Iran Agricultural Research 18:91-106 (1999)

CHARACTERIZATION OF RESISTANCE COMPONENTS TO RUSSIAN WHEAT APHID, *DIURAPHIS NOXIA* (MORDVILKO), IN SEVERAL WHEAT *(TRITICUM* SPP.) GENOTYPES

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(Received: March 16, 1998)

ABSTRACT

This study was conducted to characterize the resistance components (i.e. antixenosis, antibiosis, and tolerance) contributing to the resistance in 15 wheat *(Triticum* spp.) genotypes. These genotypes were selected after two successive mass screening tests. Using a plant resistance index (PRI), '5172' *(T. monococcum)* and '4898' *(T. aestivum)* were the most resistant genotypes and 'Orjey-E-Kazeroon' *(T. turgidum)* was the least resistant. The most resistant genotypes both exhibited the highest level of tolerance and antibiosis resistance. However, they exhibited the second rank of antixenosis resistance. '5172' and 'Orjey-E-Kazeroon' are recommended as resistant and susceptible checks, respectively. In this study, correlations within and between plant height measurements and damage rating scales were compared. Methods for measuring antibiosis were also compared.

Keywords: antibiosis, antixenosis, Russian wheat aphid, tolerance, wheat

تحقیقات کشاورزی ایران

۱۸ :۹۱-۱۰۶ (۱۳۷۸)

توصیف و تعیین اجزاء متشکله مقاومت به شته روسی گندم

(*Triticum* spp.) در چندین ژنوتیپ گندم (*Diuraphis noxia*)(Mordvilko)

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به ترتیب دانشجوی سابق کارشناسی ارشد و استاد فقید بخش گیاهپزشکی دانشکده کشاورزی دانشگاه شیراز، شیراز، جمهوری اسلامی ایران .

چکیده

بررسی حاضر به منظور توصیف و تعیین اجزاء متشکله مقاومت (یعنی آنتی زنوز، آنتی بیوز و تحمل) سهیم در مقاومت ۱۵ ژنوتیپ گندم (*Triticum* spp.) اجرا گردید. این ژنوتیپ ها پس از دو آزمایش غربال انبوه متوالی انتخاب شدند. بر پایه شاخص مقاومت گیاهی (PRI) ژنوتیپ های "۵۱۷۲" (*T. monococcum*) و "۴۸۹۸" (*T. aestivum*) مقاومترین ژنوتیپ ها بودند و " اورجی کازرون" (*T. turgidum*) حساسترین ژنوتیپ بود. هر دو ژنو تیپ مقاوم بیشترین میزان مقاومت تحمل و آنتی بیوز را داشته، اما از نظر مقاومت آنتی زنوز در رتبه دوم قرار گرفتند. ژنوتیپ های "۵۱۷۲" و اورجی کازرون" به ترتیب به عنوان شاهد های مقاوم و حساس پیشنهاد شدند. در این بررسی، همبستگی بین و داخل اندازه گیری های ارتفاع گیاه و مقیاس های درجه بندی خسارت مقایسه شدند. روش های اندازه گیری آنتی بیوز نیز مقایسه گردید.

INTRODUCTION

The Russian wheat aphid (RWA), *Diuraphis noxia* (Mordvilko), is a serious small grain pest in different parts of the world. It appears that pest damage has been most severe on wheat *(Triticum aestivum* L.) and barely (*Hordeum vulgare* L.) (10). A very encouraging aspect of RWA management is the identification of plants that resist feeding damage of this pest. Modes or components of resistance have been identified in many RWA-resistant cereals and range grasses.Various studies showed that resistance in triticale (*X Tritosecale* Wittmack) has been expressed primarily as antibiosis and tolerance (18) and/or mainly as antibiosis (22). A genetic study by Nkongolo *et al.* (13) on Imperial rye (*Secale cereale* L.) a line resistant to RWA, indicated that resistance was controlled by more than one gene located on different chromosomes. Kindler *et al.* (11) studied resistance to RWA in tall wheatgrass, *Agropyron elongatum* (Host) Beauvois. They found high levels of antibiosis and strong antixenosis as resistance modes on three of these resistant grasses.

Resistance in PI 137739 and PI 262660, the first RWA-resistant wheat sources, is expressed as antibiosis and antixenosis in PI 137739, and tolerance in PI 262660 (5). Characterization of the components of resistance in resistant Tunisian wheats indicated that these accessions had various combinations of antixenosis, antibiosis, and tolerance components (7). Smith *et al.* (20) found a significant level of tolerance in all wheat entries and a low level of antixenosis in PI 137739, PI 262660 and PI 294994 originated from Iran. Characterization of resistance components in PI 140207, a hard white spring accession from Iran, indicated that antibiosis is the most important component (1).

The objectives of this study were characterization of the components of resistance in 15 wheat (*Triticum* spp.) genotypes, and introducing one susceptible check, to be used in future RWA-resistance studies.

MATERIALS AND METHODS

Plants and Aphids

The components modes of resistance, as originally defined by Painter (14), were determined in 15 wheat genotypes. The genotypes used (Table 1) were selected after two mass screening tests (12). Russian wheat aphids used in these tests were obtained from aphid cultures maintained in the greenhouse on 6-row barley, using rearing procedure described for greenbug, *Schizaphis graminum* Rondani (21) . All evaluations were carried out under greenhouse conditions when plants reached the 1-leaf stage 'Zadoks' growth stage (ZGS) 11 (25). Temperature and photoperiod were 18-23° C and 16:8 (L:D) hr, respectively.

Resistance Components

Antixenosis. This test was similar to that described by Webster *et al.* (24), with some modifications as follows. Seeds were randomly planted in a circular pattern near the edge of a pot (15 cm diameter). Plants were infested by releasing 75 adult apterous RWAs (5 aphids per plant) on the soil in the center of each pot when the plants reached the 1-leaf stage. The plants and aphids were then covered with plastic cages (13 by 20 cm) with a cloth on the top and side hole. After 48 hr, when the aphids selected thier hosts, the number of RWAs on each plant was recorded. This test was conducted in a randomized complete block design, with 10 replications (pots).

Table 1. Characteristics and plant damage ratings of 15 wheat genotypes selected from previous mass screening tests.

Entry†	Genetic state§	Damage rating¶	
		Leaf chlorosis	Leaf rolling or trapping
'2701'	E, T.A.	4.20	1.87
'Arwand'	C, T.A.	4.12	1. 87
'Sholeh'	C, T.A.	3.55	1.70
'Khazar'	C, T.A.	3.55	1.80
'Kaveh'	C, T.A.	2.45	1.00
'Karaj 2'	C, T.A.	2.02	1.12
'1565'	E, T.A.	2.00	0.80
'Altar'	C, T.D.	2.00	1.25
'Orjey-E-Kazeroon'	C, T.D.	2.00	1.40
'1137'	E, T.A.	1.95	1.29
'5172'	E, T.M.	1.66	1.00
'4898'	E, T.A.	1.50	0.50
'Omid'	C, T.A.	1.40	0.30
'Azadi'	C, T.A.	1.30	0.32
'1881'	E, T.T.	1.10	0.20

†. The first four wheat genotypes were selected as susceptible entries and the others as resistant genotypes.

§. E: Endemic, C: Commercial, T.A.: *Triticum aestivum*, T.D.: *T. durum*, T.M.: *T. monococcum*, T.T.: *T. turgidum*.

¶. Means of two replications in a randomized complete block design. Leaf chlorosis rating (1=no damage to 6=plants dying), leaf rolling or trapping (0=no damage, 3=100% of leaves dying).

Antibiosis. This test was conducted in a randomized complete block design, with four replications. The embryo count method can be used as a successful and rapid method for discriminating various levels of antibiosis to RWA (4). In this test nymph count was performed following the embryo count, using a procedure described by Scott *et al.* (17), except for some modifications that follow. One plant of each genotype was grown in a pot and infested by 3 adult apterous RWAs when plants reached the 1-leaf stage. The pots were then caged as previously described. Aphids of the first generation were observed daily until at least 5 nymphs were produced. The adults were then removed, leaving 5 nymphs on each plant. The nymphs were allowed to mature on the plants and begin to produce. All nymphs were then removed and two of the three adults were placed in 70% ethanol for embryo count. The number of embryos per adult was recorded, after dissecting collected aphids under binocular (with 35× magnification) . Only embryos with pigmented eyes were counted (5) . The remaining aphids were used for nymph count. Newly born nymphs were recorded twice per week, for 21 days. One replication in the embryo count method consisted of one test plant with two RWAs, while in nymph count method one replication consisted of one test plant with one RWA. This provided a total of eight RWAs in the embryo count method and four RWAs in the nymph count method.

Tolerance. This test was conducted in a randomized complete block design with three replications. Seeds were separately planted in pots. Plant height for both infested and control plants was measured at the time of infestation (initial plant height) and in the end of test (final plant height). Because of the variability in plants height, control plants were paired as closely as possible so that each replicate, at the time of infestation, included one infested and one control plant of approximately the same height (23). When plants reached the 1-leaf stage, one plant (pot) of each replicate was infested with 10 RWAs. The pots were caged and checked at 48 hr intervals to remove or add aphids as needed to maintain 10 RWAs per plant. Three weeks later, the infested plants were visually rated for damages. The following scales were used for damage ratings:

A) 1-6 scale for leaf chlorosis [after Scott *et al.* (18)].

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.* (19)]

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

Percent plant height (final plant height of infested plants as a percentage of final plant height of uninfested plants) and actual stunting (difference between initial and final plant heights of uninfested plants minus those of infested plants) were also calculated for each genotype.

Statistical Analysis

All recorded data were subjected to analysis of variance (ANOVA) and all means were separated by using Duncan's new multiple range test (DNMRT) (16). Relationships between different measurements were determined using linear correlation.

Plant Resistance Index

For evaluating all resistance components, a plant resistance index (PRI) was calculated for each genotype. 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. A plant resistance index was then calculated for each genotype using Ullahl's equation (1985) 1/XYZ, where X=the antixenosis index, Y=the antibiosis index, and Z=the tolerance index, respectively (see 24).

RESULTS

Resistance Components

Antixenosis. Number of RWA per plant ranged from 7.0 on '1565' and 'Orjey-E-Kazeroon' to 1.8 on '1881' (Table 2) : 'Khazar 1' showed more antixenotic resistance than other wheat genotypes, despite it being rated as susceptible in the previous mass screening tests (Table 1) and showed also a low plant resistance index (Table 5).

Antibiosis. The highest and the lowest numbers of embryo per adult RWA on each genotype were 6.0 on 'Altar' and 1.0 on '5172' and '4898', respectively (Table 3). The same results were obtained in nymph count method. A significant correlation (r=0.80) was obtained between the results of embryo count and nymph count methods.

Table 2. Number of adult RWA on each genotype, 48 hr after release.

Genotypes	Number of adult RWA†
'1565'	7.0a
'Orjey-E-Kazeroon'	7.0a
'Karaj 2'	5.4ab
'2701'	4.4bc
'1137'	4.2bcd
'Arwand'	4.2bcd
'Kaveh'	3.0cde
'Azadi'	2.8cde
'Sholeh'	2.8cde
'Altar'	2.6cde
'Khazar 1'	2.2de
'Omid'	2.2de
'5172'	2.2de
'4898'	2.2de
'1881'	1.8e
MSe	3.8137
DF	126

†. Means of two replications in a randomized complete block design. Means followed by the same letters are not significantly different (Duncan's new multiple range test at P>0.05).

Tolerance. Results of the tolerance test (Table 4) indicated that the highest level of tolerance based on leaf chlorosis was observed on '4898' and '5172' (1.0). Based on leaf rolling or trapping, '1881', 'Azadi' , '4898' and '5172' all rated 0.0.

Based on percent plant height, '5172' was affected more than other genotypes, however '4898' had an intermediate response. 'Orjey-E-Kazeroon' and 'Altar' (based on plant stunting) , and 'Sholeh' (based on percent plant height) were affected less than other genotypes.

'Khazar 1', based on both damage ratings, was the most susceptible genotype. However, based on percent plant height it had an intermediate response. Plant stunting was not severe among wheat genotypes and some resistant genotypes, sach as '5172', showed more stunting than some susceptible genotypes. Growth of infested and control plants were compared

(Fig. 1). The highest and the lowest difference between infested and control plants were observed on 'Omid' and '4898', respectively.

Table 3. Number of RWA embryos and nymphs on 15 wheat genotypes.

Genotypes	Embryo/Adult†	Nymph/Adult§
'Altar'	6.00a¶	20.00a
'Orjey-E-Kazeroon'	4.75ab	19.75a
'Khazar 1'	4.62ab	18.75ab
'Sholeh'	4.50bc	16.25bc
'2701'	4.37bc	16.00c
'1565'	3.75bcd	14.50cd
'1137'	3.37bcde	16.25bc
'Omid'	3.25bcde	13.25de
'Azadi'	3.00cde	11.50e
'Arwand'	3.00cde	16.00c
'Karaj'	2.50de	16.75bc
'Kaveh'	2.12ef	12.00de
'1881'	2.00ef	12.00de
'5172'	1.00f	11.75e
'4898'	1.00f	11.00e
MSE	0.8575	2.6444
DF	42	42
$LSD_{0.05}$	1.3214	2.3205
Correlation§	0.8048	

†. Mean number of embryos produced by different RWAs on a singlre plant.

§. Number of nymphs produced by individual RWA adults.

¶. Means of four replications in a randomized complete block design (Means of 8 RWAs plant^{-1} and 4 RWAs plant^{-1} for embryo count and nymph count, respectively, in each replicate). Means in each column followed by the same letters are not significantly different (Duncan's new multiple range test at P>0.05).

Significant (P< 0.05) correlations were found between leaf chlorosis and leaf rolling or trapping (r=0.89), as well as between percent plant height and plant stunting (r=-0.83). However, correlations between percent plant height with leaf chlorosis and leaf rolling or trapping (r=0.20 and r=0.01, respectively) , as well as correlations between plant stunting with leaf chlorosis and leaf rolling or trapping (r=-0.28 and r=-0.10, respectively) were not significant.

Table 4. RWA damage ratings and height measurements of 15 wheat genotypes.

Genotypes	Leaf chlorosis	Leaf rolling or trapping	Percent† plant hight	Plant (cm) stunting§
'Khazar1'	5.00a¶	2.33a	69.85ab	10.02ab
Orjey-E-'Kazeroon'	4.50ab	2.00ab	77.14ab	4.35b
'Arwand'	4.33ab	2.00ab	68.64ab	11.10ab
'2701'	3.50bc	2.00ab	66.65ab	15.70ab
'Sholeh'	3.33bcd	1.38bc	104.68a	9.33ab
'Kaveh'	2.66cde	1.00c	63.16ab	13.80ab
'Altar'	2.00cdef	1.00c	75.12ab	5.40b
'1137'	2.00cdef	1.00c	68.04ab	15.60ab
'Omid'	2.00cdef	0.66cd	53.01ab	23.43a
'1565'	2.00cdef	0.66cd	67.41ab	15.70ab
'Karaj 2'	1.83def	0.66cd	57.97ab	17.26ab
'1881'	1.50ef	0.00d	68.34ab	18.70ab
'Azadi'	1.33ef	0.00d	79.04ab	8.66ab
'4898'	1.00f	0.00d	78.20ab	13.20ab
'5172'	1.00f	0.00d	37.56b	23.67a
MSe	0.6535	0.2507	692.584	82.1370
DF	28	28	28	28

†. Final plant height of infested plants as a percentage of final plant height of uninfested plants.

§. Difference between initial and final plant heights of uninfested plants minus those of infested plants.

¶. Means of three replications in a randomized complete block design. Means in each column followed by the same letters are not significantly different (Duncan's new multiple range test at P<0.05).

Plant Resistance Index

Table 5 shows normalized indices of resistance components and plant resistance indices (PRI) of the selected genotypes. Genotypes '5172' and '4898' exhibited the highest level of resistance to RWA. Following them, with a sudden drop, the highest PRIs belonged to '1881' and 'Azadi'. The lowest PRIs were found for 'Orjey-E-Kazeroon' and then '2701' genotypes.

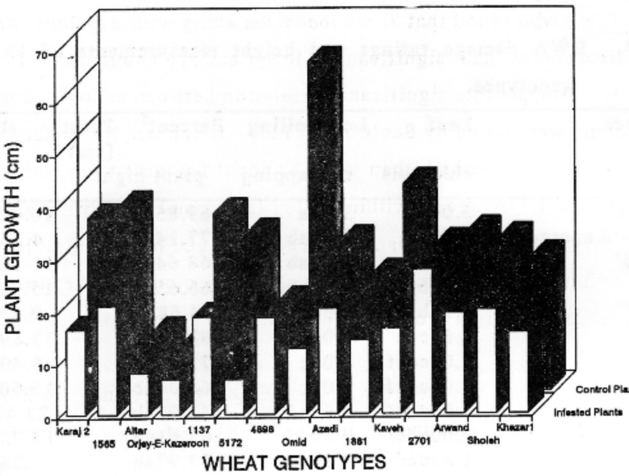

Fig. 1. Comparison of the growth (cm) of infested and control plants in tolerance test, based on the difference between final plant height and initial plant height.

DISCUSSION

Resistance Components

Antixenosis. Although genotypes '1565' along with 'Orjey-E-Kazeroon' showed the highest antixenosis to RWA (Table 2), their different reactions in antibiosis and tolerance tests may be the resulted in different plant resistance indices (Table 5). If the antixenosis detected in 'Khazar 1'occurs in the field, it could influence the initial infestation level of RWA. When given a choice of hosts, RWA might select a genotype other than 'Khazar 1', but with no choice RWA would be able to survive on it. Thus, this antixenotic resistance is unlikely to make a significant contribution to the field resistance of 'Khazar 1'. Similar result was reported by Robinson (15) for S13 barley (susceptible control) , which had high antixenosis and low plant resistance index.

Antibiosis. Embryo count data with 'Altar' (*T. durum*) and '5172' (*T. monococcum*) wheats, are in agreement with the results of Butts and Pakendorf (4) who found that *T. monococcum* along with *Aegilops squarosa* and *T. dicoccoides* had significantly lower embryo counts, than *T. durum* and barley. Comparable significant correlation between embryo counts and nymph counts were noted by Scott *et al.* (17). It appears that embryo count is a more suitable method than nymph count for measuring antibiosis to RWA, because RWA feeds within rolled leaves and measuring antibiosis must involve minimal disturbance to the aphids and host plants. However, embryo counts are closely related to the daily reproductive rates for limited temporal periods within a productive period.

Table 5. Normalized indices for components of resistance to RWA and RWA plant resistance indices (PRI) of 15 selected wheat genotypes.

Genotypes	Normalized Indices				PRI¶	
	Antixenosis (X)	Antibiosis† (Y)	Tolerance§ (Z_1)	(Z_2)	1	2
'5172'	0.31	0.16	0.20	0.00	95.4540	19.090
'4898'	0.31	0.16	0.20	0.00	95.4540	19.090
'1881'	0.25	0.32	0.30	0.00	38.8880	11.660
'Azadi'	0.40	0.50	0.26	0.00	18.7960	5.000
'Omid'	0.31	0.54	0.40	0.28	14.6850	4.577
'Kaveh'	0.42	0.32	0.53	0.42	12.3830	4.609
'Karaj 2'	0.77	0.41	0.36	0.28	8.5000	2.424
'1137'	0.60	0.56	0.40	0.42	7.4070	2.073
'Altar'	0.37	1.00	0.40	0.42	6.7300	1.883
'Sholeh'	0.40	0.75	0.66	0.57	5.0050	2.122
'Khazar 1'	0.31	0.77	1.00	1.00	4.1270	2.063
'1565'	1.00	0.62	0.40	0.28	4.0000	1.246
'Arwand'	0.60	0.50	0.86	0.85	3.8490	1.793
'2701'	0.62	0.72	0.70	0.85	3.1160	1.174
'Orjey-E-Kazeroon'	1.00	0.79	0.90	0.85	1.4030	0.697

†. Antibiosis index was based on embryo count data.

§. Z_1= leaf chlorosis index, Z_2= leaf rolling or trapping index.

¶. Plant Resistance Index=1/XYZ.

Columns 1 and 2 are calculated PRIs using Z_1 and Z_2 tolerance indices, respectively [$PRI_1=1/XYZ_1$], [$PRI_2=1/XY(Z_2+1)$].

Tolerance. Significant correlation between leaf chlorosis and leaf rolling or trapping (Table 4) indicates that wheat genotypes expressed similarly both damage ratings. This result is consistent with those of Burd *et al.* (3) that damage ratings based on percentage of chlorosis accurately identify highly resistant and highly susceptible cereals.

The absence of significant correlations between height measurements and damage ratings are consistent with results of Du Toit (5) and Scott *et al.* (17) who indicated that some resistant lines were severely stunted regardless of their low damage ratings.

Comparisons between different plant height criteria (e.g., percent plant height, plant stunting, and growth) with each other and with damage rating scales indicates that a genotype may respond differently based on different plant height criteria. On the other hand, this test examined seedlings and did not follow them to maturity. Hence, these plants may have had an opportunity to compensate for their height reduction during the rest of their growing season.

Plant Resistance Index

Plant resistance indices rank the entries in terms of the combination of their resistance components and do not indicate any statistical differences (15). In our tests, genotypes with the highest level of resistance to RWA, '5172' and '4898', both exhibited the lowest indices (the highest resistance) for tolerance and antibiosis components, and the second highest antixenosis index (Table 5) .

The most resistant wheat genotype, '5172', was a *T. monococcum* wheat, confirming observations of Butts and Pakendorf (4) and Du Toit and Van Niekerk (6), who also showed that RWA-resistance exists in *T. monococcum* and other ancestral wheat species.

With respect to possible desirable characteristics of *T. monococcum* wheats, such as resistance to cooling, heating and dryness (9), '5172' is a valuable source for germplasm enhancement efforts in order to transfer desirable genes to common cultivated cultivars. The two other resistant genotypes '4898' *(T. aestivum)* and '1881' *(T. turgidum)* could be utilized in breeding programs for developing RWA-resistant common cultivated bread wheats. This is true especially with '4898', which has a genome identical to common bread wheats.

'Orjey-E-Kazeroon' a *T. durum* wheat, and '5172', a *T. monococcum* wheat are recommended as susceptible and resistant checks, respectively, for evaluating RWA-resistance in future studies. Cultivation of 'Azadi' wheat may be recommended for lessening RWA damage at the present. 'Azadi' wheat could be planted in temperate and cool areas of the country where RWA may cause more damage (8). 'Azadi' also possesses other desirable features such as suitable height, early maturity, high yield, and relative resistance to cereal rusts and lodging (2).

Resistance of these sources should be tested in the presence of natural RWA infestation under field conditions. This is a necessary step before widespread use of these resistant plants. These RWA-resistant sources may have some levels of resistance or susceptibility to other pests and/or pathogens. Their response should be tested especially for major pest, *Eurigaster integriceps* Put. and cereal rusts. Genetics and allelism of resistance, presence of probable RWA biotypes, and biochemical and physiological bases of resistance could be studied in future studies.

LITERATURE CITED

1. Baker, C.A., J.A. Webster and D.R. Porter. 1992. Characterization of Russian wheat aphid resistance in a hard white spring wheat. Crop Sci. 32:1442-1446.
2. Behnia, M.R. 1994. Cold Season Cereals. Tehran Univ. Public. 610 p . (in Farsi).
3. Burd, J.D., R.L. Burton and J.A. Webster. 1993. Evaluation of Russian wheat aphid (Homoptera:Aphididae) damages on resistant and susceptible hosts with comparison of damage ratings to quantitative plant measurements. J. Econ. Entomol. 86:974-980.
4. Butts, P.A. and K.W. Pakendorf. 1984. The utility of embryo count method in characterizing cereal crops for resistance to *Diuraphis*

noxia. pp 53-57. In: M.C. Walters (ed.). Progress in Russian wheat aphid *(Diuraphis noxia* Mordvilko) research in the Republic of South Africa. Tech. Commun. No. 191. Dept. Agric. Rep. South Africa, Pretoria.

5. Du Toit, F. 1989. Components of resistance in three bread wheat lines to *Diuraphis noxia* (Homoptera:Aphididae) in South Africa. J. Econ. Entomol. 82:1779-1781.
6. Du Toit, F. and Van Niekerk. 1985. Resistance in *Triticum* species to the Russian wheat aphid, *Diuraphis noxia* (Mordvilko) (Homoptera:Aphididae). Cereal Res. Commun.13:371-378.
7. Formusoh, E.S., G.E. Wilde, J.H. Hatchet and R.D. Collins. 1992. Resistance to Russian wheat aphid (Homoptera:Aphididae) in Tunisian wheats. J. Econ. Entomol. 85:2005-2009.
8. Gonzalez, D., C.G. Summers and C.Q. Qualset. 1992. Russian wheat aphid: Natural enemies, resistant wheat offer potential control. Calif. Agric. 46:32-34.
9. Karimi, H. and F. Mokhtare. 1973. Wheat. Vol. 1 Tehran Univ. Public., Tehran, 2nd ed. (in Farsi). 304 p.
10. Kindler, S.D. and T.L. Spriger. 1989. Alternate hosts of Russian wheat aphid (Homoptera:Aphididae). J. Econ. Entomol. 82:1358-1362.
11. Kindler, S.D., T.L. Spriger and K.B. Jensen. 1995. Detection and characterization of the mechanisms of resistance to Russian wheat aphid (Homoptera:Aphididae) in tall wheatgrass. J. Econ. Entomol. 88:1503-1509.
12. Nematollahy, M.R., A.A. Ahmadi, Y. Emam and M.T. Assad. 1998. Evaluation of wheat *(Triticum* spp.) resistance to the Russian wheat aphid, *Diuraphis noxia* (Mordvilko). Iran Agric. Res. 17:1-18.
13. Nkongolo, K.K., J.S. Quick, F.B. Peairs and W.L. Meyer. 1990. Gene location for Russian wheat aphid (Homoptera:Aphididae) resistance of Imperial rye, using wheat-rye addition line. Cereal Res. Commun. 18:307-314. (Abst: Abst. Entomol. 1991. AB(5). Ref. No. 105889).
14. Painter, R.H. 1951. Insect Resistance in Crop Plants. The Univ. of Kansas. London, England. 520 p.

15. Robinson, J. 1992. Assessment of Russian wheat aphid (Homoptera:Aphididae) resistance in barley seedlings in Mexico. J. Econ. Entomol. 85:1954-1962.

16. SAS Institute. 1988. Staistical analysis system for personal computers. Version 6.03. SAS Instit., Cary, N.C.

17. Scott, R.A., W.D. Worral and W.A. Frank. 1990. Comparison of three techniques for measuring antibiosis to the Russian wheat aphid. Southwest. Entomol. 15:439-445.

18. Scott, R.A., W.A. Worral and W.A. Frank. 1991. Screening for resistance to Russian wheat aphid (Homoptera:Aphididae) in triticale. Crop Sci. 31:32-36.

19. Smith, C.M., D. Schotzko, R.S. Zemetra, E.J. Souza and S. Schroeder-Teeter. 1991. Identification of Russian wheat aphid (Homoptera:Aphididae) resistance in wheat. J. Econ. Entomol. 84:328-332.

20. Smith, C.M., D.J. Schotzko, R.S. Zemetra and E.J. Souza. 1992. Categories of resistance in plant introductions of wheat resistant to the Russian wheat aphid (Homoptera:Aphididae). J. Econ. Entomol. 85:1480-1484.

21. Starks, K.J. and R.L. Burton. 1977. Greenbugs: Determination of biotypes, culturing, and screening for plant resistance; with notes on rearing parasitoids. USDA, Tech. Bull. NO. 1556. Washington DC, U.S.A.

22. Webster, J.A. 1990. Resistance in triticale to the Russian wheat aphid (Homoptera: Aphididae). J. Econ. Entomol. 83:1091-1095.

23. Webster, J.A., C.A. Baker and D.R. Porter. 1991. Detection and mechanisms of Russian wheat aphid (Homoptera: Aphididae) resistance in barley. J. Econ. Entomol. 84:669-673.

24. Webster, J.A., K.J. Starks and R.L. Burton. 1987. Plant resistance studies with *Diuraphis noxia* (Homoptera: Aphididae), a new United States wheat pest. J. Econ. Entomol. 84:944-949.

25. Zadoks, J.D., T.T. Chang and C.F. Konzak. 1974. A decimal code for the growth stages of cereals. Weed Res. 14:415-421.