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Inheritance and Allelism of Resistance to Russian Wheat Aphid, *Diuraphis noxia* (Mordvilko) in Iranian Wheat Cultivars

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ABSTRACT

The Russian Wheat Aphid (RWA), *Diuraphis noxia* (Mordvilko) is one of the major pests on cereal especially wheat and barley in some cereal-growing regions of the world. The use of resistant cultivars is an effective strategy to control RWA. This genetic study was conducted to determine the inheritance and allelic relationship of RWA resistance in two Iranian cultivars ''Azadi'' and ''Omid''. The resistant cultivars were crossed with each other and to a susceptible cultivar ''Sholeh''. Seedlings of the parents, F_1, F_2, BCS (backcross to the susceptible parent) and BCR (backcross to the resistant parent) were screened for resistance to RWA under greenhouse conditions. The response of seedlings to RWA was scored 21 days after artificial infestation using a 1-9 scale for leaf chlorosis and a 0-3 scale for leaf rolling. Unlike previous studies, leaf chlorosis and leaf rolling were considered as two separate traits. Different phenotypic segregation ratios were tested in the F_2 population for goodness of the fit. The results of leaf chlorosis measurements showed that one and two dominant genes control the resistance to RWA in ''Azadi'' and ''Omid'', respectively. Leaf rolling measurements indicated that resistance in the 'Azadi' cultivar is governed by one recessive gene and in 'Omid' by two genes, one dominant, and one recessive. Segregation in the F_2 population of the cross between two resistant cultivars indicated that their resistance genes are different for the two traits. Therefore, these different genes can be incorporated into an adapted wheat cultivars in order to produce a more durable resistance.

Key Words: *Diuraphis noxia*; Inheritance; Resistance; Wheat

INTRODUCTION

The Russian Wheat Aphid (RWA), *Diuraphis noxia* (Mordvilko), has become one of the most important pests of cereal crops in many wheat-growing areas of the world. It was first reported in 1900 in the Mediterranean region and Southern Russia (Elsidaig & Zwer, 1993). RWA was introduced to the USA in 1986 (Webster *et al.,* 1987). RWA feeding causes leaf chlorosis, leaf rolling and also purple coloration of leaves under cold temperatures or short day length. Under severe infestation, plants may be stunted and spikes deformed. The RWA has been known to act as a vector of viruses such as barley yellow dwarf, brome mosaic, and barley stripe mosaic (Storlie *et al.,* 1993).

Use of resistant cultivars is an effective and economically important strategy for protecting the crops from RWA and to minimize the use of pesticides. Du Toit (1987) reported that two wheat germplasm lines, PI137739, hard red wheat from Iran, and PI262660 a hard white winter wheat from the former Soviet Union, showed resistance to RWA in greenhouse tests. Resistance to RWA has also been identified in several wheat lines and related species (Du Toit, 1988; Webster *et al.,* 1988; Frank *et al.,* 1989; Nkongolo *et al.,* 1989; Zemetra *et al.,* 1990; Quick *et al.,* 1991; Smith *et al.,* 1991; Souza *et al.,* 1991; Saidi *et al.,* 1996; Martin & Harvey, 1997).

Genetic studies have shown that dominant genes *Dn1* and *Dn2* control resistance in PI137739 and PI262660 respectively (Du Toit, 1989). The resistance to RWA in PI372129 appeared to differ from *Dn1* and *Dn2* on the basis of an allelism test, and it was designated as *Dn4* (Saidi & Quick, 1996). Elsidaig and Zwer (1993) reported that two genes, a dominant gene at one locus and a recessive gene at the other locus controlled the resistance in PI294994. According to Marais and Du Toit (1993), however, resistance in this line is controlled by a single dominant gene (*Dn5*). Monosomic analysis indicated that *Dn1* (in PI137739) and *Dn5* (in PI 294994) are located on chromosome *7D* (Marais & Du Toit, 1993; Schroeder *et al.,* 1994). Resistance in PI 243781 from Iran was reported to be controlled by a dominant gene designated as *Dn6* (Saidi & Quick, 1996). Dong *et al.* (1997) Reported that the resistance in CI2401 is controlled by two dominate genes and resistance in CI6501 and CI94365 by one dominant gene. Allelism analysis showed that one of the resistance genes in CI2401 was the same allele as *Dn4* and the resistance gene in CI6501 was the same as *Dn6* (Dong *et al.,* 1997). Resistance in PI372129 (Iranian spring wheat) is controlled by two independent genes with additive effects (Ehdaie & Baker, 1999).

Development of resistant cultivars is the most effective method of controlling this pest in small grain crops. In order to efficiently use the resistant germplasm, it is important for breeders to determine the inheritance of the RWA resistance of outstanding lines and to determine the genetic relationship among various sources of resistance. The objective of this study was to determine the inheritance of resistance in two resistant Iranian cultivars ''Omid'' and ''Azadi'' and to identify the allelic relationship between resistance genes in these two cultivars.

MATERIALS AND METHODS

Two Iranian winter wheat cultivars ''Azadi'' and ''Omid'', previously identified as resistant to the Russian Wheat Aphid, were crossed with each other and with a susceptible cultivar ''Sholeh''. The F_2 populations were produced for each cross by selfing some of the F_1 plants. Backcross populations were produced by crossing F_1 plants with the resistant (BCR) and susceptible (BCS) parents. Seedling response to the RWA was studied at different times in separate experiments. Parents, F_1, F_2, BCR, and BCS of each cross were planted in a greenhouse employing a 14 h photoperiod at 30/20^{o}C day/night temperature. Each seed was planted in a small pot with 9 cm diameter. After emergence, 20 plants of each parent, 40 of each F_1, 200 of the F_2 and 100 plants of each backcross that were at the same growth stage were selected. The pots were placed close to each other (10 cm distance between two plants of each generation). The pots were uniformly irrigated throughout the experiment.

Aphids were collected from volunteer common wheat in the province of Qazvin, Iran. To obtain a colony of *D. noxia*, several aphids were reared on a winter wheat, 'Alamout' separately under a light plastic cage with mesh top and mesh-covered ventilation holes on the side. After a month a colony was obtained from each aphid. Only one of the aphid colonies was used in all experiments.

Seedlings were infested with RWA one week after planting according to Nkongolo *et al.* (1989) with some modifications. Individual plant at first- leaf seedling stage was infested with five late instar aphids using a moistened camel hairbrush. Plants and aphids were observed and controlled daily. Plants were evaluated for *D. noxia* feeding damage by measuring leaf rolling and leaf chlorosis 21 days after infestation. Different scales were used to assess different phenotypes (leaf rolling and leaf chlorosis). Preliminary observations revealed that the two symptoms were expressed independently. Plants with minor chlorosis were observed with severe rolling and plants with leaf chlorosis without leaf rolling. Thus leaf rolling and leaf chlorosis were considered as two different traits and studied separately. For leaf rolling, plants were rated 0-3 as: 0, no leaf rolling; 1, <50% of leaves rolled; 2, >50% of leaves rolled and 3, 100% of leaves rolled. Seedlings showing leaf-rolling rate as 0-1, were considered resistant and those rated 2-3 were taken as susceptible (Smith *et al.*, 1991). Leaf chlorosis was measured using a 1-9 scale in which: 1, healthy plants; 2, prominent chlorosis spots; 3, less than 15% chlorosis; 4, 15-25% chlorosis; 5, 25-40% chlorosis; 6, 40-55% chlorosis; 7, 55-70% chlorosis; 8, 70-85% chlorosis and finally 9 represents dead plants (Webster, 1987). Seedlings with scores 1-4 and those with scores 5-9 were considered as resistant and susceptible, respectively.

Counts of seedlings within the different damage classes were done when the susceptible parent showed severe streaking and rolling on the leaves. Data obtained from the F_2 populations (derived from crosses of resistant and susceptible parents) and BC populations were tested for goodness of the fit to different phenotypic segregation ratios. The Chi- square (X^2) test (Steel *et al.,* 1997) with Yates correction was employed to test the goodness of fit of the F_2's and BC's observed segregation to expected phenotypic ratios.

RESULTS AND DISCUSSION

The data of F_2 populations derived from each cross for both traits were tested for goodness of fit to different phenotypic segregation ratios. The segregation ratios are presented in Tables I and II for data that fit appreciates (X^2 were non-significant).

For leaf rolling, the numbers of resistant and susceptible plants of the parents, F_1, F_2, BCR, and BCS along with their F_2 segregation ratios are shown in Table I. The resistant cultivars ''Azadi'' and ''Omid'' showed no or very little leaf rolling (rating of 0-1) and the susceptible cultivar ''Sholeh'' had tightly rolled leaves (rating 2-3). The F_1 seedlings of the cross between ''Azadi'' and ''Sholeh'' were all susceptible, indicating that the resistance in ''Azadi'' is recessive. Segregation in BCS, 0R: 1S, confirmed the presence of recessive gene in,'Azadi', A 1R: 3S segregation ratio in the F_2 population of this cross, suggests that this resistance is controlled by one recessive gene. A Segregation ratio 1R: 1S in BCR plants provided further evidence that a single recessive gene controls the resistance in Azadi.

The F_1 and BCR plants from cross ''Omid'' and ''Sholeh'' were all resistant indicating that the resistance in ''Omid'' is dominant. The Segregation ratio of 1R: 1S in BCS of this cross, confirmed the dominance of resistance in ''Omid''. However, the F_2 population segregated in a 13R: 3S ratio which fit a two gene model where resistance is conferred by two genes, a dominant gene at one locus and a recessive gene at the second. The relationship between the genes of two resistant cultivars was studied using the F_2 population. The observed segregation of 55R: 9S ratio (Table I) indicated that the recessive gene in 'Azadi' is different from the recessive and dominant genes in 'Omid'.

For leaf chlorosis, segregation ratios are given in Table II. 'Azadi' and 'Omid' cultivars were found resistant based on leaf chlorosis; whereas, 'Sholeh' showed severely streaked

Table I. Segregation for resistance (based on leaf rolling symptom) to the RWA among Parents, F_1, F_2, BCR (backcross to resistant parent) and BCS (backcross to susceptible parent) progenies of wheat cultivars in seedling screening tests

Parents & Progenies	Segregation ratio				X^2	P
	Expected		Observed			
	R	S	R`	S		
'Azadi'	1	0	20	0		
'Omid'	1	0	20	0		
'Sholeh'	0	1	0	20		
'Azadi'/'Sholeh'						
F_1	0	1	0	37		
BCR	1	1	41	47	0.28	0.62
BCS	0	1	0	94		
F_2	1	3	56	127	2.82	0.095
'Omid'/'Sholeh'						
F_1	1	0	37	0		
BCR	1	0	89	0		
BCS	1	1	53	44	0.66	0.44
F_2	13	3	136	38	0.8	0.40
'Azadi'/'Omid'						
F_2	55	9	163	30	0.27	0.63

Table II. Segregation for resistance (based on leaf chlorosis symptom) to the RWA among Parents, F_1, F_2, BCR (backcross to resistant parent) and BCS (backcross to susceptible parent) Progenies of wheat cultivars in seedling screening tests

Parents & Progenies	Segregation ratio				X^2	P
	Expected		Observed			
	R	S	R	S		
'Azadi'	1	0	20	0		
'Omid'	1	0	20	0		
'Sholeh'	0	1	0	20		
'Azadi'/'Sholeh'						
F_1	1	0	37	0		
BCR	1	0	86	0		
BCS	1	1	46	54	0.49	0.49
F_2	3	1	133	50	0.41	0.53
'Omid'/'Sholeh'						
F_1	1	0	40	0		
BCR	1	0	94	0		
BCS	3	1	70	27	0.28	0.62
F_2	15	1	157	17	2.06	0.17
'Azadi'/'Omid'						
F_2	15	1	186	7	1.79	0.20

leaves. The F_1 and BCR plants from crossing 'Azadi' and 'Sholeh' were all resistant, indicating that resistance in 'Azadi' is dominant. Segregation in BCS (1R: 1S) and in F_2 population (3R: 1S) indicated that the resistance to RWA in 'Azadi' is controlled by one dominant gene.

The resistance level of F_1 and BCR plants of crossing 'Omid' and 'Sholeh' was similer to the level of their resistant parent 'Omid', indicating that the resistance based on leaf chlorosis in 'Omid' is dominate. The BCS and F_2 populations segregated in 3R: 1S and 15R: 1S ratio, respectively. This suggests that two dominant genes control the resistance based on leaf chlorosis in 'Omid'.

Segregation ratio of 15R: 1S in the F_2 population of the crossing between two resistant cultivar 'Azadi'/'Omid' indicated that one of the two resistance genes in 'Azadi' is same as single recessive gene in 'Omid'.

It is evident from this study that two different genes govern the resistance in 'Azadi'; one dominant gene for leaf chlorosis and a recessive gene for leaf rolling. The presence of different genes for resistance to *D. noxia* was previously reported. Elsidaig and Zwer (1993) showed that the resistance to RWA in PI294994 is controlled by one dominant gene and one recessive gene. Dong *et al.* (1997) have reported that the resistance to RWA in lines PI151918 and PI94355 may be conditioned by either one dominant or one dominant and one recessive gene. Nkongolo *et al.* (1991) also found a single recessive gene for resistance to RWA in an accession of *Aegilops tauschii*.

The 15R: 1S ratio in F_2 population of crossing 'Omid'/'Sholeh' for leaf chlorosis shows that there is a duplicate dominant epistasis between two genes in 'Omid, i.e. the presence of any one of the dominant alleles confers complete resistance to RWA with regard to leaf chlorosis. The 13:3 ratio of the F_2 for leaf rolling suggests that there is a dominant and recessive interaction between two genes controlling the resistance in 'Omid'. The presence of non-additive interaction between two RWA resistance genes was similarly observed by Dong *et al.* (1997) in lines CI2401 (duplicate dominant interaction), PI151918 and PI94355 (dominant and recessive interaction). Ehdaie and Baker (1999), however, concluded that there might be additive effect of two independent dominant genes controlling resistance to RWA in G5864. It can therefore be concluded that different genes with different effects control resistance to RWA in different genotypes.

Segregation in the F_2 population derived from the cross between 'Azadi' and 'Omid' showed that there are independent genes for resistance to RWA. These genes could therefore be simultaneously incorporated into a cultivar to obtain a more durable resistance to different *D. noxia* biotypes. Although the presence of different biotypes of RWA has not yet been reported, it could occur upon development of resistant cultivars as it has for the green bug, *Shizaphis graminum* (Painter 1985). Production of new biotypes is likely to overcome monogenic resistance in wheat. Breeding strategies are necessary to minimize the development of aphidses. The most important of these strategies is development of cultivars having a combination of different resistance genes.

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