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Resistance of Nine Wheat Cultivars and Lines to Greenbug, *Schizaphis graminum* (Rondani) in Iran

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ABSTRACT

Greenbug, *Schizaphis graminum* (Rondani), is the main pest of wheat that can considerably limit profitable crop production, either through direct feeding or via transmission of plant pathogenic viruses. One of the most effective approaches of pest control is the use of resistant cultivars and lines. Based on the initial screening test of 35 wheat cultivars and lines, we selected five cultivars (Pishtaz, Omid, Yavaras, Akbari, and Bahar) and four lines (R1-10, R2-9, R3-16, and R3-17) with different levels of resistance to *S. graminum* for antixenosis and antibiosis experiments. In the antixenosis test, the number of *S. graminum* attracted on R1-10 was the lowest after 24, 48, and 72 hours. In life table study, *S. graminum* reared on Yavaras and R1-10 had the lower survival rate, fecundity, and reproductive period compared with other host plans tested. Values of the intrinsic rate of natural increase (r_m), finite rate of increase (λ), net Reproductive rate (R_0), and Doubling Time (DT) indicated lowest population growth of *S. graminum*, when fed on Yavaras (0.26 d^{-1}, 1.30 d^{-1}, 17.66 offspring and 2.62 days, respectively). Based on the antixenosis and antibiosis analyses in this study, we concluded that R1-10 and Yavaras were more resistant to *S. graminum*. These findings could be useful for integrated pest management of *S. graminum* in wheat fields.

Keywords: Antixenosis, Antibiosis, **cv.** Yavaras, Integrated pest management, Pest control.

INTRODUCTION

The greenbug, *Schizaphis graminum* (Rondani) (Hemiptera: Aphididae), is a serious pest of small grains; especially wheat, *Triticum aestivum* L. The greenbug damage host plant by feeding on plant sap directly and injecting toxic saliva into the plant, which disturbs chloroplast and plant cell walls and subsequently reduces photosynthesis (Yang *et al*., 2008; Najafi *et al*., 2013). This pest, at the low density (15 aphids per plant), can decrease grain weight up to 35-40% in winter wheat (Kieckhefer and Gellner, 1992). In addition, *S. graminum* is one of the most important aphid vectors of plant pathogenic viruses such as barley yellow dwarf virus and maize dwarf mosaic (Nault and Bradley, 1969; Du *et al*., 2007).

Today, there is a great emphasis on application of non-chemical methods together with selective pesticides in programs of integrated pest management because of injurious effects of chemical pesticides on the non-target organisms and the environment. One of the most environmentally safe and economically efficient ways to control the pests is utilization of resistant plant varieties (Papp and Mesterhazy, 1993; Arzani and Lapitan, 2007). Resistant cultivars could synergize the effects of pest-suppression strategies. The defense of resistant plants from insect pests functions at a very basic level, disturbing the normal relationship of the pest

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with its host plant (Teetes, 2007). However, how the host plants influence the insect is affected by the type of resistance, e.g. antixenosis (non-preference), antibiosis, or tolerance (Teetes, 2007). Antibiosis affects the biology of the insect; so, pest number and the consequent damage are diminished compared to that which would have happened, if the insect was on a sensitive crop variety. Antibiosis resistance frequently results in higher mortality or lowered longevity and reproduction of the insect (Painter, 1951; Kogan and Ortman, 1978; Teetes, 2007). The effect of host plant varieties on population growth characteristics of insects, especially aphids, have been studied by a lot of researchers (Webster *et al.*, 1987; Thackray *et al*., 1990; Ozder, 2002; Lage *et al*., 2004; Razmjou *et al*., 2011; Tofangsazi *et al*., 2011; Ahmadi and Safavi, 2013; Doryanizadeh *et al*., 2016; Tazerouni *et al*., 2016). Furthermore many studies have focused on the type and level of resistance to greenbug in wheat varieties. For example, some research regarded reproductive and developmental rates of two greenbug biotypes in relation to two wheat host resistance genes on four wheat genotypes (Lazar *et al.*, 1995), resistance modalities including antixenosis, antibiosis and tolerance of different wheat varieties, against *S. graminum* (Castro *et al.*, 1998; Akhtar and Mujahid, 2006; Mojahed *et al.* 2012), and the demographic characterization of *S. graminum* on different wheat cultivars and lines (La Rossa *et al.*, 2002; Najafi *et al.* 2013; Mojahed *et al.* 2013). Secondary plant chemicals could play an important role in chemical defense against pests. Among these, phenolic compounds are one of the most key resistance factors of plants, causing unfavorable effects on insect growth and feeding behavior (Cipollini *et al*., 2008; Wójcicka, 2010).

Resistant wheat cultivars could minimize initial infestation of *S. graminum* or limit its population growth and in result be effective in reducing insecticide use. The present study was designed to compare the antixenosis and antibiosis of the wheat cultivars and lines, chosen by an initial screening test, to *S. graminum* under controlled conditions. Besides, we aimed to survey the attraction preference of *S. graminum* in a free-choice test, and also to determine the life table parameters of this aphid on wheat cultivars and lines in no-choice test.

MATERIALS AND METHODS

Plant and Insects Culture

This research was conducted in the greenhouse and a laboratory of plant protection department, Faculty of Agriculture, University of Shahid Bahonar, Kerman, Iran. We used 17 wheat cultivars and 18 wheat lines in this study. The seeds of tested plants were obtained from Agricultural Research, Education, and Natural Resources Center of Kerman, Iran, and were planted for breeding of aphid colony and conducting the experiments. The plants were reared in greenhouse conditions (25-35˚C, 65±10% RH and under the natural light) and then were kept in a laboratory condition (growth chamber) with 25±1˚C, 60±5% RH and photoperiod of 16:8 hours (L:D). The aphids used in this investigation were acquired from the aphid colony reared in the laboratory of Institute of Environmental Sciences, Hi-tech University of Kerman, Iran. The aphids originally were collected from alfalfa fields of Baft region, Kerman province, in September 2015. To establish a colony of *S. graminum*, nymphs and adults of aphids were transferred to the potted wheat plants (cv. Mahdavi) in the above-mentioned conditions. To maintain a suitable aphid colony, some greenbugs were transferred from infested plants to new young plants every week. After rearing the aphid for several generations on the wheat plant, adult apterous aphids were used in the experiments. At first, we carried out a screening test based on the mean number of aphids per plant (14 days after infestation) and, therefore, nine wheat cultivars and

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lines, namely, Yavaras, Bahar, Akbari, Omid, Pishtaz, R2-9, R3-17, R3-16, and R1-10 were selected for further investigations (antixenosis and antibiosis tests).

Antixenosis Test

The antixenosis test was conducted in a growth chamber (25±1°C, 60±5% RH, and 16 L:8 D using a completely randomized design. Seeds of nine wheat cultivars and lines tested were randomly planted in a circle into trays filled with a mixture of soil, sand, and manure (2:1:1). At two-leaf stage of plants, 150 apterous viviparous adults were released at the same time in the center of each tray (held by a transparent plastic cage). The number of aphid attracted on each wheat cultivar and line was counted after 24, 48, and 72 hours. This experiment was carried out in 10 replicates for every three times.

Antibiosis Test

Prior to the antibiosis test, two adult apterous aphids were randomly selected from the stock culture and then were placed on the leaf of each plant of wheat cultivars and lines studied. Each plant was covered with cylindrical plastic cage (6 cm in diameter and 30 cm in height) to prevent parasitism and escape of aphids. A suitable hair brush was used for transferring aphids on the tested wheat lines and cultivars. After 24 hours, aphid mother and all nymphs, except one nymph, were deleted. Therefore, fifty nymphs were provided for each wheat cultivar and line in the beginning of the experiment. These nymphs were individually placed in plant cages. Each cage was monitored daily until the maturity of the nymph to determine nymphal developmental time and survival rate of *S. graminum* on nine wheat cultivars and lines. After maturity of the aphids, regular observations were continued for 20 cages of each cultivar and line. The number of producing nymphs per aphid were documented and then removed regularly until the death of the last greenbug. The obtained data from this experiment was used for assessing the life table parameters by Carey's formula (Carey, 1993).

Determination of Total Phenolic

The amount of phenolic compounds in leaves of wheat cultivars and lines was measured based on Ronald and Lamia (1999). A 0.1 mg sample of leaf was milled in 95% ethanol and permitted to extract for 24-72 hours. Thereafter, to 1 mL of the sample, 1.5 mL of 95% ethanol was added and made up to a volume of 5 mL with distilled water. To this mixture, 0.5 mL of 50% Folin's reagent and 1 mL of 5% sodium carbonate was added and vortexed. The mixture was kept in the dark for 1 hour. Then, the absorbance was measured at 725 nm using a spectrophotometer (Ronald and Lamia, 1999).

Statistical Analysis

Data were assessed for normality with the Kolmogorov-Smirnov test. Variables were evaluated using the one-way analysis of variance in SPSS version 22.0 (SPSS, 2016). The Jackknife technique was used for estimating the variance of the life table parameters (Maia *et al*., 2000). The comparison of differences between treatments means was done using Tukey's test ($P< 0.05$).

RESULTS

Screening Test

Screening test indicated that the mean number of aphids per plant (14 days after infestation) was significantly different between the 35 wheat cultivars and lines ($F= 5.55$; df= 34, 105; $P< 0.001$). The

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dendrogram of tested host plants is shown in Figure 1. These cultivars and lines were divided into two groups and three subgroups: the highest average number of greenbug was in subgroup B (Kavir, Marvdasht, Rasul, Pishtaz, Ghods, R3-21 and MV-17) and the lowest in subgroup A (Atrak, Chamran, Yavaras, Nicknejad, Roshan, R1-3, R1-10, R1-16, R1-20, R2-1 and R3-16). Wheat cultivars and lines in subgroup C had intermediate status. However, the number of aphids generated on Omid, Akbari, Bahar, Alvand, R0-6 and R3-1 were lower compared with Mahdavi, Sabalan, Alamut, Azar and R2-9, R2-3, R2-19, R2-23, R3-2, R2-5, and R3-17 (Figure 1).

Antixenosis Test

There were significant differences in the number of aphids attracted to the nine wheat cultivars and lines 24, 48, and 72 hours after the release (Table 1). After 24 hours, the number of aphids found on R1-10, R3-16 and Yavaras was significantly lower than on Pishtaz, but did not differ in comparison with other wheat cultivars and lines (F= 4.65; df= 8, 81; P< 0.001; Table 1). After 48 hours, the lowest and highest number of aphids were recorded on R1-10 and Pishtaz, respectively (F= 5.54; df= 8, 81; P< 0.001; Table 1). After 72 hours, the number of aphids on R1-10 and R3-16 were significantly lower than those on Pishtaz, R2-9 and R3-17. Furthermore, fewer aphids were attracted to Yavaras compared with R2-9 and Pishtaz. In the third period, the number of aphids on Bahar, Akbari and Omid did not differ significantly from other cultivars and lines tested (F= 7.52; df= 8, 81; P< 0.001; Table 1).

Antibiosis Test

Wheat cultivars and lines had a significant effect on nymphal development time of *S. graminum* (F= 7.69; df= 8, 363; P< 0.001; Table 2). The nymph periods on Yavaras, Bahar, Akbari and R3-17 were significantly longer than on Pishtaz and R2-9. This developmental time on R1-10 was lower than on Pishtaz, but did not differ significantly in comparison with R2-9. Furthermore, nymph period on Omid and R3-16 did not vary significantly compared with the other tested wheat cultivars and lines (Table 2). There was a significant difference in nymphal survival rates among nine wheat lines and cultivars. The nymphal survival rate was lowest on Yavaras and R1-10 and highest on Pishtaz (F= 9.27; df= 8, 81; P< 0.001; Figure 2).

Based on the results, wheat cultivars and lines had significant effects on the longevity and reproductive period of greenbug (F= 18.49; df= 8, 171; P< 0.001 and F= 19.99; df= 8, 171; P< 0.001, respectively) (Table 2). The shortest reproductive period was on Yavaras and R1-10 and the highest on Pishtaz cultivar (Table 2). The lowest number of nymph produced per female was observed on Yavaras and R1-10, but was not significantly different compared with R3-16. The highest fecundity of the greenbug was calculated on Pishtaz and R3-17, which did not show significant differences compared with Omid and R2-9 (F= 19.26; df= 8, 171; P< 0.001; Table 2).

In this study, the intrinsic rate of natural increase of *S. graminum* was lowest on Yavaras (0.26 d^{-1}) and highest on Pishtaz and R2-9 (0.34 d^{-1}) (F= 10.35; df= 8, 171; P< 0.001; Table 3). The least net Reproductive rate (R_0) of this aphid was significantly the lowest on Yavaras, R1-10, R3-16 and the greatest value of this parameter was on Pishtaz (F= 27.89; df= 8, 171; P< 0.001; Table 3). Also, the lowest and highest values of finite rate of increase (λ) were recorded on Yavaras (1.298 d^{-1}) and Pishtaz (1.413 d^{-1}), respectively (F= 10.80; df= 8, 171; P< 0.001; Table 3). The generation Time (T) of greenbug on R1-10 and R3-16 was significantly lower than on Bahar, Omid and R3-17 (F= 5.11; df= 8, 171; P< 0.001; Table 3). *T* values on Yavaras, Akbari, Pishtaz and R2-9 did not

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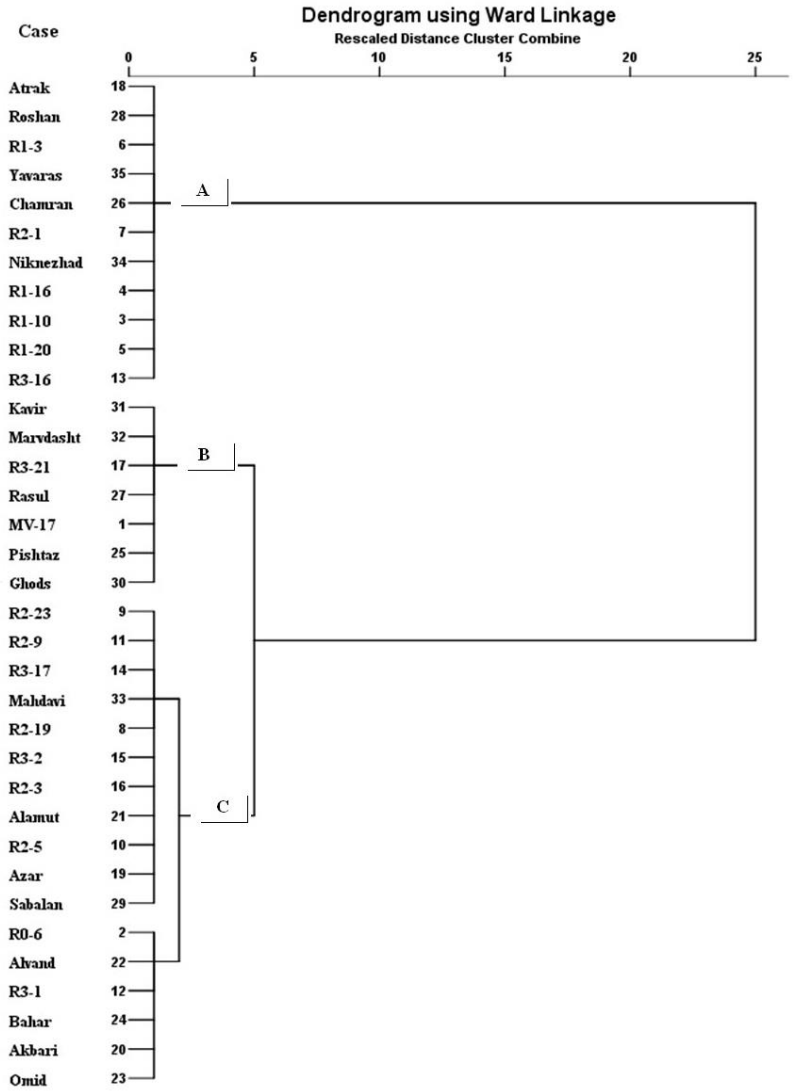

Figure 1. Dendrogram of 17 wheat cultivars and 18 lines infested to *S. graminum* (after 14 days) using Wards method.

Table 1. Mean (±SE) of attracted *S. graminum* on nine wheat cultivars and lines after 24, 48, and 72 hours.

Wheat cultivars and lines	Number of aphid per plant [a]		
	24 h	48 h	72 h
Yavaras	4.25±0.25b	10.25±0.75bc	11.5±2.87bc
R1-10	3.75±0.48b	4.50±1.89c	4.25±0.95c
R3-16	4.00±0.71b	6.75±0.48bc	6.00±0.91c
Bahar	8.50±0.50ab	12.75±1.03abc	15.25±1.18abc
Akbari	11.75±1.81ab	13.50±0.87abc	13.75±2.02abc
Omid	9.00±0.71ab	13.50±1.50abc	16.50±2.59abc
R3-17	12.50±2.59ab	16.25±4.01ab	19.50±5.48ab
R2-9	14.00±3.03ab	18.00±1.78ab	24.75±0.85a
Pishtaz	16.50±4.86a	22.75±4.80a	24.25±2.98a

[a] Means followed by a different letter within a column are significantly different (Tukey's test; $P \leq 0.05$).

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Table 2. Mean (±SE) nymph developmental time, adult longevity and fecundity of *S. graminum* on nine wheat cultivars and lines under laboratory conditions.[a]

Wheat cultivar and lines	Nymph developmental time (d)	Longevity (d)	Reproductive period (d)	Numbers of progeny
Yavaras	6.55± 0.24 (33) a [,b]	15.50 ± 0.98 (20) cd	11.15 ± 0.96 (20) d	22.60 ±2.48 (20) d
R1-10	6.23± 0.12 (35) ab	12.75 ±0.81(20) d	8.70 ± 1.79 (20) d	21.25 ± 2.84(20) d
R3-16	6.10± 0.09 (39) abc	15.30 ±0.92 (20) cd	11.70 ± 1.02 (20) cd	23.60 ±3.10(20) cd
Bahar	6.60± 0.16 (45) a	21.40 ±2.07 (20) bc	17.60 ± 2.11(20) bc	37.25 ±4.06(20) bc
Akbari	6.51± 0.16 (43) a	23.50 ±1.90 (20) ab	18.60 ±1.98 (20) b	39.10 ±3.76 (20) b
Omid	6.17± 0.11 (42) abc	26.25 ± 1.27 (20) ab	23.10 ± 1.20 (20) ab	47.85 ± 2.46(20) ab
R3-17	6.23± 0.13 (44) ab	26.75 ± 1.14(20) ab	22.90 ± 1.23 (20) ab	57.40 ± 3.65(20) a
R2-9	5.62± 0.09 (45) bc	24.90 ±1.83 (20) ab	21.10 ± 1.76 (20) ab	44.65 ±3.85(20) ab
Pishtaz	5.57± 0.13 (46) c	29.50 ±0.64 (20) a	26.90 ± 0.80 (20) a	57.35 ± 2.32(20) a

[a] Means followed by a different letter within a column are significantly different (Tukey's test; P≤ 0.05). [b] Numbers in parentheses indicate the number sampled.

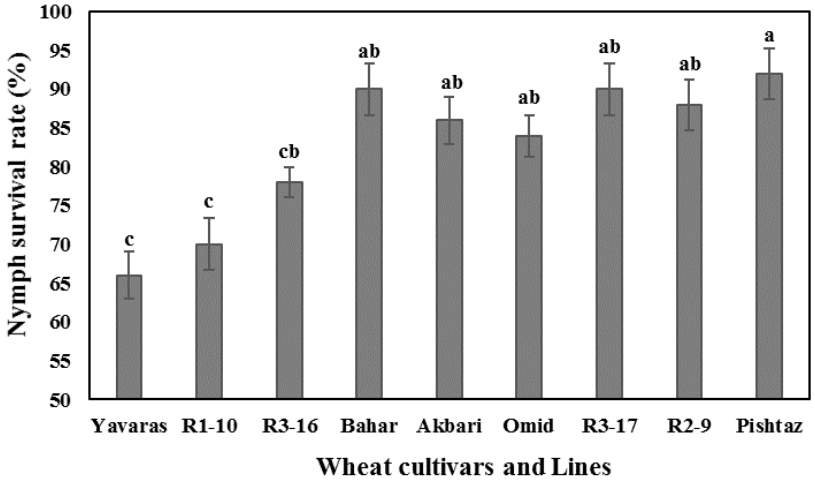

Figure 2. Nymph survival rate of *S. graminum* on nine wheat cultivars and lines (Tukey's test; P≤ 0. 05, n= 10).

differ significantly in comparison with the other tested wheat cultivars and lines (Table 3). The lowest and highest values of Doubling Time (DT) were recorded on Yavaras and Pishtaz, respectively (F= 6.98; df= 8, 171; P< 0.001; Table 3).

Total Phenolic

The amount of phenolic compounds varied significantly among different wheat cultivars and lines (F= 3.68; df= 8, 27; P= 0.005; Table 4). The levels of total phenolic were highest on Yavaras (0.56 mg g^{-1} FW) and R1-10 (0.54 mg g^{-1} FW), and lowest on R2-9 (0.08 mg g-^{1} FW).

DISCUSSION

The results of the initial screening test demonstrated the population density of *S. graminum* could be influenced by different wheat cultivars and lines. Screening to classify aphid-resistant varieties through

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Table 3. Mean (±SE) life table parameters of *S. graminum* on nine wheat cultivars and lines under laboratory conditions.[a]

Wheat cultivar and lines	Sample size (n)	Life table parameters (Mean±SD)[b]				
		R_0 (Female offspring)	r_m (d^{-1})	λ (d^{-1})	T (d)	DT (d)
Yavaras	20	17.66 ± 1.58 d	0.262 ± 0.009 d	1.299 ± 0.012 e	11.02 ±0.39 ab	2.62 ±0.11 a
R1-10	20	17.35 ± 1.97 d	0.276 ± 0.009 cd	1.317 ± 0.012 de	10.43 ± 0.34 b	2.50 ± 0.09 ab
R3-16	20	20.42 ± 2.41 d	0.291 ± 0.009 bcd	1.338 ± 0.013 cde	10.42 ± 0.30 b	2.37 ± 0.09 abc
Bahar	20	35.36 ± 3.58 c	0.293 ± 0.009 bcd	1.341 ± 0.012 cde	12.16 ± 0.42 a	2.36 ± 0.08 abc
Akbari	20	35.79 ± 3.22 c	0.301 ± 0.012 bc	1.351 ± 0.016 cd	11.90 ± 0.53 ab	2.30 ± 0.10 abcd
Omid	20	43.88 ± 2.31 abc	0.309 ± 0.008 abc	1.362 ± 0.010 bcd	12.23 ± 0.37 a	2.24± 0.06 bcd
R3-17	20	53.09 ± 3.20 ab	0.317 ± 0.006 ab	1.372 ± 0.008 abc	12.55 ± 0.25 a	2.19 ± 0.04 bcd
R2-9	20	42.44 ± 3.44 bc	0.340 ± 0.007 a	1.405 ± 0.009 ab	11.04 ± 0.20 ab	2.04 ± 0.04 cd
Pishtaz	20	54.66 ± 2.15 a	0.346 ± 0.007 a	1.413 ± 0.010 a	11.57 ± 0.19 ab	2.00 ± 0.04 d

[a] Means followed by a different letter within a column are significantly different (Tukey's test; P≤ 0.05), [b] R_0= Net Reproductive rate; r_m= Intrinsic rate of increase; λ= Finite rate of increase; T= Mean generation Time, and DT= Doubling Time.

Table 4. Mean (±SE) of total phenol in leaves of nine wheat cultivars and lines.[a]

Wheat cultivars and lines	Total phenol (mg g^{-1} fresh weight)
Yavaras	0.56±0.16a
R1-10	0.54±0.05a
R3-16	0.39±0.04ab
Bahar	0.25±0.11ab
Akbari	0.12±0.07ab
Omid	0.31±0.11ab
R3-17	0.12±0.10ab
R2-9	0.08±0.06b
Pishtaz	0.35±0.07ab

[a] Means followed by a different letter within a column are significantly different (Tukey's test; P≤ 0.05).

artificial infection of plants by aphids in the greenhouse or laboratory is essential (Porter *et al*., 1993; Tolamy *et al*., 1999). Based on screening test, cultivars and lines in subgroup A, with the lower population density of greenbug, were more resistant, and those in subgroup B, with the higher population, were more susceptible. The low population of *S. graminum* in subgroup A, especially on Yavaras, R1-10, and R3-16 among all test cases in current research could result in less pest damage. The differences in population density of greenbug among wheat cultivars and lines could be attributed to nutritional contents and biochemical compounds. Akhtar *et al.* (2006) studied the categories of resistance of 20 wheat cultivars against *S. graminum* and introduced MAW-I, BARS-I, Kt-2000 and Faisalabad as resistant varieties. Significant differences in the average number of aphids on various wheat genotypes based on the screening method have also been reported in some previous studies (Razmjou *et al*., 2011; Mojahed *et al*., 2013). The content of secondary compounds in wheat genotypes used in screening test has not been determined. In this research, lines and cultivars tested for antixenosis and antibiosis experiments were selected from each

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subgroup with different resistance levels. Also, those were chosen based on more current cultivation in Kerman.

Our results from antixenosis experiment showed the influence of wheat cultivars and lines tested on the host preference of *S. graminum*; as Pishtaz characterized weak antixenosis (more preferred host plant), whereas R1-10 displayed strong antixenosis (less preferred host plant) after 24, 48, and 72 hours. The difference in the number of aphids attracted can be due to variations in chemical compounds, olfactory, and tactile stimuli in host plants. Antixenosis may be important solely, and it can demonstrate to be complementary for the antibiosis method by diminish selection on resistance-breaking biotypes of the aphid, thereby extending the efficiency of plant resistance as a non-chemical way of pest management (Hesler and Dashiell, 2011). Earlier reports suggested that differences in antixenosis resistance can vary among different plant species and cultivars (Castro *et al*., 1998; Akhtar *et al*., 2006).

Our results of antibiosis test clearly indicated that wheat cultivars and lines influenced biological parameters such as developmental time and survival rate as well as reproduction of *S. graminum*. There are several reports about the effects of various host plants on these biological characteristics of aphids (Razmjou *et al*., 2011; Mojahed *et al*., 2013). Najafi *et al*. (2013) reported that *S. graminum* nymphs completed their development on different wheat lines in 6-7 days, which was a greater period than our finding on Pishtaz cultivar (5.57 days) and R2-9 line (5.62 days). That could be attributed to the difference in chemical properties and nutrition qualities of host plants. Actually, nymphal feeding on cultivars with poor nutrient quality could increase the development period. Furthermore, our surveys showed that survival rate, total fecundity, and reproductive period of *S. graminum* were lower on Yavaras and R1-10 than on other host plans tested, indicating their minor suitability compared to the others. Both of these host plants in our study had higher levels of phenolic compounds that led to reduced fecundity. Lazar *et al.* (1995) showed the nymphal development time of biotypes C greenbug, *S. graminum*, lasted 5.37 and 6.73 days when reared on TAM105 and TAM107 winter wheat cultivars, respectively. La Rossa *et al.* (2002) studied biological parameters of *S. graminum* on different wheat cultivars at 20±1°C and reported that nymphal period of this aphid was longer (8.9-9.5 days) on A Baguette Premium 11 and BioInta 2004 cultivars, whereas it was shorter (5.42-5.66 days) on Colibri and BioInta 1002 cultivars. The differences between various studies could be attributed to thermal condition, aphid biotype, and genotype of host plants. In our research, values of fecundity significantly ranged from 21.3 -57.40 nymphs among nine cultivars and lines. Lazar *et al.* (1995) also found significant differences in number of nymphs produced per adult (19.74 and 72.60 nymphs) for biotype C greenbugs and (53.46 and 64.02 nymphs) for biotype E greenbugs when fed on wheat genotypes TAM105 and TAM107, respectively. Values of fecundity on Yavaras (22.6 nymphs) and R1-10 (21.3 nymphs) in the present study were consistent with value of fecundity measured (21 nymphs) for *S. graminum* on Timstein cultivar (Castro *et al.*, 1998). However, in our study, fecundity on these plants was usually lower than what has been reported previously on wheat cultivars or lines. For example, in similar thermal condition, greenbug females reproduced 33.9-64.4 nymphs on different wheat lines (Najafi *et al*., 2013). In another study, fecundity of *S. graminum* females was altered from 47.6 nymphs on ERWYT 87-16 line to 66.0 nymphs on Kouhdasht cultivar in the same condition (Mojahed *et al*., 2013). These differences between various studies could be because of diverse host plants containing different chemical profiles. Furthermore, aphid biotype and rearing conditions could influence number of nymphs produced per *S. graminum* adult.

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The growth population parameters, particularly intrinsic rate of natural increase (r_m), are appropriate indexes to compare the effects of different host plants on pest performance. Some researchers recommended the distinction effects of wheat varieties on the performance of aphids (Lage *et al*., 2004; Hesler and Tharp, 2005; Razmjou *et al*., 2011; Mojahed *et al*., 2013), which were similar to our finding. In the present study, significant differences were found in the r_m values of *S. graminum* on tested wheat cultivars and lines (0.26 and 0.35 d^{-1} when reared on Yavaras and Pishtaz, respectively). Lazar *et al.* (1995) reported the intrinsic rate of increase of biotype C greenbugs was significantly different (0.113 and 0.244 d^{-1}) when reared on wheat genotypes TAM105 and TAM107 (resistant and susceptible, respectively). La Rossa *et al.* (2002) investigated demographic parameters of *S. graminum* on different wheat cultivars and found the intrinsic rate of increase (r_m) was significantly higher on Colibri cultivar (0.279 d^{-1}). In another study, there were significant differences in antibiotic resistance calculated in terms of the intrinsic rate of population increase of *S. graminum* among collection of 26 wheat cultivars (Castro *et al.,* 1998). Values of this parameter in their research were lower on Dwarf A (0.317 d^{-1}), Probus (0.326 d^{-1}), and Sava (0.338 d^{-1}). The quality of host plant, applying different methodology and geographic populations of *S. graminum* could be cited as various reasons for the difference in the growth population parameters measured in different studies. Our data demonstrated that the population growth of this aphid on Yavaras was limited mostly by the lower survival rate, longer developmental time of the nymphal stage, and poor fecundity. In addition, the faster developmental time of nymph stage on Pishtaz resulted in a higher fecundity and population increase.

The resistance of different plant cultivars to aphids could be likely due to differences in amounts of phagostimulant compounds, nutritional quality, and defensive metabolites (van Emden *et al*., 1969; Cole, 1997). Secondary compounds and certain phytochemicals, such as DIMBOA, are involved in the resistance levels of wheat to aphids via feeding avoidance and antibiosis (Thackray *et al*., 1990; Gianoli *et al*., 1996). Phenolics are biologically effective secondary metabolites, causing negative effects on development, reproduction, and growth population parameters of the aphids (Wójcicka, 2010). In our study, Yavaras and R1-10 cultivars with the high levels of phenolic compounds were more resistant to greenbug. Furthermore, negative associations between phenolic compounds present in plant species and aphid's invasion have been recorded for *S. graminum* and other aphid species such as *Diuraphis noxia* and *Metoplophium dirhodum* (Havlíčková, 1995; Sandström *et al*., 2000). Wójcicka (2010) suggested that the amount of phenolic compounds could play a significant role in the resistance of winter triticale hybrids to bird cherry-oat aphid *Rhopalosiphum padi* (L.) and grain aphid *Sitobion avenae* (F.). In the triticale plants, the *o*-dihydroxyphenols even at low concentration showed a negative influence on aphids (Todd *et al*., 1971; Wójcicka, 2010). Cichocka *et al*. (1999) showed the acceptance of broad bean cultivars for *Aphis fabae* was negatively associated with phenolic compound concentrations. Also, flavonoids are found to be effective in plant resistance to herbivores (Bennett *et al*., 1994; Wu *et al*., 2007). Aphid-resistant lines of cow pea had higher amounts of flavanoids, including kaempferol, in comparison with susceptible lines (Lattanzio *et al.,* 2000). Additionally, wheat varieties containing high concentration of Hydroxamic acids are relatively resistant to aphid's invasion (Bohidar *et al*., 1986; Givovich and Niemeyer, 1995). The most abundant hydroxamic acid in wheat plants is DIMBOA (Niemeyer and Perez, 1995). The level of this substance in plants is associated to allelopathic effects of cereals and the resistance to insects (Copaja *et al*., 1991).

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We didn't survey the variation in these compounds among wheat lines and cultivars tested. Further research is needed to conclude if these compounds can interfere in the resistance differences of the test cases to greenbug.

CONCLUSIONS

We concluded that Yavaras and R1-10 were less suitable, whereas Pishtaz and R2-9 were more suitable host plants for greenbug. Therefore, poor performance of *S. graminum* on Yavaras and R1-10 indicated relative resistance of these host plants to this aphid. This study could be useful in breeding programs for cereal aphid resistance and improving the efficiency of integrated greenbug management in wheat production.

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مقاومت نه رقم و لاین گندم به شته سبز گندم، *Schizaphis graminum* (Rondani) در ایران

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چکیده

شته‌ی سبزگندم، *Schizaphis graminum* (Rondani) یکی از آفات مهم گندم می‌باشد که می‌تواند به‌طور قابل ملاحظه‌ای تولید سودآور محصول را از طریق تغذیه مستقیم یا انتقال ویروس‌های بیماریزای گیاهی محدود کند. یکی از موثرترین روش‌های کنترل این آفت استفاده از ارقام و لاین‌های مقاوم است. در این پژوهش بر اساس آزمایش غربالگری اولیه ۳۵ رقم و لاین گندم، پنج رقم (Pishtaz، Omid، Yavaras، Akbari و Bahar) و چهار لاین (R1-10، R2-9، R3-16 و

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R3-17) با سطوح مختلف مقاومت به *S. graminum* برای آزمایش‌های آنتی زنوز و آنتی بیوز انتخاب شدند. در آزمایش آنتی زنوز، کمترین تعداد شته‌های جلب شده پس از ۲۴، ۴۸ و ۷۲ ساعت روی R1-10 مشاهده شد. در مطالعه جدول زندگی، *S. graminum* پرورش یافته روی Yavarasو R1-10 دارای نرخ بقا، باروری و دوره تولیدمثل کمتری در مقایسه با دیگر گیاهان میزبان مورد مطالعه بود. مقادیر نرخ ذاتی افزایش جمعیت (r_m)، نرخ متناهی افزایش جمعیت (λ)، نرخ خالص تولید مثل (R_0) و مدت زمان لازم برای دوبرابر شدن جمعیت (DT) نشان داد کمترین رشد جمعیت آفت با تغذیه از رقم Yavaras می‌باشد. دراین مطالعه بر اساس نتایج آنتی زنوز و آنتی بیوز، R1-10 و Yavaras به شته سبز گندم مقاوم‌تر بودند. این یافته‌ها می‌تواند در مدیریت تلفیقی *S. graminum* در مزارع گندم مفید باشد.

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