European Journal of Plant Pathology **101**: 405–409, 1995.
© 1995 *Kluwer Academic Publishers. Printed in the Netherlands.*

Evidence of durable resistance in nine Chinese land races and one Italian cultivar of *Triticum aestivum* to *Puccinia striiformis*

Zhong-Jun Zhang
Department of Plant Protection, Beijing Agricultural University, Beijing 100094, P.R. China

Accepted 28 December 1994

Key words: old Chinese cultivar, quantitative resistance, slow rusting, stripe rust, wheat

Abstract

In this study carried out from 1987 to 1994, in a very conducive environment to stripe rust, nine Chinese land races and one Italian cultivar of wheat showed fair levels of quantitative resistance to rust disease. The nine old Chinese cultivars had a commercial planting history in this conducive environment ranging from 20 to 100 years, in a cultivation area of 20 to 467 thousand hectares p.a. with no apparent erosion of resistance. The Italian cultivar has been used commercially for 15 years in China without showing a decrease in the level of quantitative resistance. All these data warrant the conclusion that the ten cultivars have a form of durable resistance to stripe rust.

Introduction

Stripe rust (caused by *Puccinia striiformis* West.) is the most destructive disease of wheat (*Triticum aestivum* L.) in the region between the Great Wall and the Yangtze River where the production of wheat is the staple food for more than 25% of the population in China [Cai Shenglin and He Renrei, 1992]. The use of resistance is the principal way to control the disease. The resistance gene Yr9, after being used in an area of more than six million hectares per year in the early 1980s, was overcome by new races of stripe rust fungus in 1985 [Wu Liren, 1993].This was the fifth boom and bust cycle since the late 1950s when the cultivation of wheat cultivars with race-specific resistance began to be extended in China [Li Zhenqi, 1980; Wu Liren, 1993].

The breakdown of race-specific Yr genes has focused attention on durable resistance in China as in other regions of the world. During the period 1979–1981, a group of plant pathologists [National Cooperative Research Group on Horizontal Resistance to Yellow Rust of Wheat, 1983] attempted to screen for horizontal resistance in wheat according to Van der Plank's idea [Van der Plank, 1968]. Partial resistance in wheat to stripe rust has been studied following the method used in the pathosystem of barley and barley leaf rust [Parlevliet, 1979; Parlevliet *et al.*, 1980] and was reported to be very rare [Broers, 1993; Danial, 1993]. The high temperature, adult plant resistance in wheat to stripe rust was shown to be of a durable form [Line, 1993]. There is evidence that some slow-rusting cultivars remain resistant for many years when widely used, while in others race-specificity has been observed [Johnson, 1992]. The diagnostic test for distinguishing between the two classes of slow-rusting cultivars is durability itself and durable resistance has been defined as 'the resistance that remains effective in a cultivar that is widely grown for a long period of time in an environment favourable to the disease' [Johnson, 1983; Johnson, 1993].

It is reasonable to believe that durable resistance in wheat was important in controlling stripe rust before the late 1950s in China, though not in an intentional way. In fact, this resistance is still being used to some extent in the remote mountain areas in Northwestern China. The objective of this

study was to identify the resistance in ten wheat cultivars as durable resistance.

Materials and methods

In 1985 and 1986, hundreds of wheat cultivars were examined for quantitative resistance in commercial fields by consulting veteran farmers, and by reference to disease data recorded by plant pathologists and breeders in experimental plots from the 1950s to the early 1980s [Zhang Jia Chuan Extension Station of Agricultural Techniques, 1957, see the footnote of Table 1 in the present paper; Gangu Experimental Station of Agriculture, 1958, see the footnote of Table 1 in the present paper; Lu Duanyi *et al.*, 1980; Jin Shanbao, 1983; Jin Shanbao, 1986; Lu Duanyi *et al.*, 1986]; thirty of these cultivars were chosen for further study during the period 1987–1994. After 1990, twenty of the 30 cultivars were removed from the tests as their levels of quantitative resistance were too low to be of practical interest. Table 1 gives the commercial use data of the 10 cultivars retained. Nine of the 10 cultivars are Chinese land races and the other, Libellula, was introduced from Italy. Cultivar 47–3, with the neutralized race-specific resistance conferred by Yr9 gene, was used as a susceptible reference.

The field trial consisted of a randomized complete block design with three replicates. Each replicate, with 11 to 33 plots depending on the year, was surrounded by a strip of universally susceptible plants 1.2 m wide. Each plot was 2.4 m × 2.4 m in 8 rows 30 cm apart. Between the plots were 4 rows of universally susceptible plants. The sowing rate was 140 kg ha^{-1}. The plants were exposed to natural sources of inoculum.

The infection type (IT) and disease severity (DS) of each plot were assessed on the top three leaves using a 0 to 4 scale similar to that described by Stakman *et al.* [1962] and on the basis of the modified Cobb scale [Peterson *et al.*, 1948] respectively when the DS of the susceptible

Table 1. Period of cultivation, record of cultivation area and level of quantitative resistance (LQR) to stripe rust in commercial plantings of ten wheat cultivars

Cultivar	Period of cultivation	Area of cultivation(× 1000 hectares)	LQR[a]
Bai Qimai	1860s–1960s	100 p.a. in early 1950s	Moderate[b,c]
Hong Huomai	1860s–1960s	20 p.a. in early 1950s	High[c,d]
Hong Qimai	1877–1960s	47 p.a. in early 1950s	Moderate[b,c]
Qing Shoumai	1880s–1960s	40 p.a. in late 1950s	Moderate[b,c]
Yu Zhonghong	1900s–1960s	40 p.a. in late 1950s	High[b]
Ma Zhamai	1934–1950s	467 p.a. in late 1950s	Moderate[e]
Qinan Hong Mazha	1950s–1970s	20 p.a. in early 1950s	High[b]
He Shangtou	1950s–1994	30 in 1979	Moderate[b]
Xian Nong4	1975–1994	27 in 1981, 42 in 1994	Moderate[b,f]
Libellula	1980–1994	38 in 1986, 32 in 1994	Moderate[b,f]

[a] The level of quantitative resistance was estimated from 1950 to 1994 in commercial fields and no information about disease resistance in these cultivars was available before 1949.

[b] Hu Yuguo and Wang Yingcai (1989) Records of Wheat Varieties of Gansu Province. Publications of Food Crop Institute of Gansu Academy of Agricultural Sciences, Lanzhou, 165pp (in Chinese, available from Scientech Documentation and Information Centre of Chinese Academy of Agricultural Sciences, Beijing 100081, P.R. China)

[c] Gangu Experimental Station of Agriculture (1958) Survey's Reports on the Local Wheat Varieties in the Upper Reaches of Wei River and Jia Ling River. Publications of Gangu Experimental Station of Agriculture, Gangu, 15 pp (in Chinese, available from Scientech Documentation and Information Centre of Chinese Academy of Agricultural Sciences, Beijing 100081, P. R. China)

[d] Zhang Jia Chuan Extension Station of Agricultural Techniques (1957) Survey's Reports on the Local Wheat Varieties and Cultivation Techniques in Zhang Jia Chuan County. Publications of Gangu Experimental Station of Agriculture, Gangu, 19 pp (in Chinese, available from Scientech Documentation and Information Centre of Chinese Academy of Agricultural Sciences, Beijing 100081, P. R. China)

[e] Jin Shanbao (1983) Genealogies of Wheat Varieties of China. Agricultural Press of China, Beijing, 417 pp (in Chinese)

[f] Gansu Seeds Company (1994) Survey's Reports on the Cultivation and Distribution of Wheat Cultivars (in Chinese, available from Gansu Seeds Company, Lanzhou 730070, P. R. China)

reference cultivar reached about 90%. The DSs of a cultivar over the three plots (replicates) were averaged. In commercial planting fields which were within the area of 5 km^2 surrounding the plot trial, the three cultivars Xian Nong4, Libellula and 47–3 were also assessed for their DS at the same time as in the trial.

The trial was located on the mid slope of the Laojun Hill with an elevation 1660 m in Northwestern China where most of the races of stripe rust in China could be detected [National Cooperation Group for Surveying Race of Wheat Stripe Rust Fungus in China, 1972–1986]. This environment is very conducive to stripe rust.

Results

The years varied widely in conduciveness to stripe rust. The years 1989 and 1990 were rainy and cold and thus extremely favourable rust years; the other six years were unfavourable due to dry and hot weather. The IT and DS are listed in Tables 2 and 3 respectively.

The ITs of ten test cultivars were all lower than those of the susceptible reference cultivar 47–3, with the exception of 'Libellula' in 1989 and 1990. Within each of the cultivars, the IT varied with years and even with replicates or plots within the same year, revealing the instability of IT.

The DSs of ten test cultivars were much lower than those of 47–3, indicating the presence of slow rusting or quantitative resistance. In commercial fields, Xian Nong4 and Libellula showed a DS less than that in the experimental plot. This confirms the results reported by Johnson [1992] that heavy infection to some slow rusting cultivars in plot experiments did not normally arise in commercial plantings of these cultivars.

On the basis of these observations, it can be concluded that the ten cultivars had fair to good levels of slow rusting or quantitative resistance to stripe rust.

Discussion

All ten test wheat cultivars had a history of commercial use in Northwestern China where the environment was very conducive to stripe rust. The five oldest cultivars of Bai Qimai, Hong Huomai, Hong Qimai, Qing Shoumai and Yu Zhonghong, maintained their quantitative resistance over substantial areas for at least 60 years [Hu Yuguo and Wang Yingcai, 1989]. The cultivation area of 'Qinan Hong Mazha' reached 20,000 hectares p.a. in the late 1940s, and decreased in the early 1950s as the modern cultivars were introduced, but again increased because of its high level of quantitative resistance in the late 1950s when race-specific resistance in the modern cultivars was overcome. This increasing and decreasing cycle repeated itself several times, but the quantitative resistance in the cultivar continued to be effective in the 1970s [Hu Yuguo and Wang Yingcai, 1989]. 'He Shangtou', mainly used on a sub-area with a shortage of rainfall since the late 1950s, was not replaced by modern cultivars and lasted to the

Table 2. Infection types of 11 wheat cultivars over eight years

Cultivar	Years								Range
	1987	1988	1989	1990	1991	1992	1993	1994	
Bai Qimai	2–4	3–4	3–4	3–4	2–3	3	2–4	2–3	2–4
Hong Huomai	1–3	3	3	3	3	3	2–3	2–3	1–3
Hong Qimai	3	3	3–4	3–4	3	3	3	3	3–4
Qing Shoumai	3–4	3	3–4	3–4	3	3	2–4	3	2–4
Yu Zhonghong	2–3	2–3	3	3	3	2–3	2	2	2–3
Ma Zhamai	3–4	3	3–4	3–4	3–4	3–4	3–4	3	3–4
Qinan Hong Mazha	3	2–3	3	3	3	3	3	3	2–3
He Shangtou	1	2–3	3	3	1–3	1–3	1–2	2	1–3
Xian Nong4	3	3	3–4	3–4	3	3	3	3	3–4
Libellula	2–3	2–3	4	4	2–3	2–3	2–3	2–3	2–4
47–3	4	4	4	4	4	4	4	4	4

Table 3. Disease severities of 11 wheat cultivars in plot trials and those of three wheat cultivars in commercial fields over eight years

Cultivar	Years								Mean
	1987	1988	1989	1990	1991	1992	1993	1994	
Bai Qimai	12	15	25	30	13	15	12	15	17
Hong Huomai	2	7	12	13	5	5	5	7	7
Hong Qimai	15	15	25	34	12	15	15	15	18
Qing Shoumai	7	12	22	30	15	10	12	10	15
Yu Zhonghong	5	5	13	20	5	5	5	5	8
Ma Zhamai	23	30	38	43	25	28	30	25	30
Qinan Hong Mazha	2	5	5	8	5	5	3	5	5
He Shangtou	5	8	18	25	5	7	7	8	10
Xian Nong4	10	15	42	45	15	17	15	10	21
	5	5	30	38	7	9	5	5	13[a]
Libellula	8	12	35	35	5	8	7	5	14
	2	2	28	25	1	1	3	1	8[a]
47–3	88	86	91	90	90	90	85	84	88
	65	67	90	95	80	–	–	–	79[a]

[a] The disease severity averaged over ten randomly sampled commercial fields of about 700 m^2 each.

present time because of its fair drought tolerance and high level of quantitative resistance, while during its cultivation period of 37 years twenty-nine races of stripe rust fungus occurred intermittently and nearly a hundred cultivars with race-specific resistance were defeated by the pathogen over a wide area [Li Zhenqi, 1980; Wu Liren, 1993]. It is reasonable to believe that the remarkable planting areas of 'Ma Zhamai' (467,000 ha p.a. at its maximum, Table 1) must have induced a severe selection pressure on the population of stripe rust, but no adapted race arose. 'Xian Nong4' and 'Libellula' have been used on a wide area for at least 15 years and no erosion of their resistance seems to have occurred. All the records shown in Table 1 combined with the data in Table 3 which reveals a fair level of quantitative resistance warrant the conclusion that the ten cultivars have a form of durable resistance to stripe rust.

Acknowledgements

This study was supported in part by the International Foundation for Science (in Sweden) and the National Natural Science Foundation of China. The author wishes to thank Mr. Zi-Cheng He for looking after the trial over the past eight years.

References

Broers LHM (1993) Breeding for partial resistance in wheat to stripe rust. In: Jacobs Th and Parlevliet JE (eds) Durability of Disease Resistance (pp. 179–183) Kluwer Academic Publishers, Dordrecht, Boston and London

Cai Shenglin and He Renrei (1992) Annals of Agriculture of China. Agricultural Press of China, Beijing, 624 pp (in Chinese)

Danial DL (1993) Is partial resistance a suitable approach to obtain durable resistance in wheat to stripe rust? In: Jacobs Th and Parlevliet JE (eds) Durability of Disease Resistance (pp. 185–189) Kluwer Academic Publishers, Dordrecht, Boston and London

Hu Yuguo and Wang Yingcai (1989) Records of Wheat Varieties of Gansu Province. Publications of Food Crop Institute of Gansu Academy of Agricultural Science, Lanzhou, 165 pp (in Chinese, available from Scientech Documentation and Information Centre of Chinese Academy of Agricultural Sciences, Beijing 100081, P.R. China)

Jin Shanbao (1983) Genealogies of Wheat Varieties of China. Agricultural Press of China, Beijing, 417 pp (in Chinese)

Jin Shanbao (1986) Records of Wheat Varieties of China. Agricultural Press of China, Beijing, 489 pp (in Chinese)

Johnson R (1983) Genetic background of durable resistance. In: Lamberti F, Waller JM and Van der Graaff NA (eds) Durable Resistance in Crops (pp. 5–26) Plenum Press, New York

Johnson R (1992) Reflections of a plant pathologist on breeding for disease resistance, with emphasis on yellow rust and eyespot of wheat. Plant Pathology 41: 239–254

Johnson R (1993) Durability of disease resistance in crops: some closing remarks about the topic and the symposium. In: Jacobs Th and Parlevliet JE (eds) Durability of Disease Resistance (pp. 283–300) Kluwer Academic Publishers, Dordrecht, Boston and London

Li Zhenqi (1980) The variation of wheat variety resistance to stripe rust in China and the way of its solution. Scientia Agricultura Sinica (3): 72–76 (Including English abstract)

Line RF (1993) Durability of resistance to *Puccinia striiformis* in North American wheat cultivars. In: Jacobs Th and Parlevliet JE (eds) Durability of Disease Resistance (p. 332) Kluwer Academic Publishers, Dordrecht, Boston and London

Lu Duanyi, Yuan Wenhuan, Li Jianyan, Li Dengke and Yu Xiaoru (1980) Studies on stripe rust resistance of the cultivar resources of wheat. Scientia Agricultura Sinica (1): 15–22 (Including English abstract)

Lu Duanyi, Yu Xiaoru, Yuan Wenhuan and Li Gaobao (1986) Studies on stripe rust resistance of the rural wheat varieties from the low and middle reaches of the Yellow River valley. Scientia Agricultura Sinica (5): 26–31 (Including English abstract)

National Cooperation Group for Surveying Race of Wheat Stripe Rust Fungus in China (1972–1986) Survey Reports on the Race of Wheat Stripe Rust Fungus. Publications of Plant Protection Institute of Chinese Academy of Agricultural Science (CAAS), Beijing (in Chinese, available from Scientech Documentation and Information Centre of CAAS, Beijing 100081, P.R. China)

National Cooperative Research Group on Horizontal Resistance to Yellow Rust of Wheat (1983) Preliminary report on the screening of wheat cultivars with horizontal resistance to yellow rust (*Puccinia striiformis*) by regional trials. Scientia Agricultura Sinica (4): 58–67 (Including English abstract)

Parlevliet JE (1979) Components of resistance that reduce the rate of epidemic development. Annual Review of Phytopathology 17: 203–222

Parlevliet JE, Lindhout WH, Van Ommeren A and Kuiper HJ (1980) Level of partial resistance to leaf rust, *Puccinia hordei*, in West-European barley and how to select for it. Euphytica 29: 1–8

Peterson RF, Campbell AB and Hannan AE (1948) A diagrammatic scale for estimating rust severity on leaves and stems of cereals. Canadian Journal of Research Section C 26: 496–500

Stakman EC, Stewart DM and Loegering WQ (1962) Identification of physiologic races of *Puccinia graminis* var *tritici* (pp. 1–53) US Department of Agricultural Publications E-617. USDA, Washington, DC

Van der Plank JE (1968) Disease Resistance in Plants. Academic Press, New York and London, 206 pp

Wu Liren (1993) On the variation of resistance of Mianyang cultivars to wheat stripe rust. Southwest China Journal of Agricultural Science 6(1): 71–74 (Including English abstract)