RL6004	10	1 ⁻	;	H	H	H	H	H	H	H	H	H	;	;	H	H	H
Hussar	11	1 ⁺ 3	H	H	H	H	H	H	H	H	3c	3c	3c3	3c3	3c3	H	H
RL6011	12	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Manitou	13	X ⁺	H	H	H	H	X ⁺	X	X ⁺	X	H	H	H	H	H	H	H
RL6013	14a	3c	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
RL6006	14b	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
RL6052	15	;	;	;	;	H	;	;	1 ⁻	1 ⁻	1	H	H	H	H	;	H
RL6005	16	3c3	1	1 ⁺	;	1 ⁺ 3c	1 ⁺	1	1 ⁺	1 ⁺ 3c	1 ⁺	1	1 ⁺	1	1 ⁺	1 ⁺	1 ⁺
RL6008	17	;	H	H	H	H	H	H	H	H	;	H	;	;	;	H	H
RL6009	18	22 ⁺	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
RL6040	19	0;	0;	;	H	0;	0;	0;	0;	0;	0;	0;	0;	0;	0;	0;	0;
Thew	20	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
RL6043	21	2 ⁺ 3c	12	12	12	3c	12	12 ⁺	12	22 ⁺	2	12	12	2	12	12	2 ⁺ 3
RL6044	22a	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Thatcher	22b	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
RL6012	23	1	;	;	1	H	H	H	H	H	H	23c	3c	H	H	;	H
RL6064	24	;	;	;	;	;	;	0;	;	;	;	;	;	;	H	;	;
Transec	25	0;	;	;	0;	H	0;	0;	0;	0;	0;	0;	0;	0;	0;	0;	0;
RL6078	26	1	1	;	0;	H	H	H	H	H	;	;	H	H	H	H	H
Gatcher	10,27+31	;	;	;	XX ⁺	H	X	X	X ⁻	X	H	H	X	X ⁻	H	H	H
CS2D-2M	28	0;	0;	0;	0;	0;	H	H	H	H	H	H	H	H	H	0;	;
RL6080	29	1	;	;	;	;	1	;	12 ⁻	12	;	1	;	;	;	;	12
RL6049	30	23c	22 ⁺	12 ⁻	23 ⁻	12 ⁻	23c	3c3	23 ⁻	23c	22 ⁺	23 ⁻	12 ⁻	23 ⁻	23 ⁻	12	12
RL5497	32	22 ⁺	2	12	22 ⁺	12	12	23c	23 ⁻	12	22 ⁺	12	12	12	12	1 ⁺ 2	12
RL6057	33	3 ⁻	23 ⁻	3 ⁻	3 ⁻	23C	22 ⁺	3C3	3 ⁻	22 ⁺	2 ⁺ 3c	23 ⁻	22 ⁺	3 ⁻	2 ⁺ 3 ⁻	3 ⁻	3 ⁻
RL6058	34	H	3-3	3-3	H	H	H	H	H	H	H	H	H	H	H	H	H
RL5711	35	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H

^a Infection types follow 0–4 scale (22): 0 = no uredinia or other macroscopic signs of infection; ; = no uredinia, but hypersensitive necrotic or chlorotic flecks of varying size; 1 = small uredinia surrounded by necrosis; 2 = small to medium uredinia surrounded by green islands; X = random distribution of variable-sized uredinia on single leaf with a pure culture; 3, 4 (=H) = medium to large uredinia without chlorosis or necrosis; + = uredinia somewhat larger than normal for the infection type; – = uredinia somewhat smaller than normal for infection type; c = more chlorosis than normal for infection type. More than one designation = range of infection types.

^b 9-day-old seedlings inoculated.

^c 14-day-old seedlings inoculated.

^d High; infection type 3 or higher.

Table 4. Seedling infection types displayed by 61 Chinese spring wheats when tested with 14 races of *Puccinia triticina* and postulated *Lr* genes

Cultivar ^b	<i>P. triticina</i> race and infection type ^a																Postulated <i>Lr</i> genes
	BBB/ BB	CBJ/ QB	CBJ/ QL	CBJ/ QQ	CCJ/ SP	LCJ/ BN ^c	LCJ/ BN ^d	NCJ/ BN ^c	NCJ/ BN ^d	TBB/ JP	TBD/ TM	TCB/ TB	TCB/ TD	MFB/ SP	MCJ/ QM	MCJ/ SP	
1 to 11	H ^e	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	None
12	0;	0;	0;	0;	0;	0;	H	H	H	H	H	H	H	H	H	H	1
13 to 14	;	H	H	H	H	;	;	;	;	H	H	H	H	H	H	H	3bg
15	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	10
16 to 31	1	;	1 ⁺ 3c	1	1 ⁺	1	1 ⁺	1	1	1 ⁺	1 ⁺	1	1 ⁺	1	1 ⁺	1 ⁺	16
32 to 36	13c	;	0;	0;	H	H	H	H	H	;	;	H	H	H	H	H	26
37	;	;	0;	23c	;	;	;	;	;	;	;	H	H	H	3c	23c	3,26
38 to 40	;	;	0;	22 ⁺	;	;	;	;	;	;	;	H	H	H	3c	23c	3,26
41 to 44	;	;	0;	1	1	11 ⁺	1	1 ⁺	;	;	;	1	;	1	1 ⁺	1 ⁺	16,26
45	;	;	0;	H	H	H	H	H	;	;	;	2 ⁺ 3	H	3 ⁻	3c	H	26,+ ^g
46	1	;	0;	H	H	H	H	H	;	;	;	H	H	2 ⁺ 3c	H	H	26,+
47	1	;	0;	3c3	H	23c	3c3	2 ⁺ 3	;	;	;	23c	H	H	3c3	3c3	26,+
48	1	1	0;	3c3	3c	2 ⁺ 3c	23c	3c3	;	;	;	23c	2 ⁺ 3	1 ⁺ 2	1 ⁺ 3c	2 ⁺ 3c	26,+
49	1	–	0;	2 ⁺ 3c	2 ⁺ c	H	3c3	;	;	;	;	22 ⁺ c	H	1 ⁺	2 ⁺ 3c	H	26,+
50	;	–	0;	0;	H	3c3	2 ⁺	H	;	;	;	12	2 ⁺ 3	2 ⁺	2 ⁺ 3c	23c	1,26,+
51 to 58	;	–	0;	1 ⁺	1	1 ⁺	1 ⁺	1 ⁺	;	;	;	11 ⁺	1	1	;	1 ⁺	16,23,26
59	3-3	;	12 ⁻	3c	2 ⁺ 3	3 ⁻ c	2 ⁺ 3c	1 ⁺	12	2	1	3c3	3c	22 ⁺	22 ⁺	2 ⁺	+
60	H	1	X	;	H	H	H	H	H	H	H	H	H	H	H	H	+
61	H	;	1 ⁺ 3c	1	H	H	H	H	H	H	H	H	H	H	H	H	+

^a Infection types follow 0–4 scale (22): 0 = no uredinia or other macroscopic signs of infection; ; = no uredinia, but hypersensitive necrotic or chlorotic flecks of varying size; 1 = small uredinia surrounded by necrosis; 2 = small to medium uredinia surrounded by green islands; X = random distribution of variable-sized uredinia on single leaf with a pure culture; 3, 4 (=H) = medium to large uredinia without chlorosis or necrosis; + = uredinia somewhat larger than normal for infection type; – = uredinia somewhat smaller than normal for infection type; c = more chlorosis than normal for infection type. More than one designation = range of infection types.

^b Numbers of cultivars refer to those given in Table 1.

^c 9-day-old seedlings inoculated.

^d 14-day-old seedlings inoculated.

^e High; infection type 3 or higher.

^f Data not available.

^g + indicates presence of an unidentified resistance gene.

some winter wheats appears to be European wheat cultivars Lovrin 10, Lovrin 13, Predgorina 2, Rusalka, Kavkaz, etc. (Tables 1 and 2) (10). There is a problem in the pedigree of spring wheat Guinong 93-9, supposedly derived from an intergeneric cross involving a durum wheat, *Haynaldia villosa*, and *Avena fatua* (Table 1). None of the three parents could have contributed the wheat-rye translocation, but it is nevertheless present in Guinong 93-9. Similarly, pedigrees of all other wheats (numbered 38-40 and 51-58, Table 1) are doubtful because each cultivar carries the 1B.1R translocation (Table 4).

Gene *Lr1* was present in combination with *Lr13* in Tianshui 872, with *Lr26* in Yumai 13, and with an unidentified gene in Bainong 3217, Bainong 64, and Ji 89-6232 (Table 5). Postulation of the *Lr1-Lr13* combination was based on the low IT 0; of Tianshui with *Lr1* avirulent races BBB/BN, CBJ/QB, CBJ/QL, CBJ/QQ, and

CCJ/SP; IT X or 3c with *Lr13* avirulent races LCJ/BN and NCJ/BN; and high ITs with the remaining races that carried virulences for *Lr1* and *Lr13*. Postulations of other combinations involved similar criteria. The unknown gene (or genes) involved in combination with *Lr1* conferred ITs in the 2 to 2+3 range, and it appears that virulence was absent for gene(s) present in at least Bainong 64 and Ji 89-6232. Among other gene combinations, the most frequent involved *Lr3* and *Lr26* in four spring (37 to 40, Table 4) and two facultative/winter wheats (Jinhua 5 and Siyang 128, Table 5); *Lr16* and *Lr26* in four spring (41 to 44, Table 4) and seven facultative/winter wheats (70 to 76, Table 5); and *Lr26* and an unidentified resistance gene in five spring (45 to 49, Table 4) and eight facultative/winter wheats (78 to 85, Table 5).

Eight spring wheats (51 to 58, Table 4), all supposedly derived from a *T. durum*/*Haynaldia villosa* cross, carried genes

Lr16, *Lr23*, and *Lr26*. This indicated that the pedigree is incorrect. It is likely that a *Lr23*-carrying durum was crossed with a bread wheat carrying *Lr16* and *Lr26*. Combinations involving three genes were also present in eight winter wheats (Table 5). Low infection types of three spring (59 to 61, Table 4) and nine facultative/winter wheats (94 to 102, Table 5) could not be associated with any known resistance gene. This included winter wheat Zhong 4, which is known to carry seven pairs of chromosomes from *Agropyron intermedium*. Lack of virulence for some of these genes indicates their likely usefulness in reducing losses caused by leaf rust.

Evaluation of 28 spring wheats at two field locations indicated that about half of them carried good to moderate levels of resistance under heavy rust pressure (Table 6). In general, cultivars displayed similar ratings at both locations. Although six cultivars, Chuanyu 5, Xuzhou 21, Zhejiang

Table 5. Seedling infection types displayed by 102 Chinese facultative and winter wheats when inoculated with 14 races of *Puccinia triticina* and postulated *Lr* genes

Cultivar ^b	<i>P. triticina</i> race and infection type ^a																Postulated <i>Lr</i> genes
	BBB/ BB	CBJ/ QB	CBJ/ QL	CBJ/ QQ	CCJ/ SP	LCJ/ BN ^c	LCJ/ BN ^d	NCJ/ BN ^c	NCJ/ BN ^d	TBB/ JP	TBD/ TM	TCB/ TB	TCB/ TD	MFB/ SP	MCJ/ QM	MCJ/ SP	
1 to 18	H ^e	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	None
19 to 22	0;	— ^f	—	0;	0;	H	H	H	H	H	H	H	H	H	H	H	1
23 to 24	3c	H	H	H	H	X	X	X	X	H	H	H	H	H	H	H	13
25	3c	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	14a
26 to 34	3c3	1 ⁺	1	1	1 ⁺ 3c	1	1 ⁺	1 ⁺	1 ⁺	1 ⁺	1 ⁺	1 ⁺	1 ⁺	1 ⁺	1 ⁺	1 ⁺ 3c	16
35 to 61	1	1	;	0;	H	H	H	H	H	;	;	H	H	H	H	H	26
62	0;	0;	0;	0;	0;	3c	X	X	X	H	H	H	H	H	H	H	1,13
63	0;	0;	0;	0;	0;	H	H	H	H	;	;	H	H	H	H	H	1,26
64	0;	0;	0;	0;	0;	H	H	H	2 ⁺ 3c	2 ⁺ 3c	22 ⁺	2 ⁺ 3c	H	H	H	2 ⁺ 3	1, ⁺ g
65 to 66	0;	0;	0;	0;	0;	2 ⁺ 3c	2 ⁺	2 ⁺	2 ⁺ 3	22 ⁺	2	22 ⁺	2 ⁺	2	22 ⁺	2 ⁺ 3	1, ⁺
67 to 68	;	1	;	;	22 ⁺	1 ⁺	1	;	;	;	;	H	H	H	12	3-3	3,26
69	;	—	—	23 ⁻	12	1	1	;	1 ⁺	23 ⁻	H	H	H	12	3 ⁻	3 ⁻	3, ⁺
70 to 76	1	1 ⁺	1	0;	1 ⁺ 3c	1	1	1 ⁺	1 ⁺	;	;	1 ⁺	1 ⁺	1 ⁺	12	3c	16,26
77	;	1 ⁺	1	0;	1 ⁺	1	1 ⁺	1 ⁺	1 ⁺	1 ⁺	1 ⁺	1 ⁺	1 ⁺	1 ⁺	12	1 ⁺	16, ⁺
78 to 79	1	1	;	0;	H	H	H	H	H	;	;	H	H	2 ⁺	H	H	26, ⁺
80	1	—	—	0;	2 ⁺ 3	H	H	H	3c3	;	;	H	H	2	3c	3c3	26, ⁺
81	1	—	—	0;	—	H	H	H	H	;	;	H	H	2 ⁺ 3	H	H	26, ⁺
82	1	1	;	0;	3c3	1 ⁺	22 ⁺ c	1 ⁺ 2 ⁺	2 ⁺ 3	;	;	2 ⁺ 3c	2 ⁺ 3	H	1 ⁺ 2	H	26, ⁺
83	1	—	—	0;	H	22 ⁺	2 ⁺	H	3c	;	0;	H	H	2 ⁺ 3	2 ⁺ 3	H	26, ⁺
84	1	—	—	0;	2 ⁺ 3c	H	H	H	H	;	;	H	H	1 ⁺	H	H	26, ⁺
85	1	—	—	0;	2 ⁺ 3c	2 ⁺	2 ⁺	H	H	;	;	H	H	2 ⁺ 3	3c	H	26, ⁺
86	0;	—	—	0;	0;	X	X ⁺	X	X ⁺	;	;	H	H	H	H	H	1,13,26
87	—	—	—	0;	0;	0;	X	1	H	;	;	2	X ⁻	1 ⁺ 3c	12	;	1,26, ⁺
88 to 90	;	;	1 ⁻	0;	1 ⁻	;	;	0;	;	;	0;	12	12	1 ⁺	12	1 ⁻	3,16,26
91 to 92	0;	—	—	0;	1 ⁻	1 ⁻	12 ⁻	;	;	;	;	3c	23c	3c	23c	12	3,26, ⁺
93	—	—	—	0;	1	1 ⁺	1 ⁻	;	;	;	;	1 ⁺	1 ⁺	1	1	12	16,23,26
94	3c	H	H	3c3	H	3c	H	H	H	2 ⁺ 3c	22 ⁺	H	H	H	22 ⁺	3c3	+
95	H	—	—	H	H	H	H	H	H	H	H	2 ⁺ 3	H	22 ⁺	H	2 ⁺ 3	+
96	H	—	—	H	3c3	H	H	H	H	H	22 ⁺	H	H	22 ⁺	3c3	3c3	+
97	2 ⁺ 3	—	—	H	H	H	H	H	2 ⁺ 3	22 ⁺	2	H	H	H	H	H	+
98 to 100	23 ⁻	—	—	23 ⁻	3-3	23 ⁻	3 ⁻	3-3	3c3	12	12	2 ⁺ 3	3c3	12	3-3	3-3	+
101	0;	—	—	1 ⁻	0;	0	0;	;	0;	0;	0	;	;	0;	0;	;	+
102	2 ⁺ 3c	—	—	2 ⁺ 3	3c3	2 ⁺	22 ⁺	H	H	2 ⁺ 3	2	2 ⁺	H	2 ⁺	2 ⁺ 3	H	+

^a Infection types follow a 0 to 4 scale (22), where 0 = no uredinia or other macroscopic signs of infection; ; = no uredinia, but hypersensitive necrotic or chlorotic flecks of varying size present; 1 = small uredinia surrounded by necrosis; 2 = small to medium uredinia surrounded by green islands; X = random distribution of variable-sized uredinia on single leaf with a pure culture; 3 and 4 (=H) = medium to large uredinia without chlorosis or necrosis; + = uredinia somewhat larger than normal for the infection type; - = uredinia somewhat smaller than normal for the infection type; c = more chlorosis than normal for the infection type. More than one designation represents a range of infection types.

^b Numbers of cultivars refer to those given in Table 2.

^c 9-day-old seedlings inoculated.

^d 14-day-old seedlings inoculated.

^e High; infection type 3 or higher.

^f Data not available.

^g + indicates presence of an unidentified resistance gene.

4, Fujing 5114, Wuhan 3, and Zhengzhou 871, displayed high seedling reactions with at least one of the two races, their resistance in adult plant tests indicated the presence of effective adult plant resistance genes. It is also interesting to note that cultivars that displayed low seedling infection type due to the presence of *Lr16* were not always resistant in the field tests. The most susceptible and the most resistant cultivars with *Lr16*, Mianyang 11 and Yangmai 87-158, displayed 100S and 10MSS responses, respectively; responses of other cultivars fell somewhere in between. This is in agreement with earlier results (19) that showed that although *Lr16* is effective at the seedling stage, it does not confer much resistance in adult plants. Therefore, additional genes for adult plant resistance must be present in some of these wheats with *Lr16*.

Gene *Lr34*, known to confer slow rusting resistance to leaf rust (18), may be

present in at least seven cultivars, Xuzhou 21, Shanghai 3, Shanghai 5, Chuanmai 18, Fujing 5114, Wuhan 3, and New Kehan 9. These cultivars displayed clear symptoms of leaf tip necrosis, known to be linked to *Lr34* (15). The presence of *Lr34* in Chinese wheats is not surprising, as Dyck (6) has shown its presence in Chinese Spring wheat. Other cultivars that do not show leaf tip necrosis clearly may still carry *Lr34*, as the symptoms of necrosis can be modified in some genetic backgrounds. The slow rusting resistance (based on *Lr34*) of these cultivars should be of a durable nature (7,21).

In conclusion, it can be stated that only limited genetic diversity was observed for the named genes involved in seedling resistance of Chinese wheat cultivars. In total, nine named genes, *Lr1* (in 13 cultivars), *Lr3* (12), *Lr3bg* (2), *Lr10* (1), *Lr13* (4), *Lr14a* (1), *Lr16* (49), *Lr23* (9), and *Lr26* (81), were identified. These known

genes would be ineffective in many areas of the world. Thirty-two cultivars carried resistance that could not be attributed to any named gene. In most cases, the level of this resistance was slight, and resistance was expressed with only a few races. Zhong 4, a 56-chromosome line carrying all chromosomes of *Agropyron intermedium*, displayed very low seedling reactions with all races (entry 101, Table 5). However, this resistance will have to be transferred to a wheat chromosome before it can be of any use. The adult plant resistance conferred by either *Lr34* or unknown slow rusting genes in the studied spring wheats should interest breeders, as such resistance is often durable (3,13,21). Pedigrees of 12 cultivars, supposedly derived from intergeneric crosses, are incorrect. Small seed samples of the Chinese cultivars can be obtained from Z. H. He.

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Table 6. Seedling reactions, postulated *Lr* genes, and adult plant leaf rust ratings at two field locations of 28 Chinese spring wheat cultivars when tested with two *Puccinia triticina* races

No. ^b	Cultivar	<i>P. triticina</i> race and seedling IT ^a		Postulated <i>Lr</i> genes ^c	Field leaf rust rating ^d	
		TBD/TM	TCB/TD		Cd. Obregon	El Batan
9	Chuanyu 5	H	H	None	40S	40MSS
10	Chuanmai 22	H	H	None	100S(N)	100S(N)
12	Xuzhou 21	H	H	None	30MSS	40MSS
14	Ningxia 86Y1608	H	H	<i>Lr3bg</i>	100S(N)	100S(N)
15	Kefeng 3	H	;1=	<i>Lr10</i>	100S	100S(N)
16	Yangmai 4	1+	1+	<i>Lr16</i>	40MSS	30MSS
17	Yangmai 5	1+	1+	<i>Lr16</i>	20MSS	10MSS
19	Yangmai 85-85	1	1+	<i>Lr16</i>	70MSS	60MSS
20	Yangmai 87-158	12	1+	<i>Lr16</i>	10MSS	10MSS
24	Mianyang 11	1+	1+	<i>Lr16</i>	100S(N)	100S
25	Chuanyu 10	1	1+	<i>Lr16</i>	80S	70MSS
26	Kefeng 5	1+	1+	<i>Lr16</i>	40MSS	30MSS
27	Kehan 10	1	;1	<i>Lr16</i>	80MSS	80MSS
28	Shanghai 3	3c3	1+3c	<i>Lr16</i>	40MSS	30MSS
29	Shanghai 5	1+	1+	<i>Lr16</i>	20MSS	20MSS
32	Zhejiang 4	;	H	<i>Lr26</i>	60MSS	60MSS
33	Yumai 5	;	H	<i>Lr26</i>	100S(N)	100S(N)
34	Yumai 7	;	H	<i>Lr26</i>	100S(N)	100S(N)
35	Yumai 15	;	H	<i>Lr26</i>	100S(N)	100S
37	Chuanyu 11	;	H	<i>Lr3,26</i>	100S	100S(N)
41	Chuanmai 18	;	;1	<i>Lr16,26</i>	30MSS	30MSS
45	Fujing 5114	;	H	<i>Lr26,+</i>	5MS	15MS
46	Wuhan 3	;	H	<i>Lr26,+</i>	15MS	15MSS
47	Zhengzhou 871	;	H	<i>Lr26,+</i>	20MSS	30MSS
48	Zhengzhou 872	;	2+3	<i>Lr26,+</i>	100S(N)	100S(N)
59	New Kehan 9	1	3c	+	5MS	1MS
60	Chuanyu 8	H	H	+	60S	80S
61	Chuanyu 12	H	H	+	100S(N)	100S(N)

^a Taken from Table 4 and based on the 0 to 4 scale (22), where 0 = no uredinia or other macroscopic signs of infection; ; = no uredinia, but hypersensitive necrotic or chlorotic flecks of varying size present; 1 = small uredinia surrounded by necrosis; 2 = small to medium uredinia surrounded by green islands; X = random distribution of variable-sized uredinia on single leaf with a pure culture; 3 and 4 (=H) = medium to large uredinia without chlorosis or necrosis; + = uredinia somewhat larger than normal for the infection type; - = uredinia somewhat smaller than normal for the infection type; c = more chlorosis than normal for the infection type. More than one designation represents a range of infection types.

^b Numbers of cultivars refer to those given in Table 1.

^c Taken from Table 4.

^d Although independent tests were carried out with races TBD/TM and TCB/TD, we reported only the higher ratings in the two tests at each location. Leaf rust ratings involve two components: percent disease severity based on the modified Cobb scale (11), and reaction type as described in Roelfs et al. (12). The reaction types are: MS = moderately susceptible, medium sized uredinia without chlorosis or necrosis; S = susceptible, large uredinia without chlorosis or necrosis; MSS = moderately susceptible to susceptible; (N) = necrotic leaves following high leaf rust infection.

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