JOURNAL OF AGRICULTURE AND BASIC SCIENCES
ISSN Online: 2518-4210
http://www.jabsjournal.com/

Full Length Research Article

Resistance Pattern against *Schizaphis graminum* (Rondani) in Rain Fed Wheat Genotype

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Abstract

Wheat greenbug (*Schizaphis graminum*) being the most important pest of wheat is responsible for viral transmission of plant disease like barley yellow dwarf virus (BYDV). Host plant resistance (HPR) is an important pillar to minimize the effect of pest in integrated pest management (IPM) strategy. This experiment was conducted at Key Laboratory of Integrated Pest Management in Crops, Institute of Plant Protection, Chinese Academy of Agricultural Sciences (CAAS), Beijing, People's Republic of China to study the seedling bulk test and three components (antixenosis, antibiosis and tolerance) on National Uniform Wheat Yield Trails (NUWYT)-rain fed against cereals aphid greenbug. Out of 23, five genotypes AUR-0809, V-08314, NR-399, NR-400, 9C037 were found to be resistant, thirteen genotypes PR-105, AZRC-2, PR-104, DN-84, VO BT022, DH-31, 10C033, NRL-0707, 06FJS3013, AUP-1052, V-11183, AUP-1059 and PIRSABAK-05 were found moderately resistant and rest of the five (NR-419, NR-420, NIA-MB-2, NR-403 and NARC-2009) showed susceptibility to disease. In addition, NRL-0707 genotype was highly preferred while AUR-0809 and AUP-1059 were the least tolerant varieties. It is determined that genotypes with high resistance, high tolerance, least fecundity and least preference should be endorsed for farmers and future breeding program.

Keywords: Wheat, *Schizaphis graminum* (Rond.), *Triticum aestivum*, Insect pest resistance, host plant resistance

Introduction

Cereal aphids have been documented as serious limiting factors of yield and other related traits. In wheat, these aphids predominantly affect the number of grains and spike weights. These aphids could be functional substrates for some viruses such as barley yellow dwarf virus (BYDV) and their combine action led to shattering and other severe magnitudes (Thackray *et al*. 2009; Liu *et al*. 2014). Accumulative evidences suggest that more than 10% yield losses per annum occur due to infestation of cereal aphids in China (Chinese National Agro-Tech Extension and Service Center [NATESC] database, http://www.natesc.moa.gov.cn/). The widely used insecticide applications effectively eliminate their robust damage. However, apart from elimination, their application generally results in generating other early growth limiting factors such as residues, resistance, and resurgence (Peng *et al*. 2000, Sun *et al*. 1993). Strikingly, development of resistant wheat varieties in some parts of the world has greatly reduced the insect's pest populations (Lowe 1984, Havličková 1993, Caillaud *et al*. 1995, Di Pietro *et al*. 1998, Riazuddin and Khattak 2004, Silva *et al*. 2013). Resistance varieties development strategy has been proved environmental-friendly and also have potential to control different crop pests like Russian wheat aphid (*Diuraphis noxia)* (Kurdjumov) and green bug (*Schizaphis graminum)* (Rodani) (Dogimont *et al*. 2010).

Green bug occurs mainly as winter pest in the world (Akhtar *et al*. 2010) and can survive throughout the year (Llewellyn *et al*. 2003). Aphids are the major agricultural pests around the globe, commonly known as black or green fly and there are only few plants that are not likely to be infested by this pest (Van *et al*. 2017). It can cause damage directly as well as indirectly to different agricultural crop, orchards, vegetables and ornamental plants (Qamar *et al*. 2015). It can cause direct damage by sucking cell sap from phloem tissues, diminishing the juvenile shoot growth, curling of leaves, bending of shoots, stunted growth, flaccid leaves, twisting and leaf fall (Naeem, 1996). Aphids are directly involved to spread viruses and damage the plant indirectly by depositing the honey dews on the upper surface of the leaves which lead toward the development of sooty mould in the leaf surface. Consequently, the photosynthetic activity is diminished; sometimes it may result in the early leaf senescence (Akhtar and Khaliq, 2003). Pons *et al*. (1989) observed that *Sitobion avenae* was found abundantly on the ears than the leaves. Akhtar and Mujahid (2006a) reported 20-80 % yield losses due to aphids.

Besides various factors of less production, insect pests on wheat are still overlooked in Pakistan which includes aphid, armyworm and termites (Ijaz and Aslam, 2003). Among these pests, aphids pose serious threat to wheat and affect the production adversely (Hamid, 1983). Population of aphid has been increasing on wheat crop for the past few years and attaining the status of economic pests (Aheer *et al*. 1994; Zia *et al*. 1999). In Pakistan, prevalent aphid species on wheat crop have been reported including *Sitobion avenae* Fabricius, *S. Miscanthi* Takahashi, *Sipha maydia* Passirinae, *R. maidis* Fitch, *Rhopalosiphum padi* L., *R. Rufiabdominalis* Sasaki, *Schizaphis graminum* Rondani, *Metopolophium dirhodum* Walker and *Macrosiphum granarium* Fabricius (Hashmi *et al*. 1983).

Studies showed that *Rhopalosiphum padi* and *Schizaphis graminum* are most important which limits the production of winter wheat in southern USA (Riedell *et al*. 1999, Kindler *et al*. 2002). In Pakistan (Punjab), it has been reported that late sowing of wheat varieties suffered more as compared to early varieties due to aphid attack that reached up to 8.88 aphids per tiller (Aheer *et al*. 1993a). In Pakistan, limited work has been done on the population dynamics of cereal aphids (Aheer *et al*; 1993 b, 1994 and 1998).

To inhibit losses by aphid, a number of methods have been used i.e., chemical, physical, cultural, biological, mechanical and integrated pest management (IPM) (Sultana *et al*., 2009). Control through chemical insecticide is creating several problems such as killing of insects which are beneficial and resistance development in pests (Roush *et al*. 2012). IPM is a comprehensive approach of controlling insects, plant pathogens and weeds with economically and environmentally sound manner (Kekeunou *et al*. 2006). To reduce economic losses caused through different aphid species, the use of resistant cultivars is an economically and environmentally sound method (Webster *et al*. 1986). Host plant resistance to insect pests is found to be an effective, environmentally friendly and economically suitable pest control method which plays an essential role in sustainable agriculture (Wiseman, 1999).

Keeping in view the importance of adverse effect of *Schizaphis graminum* on wheat cultivars, these studies have been carried out to evaluate wheat germplasm against greenbug (*S. graminum*) for resistance.

Materials and Methods

The experiment was conducted in the Key Laboratory of Integrated Pest Management in Crops, Institute of Plant Protection, Chinese Academy of Agricultural Sciences (CAAS), Beijing, People's Republic of China to study the seedling bulk test and three components of resistance, antixenosis, antibiosis and tolerance on National Uniform Wheat Yield Trails Rain Fed (NUWYT-RF) against greenbug (*S. graminum* R).

Total 23 genotypes i.e. PR-105, AZRC-2, AUR-0809, DN-84, V-08314, NR-400, NR-399, 9C037, NIA-MB-2, 10C033, DH-31, UP-1052, 06FJS3013, NR-419, V-11183, NR-420, NRL-0707, NR-403, PR-104, AUP-1059, PIRSABAK-05, VO*BT022 and NARC-2009 were evaluated in the laboratory by seedling bulk test, antixenosis, antibiosis and tolerance test for finding susceptible (S), moderately resistant (MR) and resistant (R) genotypes against *S. graminum* R. These experiments were conducted under controlled environmental conditions keeping temperature at 27 ± 2 °C, relative humidity at 40 ± 5 % and photoperiod of 16:8 hours (light-dark). Experiments were laid out following completely randomized design (CRD) with five replicates.

Survey of field and mass rearing of *Schizaphis graminum* R. culture

Each field of wheat was observed in CAAS for collection of Green bug (*S. graminum* R.). The culture was maintained under controlled conditions of temperature, 27±2°C and RH 55-60% with a photoperiod of 16L: 8D h in rearing room in specially made plastic racks measuring 112 x 50 x 62 cm, enlightened with five florescent tube lights (20 W). Susceptible wheat variety Chakwal-97 was used for mass rearing of aphids. About 20 seeds of Chakwal-97 were sown in a plastic pot of 11.5 cm diameter to obtain seedlings for mass rearing of *S. graminum*. Mass reared aphids were used in different experiments.

Seedling bulk test:

In this test, one row of each NUWYT-RF line was sown in metal tray measuring 51x35x9cm. There were eight rows in each tray created with wooden mould and 20 seeds of each entry were sown in a row. At seedling height 5.6-5.8 cm, approximately 50 nymphs of *S. graminum* were released on each line. Lodging started after infestation within about 10-15 days, damage rating was visually recorded within 0-9 damage rating (DR) scale. The entries were classified as highly resistant (HR) with DR 1, resistant (R) with DR 2-3, moderately resistance (MR) with DR of 4-6 and susceptible (S) with DR of 7-9 (Inayatullah *et al*.1993).

Antixenosis test:

In antixenosis test, the genotypes of NUWYT-RF were planted in a round pattern about 3cm from the edge of 30cm diameter plastic pots. At seedling height 5.6-5.8 cm, 50 aphids of *S. graminum*, were released on 3 cm diameter circular paper in the center of the pot. The seedlings were covered with plastic cages of 30 cm diameter having muslin cloth at the top of the cage. Muslin cloth covered ventilation holes on the sides of the cage and aphids were allowed to settle on that entry which they prefer. After 24 hours aphids settled on each entry were counted. After 48 hours and 72 hours reading were taken. The entries were categorized as highly preferred (HP), moderately preferred (MP) and least preferred (LP) having highest, moderate and least number of aphids respectively (Akhtar and Mujahid, 2006).

Antibiosis test:

Two seeds of NUWYT-RF entry were sown in soil mix of 7cm diameter pot. When seedlings attained height of 5.6-5.8 cm, one seedling of each variety was removed and one was retained. One mature aphid was released to each seedling pot covered with plastic cage (6 cm diameter: height 30 cm) and also covered with muslin cloth from top and both sides with ventilation holes. At start of reproduction on these seedlings, nymphs were removed except one, which was allowed to grow on test entries until it became mature and started reproduction. Numbers of nymphs reproduced daily were counted and then removed from each seedling, until mature female stopped reproduction and died. The entries were categorized as least fecundity (LF), moderately fecundity (MF) and highly fecundity (HF) having least, moderate and highest number of nymphs per seedling respectively. Data was collected for 10 days continuously (Akhtar and Mujahid, 2006).

Tolerance test:

In Tolerance test, two seeds of each variety of NUWYT-RF were sown in soil mix in 7cm diameter pot and repeated for five times. When seedling attained height of 5.6-5.8 cm, one seedling of each variety were removed and one was retained. Total 10 aphids of *S. graminum* were released to each seedling and pot was covered with plastic cage (6 cm diameter and height 30 cm) having muslin cloth on top with both side ventilation holes. Population of 10 aphids on each entry was maintained every day. After 10 days of release, data regarding damage was recovered visually with 0-9 rating scale (where 9 denotes for dead and 0 for healthy). The entries were classified as tolerant (T), least tolerant (LT), moderately tolerant (MT), and highly tolerant (HT) (Inayatullah *et al*.1993).

Results

Seedling bulk test of varieties NUWYT-RF showed that out of 23 varieties five genotypes AUR-0809, V-08314, NR-399, NR-400 and 9C037 were found resistant; following 13 genotypes V-11183, PR-104, DN-84, PR-105, NRL-0707, VO*BT022, DH-31, 10C033, 06FJS3013, AZRC-2, AUP-1052, AUP-1059 and PIRSABAK-05 were proved moderately resistance; five genotypes including NR-419, NR-420, NIA-MB-2, NR-403 and NARC-2009 were identified as susceptible (Table 1)

Results of antixenosis test showed that out of 23 NUWYT-RF wheat genotypes AZRC-2 and DN-84 with mean aphid population of 0.9 were the genotypes with least preferred (LP). Genotypes VO*BT022, AUP-1059, V11183, V08314, NARC-2009, PR-104, AUP-1052, NR-419, Pirsabak-05, NR-420, PR-105, 9C037, NIA-MB-2, NR-403, 10C033, DH-31, NR-399, AUR-0809, 06FJS3013 and NR-400 were under the category of moderately preferred genotypes with mean aphid population 1.2, 1.2, 1.3. 1.5, 1.5, 1.6, 1.7, 1.9, 1.9, 2.0, 2.1, 2.1, 2.1, 2.1, 2.3, 2.4, 2.5, 2.7, 2.7 and 3.1, respectively. Genotype NRL-0707 with mean aphid population of 3.6 was highly preferred (HP; Figure 1).

It is found in antibiosis test that out of 23 NUWYT-RF wheat genotypes, following genotypes viz. PR-104, PR-105, AUR-0809, AZRC-2, DN-84, 9C037, 10C033, NIA-MB-2, AUP-1052 AUP-1059, NRL-0707, VO*BT022, DH-31, NR-419, PIRSABAK-05, NARC-2009, NR-400, V-11183, V-08314, NR-420, NR-403 and NR-399 were observed as moderately preferred genotypes with mean aphid population of 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.1, 1.1, 1.1, 1.1, 1.1, 1.1, 0.9, 1.2, 1.2, 1.2, 1.0 and 1.5 respectively. In our experiment, these are the most suitable genotypes against *S. granimum*. On the other hand, most preferred genotype not suitable for our breeding programs against this pest is 06FJS3013 which was highly fecund with mean no. of nymphs laid 1.9. (Figure 2).

Results of tolerance test showed that genotypes AZRC-2, DN-84 and 9C037 were declared as tolerant (T) with mean damage rating of 3.7, 3.75 and 3.7; these were the genotypes with least number of aphid population and found most suitable genotypes against *S. graminum.* Moderately tolerant (MT) genotypes were PR-104, PR-105, NRL-0707, V-11183, V-08314, VO*BT022, NR-400, DH-31, 10C033, 06FJS3013, NR-399, NR-420, NR-403, PIRSABAK-05, NIA-MB-2, UP-1052 and NARC-2009. On the other hand, least tolerant (LT) genotypes, not suitable for our breeding programs against these pest were AUR-0809 with mean damage rating of 8.66, NR-419 with mean aphid population of 8.5, and AUP-1059 with mean aphid population of 8.15. (Figure 3).

Discussion

Mass screening technique is used for the evaluation of resistance against aphid at seedling stage (Smith, 2005). The resistance mechanism in plants has a strong impact on population and infestation of insect, specifically in phloem feeding insects (Puterka *et al*., 1992). So, it is very important to have knowledge about role of resistance. Many accessions of triticale, barley and wheat have been recognized having tolerance, antibiosis, antixenosis (Smith *et al*., 1992, Formusoh *et al*., 1992). Scientists have recognized numerous resistance genes from germplasm and were capable to transfer these genes into wheat genotypes to confer resistance against insect attack, leaf rust, stem rust, yellow rust and powdery mildew (Friebe *et al*., 1996).

Similar research reported by Akhtar *et al.* (2007) who tested NUWYT Rain Fed wheat lines and found three resistant (PR-87, NR -234 & NR-241), two susceptible (Chakwal-97 & V-002467) and seven moderately resistant lines against aphid attack in Seedling Bulk Test. In another study by Akhtar *et al*. (2006a) who screened out three rainfed lines of wheat (DN-18, MAW-1 & Faisalabad-85) least preferred in antixenosis. Total eight lines (Wafaq-2001, PR-77, NR 206, KT 2000, 97B2333 NR 192, 2KC050 & SN-7) were reported as preferred and five lines (NRL-9912, 98C0170, Bars1, V 00146 & V-6,) as highly preferred. In other studies Akhtar *et al.* (2006b) evaluated resistance by antixenosis of NUWYT (National Uniform Wheat Yield Trails) against greenbug (*Schizaphis graminum)* and showed that these genotypes V-5, 99B2460, MAW-I, and D-98627 were least preferred while genotypes PR-74, CT-00231 and V-99022 were highly preferred and 12 lines were moderately preferred. In seedling bulk test, out of 20 NUWYT wheat cultivars, 6 (TD-1, V-99022, 99-B-2237, PR-76, SKD-I, and MAW-I) were resistant, 12 cultivars evidenced to be moderately resistant and 2 genotypes 99B2460 and SN-122 were proved susceptible.

Junaid *et al*. (2016) conducted three different experiments (antixenosis, tolerance & antibiosis) using 10 cultivars of wheat to determine categories of resistance against *S. graminum*. During antixenosis, none of cultivar showed resistant while in tolerance MPT-V33 genotype showed significant result. In third experiment regarding antibiosis, tolerance was identified in MPT-V5 genotype; where greenbug took longer time 8.5 days to produce 31.3 nymphs as compared to the tested genotypes.

The results of current studies are in line with Yasmin & Begum (2008), Akhtar *et al.* (2009), Akhtar *et al.* (2013) and Zeb *et al*. (2015), who screened the wheat varieties in the same way and selected the tolerant varieties. Wheat aphid seasonal distribution on different genotype of wheat depends upon climate, host plant quality, agricultural practices and natural enemies (Brewer and Elliott, 2004). Morphological characters of plants such as plant height, growth stage, growth habit and leaf color of different wheat genotypes effects the seasonal dynamics of the aphids (Markova & Tomchev 2013).

Conclusion

It is concluded that wheat genotypes RF with high tolerance, high resistance, least preference and least fecundity proved to be effective against *Schizaphis graminum*. These data can be added to the wealth of information available about these lines, so that resistant wheat genotypes with worthy agronomic qualities and multiple pest resistance can be used in future wheat variety breeding and development programs.

Conflicts of interest

Authors have declared no conflict of interest.

Authors Contribution

TN and DQ conceived and designed the experiments. TN conducted the experiments. NHB and TN did data analysis. TN and HHI prepared the manuscript. DQ reviewed and edited the manuscript. DQ provided technical assistance for the study.

Funding

This research was supported by the National Key Research and Development Program of China (2017YFD0200900).

Acknowledgements

The authors are grateful to National Agricultural Research Centre (NARC) Islamabad, Pakistan for providing twenty three genotypes of National Uniform Wheat Yield Trails Rain Fed (NUWYT-RF). Authors are grateful to Mian Faisal Nazir for his support in designing the experiments.

Data Availability

The data used to support the findings of this study are included within the supplementary information file (Supplementary Data 1, 2, 3 and 4).

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Table 1: Damage caused by aphids in Seedling Bulk Test on Wheat Varieties of NUWYT-RF

Sr. No.	Genotypes	1st Damage Rating	2nd Damage Rating	Remarks
1	PR-104	4	5	MR
2	PR-105	3	4	MR
3	AUR-0809	3	3	R
4	AZRC-2	4	4	MR
5	NRL-0707	5	6	MR
6	DN-84	4	4	MR
7	VO*BT022	5	4	MR
8	V-11183	3	4	MR
9	V-08314	4	3	R
10	NR-399	3	3	R
11	NR-400	3	3	R
12	9C037	4	3	R
13	DH-31	3	4	MR
14	10C033	4	4	MR
15	06FJS3013	4	4	MR
16	NR-419	9	8	S
17	NR-420	9	9	S
18	NIA-MB-2	8	8	S
19	NR-403	8	7	S
20	AUP-1052	7	6	MR
21	AUP-1059	8	6	MR
22	PIRSABAK-05	7	6	MR
23	NARC-2009	8	7	S

Susceptible (S), Moderately Resistant (MR), Resistant (R)

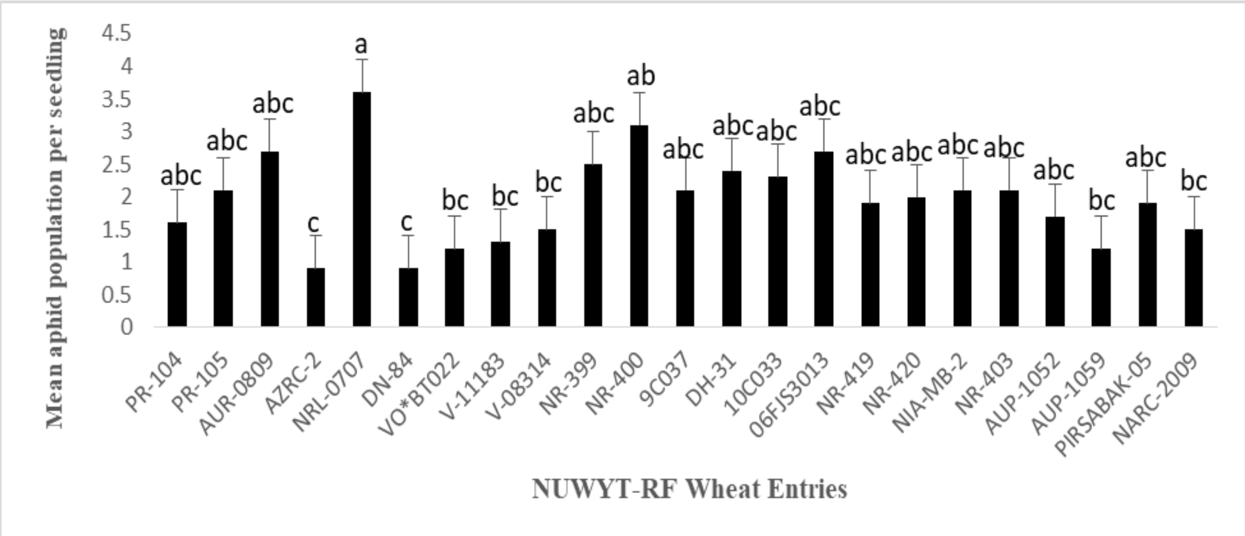

Figure 1: Antixenosis Data of NUWYT-RF against *S. gramanium*

Figure 2: Antibiosis Data of NUWYT-RF against *S. gramanium*

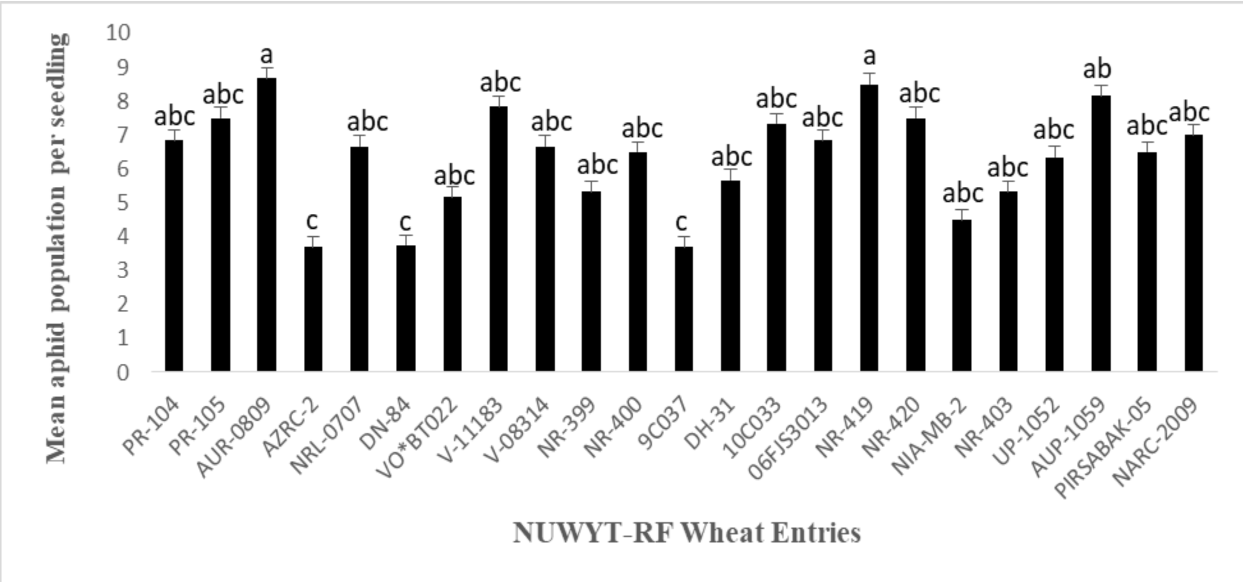

Figure 3: Tolerance Data of NUWYT-RF against *S. gramanium*