African Journal of Biotechnology Vol. 10(63), pp. 13930-13935, 17 October, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.1184
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Evaluation on the resistance to aphids of wheat germplasm resources in China

Haibo Zhou[1,2], Julian Chen[1]*, Dengfa Cheng[1], Frédéric Francis[2], Yong Liu[3], Jingrui Sun[1], Ying Huang[4], Xiaosong Wang[4], Xingwang Liu[4], Liu Xiaoming[4] and Jiandong Zeng[5]

[1]State Key Laboratory for Biology of Plant Disease and Insect Pests, Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, 100193, Peoples Republic of China.
[2]Functional and Evolutionary Entomology, Gembloux Agro-Bio Tech, University of Liege, Gembloux, 5030, Belgium.
[3]College of Plant Protection, Shandong Agricultural University, Taian, 271018, Peoples Republic of China.
[4]Mianyang Agricultural Bureau, Mianyang 621000, Peoples Republic of China.
[5]Jiangyou Agricultural Bureau, Jiangyou 621700, Peoples Republic of China.

Accepted 18 August, 2011

A collection of more than 200 wheat lines from the main wheat-producing areas of China was evaluated for resistance to wheat aphids, using fuzzy recognition technique in five field experiments over 2 years. The results show that susceptibility to wheat aphids was exhibited in most of the lines tested, and no immune and highly resistant lines to wheat aphids was observed. The average percentage of wheat germplasm lines with resistant, lowly susceptible, moderately susceptible and highly susceptible to aphid were 9.30, 23.15, 42.32, and 25.23%, respectively. 5 moderately resistant wheat germplasm lines to wheat aphids (Lantian18, Lantian20, Lantian22, Lantian00-30 and Shanmai175) were found in Jiangyou experimental station in 2009. More importantly, 2 wheat germplasm lines (Lantian20, Lantian22) with the continuous resistance to wheat aphid in the five experimental stations over 2 years were discovered. Although, resistance of wheat germplasm lines had a close relation to their genetics and inheritance, we also found that the resistance of the same wheat germplasm lines was varied in different experimental stations. It would be helpful to make wheat germplasm selections for breeding programs, especially if they have unique genes that may provide resistance to future biotypes of wheat aphids. A valuable method for evaluating the potential of aphid-resistance for wheat germplasm lines was also confirmed.

Key words: Wheat germplasm lines, aphid, resistance identification.

INTRODUCTION

Sitobion ave*nae* (*Fabricius*), *Schizaphi*s *graminum* (Rondani), *and Rhopalosiphum padi (Linnaeus*), the dominant and destructive pests in wheat production regions of China (Ma et al., 2006; Wang et al., 2009; Zhao et al., 2009), can cause heavy economic damage to wheat both as a phloem feeder and as a vector of plant viruses (Quillec et al., 1995; Van Emden and Harrington, 2007; Liu et al., 2009; Ma et al., 2010). To avoid environmental pollution and health problems caused by the overuse of traditional synthetic pesticides, exploration of host plant resistance to pest management is a necessary research theme in sustainable agriculture system. Host plant resistance plays important roles in controlling pests and protecting of natural enemies in an agroecosystem (Francis et al., 2001; Messina and Sorenson, 2001), and the effect on application of insect-resistance plant varieties in reducing pest damage is considered to be conspicuous (Painter, 1958). A field study of Russian wheat aphid on yield and yield components of field grown susceptible and resistant spring barley in Laramie, showed highly resistant lines maintained or increased yield components and grain yield (average grain yield increase 5%) under aphids feeding pressure, and susceptible cultivars had a large reduction in yield components and grain yield (average reduction

*Corresponding author. E-mail: jlchen1965@126.com. Tel: +86-10-62813685(O). Fax: +86-10-62895365.

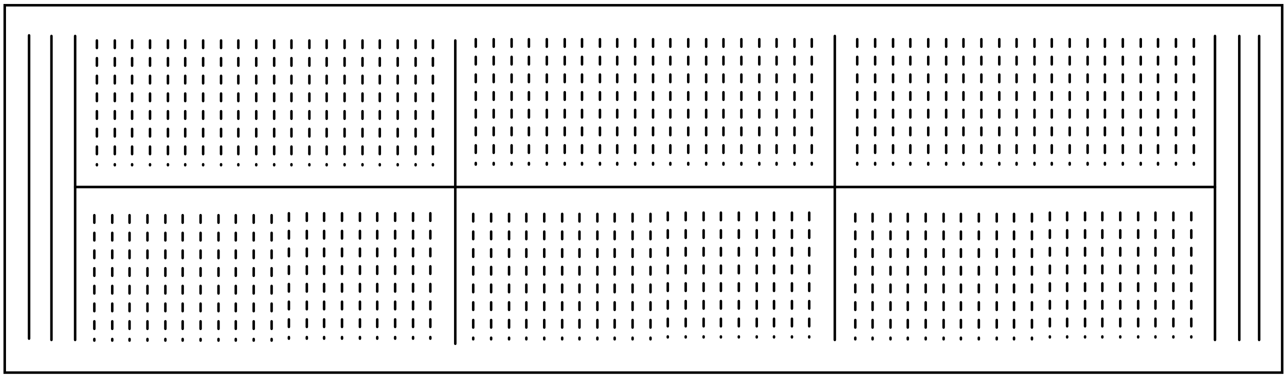

Figure 1. The sketch map of nursery for evalution in field. ☐: Border dike; ___:Control wheat variety; ___: Evaluated wheat varieties.

56%) (Mornhinweg et al., 2006). In assessing the effect of a resistant variety on an insect population, the literature suggests that the effect is likely to be cumulative. Three times as many pea aphids in the field on susceptible varieties as on resistant ones was found in each year during a 9-year study (Maltais, 1951). Brewer et al. (1999) also reported that the abundance of *Diuraphis noxia* on resistant barley lines was lower than that on more susceptible lines.

In a separate field study, the host plant resistance against aphids enhanced the parasitism of aphid species, *Sitobion avenae* (F.) by its parasitoid *Aphidius* spp. in wheat field (Cai et al., 2009). The evaluations on identification of resistance to cereal aphids in wheat germplasm lines have also been studied. Smith et al. (1991) working with the Russian wheat aphid, identified five new sources of low levels of resistance (PI 47545, PI 94355, PI 94365, PI 94460, and PI 151918) from Iran and the Soviet Union in three breeding lines from Idaho, one breeding line from Texas. About 8 wheat varieties have been identified as cereal aphids-resistant wheat germplasm lines over a 5-year field study from 577 varieties in Henan Province, China (Li et al., 1998). Seedlings in greenhouse flats have ample moisture and nutrients as well as favorable temperatures and are not exposed to natural stresses that may occur in the field during any growing season and which could impact the expression of resistance (Mornhinweg et al., 2006), and aphids are protected from exposure to parasites and predators compared in the field, as well as wind and rain. As a result, aphids build up to great numbers even on flat leaves of resistant seedlings. So, the evaluation based on seedlings in greenhouse could be susceptibility. Biotypes, the presence of biological strains of insects, constitute an important feature of the environment that may modify the expression of resistance, and such biotypes may occupy definite geographic areas. For those reasons that we were beginning to screen and evaluate the resistance to aphids of wheat germplasm lines in three wheat-producing areas of China, the approaches and strategies for structuring fuzzy recognition technique in evaluation on aphid-resistant wheat germplasm lines was also discussed.

MATERIALS AND METHODS

Experimental field and wheat varieties

The experiment was conducted during two seasons (2009- 2010) at Langfang, Hebei Province in Northern wheat region, Jiangyou, Sichuan Province in Southwestern wheat region and Xinxiang, Henan Province in Huan-Huai-Hai wheat region, sites representing diverse environments in China. Langfang, at 20 m above sea level (m a.s.l.), represents the warm temperate continental monsoon climate with 554.9 mm annual rainfall. Jiangyou at 510 m a.s.l. is in the humid subtropical monsoon climate and receives 859.9 mm of rainfall. Xinxiang, at 75 m a.s.l., also represents the warm temperate continental monsoon climate with 656.3 mm annual rainfall. More than 200 wheat germplasm lines recommended from the Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Northwest A&F University, and academy (institution) of agricultural sciences of some provinces and cities in China were evaluated in the field and those susceptible to cereal aphids variety, c.v. Beijing 837 were planted as control variety (CV).

Methods

The experiment was conducted as described in the rules for resistance evaluation of wheat to diseases and insect pests, Part 7 : Rule for resistance evaluation of wheat to aphids, Agriculture industry standard of the People's Republic of China (NY/T 1443.7-2007).

Nursery of resistance evaluation

The wheat was sown in drill in the nursery (250 cm border width, 50 cm border dike width) as sketch map in Figure 1, and the length of the nursery depended on the terrain of the cultivated area. The evaluation for each variety was laid out in a randomized complete block design with three replications. Two rows, 1-m-long for every wheat line and 1 CV in every 9 varieties were planted at a spacing of 0.3 m between rows. In order to attract more aphids, the CV was also planted in line in and around the field. Wheat was sown at

Table 1. Rating scale infested by wheat aphids.

Level	Rating scale of aphids in one plant
0	None
1	Less than 10 aphids
2	10-20 aphids, wheat ear infested with none or 1-5 aphids
3	21-50aphids, wheat ear infested with 6-10 aphids
4	More than 50 aphids, one-fourth of wheat ear infested with aphids
5	One-fourth to three fourth of wheat ear infested with aphids
6	The whole plant infested with aphids

Table 2. The evaluation index (R) of resistance to cereal aphids.

Resistance level	R	Resistance to wheat aphid
0	0	Immune (I)
1	0.01 ~ 0.30	Highly resistant (HR)
2	0.31 ~ 0.60	Moderately resistant (MR)
3	0.61 ~ 0.90	Lowly resistant (LR)
4	0.91 ~ 1.20	Lowly susceptible (LS)
5	1.21 ~ 1.50	Moderately susceptible (MS)
6	>1.50	Highly susceptible (HS)

rates to provide 100 seeds per 1-m-long row in all varieties. No pesticides and herbicides were applied on the fields during the entire growing season.

Investigation method of wheat aphids

In the gain-filling stage of most wheat lines, the high occurrence period of cereal aphids, the levels infested by cereal aphid metapopulation including *S. avenae* (Fabricius), *S. graminum* (Rondani), *R. padi* (Linnaeus), *M. dirhodum* (Walker) were recorded using fuzzy recognition technique by 6 regular investigators divided 3 groups. The wheat infested with the most abundant aphids selected to be as the criterion of the wheat variety, and the rating scale infested by wheat aphids is presented in Table 1.

The evaluation index (R)

The R index, introduced by Painter (1951), a parameter to evaluate the resistance to wheat aphid for wheat varieties is presented in Table 2.

$$\hat{I} = \frac{\sum_{i=1}^{n}\left(M_{i1} + M_{i2} + M_{i3}\right)}{3n} \qquad R = \frac{I}{\hat{I}}$$

Where, *M* is the mode of the level of rating scale infested by wheat aphid for each replication; *n* is the total of wheat varieties and *I* is the maximum value of mode for each wheat variety in three replications.

RESULTS

The results for evaluation of resistance to cereal aphids in two years are presented in Tables 3 and 4. There were 29 and 24 wheat varieties with resistance to cereal aphids in Jiangyou and Langfang respectively in 2009; 24, 23 and 10 wheat varieties with resistance to cereal aphids were observed in Jiangyou, Langfang and Xinxiang respectively in 2010. Most of the wheat varieties with resistance to aphid in this evaluation were lowly resistant, except for 5 wheat varieties (Lantian18, Lantian20, Lantian22, Lantian00-30 and Shanmai175) with moderate resistance in Jiangyou in 2009. The average percentage of the wheat germplasm lines with resistant, lowly susceptible, moderately susceptible and highly susceptible to cereal aphids were 9.30, 23.15, 42.32 and 25.23% in entire wheat germplasm resources respectively.

The comparative study of wheat varieties with resistance in one location showed several wheat varieties displayed consistent resistance to cereal aphids in 2 years (Table 5). The consistent wheat varieties in Sichuan were Lantian-18, Lantian-20, Lantian-22, Mianmai-37, Mianmai-185, Hanmai-111, Linzao51329 and Changwu134; and in Hebei, 7 wheat varieties, including

Mianmai37, Maimian39, Ningmai13, Lantian17, Lantian20, Lantian21 and Lantian22, also displayed consistent resistance to cereal aphids. We also found that 2 wheat varieties, Lantian20 and Lantian22 possessed

Table 3. The result for evaluation of resistance to aphids of wheat germplasm lines in two years.

Year	Location	MR	P%*	LR	P%	LS	P%	MS	P%	HS	P%	T**
2009	Jiangyou.Sichuan	5	2.36	24	11.32	33	15.57	64	30.19	86	40.57	212
	Langfang.Hebei	0	0	24	11.32	53	25.00	135	63.68	0	0	212
2010	Jiangyou.Sichuan	0	0	24	9.16	86	32.82	73	27.86	79	30.15	262
	Langfang.Hebei	0	0	23	8.07	33	11.58	110	38.60	119	41.75	285
	Xinxiang.Henan	0	0	10	4.27	72	30.77	120	51.28	32	13.68	234
Mean			2.36		8.83		23.15		42.32		25.23	

*Percentage of the total wheat varieties, ** the total wheat varieties.

Table 4. The varieties of resistance to cereal aphids in two years.

Jiangyou.Sichuan				Langfang.Hebei				Xinxiang.Henan	
2009		2010		2009		2010		2010	
Variety	RCA*	Variety	RCA	Variety	RCA	Variety	RCA	Variety	RCA
Lantian18	MR	Lantian18	LR	Mianmai37	LR	Mianmai37	LR	Mianmai185	LR
Lantian20	MR	Lantian20	LR	Mianmai39	LR	Mianmai39	LR	Xikemai5	LR
Lantian22	MR	Lantian22	LR	Mianmai45	LR	Mianmai46	LR	Lantian20	LR
Lantian00-30	MR	Xikemai4	LR	Xikemai2	LR	Mianmai185	LR	Luohan8-1	LR
Shanmai175	MR	Yumai52	LR	Xikemai4	LR	Hanmai111	LR	Mianmai39	LR
Zhoumai17	LR	Yunong035	LR	XK0106-108D6	LR	Ningmai13	LR	Lantian17	LR
Aikang58	LR	Zhoumai16	LR	Beijing0045	LR	Zhoumai18	LR	Mianmai46	LR
Mianmai37	LR	Yan2415	LR	Een1	LR	Lantian17	LR	Lantian21	LR
Mianmai45	LR	Yan5158	LR	Emai12	LR	Lantian20	LR	Lantian22	LR
Mianmai185	LR	Lantian15	LR	Emai23	LR	Lantian21	LR	Lantian23	LR
Xikemai2	LR	Mianmai37	LR	Huamai8	LR	Lantian22	LR		
Xikemai5	LR	Youmai8004	LR	Ningmai13	LR	Youmai8004	LR		
Hanmai111	LR	Mianmai185	LR	Yannong19	LR	Linmai4	LR		
Emai16	LR	Chang6359	LR	Zhenmai5	LR	Wenqian(4)1	LR		
Huaimai17	LR	Lunong116	LR	Zhengmai004	LR	Xinong9871	LR		
Ningmai13	LR	Hanmai111	LR	Lantian15	LR	Yang06-144	LR		
Zhoumai22	LR	Hengguan111	LR	Lantian17	LR	Yunong202	LR		
Yannong24	LR	Linyou2618	LR	Lantian20	LR	Guan0014	LR		
Lantian99-316	LR	05-83	LR	Lantian21	LR	70222-24	LR		
Lantian21	LR	Lantian21	LR	Lantian22	LR	Neimai8	LR		
Lin867	LR	Linzao51329	LR	Zhongnong2	LR	Mian06-367	LR		
Changhan58	LR	Mianmai46	LR	Ningdong10	LR	Mian06-374	LR		
Linzao51329	LR	Mianmai39	LR	Shan715	LR	Mian1971-98	LR		
Luohan7	LR	Changwu134	LR	Luohan7	LR				
Luohan8-1	LR								
Xinong889	LR								
Xinong3517	LR								
Changwu134	LR								

Hengguan136	LR

* RCA=Resistance to cereal aphids

Table 5. The consistent wheat varieties with resistance to cereal aphids in two years.

Jiangyou. Sichuan				Langfang. Hebei			
2009		2010		2009		2010	
Variety	**RCA**	**Variety**	**RCA**	**Variety**	**RCA**	**Variety**	**RCA**
Lantian-18	MR	Lantian18	LR	Mianmai37	LR	Mianmai37	LR
Lantian-20	MR	Lantian20	LR	Maimian39	LR	Maimian39	LR
Lantian-22	MR	Lantian22	LR	Ningmai13	LR	Ningmai13	LR
Mianmai-37	LR	Maimai37	LR	Lantian17	LR	Lantian17	LR
Mianmai-185	LR	Mianmai185	LR	Lantian20	LR	Lantian20	LR
Hanmai-111	LR	Hanmai111	LR	Lantian21	LR	Lantian21	LR
Linzao51329	LR	Linzao51329	LR	Lantian22	LR	Lantian22	LR
Changwu134	LR	Changwu134	LR				

resistance to cereal aphids in the 5-evaluation tests in the field.

DISCUSSION

The widespread development of resistance to many of these insecticides by pest species has caused thoughtful entomologists to realize that all possible means must be employed in insect control (Painter, 1958). The analysis of why plants are resistant indicates that there are three basic components: nonpreferred, antibiosis and tolerant. More so, the two reasons given subsequently could explain why a resistant plant can reduce the damage by insect:

(1) Plant resistance to insects often affects individual development, fecundity and population growth of insects by secondary plant substances, but cannot result in insect mortality (Cai et al., 2009)

(2) The attributes that often enhance aphid's predator effectiveness and directly stress aphid population development may be genetically varied among plants (Rutledge et al., 2003; Kagata et al., 2005).

It could provide a more economical, timely and efficient strategy using plant resistance as a pest control method in agroecosystems, and host plant resistance offers the only cost effective means of cereal aphids control. In this study, we found that the majority of wheat germplasm resources were evaluated as susceptible to cereal aphids, and no immune and highly resistant variety was observed. 2 wheat varieties (Lantian20 and Lantian22) with the continuous resistance to cereal aphids in the five experimental fields over 2 years were found. The germplasm must be evaluated for useful traits before it can be fully utilized (McCarty et al., 1998). Evaluations, such as the one reported here, aid plant breeders in making germplasm selections for breeding programs, especially if they have unique genes that may provide resistance to future biotypes of cereal aphids. These evaluations on reaction to aphid metapopulation could be crucial when germplasm is used in improving production and qualities of wheat cultivars. This research is part of the program to evaluate germplasm for useful traits and make this information available to the germplasm system. The resistance of these identified lines of wheat here, awaits further confirmation of the expression. Future searches for aphid-resistant germplasm should concentrate on the genetics and inheritance of aphid resistance in these new sources.

ACKNOWLEDGEMENTS

We thank Protection Station Master Liu Rudong (Jiangyou Agricultural Bureau, China) and Dr Kang Xiaohui (Southwest University of Science and Technology, China) for their guidance and support in the program. We also thank Wang Lin and Xu Yangyang (students in Southwest University, China), Wu Bo and Xie Xinxin (students in Hunan agricultural University, China), Liu Wentao (student in Southwest University of Science and Technology, China) for assistance in aphid investigation.

This research was supported by grants from the National S & T Major Project (2009ZX08012-007B), the Modern Agro-industry Technology Research System (2060302), China-Belgium Cooperation Project (2010DFA32810) and the “Cooperation Universitaire au Developpement (CUD) funded an inter-university targeted project between Belgium and China (CUD/PIC SHANDONG).

REFERENCES

Brewer M, Mornhinweg D, Huzurbazar S (1999). Compatibility of insect management strategies Diuraphis noxia abundance on susceptible and resistant barley in the presence of parasitoids. BioControl. 43(4): 479-491.

Cai QN, Ma XM, Zhao X, Cao YZ, Yang XQ (2009). Effects of host plant resistance on insect pests and its parasitoid: A case study of wheat-aphid-parasitoid system. Biol. Control, 49(2): 134-138.

Francis F, Lognay G, Wathelet JP, Haubruge E (2001). Effects of Allelochemicals from First (Brassicaceae) and Second (*Myzus persicae* and *Brevicoryne brassicae*) Trophic Levels on *Adalia bipunctata*. J. Chem. Ecol. 27(2): 243-256.

Kagata H, Nakamura M, Ohgushi T (2005). Bottom up cascade in a tri trophic system different impacts of host plant regeneration on performance of a willow leaf beetle and its natural enemy. Ecol. Entomol. 30(1): 58-62.

Liu Y, Wang WL, Guo GX, Ji XL (2009). Volatile emission in wheat and parasitism by Aphidius avenae after exogenous application of salivary enzymes of Sitobion avenae. Entomol. Exp. Appl. 130(3): 215-221.

Ma R, Chen JL, Cheng DF, Sun JR (2010). Activation of Defense Mechanism in Wheat by Polyphenol Oxidase from Aphid Saliva. J. Agric. Food Chem. 58(4): 2410-2418.

Ma XM, Liu XX, Zhang QW, Zhao JZ, Cai QN, Ma YA, Chen DM (2006). Assessment of cotton aphids, Aphis gossypii, and their natural enemies on aphid resistant and aphid susceptible wheat varieties in a wheat cotton relay intercropping system. Entomol. Exp. Appl. 121(3): 235-241.

Maltais JB (1951). The Nitrogen Content of Different Varieties of Peas as a Factor Affecting Infestations by Macrosiphum pisi (Kltb.) (Homoptera: Aphididae). A Preliminary Report Can. Entomol. 83(2): 29-33.

McCarty JC, Jenkins JN, Robinson M (1998). Cotton Germplasm Root Knot Nematode Resistance in Day Neutral Primitive Accessions. Mississippi Agric. Forest. Exp. Station Res. Rep. 22: p. 3.

Messina FJ, Sorenson SM (2001). Effectiveness of Lacewing Larvae in Reducing Russian Wheat Aphid Populations on Susceptible and Resistant Wheat. Biol. Control. 21(1): 19-26.

Mornhinweg DW, Brewer MJ, Porter DR (2006). Effect of Russian wheat aphid on yield and yield components of field grown susceptible and resistant spring barley. Crop. Sci. 46(1): 36-42.

Painter RH (1958). Resistance of Plants to Insects. Annu. Rev. Entomol. 3(1): 267-290.

Quillec FL-LE, Tanguy S, Dedryver CA (1995). Aerial flow of barley yellow dwarf viruses and of their vectors in western France. Ann. Appl. Biol. 126(1): 75-90.

Rutledge CE, Robinson AP, Eigenbrode SD (2003). Effects of a simple plant morphological mutation on the arthropod community and the impacts of predators on a principal insect herbivore. Oecologia, 135(1): 39-50.

Van Emden HF, Harrington R (2007). Aphids as crop pests, CAB International, Wallingford, UK.

Wang WL, Liu Y, Chen JL, Ji XL, Zhou HB, Wang G (2009). Impact of intercropping aphid resistant wheat cultivars withoil seed rape on wheat aphid (*Sitobion avenae*) and its natural enemies. Acta Ecol. Sinica. 29 (3): 186-191.

Zhao LY, Chen JL, Cheng DF, Sun JR, Liu Y, Tian Z (2009). Biochemical and molecular characterizations of Sitobion avenae induced wheat defense responses. Crop Prot. 28(5): 435-442.