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EVALUATION OF WHEAT (*TRITICUM* SPP.) RESISTANCE TO THE RUSSIAN WHEAT APHID (*DIURAPHIS NOXIA* MORDVILKO)

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ABSTRACT

The Russian wheat aphid (RWA), *Diuraphis noxia* (Mordvilko) , is a serious pest of wheat. To identify RWA-resistant wheats, a total of 70 wheat genotypes, comprised of 47 commercial bread wheats (*Triticum aestivum*), 11 non-bread wheats (*T. monococcum, T. durum* and *T. turgidum*), and 12 endemic bread wheats were evaluated in greenhouse tests. Two successive mass screening tests resulted in the selection of 11 wheat genotypes resistant to RWA. These genotypes were selected based on the amount of leaf chlorosis and /or other types of leaf damage. Four more susceptible genotypes were selected to introduce a susceptible check, for future RWA-resistance studies. The correlations within and between different damage rating scales and plant height measurements were also determined.

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ارزیابی مقاومت به شته روسی گندم *Diuraphis noxia* (Mordvilko) در گندم (*Triticum* spp.)

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به ترتیب دانشجوی سابق کارشناسی ارشد، استاد حشره شناسی بخش گیاهپزشکی، دانشیار و استاد یار بخش زراعت و اصلاح نباتات دانشکده کشاورزی دانشگاه شیراز.

چکیده

شته روسی گندم *Diuraphis noxia* (Mordvilko)، یک آفت جدی برای گندم می باشد. به منظور شناسایی گندم های مقاوم به شته روسی، در مجموع۷۰ ژنوتیپ گندم، شامل۴۷ گندم نان (*Triticum aestivum*)، ۱۱ گندم غیر نان (*Tturgidum*، *T. durum* و *T. Monococcum*) و ۱۲گندم نان بومی در آزمایش های گلخانه ای ارزیابی شدند. دو آزمایش غربال توده متوالی به انتخاب ۱۱ ژنوتیپ گندم مقاوم به شته روسی گندم منجر شد. این ژنوتیپ ها بر اساس میزان کلروز و یا سایر انواع خسارات برگی انتخاب شدند. برای معرفی یک شاهد حساس که در مطالعات بعدی مقاومت به شته روسی گندم استفاده شود، چهار ژنوتیپ از ژنوتیپ های حساستر نیز انتخاب شدند. در این مطالعه همبستگی های درون گروهی و بین مقیاسی مختلف درجه بندی خسارت و اندازه گیری های ارتفاع گیاه نیز تعیین شد.

INTRODUCTION

The Russian wheat aphid (RWA), *Diuraphis noxia* (Mordvilko), inflicts serious damage to wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) in many parts of the world. In Iran, RWA was first reported from Isfahan, Sirjan, and Ardekan (6, 11). Chemical control of RWA is difficult because it feeds within tightly rolled leaves, which protects it from contact insecticides (22). Host plant resistance is one of the safe and less costly alternatives to chemical control of the aphid. Many sources of RWA-resistance have been identified in triticale (× *Tritosecale* Wittmack) (14, 24, 28) and rye, *Secale cereale* L. (3, 17). Such sources could be valuable in cross breeding programs to develop RWA-resistant wheats.

It is believed that sources of RWA-resistance in wheat from Iran and the former USSR are abundant (25). Many reports (8, 10, 15, 16, 20, 25, 26, 30) indicate a high frequency of RWA-resistant wheat genotypes collected from central Asia.

Several studies (5, 7, 11, 12, 13, 18) have identified valuable sources of RWA- resistance in some non-bread wheats, including ancestral wheats. Genetic resistance to RWA in bread wheats was first reported by Du Toit (8) from South Africa. He reported that two wheat germplasm lines, PI 137739, a hard white spring wheat from Iran, and PI 262660, a hard white winter wheat from the former USSR showed resistance to RWA in greenhouse tests. Later studies (1, 9, 15, 21, 25) indicated that valuable resistance sources exist in bread wheat genotypes.

The present study was designed to: 1) screen wheat (*Triticum* spp.) genotypes for potential RWA-resistance sources, 2) identify resistance sources, and 3) compare different damage rating scales and plant height measurements.

MATERIALS AND METHODS

Russian wheat aphids used in this study were obtained from Plant Pests and Diseases Research Institute of Shiraz (Zarghan), and reared under greenhouse conditions on 6-row barley, using the procedure for rearing the greenbug, *Schizaphis graminum* Rondani (27).

All evaluations were carried out at seedling stage under the greenhouse conditions. Temperature and photoperiod were 18-23° C and 16:8 (L:D) hr, respectively.

A total of 70 wheat genotypes, comprised of 47 commercial bread wheat cultivars or breeding lines (Table 1), 11 non-bread wheat, and 12 endemic bread wheat genotypes (Table 2) were included in the study.

Table 1. Commercial bread wheat genotypes used in the study.†

1-Adl	17-Ghafghaz	33-Moghan 1
2-Ahmad-Abadi	18-Ghods	34-M-73-4
3-Alborz	19-Golestan	35-M-73-12
4-Arwand	20-Hartock	36-Navid
5-Arwand-E-Bavanat	21-Hyrmand	37-Nick-Nejad
6-Arwand mutant	22-India	38-No. 8
7-Azadi	23-Javenjani	39-Omid
8-Azadi cross	24-Jenab	40-Omid cross
9-Barkat	25-Jones	41-Rowshan cross
10-Batavia	26-Karaj 1	42-Rowshan back cross
11-Bayat	27-Karaj 2	43-Sabalan
12-Bezostaia	28-Karaj 3	44-Sardari
13-Boulani	29-Kaveh	45-Sholeh
14-Chehel-Nim-Gazi	30-Khazar 1	46-Sorkh-Tokhm
15-Darab	31-Moraco	47-Tabasi
16-Falat	32-Maroon	

† Accessions from Plant Breeding Institutes of Shiraz (Zarghan) and Isfahan.

Two successive mass screening tests were designed to evaluate simultaneously all three resistance components as originally defined by Painter (19), without delineating each individually. In the initial evaluation, all wheat genotypes were evaluated in a completely randomized design with two replications. Each replicate consisted of a single metal greenhouse flat (50×35×7 cm). The experimental unit in each replicate was a hill, 5 cm apart, consisting of two plants of each genotype. A 6-row barley and an oat

Table 2. Characteristics of diploid, tetraploid, and endemic hexaploid wheat genotypes evaluated in the study†.

Entry	Commercial or endemic of	Genetic state
3829	?	*T. monococcum*
5172	?	$(2n=2x=14)$
1522	?	*T. turgidum*
1881	"Kermanshah"	$(2n=4x=28)$
Anonym.	?	
Altar	Commercial	*T. durum*
Bavares	=	$(2n=4x=28)$
Blicket	=	
Orjey black awned	=	
Orjey white awned	=	
Orjey-E-E-Kazeroon	=	
321	"Sarab-E-Ardebil"	*T. aestivum*
475	"Khorram-Abad"	$(2n=6x=42)$
591	"Sahneh-E-Kermanshah"	
1137	"Torbat-E-Heidaryeh"	
1550	"Kashan"	
1565	"Shahband-E-Saveh"	
1567	"Neishabour"	
1796	"Ghazvin"	
1963	"Mashhad"	
2665	"Gorgan"	
2701	"Tehran"	
4898	?	

† Accessions from Plant Breeding Center of Tehran (Karaj) and Plant Breeding Institute of Shiraz (Zarghan).

cultivar were used as susceptible and resistant checks, respectively. Checks planted in each replicate as in wheat entries. After sowing, each replicate (flat) was covered with a cage to prevent contamination from other insects. Each cage consisted of a metal frame (52×37×25 cm) with clear plastic sides and a fine mesh cloth top for ventilation. All entries were infested when plants reached the 2-leaf stage, Zadoks' growth stage (ZGS) 11 (29). For infestation, crowded colonies with large number of apterous and alate aphids were selected (Klingauf, 1987, see 1). Test plants were infested by placing pieces of RWA- infested leaves from the cultures on the soil between the test entries.

Damage ratings were initiated when the susceptible check began to show damage symptoms. Ratings were continued at 4-day intervals and final ratings were done when the susceptible check died (ca. 20 days after infestation).

Damage rating scales based on leaf chlorosis have been used most frequently to evaluate RWA resistance. However, in some cases (e.g. entries 14 and 25) this rating type had no or little value for separating test entries. Moreover, Burd *et al.* (2) believe that visual damages from RWA feeding in different plants may be different and occur independently. Thus, to increase the accuracy of evaluations, leaf damage other than chlorosis (e.g. leaf rolling and leaf trapping) were also examined. The following scales for these two damage symptoms were used in the present study.

A) 1-6 scale for leaf chlorosis[after Scott *et al.*, (24)].

Rating	Symptoms
1	No damage or small isolated chlorotic spots.
2	Large isolated chlorotic spots.
3	Chlorotic spots blending together to form a few areas of large chlorotic patches.
4	Numerous and prominent chlorotic patches with pale, yellow or white streaking.
5	Severe chlorosis and/or prominent yellow or white streaking, some plants wilting.
6	Plants dead or dying (severe wilting with all or most plants lying flat and aphids migrating to other plants).

B) 0-3 scale for leaf rolling and/or trapping [after Smith *et al.*, (25)].

Rating	Symptoms
0	No damage.
1	Less than 50% of leaves damaged.
2	More than 50% of leaves damaged.
3	100% of leaves damaged with plants dying or dead.

After the initial evaluation, all wheat genotypes which were significantly different ($P \leq 0.05$) from the susceptible check, were selected as probable resistant genotypes for advanced evaluation. Since one of the objectives of the study was to introduce a susceptible check, some probable susceptible wheat genotypes, which had higher damage ratings, were also selected.

This experiment was conducted as a randomized complete block design with three replications, including one untreated control. Each replicate consisted of two adjacent metal greenhouse flats (50×35×7 cm). In each flat 16 rows, 3 cm apart, were included. Thus, the experimental unit was a single row consisting of five plants in each replicate. Each entry was also grown in a control flat, not infested with RWA. After sowing, each replicate was covered by a single cage (52×72×25 cm) as previously described. Infestation and evaluation procedures were as described for initial evaluations.

In addition to visual damage ratings, the height of test and control plants was measured from the base of the plant to the top of the longest leaf. Initial plant height (plant height at the time of infestation) and final plant height (plant height immediately after final damage ratings) were used to calculate the amount of actual stunting caused by RWA in infested plants. The height of infested plants was also expressed as a percentage of height of control plants, i.e. percent plant height (4). Damage ratings and height measurements were done for individual plants and averaged for the entire row.

Data were subjected to analysis of variance and means were separated by Duncan's new multiple range test (DNMRT) (23). Relationships between different measurements were determined using linear correlation procedures.

RESULTS

From the initial mass screening test (Table 3), 31 wheat genotypes were selected for advanced evaluation. These were comprised of 24 probable resistant genotypes, which had significantly less damage than susceptible check, and 7 probable susceptible wheat genotypes.

Table 3. Initial mass screening of 70 wheat genotypes plus resistant (oat) and susceptible (6-row barley) checks.

Entry	Leaf chlorosis†	Leaf rolling or trapping†
6-row barely	5.00 a	2.50 a
Khazar 1*	5.00 a	2.00 abc
Adl*	4.50 a	2.25 ab
2665*	4.50 a	2.25 ab
Orjey white awned*	4.25 ab	2.25 ab
Sholeh*	4.25 ab	2.25 ab
2701*	4.25 ab	2.50 a
1567*	4.00 abc	2.25 ab
Barkat	4.00 abc	2.00 abc
591	4.00 abc	2.00 abc
3829	4.00 abc	2.00 abc
1796*	4.00 abc	1.25 bcde
Blicket	3.75 abcd	2.00 abc
Bayat	3.50 abcde	2.00 abc
Jones	3.50 abcde	2.00 abc
Sorkh-Tokhm	3.50 abcde	2.00 abc
Boulani	3.50 abcde	1.75 abcd
Javenjani	3.50 abcde	150 abcde
Alborz	3.50 abcde	2.00 abc

Table 3. Continued.

Sardari	3.50 abcde	1.50 abcde
Tabași	3.25 abcdef	1.50 abcde
Karaj 1	3.25 abcdef	2.00 abc
Golestan	3.25 abcdef	1.75 abcd
Hyrmand	3.00 abcdef	1.75 abcd
Orjey black awned	3.00 abcdef	1.75 abcd
Chehel-Nim-Gazi	3.00 abcdef	1.50 abcde
Bavares	3.00 abcdef	1.50 abcde
Maroon	3.00 abcdef	1.50 abcde
Maroco	3.00 abcdef	1.75 abcd
Omid cross	3.00 abcdef	2.00 abc
Inia	3.00 abcdef	1.75 abcd
No. 8	3.00 abcdef	2.00 abc
Moghan 1	3.00 abcdef	2.00 abc
Jenab	3.00 abcdef	1.75 abcd
M-73-4	3.00 abcdef	1.75 abcd
Nick-Nejad	3.00 abcdef	2.00 abc
Hartock	3.00 abcdef	1.50 abcde
Ghafghaz	3.00 abcdef	2.00 abc
Rowshan cross	3.00 abcdef	1.50 abcde
Darab	3.00 abcdef	1.50 abcde
321	3.00 abcdef	1.50 abcde
475	3.00 abcdef	1.75 abcd
Bezostaia	3.00 abcdef	1.75 abcd
1963	3.00 abcdef	1.75 abcd
Ghods	3.00 abcdef	2.00 abc
Rowshan back cross	3.00 abcdef	1.75 abcd
Arwand mutant	3.00 abcdef	2.00 abc
Sabalan	3.00 abcdef	2.00 abc
Arwand*	2.25 bcdef	1.25 bcde
Karaj 3*	2.25 bcdef	1.00 cde
Azadi cross*	2.25 bcdef	1.25 bcde

Table 3. Continued.

Ahmad-Abadi*	2.25 bcdef	1.00 cde
M-73-12*	2.20 cdef	1.00 cde
Kaveh*	2.12 cdef	1.00 cde
Falat*	2.00 cdef	1.00 cde
1522*	2.00 cdef	1.25 bcde
1550*	2.00 cdef	1.50 abcde
Arwand-e-Bavanat*	2.00 cdef	1.25 bcde
Navid*	2.00 cdef	1.25 bcde
Batavia*	2.00 cdef	1.50 abcde
Anonym.*	2.00 cdef	1.00 cde
5172*	1.87 def	1.25 bcde
Omid*	1.75 def	1.00 cde
Altar*	1.75 def	1.25 bcde
Orjey-e-Kazeroon*	1.75 def	1.00 cde
1565*	1.75 def	1.00 cde
Karaj 2*	1.75 def	1.00 cde
1137*	1.75 def	1.00 cde
Azadi*	1.50 ef	1.00 cde
1881*	1.50 ef	0.75 de
4898*	1.50 ef	0.75 de
Oat	1.25 f	0.50 e
MSE	0.6861	0.1811
DF	69	69
$LSD_{0.05}$	1.6524	0.8491
r	0.7865 §	

† Means of two replications in a completely randomized design. Means in each column followed by the same letters are not significantly different (DNMRT P≤0.05).

* Entries selected for further evaluation.

§ Significant at P≤0.05.

The correlation coefficient (r = 0.7865) between the two damage rating scales was significant. Some of the genotypes were, however, selected by relying on only one of the damage rating scales. "Khazar 1", "Batavia", and "1550" were selected based on leaf chlorosis, while "1567" and "1796" were selected based on leaf rolling or trapping.

Data in Table 4 show the results of the advanced mass screening test. Twelve wheat genotypes, which were significantly less damaged than the most susceptible genotypes, were selected. These resistant genotypes had lower scores for both damage rating scales, except " Orjey-e-Kazeroon" and "Kaveh" which were selected based on only leaf chlorosis and leaf rolling or trapping, respectively. Four wheat genotypes which exhibited higher scores of damage were also selected. A significant correlation (r=0.7729) was obtained between two damage rating scales.

Table 4. Advanced mass screening of 31 selected wheat genotypes plus an oat resistant check.

Entry	Lear chlorosis†	Leaf rolling or trapping†
2701*	4.20 a	1.87 a
Arwand*	4.12 a	1.87 a
Sholeh*	3.55 ab	1.70 abc
Khazar 1*	3.55 ab	1.80 ab
Karaj 3	3.10 abc	1.36 abcde
1550	3.00 abcd	1.60 abcd
Orjey white awned	3.00 abcd	1.40 abcde
1561	3.00 abcd	1.67 abc
1796	3.00 abcd	1.60 abcd
Navid	2.87 abcd	1.62 abcd
Adl	2.86 abcde	1.73 abc
Falat	2.77 abcde	1.65 abcd
M-73-12	2.70 abcdef	1.45 abcde
1522	2.52 abcdef	1.50 abcde
Arwand-e-Bavanat	2.50 abcdef	1.75 abc
Batavia	2.50 abcdef	1.35 abcde

Table 4. Continued.

2665	2.50 abcdef	1.70 abc
Ahmad-Abadi	2.50 abcdef	1.36 abcde
Kaveh*	2.45 abcdef	1.00 def
Àzadi cross	2.45 abcdef	1.35 abcde
Karaj 2*	2.02 bcdef	1.12 def
1565*	2.00 bcdef	0.80 fg
Altar*	2.00 bcdef	1.25 cdef
Orjey-e-Kazeroon*	2.00 bcdef	1.40 abcde
Anonym.*	1.99 bcdef	1.00 ef
1137*	1.95 bcdef	1.29 bcdef
5172*	1.66 cdef	1.00 ef
4898*	1.50 cdef	0.50 gh
Omid*	1.40 cdef	0.30 hi
Azadi*	1.30 def	0.32 hi
1881*	1.10 ef	0.20 hi
Oat	1.00 f	0.00 I
MSE	0.5230	0.0468
DF	31	31
$LSD_{0.05}$	1.4750	0.4412
r	0.7729 §	

† Means of two replications in a completely randomized block design. Means in each column followed by the same letters are not significantly different (DNMRT P≤0.05).

* Entries selected for further evaluation.

§ Significant at P≤0.05.

Plant height measurements (Table 5) indicated that neither percent plant height nor plant stunting were correlated with leaf chlorosis (r = 0.2111 and r = -0.2480, respectively) or other leaf damages (r = 0.2240 and r = -0.2491, respectively). A significant negative correlation (r =-0.8778) was found between percent plant height and plant stunting.

Table 5. Height measurement of 32 plant entries in advanced screening test.

Entry	Percent plant height†§	Plant stunting (cm) †¶
Kaveh	120.69 a	0.88 ij
1137	108.67 ab	-1.37 j
Navid	104.48 abc	2.51 fghij
Azadi cross	103.09 abc	1.35 hij
Arwand	28.28 abcd	1.57 ghij
1796	25.38 abcde	3.49 defghij
Batavia	89.66 abcdef	8.40 bcdefghij
M-73-12	83-63 abcdef	12.19 abcdef
Azadi	82.75 abcdef	8.33 bcdefghij
Adl	82.58 abcdef	7.24 bcdefghij
Anonym.	82.44 abcdef	3.28 efghij
Karaj 3	80.81 bcdef	9.97 bcdefghi
5172	80.51 bcdef	11.68 abcdefg
Sholeh	80.35 bcdef	13.68 abcd
1550	80.30 bcdef	11.28 bcdefgh
Orjey-e-Kazeroon	79.32 bcdef	6.08 cdefghij
1561	78.71 bcdef	7.41 bcdefghij
2701	77.39 bcdef	6.64 bcdefghij
1565	77.11 bcdef	9.62 bcdefghij
2665	76.16 bcdef	8.46 bcdefghij
Oat	74.39 bcdef	11.67 abcdefg
Orjey white awned	73.80 bcdef	9.67 bcdefghi
Khazar 1	73.74 bcdef	10.38 bcdefghi
Altar	67.75 cdef	9.37 bcdefghi
1522	64.40 cdef	15.70 abc
4898	59.76 def	12.96 abcde
Omid	59.66 def	16.13 abc
Arwand-e-Bavanat	58.80 def	14.15 abc
Karaj 2	58.74 def	15.48 abc

Table 5. Continued.

Falat	56.62 ef	16.60 ab
1881	53.23 f	16.49 ab
Ahmad-Abadi	49.57 f	21.56 a
MSE	270.5830	17.4939
DF	31	31
$LSD_{0.05}$	33.5487	8.5304
r	-0.8778‡	

† Means of two replications, in relation to one control replication, in a completely randomized block design. Means in each column followed by the same letters are not significantly different (DNMRT $P \leq 0.05$).

§ Plant height in infested flats expressed as a percentage of plant height in uninfested flats.

¶ Differences between initial plant height and final plant height of infested and uninfested flats.

‡ Significant at $P \leq 0.05$.

DISCUSSION

The significant correlations between the two damage rating scales, in both mass screening tests (Tables 3 and 4) indicated that the reaction of test plants based on leaf rolling or trapping was similar to leaf chlorosis. This is consistent with the result of Nkongolo *et al.* (18) who found a close association between leaf chlorosis and leaf rolling. Therefore, one of these rating scales could be adequate for future mass screening. In the same manner, the significant negative correlation between percent plant height and plant stunting (Table 5) indicated that both of these plant height variables are equally reliable and only one of them could be adequate for future evaluations.

The non-significant correlations between the plant height measurements and the damage rating scales might be the result of different reactions of test plants, so that some resistant genotypes showed more stunting than some susceptible ones. Height measurements in the mass screening of triticale by Scott *et al.* (24) were similar to the results of this test. Moreover, Burd *et al.* (2) found no significant relationships between leaf rolling and quantitative plant measurements. Duncan's grouping of height measurements showed extreme overlapping among test entries (Table 5) and hence these results did not contribute to selecting genotypes.

The resistance reported here is an example of sympatric resistance, since the wheat genotypes evaluated most likely evolved in the presence of RWA pressure. The selected wheat genotypes will be saved for future use in RWA plant breeding programs. Future tests will be conducted to characterize the resistance components (antixenosis, antibiosis, and tolerance) contributing to the resistance of these selected genotypes and to identify and introduce at least one susceptible check for use in future RWA-resistance studies.

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