Crop Protection 70 (2015) 40–46

Contents lists available at ScienceDirect

Crop Protection

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

Intercropping influenced the occurrence of stripe rust and powdery mildew in wheat

Shiqin Cao [a, c], Huisheng Luo [a], Ming'an Jin [a], Shelin Jin [a, *], Xiayu Duan [c, *], Yilin Zhou [c], Wanquan Chen [c], Taiguo Liu [c], Qiuzhen Jia [a], Bo Zhang [a], Jin Huang [a], Xiaoming Wang [a], Xunwu Shang [b], Zhenyu Sun [a]

[a] Institute of Plant Protection, Gansu Academy of Agricultural Sciences, Lanzhou, 730070, China
[b] College of Agronomy, Gansu Agricultural University, Lanzhou, 730070, China
[c] Institute of Plant Protection, Chinese Academy of Agricultural Sciences, 2 Yuanmingyuan Xilu, Beijing, 100193, China

A R T I C L E I N F O

Article history:
Received 26 November 2013
Received in revised form
1 December 2014
Accepted 16 December 2014
Available online 9 January 2015

Keywords:
Epidemics
Intercropping
Powdery mildew
Stripe rust
Wheat
Yield

A B S T R A C T

The intercropping of three susceptible winter wheat varieties, Lantian 13, Lantian 6, and Tian 94-3, with potato, chili, maize, sunflower, benne or soybean was tested for efficacy in controlling stripe rust and powdery mildew and increasing yields in the field under different ecological conditions in Tianshui, Gansu Province, China, from 2007 to 2009. The relative control efficacies of the intercropping between wheat and maize were 16.7%–45.7% for stripe rust and 14.7%–37.0% for powdery mildew compared to the pure stands of wheat. The yield increased by 52.4%–140.0%. The relative control efficacies of intercropping between wheat and sunflower were 5.9%–28.9% for stripe rust and 11.7%–18.4% for powdery mildew. The yield increased by −1.4%–24.8%. The differences were statistically significant for control efficacy. Therefore, intercropping systems could be used extensively in South Gansu, where machinery is seldom used due to the mountainous landscape, to reduce damage caused by the two major diseases. The intercropping system of wheat with potato or chili did not result in significant differences in disease reduction compared to the pure wheat stands. However, the two crop combinations increased the yield by 150.0% or more. Other intercropping combinations did not result in a significant disease reduction or yield increase.

1. Introduction

Wheat stripe rust and powdery mildew caused by the biotrophic fungi *Puccinia striiformis* Westend f. sp. *tritici* Erikss. and *Blumeria graminis* (DC) Speer f. sp. *tritici* Emend. E. J. Marshcl, respectively, are among the most important wheat diseases worldwide, including in Gansu Province, China. The wheat variety Fan 6 and its derivatives that had maintained resistance to stripe rust for more than 20 years lost their resistance due to the emergence and expansion of the Chinese stripe rust races CYR31 and CYR32 since 1993. Eleven provinces, including Gansu and Sichuan, suffered an outbreak of stripe rust in 2002, which caused a yield loss of more than 1.3 million tons (Wan et al., 2004). A countrywide outbreak of wheat stripe rust occurred once more in 2009. The epidemic affected 4 million hectares of wheat acreage and caused widespread use of fungicides.

Wheat yield losses caused by powdery mildew were also significant, especially when the resistance gene *Pm8* lost its effectiveness in the 1990s. The yield losses were estimated at 13 million tons in 1990 and 7 million tons in 1991 (Liu and Shao, 1995). The virulent frequency of *Pm8* has been maintained at greater than 90% since the early 1990s (Duan et al., 1998 and unpublished data). Cao et al. (2010, 2011, 2012) reported that most wheat cultivars were susceptible to all or the majority of 21 testing isolates with different virulence patterns. The average acreage of wheat that is affected by powdery mildew is greater than 267,000 ha in Gansu in recent years (Li et al., 2002).

The epidemics of wheat stripe rust and powdery mildew have threatened wheat production in Gansu. Wheat stripe rust in Gansu causes not only severe yield losses locally but also provides inocula to the provinces east of Gansu through the long-distance dispersal of the pathogen, causing epidemics at a much larger geographic

* Corresponding authors.
E-mail addresses: jinshelin@163.com (S. Jin), xyduan@ippcaas.cn (X. Duan).

http://dx.doi.org/10.1016/j.cropro.2014.12.008
0261-2194/

scale when conditions favor the pathogen (Wan et al., 2004; Chen et al., 2009). The wheat powdery mildew pathogen has a similar dispersal pattern.

Gansu is a source of inocula and newly emergent virulence of the pathogens due to its unique cropping systems, landscape and favorable environmental conditions which allow both stripe rust and powdery mildew pathogens to survive the summer in the mountainous areas in the southern part of the province (Wan et al., 2004; Enjalbert et al., 2005; Duan et al., 2010). Various techniques have been used to control these diseases, including host resistance. However, the frequent selection and emergence of new virulence in pathogen populations have overcome resistance in wheat varieties as conferred by race-specific resistance genes in a short period. The severity of these diseases has motivated local famers and scientists to try various ways to reduce the impact and has drawn attention to the utilization of biodiversity to manage diseases since Zhu et al. (2000) published their results on the control of rice blast by intercropping, a traditional yet neglected Chinese practice, of rice varieties with different blast resistance.

The sustainable control of pests and diseases on rice, wheat, maize, and other crops has been studied and successfully applied (Smithson and Lenne, 1996; Zhu et al., 2000; Liu et al., 2003; Cox et al., 2004; Sun et al., 2006; Guo et al., 2007). Previous studies have demonstrated that increased biodiversity in agro-ecosystems could improve the control efficacy against natural enemies (Andow, 1991; Hou and Sheng, 1999). Wang et al. (2008) reported that the intercropping of wheat–oil rape and wheat–garlic can reduce the occurrence of *Sitobion avenae* in wheat fields. Additional results have been reported on the control of plant diseases (e.g., Mundt et al., 1995; Akanda and Mundt, 1996; Smithson and Lenne, 1996; Zhu et al., 2000; Liu et al., 2003; Cox et al., 2004). Zhu and his group intercropped different rice varieties to control rice blast, achieving good efficacy and increasing yield in large areas (Zhu et al., 2000).

There are limited studies on the effect of crop diversity on the control of stripe rust and powdery mildew in wheat in China (Xiao et al., 2005, 2006; Peng et al., 2006). In order to integrate the local policy of reducing wheat acreage to decrease inocula that can be dispersed to the eastern wheat growing areas, we conducted a series of field trials to determine the efficacies of intercropping between wheat and selected crops to control stripe rust and powdery mildew and simultaneously increase crop productivity in South Gansu from 2007 to 2009.

Table 1
Wheat varieties and crops used in the trials 2007–2009.

Year	Site[a,b]	Altitude (m)	Plot area (m^2)	Wheat variety
2007	A1	1350	100	Lantian 13
	B	1680	36	Tian 94-3
2008	A2	1270	49	Lantian 6
	B	1680	49	Tian 94-3
	C	1720	49	Tian 94-3
2009	B	1680	49	Tian 94-3

[a] A refers to experimental sites at Gangu Experimental Station, Tianshui Institute of Agricultural Sciences, B refers to Wangchuan Seed Farm at Qinzhou District, Tianshui City, and C refers to East Sanshilipu Village, Baijiawan Town, Gangu County, respectively.

[b] The intercropped crops included potato variety Keshu 1 (site A) and Longshu 3 (site B and C), chili variety Xianjiao 3, soybean variety Zhonghuang 13, maize variety Yuyu 22, benne variety Longya 9, and sunflower variety Xinkuiza 6, respectively.

2. Materials and methods

2.1. Plant materials

The wheat varieties and the inter-planted crops that were used in this study are listed in Table 1. These are commercial varieties in this region. Among the wheat varieties, Lantian 13 is moderately susceptible to stripe rust. Lantian 6 and Tian 94-3 are highly susceptible. The three varieties are all highly susceptible to powdery mildew. Except for susceptibility to the two diseases, the wheat varieties are highly adapted to the environment in South Gansu.

2.2. Field trials

The field trials were conducted at three locations in South Gansu: A) Gangu Experimental Station, Tianshui Institute of Agricultural Sciences; B) Wangchuan Seed Farm at Qinzhou District, Tianshui; and C) East Sanshilipu Village, Baijiawan Town, Gangu County. The altitudes of the trial sites range from 1270 m to 1720 m with different climatic conditions. The plot sizes are listed in Table 1. The trials were replicated three times and arranged as randomized blocks at each site. The between-row distance was 20 cm for wheat and benne, 60 cm for maize and sunflower and 80 cm for potato and chili. The intercropping combinations were wheat with potato, chili, soybean, maize, benne and sunflower. Monocultured wheat was used as a control. The intercropping ratio of wheat and other crops was 4:4 or 4:2, in which 4 rows of wheat and 4 or 2 rows of tested crops were grown manually. Wheat was sown during the last 10 days of September or the last 10 days of October, depending on the common planting dates for the locations. The other crops tested were sown during the last 10 days of March for potato, sunflower and benne or the first 10 days of April for maize and soybean or were transplanted during the last 10 days of April the following year for chili.

At Site A, the universal, highly susceptible wheat variety Mingxian 169 was planted at approximately 10 cm in diameter as the spreader in the middle of each plot and was artificially inoculated with urediniospores of a mixture of the *P. striiformis* f. sp. *tritici* isolates CYR23, CYR25, CYR29, CYR31, CYR32, CYR33, CH42, Hy4, Hy7, Hy8, Su11-4, Su-5, Su-7 and Su11-11. Equal proportions of the urediniospores were suspended in distilled water with three drops of Tween-20 in a 1.5-L watering can and sprayed to Mingxian 169 during the last 10 days of March the following year. Stripe rust infection was natural at Sites B and C. Powdery mildew developed from natural infection at each of the three sites. Both diseases were scored using the scale that is described below every 7 days from the last 10 days of April at Site A and the first 10 days of May at Sites B and C until the wheat crop matured. Five samples were collected along the two diagonal lines of each plot, and approximately 30–40 leaves were scored for each sample. The scored leaves included all of the green leaves after the flowering of wheat from 10 randomly sampled plants.

Fungicides were not used against stripe rust or powdery mildew throughout the crop seasons at any site.

2.3. Data collection and analyses

The following scale for the foliar diseases of cereal crops was, respectively, used to record the disease levels of stripe rust (Liu et al., 2000a) and powdery mildew (Liu et al., 2000b). The scale for stripe rust was 0 = no symptom; 1 = the symptom is smaller than 5% of the total leaf area; 3 = the diseased leaf area is 6–25%; 5 = the diseased leaf area is 26–50%; 7 = the diseased leaf area is 51–75%; and 9 = the diseased leaf area is greater than 75% of the total leaf area. The scale for powdery mildew was 0 = no symptom;