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COMPONENTS OF RESISTANCE TO RUSSIAN WHEAT APHID, *DIURAPHIS NOXIA* (KURDJUMOV) (HOMOPTERA:APHIDIDAE) IN SMALL GRAINS IN FARS PROVINCE[1]

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ABSTRACT

Evaluations were made in the greenhouse to determine the components of resistance in four wheat cultivars, "Adl", "Azadi", "Bayat" and "Ghods", and in one 6-rowed barley and one 2-rowed local barley to populations of Russian wheat aphid (RWA), *Diuraphis noxia* (Kurdjumov). Nymphal production and the number of adult aphids per plant were lower on "Bayat" than on the others. Furthermore, this cultivar demonstrated the most resistance to the aphid followed by "Azadi". "Azadi" was the most tolerant of all cultivars, although seedling height was affected more in this cultivar than in others. A field evaluation also showed that *Triticum monococcum* L. was more tolerant than 21 other wheat cultivars. In the present study, only two barley cultivars showed an intermediate reaction to RWA and five others proved to be susceptible to the RWA. No tolerance to the aphid was observed in 11 triticale and two rye cultivars. They showed typical visible damage symptoms caused by RWA. Oat showed tolerance to aphid feeding and only a few RWAs were found at the base of the rolled leaves.

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اجزاء تشکیل دهنده مقاومت به شته روسی گندم *Diuraphis noxia* (Kurdjumov) (Homoptera:Aphididae) در غلات استان فارس

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به ترتیب دانشجوی سابق کارشناسی ارشد و دانشیار حشره‌شناسی بخش گیاهپزشکی دانشکده کشاورزی دانشگاه شیراز، شیراز، ایران.

چکیده

اجزاء مقاومت چهار رقم گندم «عدل»، «آزادی»، «بیات» و «قدس» و دو رقم جو «شش پر» و «دوپر» به جمعیتهائی از شته روسی گندم *Diuraphis noxia* (Kurdjumov) در شرایط گلخانه مورد ارزیابی قرار گرفت. تولید پوره و تعداد شته‌های کامل در رقم بیات از دیگر ارقام کمتر بود. بعلاوه این رقم و پس از آن «آزادی» بیشترین مقاومت به شته را از خود نشان دادند. رقم آزادی در مقابل شته بیشترین تحمل را داشت هرچند که ارتفاع بوته در این رقم بیشتر از سایر ارقام تحت تأثیر قرار گرفت. آزمایش مزرعه‌ای نشان داد که گونه *Triticum monococcum* L. از ۲۱ رقم دیگر گندم متحمل تر می‌باشد. همچنین از هفت رقم جو، دو رقم حساسیت متوسط از خود نشان داده و پنج رقم دیگر به شته روسی گندم حساس بودند. در بین ۱۱ رقم تریتیکاله و دو رقم چاودار، تحمل مشاهده نشد و علائم مشخصه خسارت شته روسی گندم در آنها ملاحظه گردید. یولاف نسبت به تغذیه شته تحمل نشان داد و تنها تعداد کمی شته در پایه برگهای لوله شده آن مشاهده گردید.

INTRODUCTION

The Russian wheat aphid (RWA), *Diuraphis noxia* (Kurdjumov), a serious small grain pest in different parts of the world, was first reported in Iran by Davatchi (7). It injects a powerful toxin into the plant tissues which destroys the chlorophyll and severely inhibits the plant ability to produce carbohydrates (25,28). Leaf rolling, awn trapping, and white, yellow or purple streakings are other visible damage symptoms caused by RWA.

Resistance to insects is an inheritable property that enables plants to inhibit pest growth or to recover from injury caused by populations whose growth was not inhibited (18). Development of resistant cultivars will help cereal growers by saving the expense of insecticides, and the chemical hazards to the environment is likely avoided.

Several reports (10 ,25) have been published on recent detection of RWA-resistant cultivars and lines from Iran and the former USSR in the United States and South Africa. It is believed that the sources of RWA resistance in wheat from Iran and the former USSR are abundant (25), while resistance is not present in adapted cultivars (22). Smith *et al.* (25) identified five sources of resistance in wheat lines from Iran and the former USSR. Results from the evaluation by Harvey and Martin (13) also indicated that 37 of selected wheat accessions which are considered to be resistant to RWA were from Iran, the former USSR, and Afghanistan. Butts and Pakendorf (5) demonstrated that potential RWA resistance exists in the ancestral wheat species *Triticum monococcum* L., *T. timopheevi* (Zhuk.), *T. dicoccoides* Korn, and *Aegilops squarrosa* L. Many other wheat lines, cultivars, or varieties with varying levels of resistance to RWA have been reported by others (8,9,20,33). Reports from the USA (3) and the Ukraine

(12) indicate that barley (*Hordeum vulgare* L.) is actually damaged to a greater extent than wheat.

Mechanisms of resistance, including antibiosis, tolerance and nonpreference (21) or antixenosis (19) were assessed in four barley genotypes by Robinson *et al.* (23). They found that two genotypes were resistant to RWA. Webster *et al.* (32) in their resistance studies on 524 barley lines found various levels of antibiosis and tolerance in 9 barley lines including three from Iran. Clement and Lester (6) screened wild *Hordeum* species for resistance to RWA and observed that they are a rich source of RWA resistance genes. Investigation by Kindler and Springer (16) on wild *Hordeum* species also indicated that several accessions of *H. bulbosum* L. and an accession of *H. brevisubulatum* subsp., *violaceum* Boiss and Hohen had low leaf-curling ratings.

RWA-resistance studies on triticale (x *triticosecale* Wittmack), a cross between wheat and rye (*Secale cereale* L.), by Webster (30) and Scott *et al.* (24) led to identification of 7 and 11 resistant lines, respectively. Scott *et al.* (24), and Frank *et al.* (11) also concluded that sources of RWA-resistance exist in triticale. Rye is another small grain which is resistant to RWA (5). Nkongolo *et al.* (20) identified Imperial rye as resistant to RWA.

Based on the amount of feeding damage, two plant introductions of *Elytrigia repens* and the hybrids between *E. repens*, *E. spicata* and *E. stripifolia* have been identified to be resistant to RWA (17).

The objectives of the present study were to measure the degree of components of resistance in four local wheat and two local barley cultivars under greenhouse conditions and also the relative tolerance to RWA in 22 wheat, 6 barley, 11 triticale, 2 rye and one oat (*Avena sativa* L.) cultivars in the field.

MATERIALS AND METHODS

Four wheat cutivars (Azadi, Adl, Bayat, Ghods) and one 6-rowed and one 2-rowed local barley were obtained from the Plant Breeding Institute, Zargan (Shiraz). They were evaluated for their resistance to RWA. The RWA was obtained from colonies established from field collections made in Badjgah (Shiraz) in 1991 and maintained on a 2-rowed local barley using rearing procedure described for the greenbug, *Schizaphis graminum* Rondani (26). The temperature during the tests was 19-23°C (day) and 14-19°C (night) and the photoperiods were 14:10 (L:D). All plants received the same amount of fertilizer and water. The tests were arranged in randomized block designs. The data were analyzed by ANOVA and means were compared with Duncan's multiple range test at P=0.05 (2). Antibiosis, antixenosis, and tolerance of the cultivars were studied in the following tests:

Test 1. Antibiosis: Those adverse effects on the insect life history which result when the insect uses a resistant host for food were measured in the test plants. The procedure followed in the present study was similar to that described by Webster *et al.* (31) except that nymphal production was measured over a 21-day period rather than over the entire reproductive period of the aphid. Seeds were planted in pots (18.5 by 21.0 cm) in the greenhouse. After emergence, plants were thinned to one seedling per pot. Individual one leaf seedlings were infested with five apterous adult aphids from the laboratory culture using a moistened camel's hair brush. The plants were covered with plastic cages (13.5 by 16.0 cm) covered with a cloth on the top and side hole. The plants and aphids were observed daily. When reproduction began, the adults

were removed, leaving five nymphs on each plant. The nymphs were allowed to grow on test plants until they matured and began to reproduce. All aphids but one were then removed from the plants. Newly born nymphs were recorded and removed daily for a period of 21 days. Five replications per test plant were used.

Test 2. Antixenosis: The reaction of a plant to an insect trying to colonize it was evaluated in six test plants. The seeds were randomly planted in a circular pattern near the edge of a pot (13.5 cm diameter). When the plants were 5-8 cm tall, 42 adult apterous aphids (7 aphids per plant) were released on the soil in the center of the pot. Similar to the antibiosis test, the plants and aphids were then covered with plastic cages of the same size. After 48 h, when the aphids selected their hosts, the number of aphids on each plant was recorded. There were 20 replications (pots) in the test.

Test 3. Tolerance: The capacity of certain plant to repair injury or grow to produce an adequate yield despite supporting an insect population at a level capable of damaging a more susceptible host (19), was measured in six test plants. Seeds were separately planted in pots. Two days after emergence, one seedling was left in each pot, its height was recorded and was infested with 15 apterous adult aphids. Controls were left uninfested and their heights were recorded. The pots were caged and checked at 48 h intervals to remove or add aphids as needed to maintain 15 aphids per plant. Three weeks later, the infested plants were visually rated for damage. The following scale was used for rating:

Score	Damage Rating
< 1	no damage
1-3	resistant (R)
4-6	moderately resistant (MR) or moderately susceptible (MS)
7-9	susceptible (S)
> 9	dead or dying plant

Plant heights and the number of tillers and leaves were recorded for both infested and uninfested plants at the end of the test.

To obtain component indices (31), the data for each component were first normalized to a common scale by dividing each value by the highest value occurring for that resistance component. The equation 1/XYZ, where X=the antibiosis index, Y=the antixenosis index, and Z=the tolerance index (Ullah 1985, see 30), was followed for calculating a plant resistance index for each test plant.

In addition to the greenhouse studies, some observations were made in the field on 22 wheat, 6 barley, 11 triticale, two rye and one oat cultivars. All these cultivars had been planted under the same condition in the Badjgah Experiment Station. They were rated visually for their tolerance to RWA.

RESULTS

A. Greenhouse Test

Test 1. The lowest nymphal production (34.2) was observed on Bayat cultivar which showed a significant antibiosis to RWA compared

with 6-rowed and 2-rowed local barley, and Azadi cultivars (Table 1). The aphid reproduced most on the 6-rowed barley followed by the 2-rowed local barley. There was a significant difference between these two test plants. Significant differences were also obseved between the two barley cultivars and all wheat cultivars used in this test. Fewer nymphs were produced on "Ghods" and "Adl" cultivars than on "Azadi", although the difference was not significant. No significant differences were observed among the four wheat cultivars, except between "Azadi" and "Bayat".

Table 1. Antibiosis in four wheat and two barley cultivars to *D. noxia*.

Entry	Antibiosis (nymphs/adult†)
6-rowed barley	60.8a§
2-rowed local barley	52.4b
"Azadi" wheat	42.4c
"Ghods" wheat	40.0cd
"Adl" wheat	40.0cd
"Bayat" wheat	34.2d

† Means of five replications.

§ Means followed by the same letters are not significantly different (Duncan's multiple range test) at P=0.05.

Test 2. In this test, the number of adults per plant, 48 h after release, ranged from 4.0 on "Bayat" to 6.7 on "Azadi" (Table 2). RWA preferred "Azadi" to other cultivars. "Azadi" and "Ghods" were significantly different from "Bayat". The number of adults on the two barley cultivars were the same. No significant differences were observed between "Adl" and the two barley cultivars.

Table 2. Russian wheat aphid antixenosis in four wheat and two barley cultivars.

Entry	Average number of *D. Noxia* (adults/plant†)
"Azadi" wheat	6.70a§
"Ghods" wheat	6.50a
"Adl" wheat	5.10ab
6-rowed barley	5.10ab
2-rowed local barley	5.05ab
"Bayat" wheat	4.00b

† Means of 20 replications.

§ Means followed by the same letters are not significantly different (Duncan's multiple range test) at P=0.05.

Test 3. All plants in this test showed significant differences based on the damage ratings (Table 3). "Azadi" exhibited a high level of tolerance to RWA feeding, although, based on plant height, it was affected more than other entries. "Ghods", "Adl" and the two barley cultivars had an intermediate tolerance reaction. The

six-rowed barley was more susceptible than the other barley cultivar. "Bayat" showed the highest damage rating in the tolerance test. This was rather surprising because in the two previous tests, antibiosis and antixenosis, it was found that this cultivar is not a good host for RWA. No significant differences were observed among the test plants on the basis of plant height.

Table 3. Tolerance of four wheat and two barley cultivars to *D. noxia*.

Entry	% Uninfested plant height†	Damage rating†
6-rowed barley	70.4a§	5.22d
"Adl" wheat	64.4a	5.50c
"Ghods" wheat	63.8a	4.76e
"Bayat" wheat	61.8a	6.58a
2-rowed local barley	56.0a	6.00b
"Azadi" wheat	50.6a	3.62f

† Means of 10 replications.

§ Means followed by the same letters in a column are not significantly different (Duncan's multiple range test) at P=0.05.

Comparison between RWA-infested and uninfested test plants based on the number of leaves and tillers per plant showed that there were no significant differences among them (Table 4).

The resistance indices in Table 5 indicated that "Bayat" was the most resistant to aphid, although its resistance index is nearly similar to the other three wheat cultivars. The two-rowed local barley had the lowest resistance index followed by the 6-rowed barley.

Table 4. Mean number of leaves and tillers per plant for four wheat and two barley cultivars infested with Russian wheat aphid.

Entry	% Uninfested plant leaves†	% Uninfested plant tillers†
"Azadi" wheat	65.8a§	63.2a
"Ghods" wheat	65.0a	56.6a
"Bayat" wheat	64.4a	80.0a
"Adl" wheat	63.6a	50.6a
6-rowed barley	62.4a	76.6a
2-rowed local barley	48.4a	34.8a

† Means of 10 replications

§ Means followed by the same letters in a column are not significantly different (Duncan's multiple range test) at P=0.05.

Table 5. Normalized indices for components of resistance to *D. noxia* and overall host plant resistance indices (PRI) for four wheat and two barley cultivars.

Entry	Normalized indices			PRI†
	Antibiosis (X)	Antixenosis (Y)	Tolerance (Z)	
"Bayat" wheat	0.56	0.60	1.00	2.98
"Azadi" wheat	0.69	1.00	0.55	2.63
"Adl" wheat	0.66	0.76	0.83	2.40
"Ghods" wheat	0.66	0.97	0.72	2.17
2-rowed local barley	0.86	0.75	0.79	1.96
6-rowed barley	1.00	0.76	0.91	1.44

† PRI (plant resistance index) = 1/(XYZ)

B. Field Observation

Wheat: *Triticum monococcum* (No. 534) was the most tolerant, followed by "Oreygi", "Omid" and "Azadi" (Table 6). "Karbalaii-Heidari", "Sureh" (white awned) and "Mohammadi" were more susceptible to RWA than other wheat cultivars with damage ratings of 8.0, 7.9 and 7.6, respectively.

Barley: No resistance was found in barley cultivars assessed in the field. A 2-rowed barley (No. 221) and a 6-rowed barley (No. 1), showed an intermediate resistance to the aphid (Table 7). Damage ratings showed that four other barley cultivars were very susceptible to RWA.

Triticale: All triticale cultivars tested were susceptible to RWA feeding (Table 7). Nearly 95-100% of three triticale cultivars ($274E_2$, $286E_2$ and $261D_2$) planted in a row showed typical RWA symptoms.

Rye: The two rye cultivars were also susceptible to RWA (Table 7).

Oat: Field observations showed that oats were tolerant to RWA (Table 7) and only few leaves were observed to be rolled. Furthermore, only 2-3 RWAs were found at the base of the rolled leaves.

DISCUSSION

On the basis of greenhouse studies, "Bayat" exhibited more antibiosis and antixenosis against RWA and a good plant resistance index compared with other test plants. Field observations also indicated that this cultivar is tolerant to RWA. However, the same result was not obtained in the greenhouse tests and this cultivar showed a poor tolerance to RWA. Apparently, different rearing histories of plant and parent aphids in the greenhouse and field influence the results obtained. Vickerman and Wratten (29) have pointed out such differences in some antibiosis tests.

Table 6. Tolerance of 22 wheat cultivars to *D. noxia* in Badjgah Experiment Station (north of Shiraz) in 1991.

Entry	% Rolled leaves per plant ($\bar{X}$ ± SE)†	Damage rating ($\bar{X}$ ± SE)†
Triticum monococcum (No. 534)	5.2 ± 0.56	2.00 ± 0.47
"Omid"	18.2 ± 1.53	4.10 ± 0.58
"Djavandjani"	63.0 ± 3.03	7.40 ± 0.34
"Oreygi"	17.3 ± 0.85	4.00 ± 0.42
"Arwand"	22.0 ± 0.98	4.60 ± 0.40
"Abuii"	24.5 ± 0.97	5.00 ± 0.59
"Adl"	32.0 ± 0.78	6.15 ± 0.48
"Rowshan"	23.0 ± 0.54	4.70 ± 0.56
"Bayat"	19.2 ± 0.76	4.20 ± 0.66
"Azadi"	21.0 ± 0.84	4.30 ± 0.45
"Sureh" (Black awned)	34.0 ± 1.50	6.30 ± 0.59
"Sureh" (Red awned)	42.5 ± 2.41	6.70 ± 0.58
"Kermani"	47.5 ± 1.83	6.95 ± 0.53
72	53.0 ± 1.19	7.10 ± 0.64
71	96.0 ± 0.86	6.80 ± 0.68
"Rezakhani"	40.0 ± 1.05	6.00 ± 0.84
"Sephidu"	33.5 ± 0.70	6.25 ± 0.64
"Karbalaii-Heidari"	70.5 ± 0.94	8.00 ± 0.33
"Morwarid"	53.0 ± 0.62	7.20 ± 0.44
73	62.5 ± 2.26	7.35 ± 0.56
"Mohammadi"	65.0 ± 1.59	7.60 ± 0.37
"Sureh" (White awned)	70.0 ± 1.02	7.90 ± 0.31

† Mean of ten replications.

Table 7. Tolerance of 6 barley, 11 triticale, two rye and one oat cultivars to *D. noxia* in Badjgah Experiment Station (north of Shiraz) in 1991.

Entry	% Rolled leaves / plant ($\bar{X} \pm SE$)†	Damage rating ($\bar{X} \pm SE$)†
Barley		
1	26.50 ± 0.74	5.40 ± 0.58
221	23.00 ± 0.55	4.70 ± 0.58
236	45.00 ± 1.06	6.80 ± 0.49
337	38.00 ± 1.02	6.45 ± 0.77
320	70.00 ± 1.09	7.90 ± 0.31
321	75.50 ± 0.72	8.20 ± 0.25
Triticale		
$162C_1$	53.00 ± 0.92	7.10 ± 0.31
222D	42.30 ± 0.59	6.60 ± 0.54
411	33.50 ± 0.73	6.25 ± 0.53
$286E_2$	75.00 ± 1.46	8.20 ± 0.32
380 $Darab_1$	42.60 ± 2.63	6.70 ± 0.39
$274E_2$	82.00 ± 1.85	8.70 ± 0.15
$189C_1$	53.00 ± 2.50	7.00 ± 0.39
$95B_1$	62.00 ± 2.24	7.30 ± 0.33
$282E_3$	42.00 ± 2.92	6.85 ± 0.56
383 $Darab_2$	46.00 ± 3.07	6.85 ± 0.35
$216D_2$	60.35 ± 3.96	7.20 ± 9.46
Rye		
No. 1	53.50 ± 2.42	7.20 ± 0.39
No. 2	42.50 ± 1.95	6.70 ± 0.47
Oat	7.50 ± 1.14	2.50 ± 0.34

† Mean of ten replications.

RWA is active only in cooler areas of the Fars province (1), whereas because of its high susceptibility to chilling, "Bayat" is planted only in warmer parts such as Jahrom (15). On this basis, this cultivar can not be recommended for planting in RWA distributional areas. Thus, its RWA resistance gene(s) should be transferred to the cultivars which are planted in cooler areas.

At the present, "Azadi" appears to be the most practical RWA-resistant cultivar because:

1. It is the most tolerant cultivar (Table 3), despite the fact that it harbored the greatest number of RWAs in antixenosis test.
2. It showed the best resistance level after "Bayat".
3. It can be planted in cooler parts of the Fars province (15).
4. It possesses several useful traits including early maturity, suitable height, high yield and some tolerance to rusts and lodging.

"Bayat" and "Azadi" wheat cultivars, which showed a relatively good resistance to RWA, possess a glabrous leaf surface. Thus, it is believed that pubescence does not play a role in RWA resistance as indicated by Starks *et al.* (27) and Webster *et al.* (31). However, in the antibiosis tests on *Rhopalosiphum padi*, Kazemi (14) obtained a different result and indicated that there was a negative and significant, correlation between aphid fecundity and trichome density.

Field observation showed that *Triticum monococcum* L. is the most tolerant plant to RWA. This is in agreement with the results of Butts and Pakendorf (5) and du Toit and van Niekerk (10) who pointed out that potential RWA resistance exists in the ancestral wheat species including *T. monococcum* L.

The two barley cultivars studied exhibited weak antibiosis, antixenosis, tolerance and low plant resistance indices under greenhouse conditions. Field observations also showed that all barley cultivars are apparently

susceptible. Barley is attacked more than other RWA host plants (3,12). Triticale and rye also showed no tolerance to RWA. In the Fars province RWA successfully reproduces on triticale (unpublished results). Bush *et al.* (4) believed that rye is less preferred by the aphid. Oat appears to be tolerant to RWA in the field. On the other hand, Bush *et al.* (4) and Stern and Orloff (28) considered oat to be a poor host for RWA.

Fortunately, in Iran, sources of RWA resistance in wheat and barley cultivars are abundant. Many of these cultivars have been introduced into other countries (9,12,16,25,33).

On the basis of information obtained during this study, it is believed that resistant wheat and barley cultivars are very important in maintaining the aphid population at the present low level in the Fars province. More investigations should be carried out on the effect of other factors on the aphid.

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