International Scholars Journals

International Journal of Agroforestry and Silviculture ISSN 2375-1096 Vol. 8 (3), pp. 001-006, March, 2020. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Virulence of *Puccinia triticina* on wheat in Iran

S. Elyasi -Gomari

Azad Islamic University, Shoushtar Branch, Faculty of Agriculture, Shoushtar, Iran. E-mail: Sarhang_elyasi@yahoo.com.

Accepted 12 January, 2020

Wheat leaf rust is controlled mainly by race-specific resistance. To be effective, breeding wheat for resistance to leaf rust requires knowledge of virulence diversity in local populations of the pathogen. Collections of *Puccinia triticina* were made from rust-infected wheat leaves on the territory of Khuzestan province (south-west) in Iran during 2008 - 2009. In 2009, up to 20 isolates each of the seven most common leaf rust races plus 8 -10 isolates of unnamed races were tested for virulence to 35 near-isogenic wheat lines with different single Lr genes for leaf rust resistance. The lines with Lr9, Lr25, Lr28 and Lr29 gene were resistant to all of the isolates. Few isolates of known races but most isolates of the new, unnamed races were virulent on *Lr19*. The 35 *Lr gene* lines were also exposed to mixed race inoculum in field plots to tests effectiveness of their resistance. No leaf rust damage occurred on *Lr9, Lr25, Lr28* and *Lr29* in the field, and lines with *Lr19, Lr16, Lr18, Lr35, Lr36, Lr37* and the combination *Lr27* + *Lr31* showed less than 15% severity. A total of 500 isolates of *P. triticina* obtained from five commercial varieties of wheat at two locations in the eastern and northern parts of the Khuzestan region were identified to race using the eight standard leaf rust differential varieties of Johnson and Browder. Thirteen known wheat leaf rust races and several new, unnamed races were identified. The most common races in each year were races 57, 64, 84, 143 and 167.

Key words: *Puccinia triticina*, wheat leaf rust, specific resistance.

INTRODUCTION

Leaf rust, caused by *Puccinia triticina* Eriks., is the most common rust disease and regularly occurring disease of wheat (*Triticum estivum L.*) in Iran and worldwide. The fungus is heteroecious, and therefore requires a telial/ uredinial host (usually wheat) and an alternative (pycnial/ aecial) host (*Thalictrum speciosissimum* or *Isopyrum fumaroides*) to complete the full life cycle.

It is important to understand the genetic diversity in populations of *P. triticina*, because major genes for leaf rust resistance in wheat are race-specific. *P. triticina* has a relatively long history of population studies, with nation-wide race surveys for this rust beginning in the US in 1926 (Johnston et al., 1968), in Iran in 1968 (Bamdadian, 1973), in Canada in 1931 (Johnson, 1956) and in Australia in 1920 (Waterhouse, 1952). The wheat cultivars Malakof (*Lr1*), Webster (*Lr2a*), Carina (*Lr2b, LrB*), Loros (*Lr2c*), Brevit (*Lr2c, LrB*), Hussar (*Lr11*), Democrat (*Lr3*) and Mediterranean (*Lr3*) were designated as the International Standard set of leaf rust differentials, and used in the early race identification studies.

The use of wheat cultivars with genetic resistance to leaf rust is the most practical method of controlling this disease (Elyasi-Gomari and Lesovaya, 2009). Effective leaf rust resistance in wheat cultivars is dependent on the virulence of the regional populations of *P. triticina*. Each 1% increase in leaf rust severity decreases yield 40.07 kg ha-1 and 1000 kernel weight 0.13 g (Leonard KJ et al., 2005). In Iran and worldwide all three rusts are present but stripe rust and leaf rust are more important. Yield losses in wheat from *P. triticina* infections are usually the result of decreased numbers of kernels per head and lower kernel weights (Elyasi-Gomari and Lesovaya, 2009). *P. triticina* is now recognized as an important pathogen in wheat production worldwide, causing significant yield losses over large geographical areas (Elyasi-Gomari and Panteleev, 2006; Kolmer et al., 2007; Beyhan et al., 2008; Gilla et al,. 2008). Brennan and Murray (1988) undertook an economic analysis of losses due to wheat rust diseases in Australia and estimated the annual value of control strategies for leaf rust at $A26 million. An epidemic of leaf rust in Western Australia in 1992 affected more than 100,000 ha of wheat and caused yield losses of up to 37% (McIntosh et al., 1995). Abdel Hak et al., (1980) estimated crop losses of up to 50% due to leaf rust infection in Egypt. In 2007, Yield losses in wheat due to leaf rust were estimated to be 14% in Kansas (Kolmer et al., 2009). In Iran, leaf rust is an endemic disease of wheat in north, west and south which appears each year. In 1993, yield losses due to Leaf rust in some parts of Iran were estimated at about 1.5 million tones (Torabi et al., 1995). In particular, losses to leaf rust in spring wheat in the Khuzestan province of Iran were greater than at any time in the last 10 years (Mahdian and Dehghani, 2004). Over the last 10 years the effectiveness of many known leaf rust resistance genes (*Lr genes*) have been tested on single-gene lines in field plot tests at various locations in central and western, southern and eastern regions of Iran (Torabi et al., 1995; Torabi et al., 2001). Results showed that effectiveness of some *Lr genes* against regional populations of *P. triticina* in field tests varied among regions. On the other hand, some Lr genes showed a general tendency to lose effectiveness over time in all regions, while some others generally increased in effectiveness over time. Hence, we have analyzed the frequencies races and virulence of *P. triticina* populations in Iran. The objectives of this study were to characterize the current virulence of *P. triticina* populations the Khuzestan province (south-west) in Iran.

MATERIALS AND METHODS

Collections of *P. triticina* were made from rust-infected wheat leaves on the territory of Khuzestan province (south-west) in Iran during 2008 - 2009. In 2008, 100 isolates were obtained from each of five wheat varieties, 'Mahdavi', 'Zarin', 'Darab2', 'Atila5' and 'Niknezhad' in one location. In 2009, 100 isolates were obtained from each of five wheat varieties, 'Mahdavi', 'Zarin', 'Darab2', 'Atila5' and 'Niknezhad' in the same one location as in 2008. Thus, a total of 500 isolates were collected from this site each in each year.

Leaves with leaf rust uredinia were collected at 50 sites according to standard procedures (Peterson et al., 1948), one leaf per site, in each of the five varieties in each year. The collections were taken at equidistant sites during the time of maximum rust development (milk-dough stage). Each rusted leaf was placed in a filter paper package and the package was labeled. Packages of rusted leaves were held at 4°C in a refrigerator until urediniospores were collected for inoculation in the greenhouse. Urediniospores were collected by placing a piece of the rusted leaf sample in a flask of water plus a detergent Tween-80 (1 or 2 drops per l), and the flask was shaken to produce a suspension of urediniospores. The urediniospore suspension was sprayed onto fresh detached leaf pieces of the susceptible wheat variety 'Bulani' in a Petri dish on water agar plus benzimidazole at 0.004 μg/ml to establish isolates from single uredinia (Mikhailova and Kvitko, 1970). 'Bulani' has no known *Lr genes* for leaf rust resistance. The Petri dishes were covered with moistened filter paper to maintain 100% RH for 1 day. After 1 day, the filter paper was removed and the closed Petri dishes were incubated at 24°C under artificial light at 10^5 lux. When chlorotic spots indicating leaf rust infection became visible, leaf pieces bearing single leaf rust infections were transferred to fresh Petri dishes. At 10 days after inoculation, uredinia with abundant sporulation were present on the single uredinium leaf pieces. A soft brush was used to remove urediniospores of the single uredinial isolates and spread them over detached leaves of 'Bulani' wheat on water agar and benzimidazole in a Petri dish for a generation of urediniospore increase of each isolate prior to inoculation of the differential varieties for race identification. Two single uredinial isolates were established from each individual rusted leaf that was collected from the field. Thus, the 50 rusted leaves collected per variety at each location yielded 100 single uredinial isolates for race determination, or a total of 500 isolates over all varieties.

The single uredinial isolates were tested for virulence on the eight standard differential varieties of Johnston and Browder (Johnston and Browder, 1964; Lesovoj, and Panteleev, 2000): Malakof, Carina, Brevit, Webster, Loros, Mediterranean, Hussar, and Democrat (Tables 1, 2). Detached leaves of each differential variety were incubated under artificial light on water agar with benzimidazole as described for establishment of single uredinial isolates. In previous tests we found that infection types on detached leaf pieces under these conditions were comparable to those on intact seedlings in the greenhouse. Leaves of each differential variety were placed in a separate Petri dish. The detached leaves were inoculated by spraying them with a suspension of urediniospores of a single uredinial isolate in water with Tween 80 and incubated one day with the Petri dishes covered with moist filter paper as described above. The worksite and equipment were sterilized with 96% ethanol between inoculations with different isolates to prevent cross contamination. After one day the moist filter paper was removed from the Petri dishes and replaced with glass covers. After 10 days under artificial light at 24°C, the leaf rust reaction types on each differential variety were determined according to Mains and Jackson's (Mains and Jackson, 1926) scale, with infection types 0, 1 and 2 considered resistant and infection types 3 and 4 considered susceptible.

Selected isolates of seven races as well as isolates of unnamed races collected in 2009 were tested for virulence on 35 near-isogenic wheat lines. With the exception of one line with both *Lr27* and *Lr31*, each line had a different single *Lr gene* for leaf rust resistance (Table 3). The isolates tested included 20 each from races 57, 64, 84, 143, and 167, and 8 - 10 isolates each of races 12, 45, and the unnamed races (Table 2) . The 35 near-isogenic wheat lines were tested both as seedlings in the greenhouse and as adult plants in field plots. In the greenhouse the lines were grown in soil in boxes and were inoculated 10 days after planting when the second leaves were beginning to form. Seedlings were sprayed with a suspension of urediniospores in water with Tween-80 and the inoculated plants were incubated on day at 100% RH before being returned to the greenhouse. Infection types were scored according to Mains and Jackson's (Mains, and Jackson, 1926) scale.

In field tests, the near- isogenic lines were planted in 1 m rows in blocks surrounded with spreader rows of a susceptible wheat variety. At 17 - 20 days prior to heading, the plots were inoculated by spraying them with a suspension of urediniospores (75 - 100 mg spores per L) in water with Tween-80. The inoculums consisted of a mixture of races collected from the field in Iran. The spore suspension was applied at a rate of 60 ml per m^2 (4 - 5 mg urediniospores per m^2). To maintain leaf wetness, the soil under the inoculated rows was heavily watered and the rows were covered with polyethylene sheets for 8 - 10 h after inoculation. Infection type and severity of infection were determined at 15 days after inoculation. Infection type was scored according to Mains and Jackson's scale (Mains and Jackson, 1926). Rust severity was scored as the percentage of leaf area affected based on Strakhov's scale (Starakhov, 1951). Strakhov's scale was adapted from that of Peterson et al. (1948) with gradations of 0, 5, 15, 45, 65, and 100% infection relative to the proportion of leaf area covered by pustules at the maximum (37% of total leaf area covered by uredinia) level of leaf rust infection.

RESULTS

In present studies, Thirteen known races of *P. triticina* were identified from collections from Iran in both 2008 (Table 1) and 2009 (Table 2). In addition, 2.4% of the isolates collected in 2008 and 2.6% of those from 2009

Table 1. Race composition of collections of *Puccinia triticina* from commercial varieties of winter wheat in Iran in 2008.

Race	Avirulence/virulence**	% of isolates from indicated variety*					
		Mahdavi	Zarin	Niknezhad	Darab2	Atila5	Total
12	Ma,Wst/Ci,Bv,,Ls,Mi,Hs,Do	2	1	3	2	3	2.2
45	Ci,Bv,Wst,Ls/Ma,Mi,Hs,Do	3	2	3	2	2	2.4
54	Ma/Ci,Bv,Wst,Ls,Mi,(Hs),Do	5	4	3	4	2	3.7
57	Ma/Ci,Bv,Wst,Ls,Mi,Hs,Do	9	4	8	6	5	6.4
64	Ma,Ci,Wst/Bv,Ls,Mi,Hs,Do	21	28	22	24	26	24.2
84	/Ma,Ci,Bv,Wst,Ls,Mi,Hs,Do	10	12	10	12	10	10.8
122	Mi/Ma,Ci,Bv,Wst,Ls,Hs,Do	3	1	2	3	2	2.2
130	Ci,Bv/Ma,Wst,Ls,Mi,Hs,Do	2	0	3	3	1	1.8
143	Ci/ Ma,Bv,Wst,Ls,Mi,Hs,Do	23	22	22	24	25	23.2
144	Wst/Ma,Ci,Bv,Ls,Mi,Hs,Do	4	2	3	0	5	2.8
147	Ci,Mi,Do/Ma,Bv,Wst,Ls,Hs	1	2	1	0	0	0.8
167	Ls/Ma,Ci,Bv,Wst,Mi,Hs,Do	15	18	15	15	16	15.8
176	Ma,Ci,Bv,Wst,Ls,Mi/Hs,Do	1	0	2	3	0	1.2
Unid. ***		1	4	3	2	3	2.6
Isol. ****		100	100	100	100	100	500

*Complete names of varieties are: Mahdavi, Zarin, Niknezhad, Darab2, and Atila5. ** Differential varieties are: Malakof, Carina, Brevit, Webster, Loros, Mediterranean, Hussar, and Democrat (4). *** New races not listed in Johnston and Browder's (Johnston and Browder, 1964) international register of wheat leaf rust races. **** Number of isolates tested.

Table 2. Race composition of collections *of Puccinia triticina* from commercial varieties of winter wheat in Iran in 2009.

Race	Avirulence/virulence**	% of isolates from indicated variety*					
		Mahdavi	Zarin	Niknezhad	Darab2	Atila5	Total
12	Ma,Wst/Ci,Bv,Ls,Mi,Hs,Do	6	8	6	3	5	5.6
45	Ci,Bv,Wst,Ls/Ma,Mi,Hs,Do	4	3	1	4	1	2.6
54	Ma/Ci,Bv,Wst,Ls,Mi,(Hs),Do	4	3	3	0	1	2.2
57	Ma/Ci,Bv,Wst,Ls,Mi,Hs,Do	14	10	14	12	14	12.8
64	Ma,Ci,Wst/Bv,Ls,Mi,Hs,Do	20	22	24	27	27	24.0
84	/Ma,Ci,Bv,Wst,Ls,Mi,Hs,Do	6	10	4	5	11	7.2
122	Mi/Ma,Ci,Bv,Wst,Ls,Hs,Do	4	3	3	3	1	2.8
130	Ci,Bv/Ma,Wst,Ls,Mi,Hs,Do	2	0	1	1	2	1.2
143	Ci/ Ma,Bv,Wst,Ls,Mi,Hs,Do	18	23	27	25	19	22.4
144	Wst/Ma,Ci,Bv,Ls,Mi,Hs,Do	1	1	3	0	3	1.6
147	Ci,Mi,Do/Ma,Bv,Wst,Ls,Hs	2	0	1	0	0	0.6
167	Ls/Ma,Ci,Bv,Wst,Mi,Hs,Do	15	14	9	15	14	13.4
176	Ma,Ci,Bv,Wst,Ls,Mi/Hs,Do	2	0	2	1	2	1.6
Unid ***		3	3	2	4	0	2.4
Isol. ****		100	100	100	100	100	500

*Complete names of varieties are: Mahdavi, Zarin, Niknezhad, Darab2, and Atila5. ** Differential varieties are: Malakof, Carina, Brevit, Webster, Loros, Mediterranean, Hussar, and Democrat (4). *** New races not listed in Johnston and Browder's (Johnston and Browder, 1964) international register of wheat leaf rust races. **** Number of isolates tested.

were determined to be of races not included in Johnston and Browder's international register of races (Johnston and Browder, 1964). Races 64 and 143, the two most common races occurred at frequencies greater than 20% in both years. Race 167, the third most common race occurred at 15.8% in 2008 and 13.4% in 2009. All 13 of the known races were found among isolates collected from the leaf rust susceptible varieties Mahdavi and Niknezhad in both 2008 and 2009 (Tables 1 and 2). At least a few isolates of races 12, 45, 57, 64, 84, 122, 143, and 167 were collected from each of the five varieties from which collections of *P. triticina* were made in 2008 and 2009. The frequencies of the 13 races of *P. triticina* collected over all varieties were nearly the same in 2009 as in 2008 (Tables 1 and 2). The frequency of race 12 increased from 2.2% to 5.6% and the frequency of race 57 increased from 6.4% to 12.8% from 2008 to 2009. The frequency of race 84 decreased from 10.8% to 7.2% and the frequency of race 167 decreased from 15.8% to 13.4% from 2008 to 2009.

Tests for virulence of isolates of races 12, 45, 57, 64, 84, 143, 167, and the isolates of unnamed races on seedlings of near-isogenic *Lr gene* lines of wheat in the greenhouse indicated that the population of *P. triticina* in the Khuzestan region of Iran is highly virulent to most of the Lr genes (Table 3). However, wheat lines with *Lr9, Lr19, Lr25, Lr28* and *Lr29* gene were resistant to all of the isolates. These results confirm the effectiveness of lines with *Lr9, Lr19, Lr28*, and *Lr29* reported by Afshari (2008) in Iran. The line with *Lr26* was effective against all of the isolates of race 57 which was the most common race found in 2009, but *Lr26* was not effective against the other races. This is consistent with the observed increase in the frequency of virulence to *Lr26* in Iran since 1999 (Torabi et al., 2001).

The lines with *Lr11, Lr17* and *Lr18* appeared to be susceptible to all the isolates as seedlings in the greenhouse, but they showed considerable resistance as adult plants in field tests. The leaf rust reaction types of *Lr11, Lr17* and *Lr18* are difficult to characterize, because their intermediate level of resistance is temperature sensitive and difficult to recognize in normal greenhouse tests. Thus, it is possible that many of our isolates of *P. triticina* may lack virulence to *Lr11, Lr17* or *Lr18* but were mistakenly rated as virulent in the greenhouse tests.

Races 64 and 167, which were found at 24.2 and 15.8% frequency in 2009, appeared to be nearly homo-geneous. All isolates of these two races showed similar reactions on all the *Lr gene* lines except the line with *Lr27* + *Lr31*, which was susceptible to 52.2% of the race 64 isolates and 46.2% of the race 167 isolates. There was considerable heterogeneity among the isolates of *P. triticina* for virulence or avirulence to *Lr1, Lr2a, Lr2c* , and *Lr27* + *Lr31*. Little or no leaf rust developed on the lines with *Lr9, Lr19, Lr25, Lr28* and *Lr29* in field tests, which confirmed their resistance to all or nearly all isolates of *P. recondita* f. sp. *tritici* as seedlings in greenhouse tests. Four of the *Lr genes*, *Lr12, Lr22, Lr34*, and *Lr35* have been characterized as conferring adult plant resistance that is not expressed or poorly expressed in the seedling stage. The *Lr35* line showed a high level of resistance in the field test, and the *Lr22* line appeared to express some resistance. No resistance was apparent in the field tests with the *Lr1, Lr2b, Lr2c, Lr3ka, Lr3kb, Lr12, Lr20, Lr30, Lr33* line or the *Lr34* line.

Several other *Lr gene* lines had reduced leaf rust damage in field plot tests that could not be explained by their seedling reactions. The lines with *Lr11, Lr17* and *Lr18* have already been mentioned in connection with the difficulty of recognizing their resistance in seedling tests when temperature is not strictly controlled. Lines with *Lr17, Lr24, Lr32,* and *Lr36* had 41.5, 31.5, 35.7, and 12.8% leaf rust in field plot tests even though they were susceptible to all of the isolates tested in seedling tests in the greenhouse. It may be that some of the races in the inoculum used in the field plot inoculations were less virulent to the set of near-isogenic wheat lines than the isolates collected for race identification.

DISCUSSION

The most notable change in race frequencies compared to earlier studies was the decline in the frequency of race 84. Race 84 was once the predominant race in Iran, but it occurred at 10.8% frequency in 2008 and 7.2% in 2009. A sharp decline in frequency of race 84 has been observed in recent years. Torabi et al., (2001) noted that the frequency of race 84 had fallen to as low as 4.65 in some regions of Iran. In general, the frequencies of races were similar in collections from the five different wheat varieties ‘Mahdavi’, ’Zarin’, ’Darab2’, ’Atila5’ and ’Niknezhad’ in this study. This indicates that these varieties all lack several of the resistance genes that are included in the standard differential varieties of Johnson and Browder (Johnston and Browder, 1964). For example, race 64, the most commonly found race, is avirulent on ‘Malakof’ (*Lr1*), ‘Webster’ (*Lr2a*), and ‘Carina’ (*Lr2b, LrB*). Another common race, 167, is avirulent on ‘Loros’ (*Lr2c*), and the relatively rare race 122, which was collected from all five cultivars, is avirulent on ‘Mediterranean’ (*Lr3*).

Resistance genes *Lr9* and *Lr19* were reported to be effective against all leaf rust races in Iran as early as the Bamdadian (1973). In 1995 -1999 the lines with *Lr9, Lr19,* and *Lr23* were considered highly effective against leaf rust in all regions of Iran (Torabi et al., 2001), but by 1996, Lr23 began to lose effectiveness as races virulent to Lr23 began to increase in frequency (Bamdadian, 1997; Torabi et al., 2001). In 1997 - 1999 all leaf rust isolates tested in Iran were virulent to Lr24 (Torabi et al., 2001), but by 2005, 48% of the leaf rust isolates tested in Iran were avirulent to *Lr24*; by 1998, 61% of the isolates were avirulent; and in 1999, 80% of the isolates tested in Iran were avirulent to *Lr24* (Afshari, 2005; Afshari, 2006). It appears that during the years 1988 to 1999, virulence to *Lr24* did not occur among the leaf rust races that were selected by the resistance of new wheat varieties grown in Iran from 1988 to 1999. This trend has now been reversed. In 2009 we found that all isolates of the most common races except those of race 64 and 52.5% of those of race 84 were virulent to L24 (Table 3).

Table 3. Virulence of *Puccinia triticina* isolates of different races* found in 2008 to seedlings of near-isogenic wheat lines with different single Lr genes for resistance and severity of leaf rust on near-isogenic lines as adult plants in field plots**.

Line	Percentage of isolates of indicated race that were virulent***								Field severity (%)
	12	45	57	64	84	143	167	Unid. ****	
Lr1	0	70.5	0	0	100	65.5	100	100	100
Lr2a	0	65.5	100	0	79.2	72.2	83.4	85.4	80.2
Lr2b	0	100	100	0	100	100	100	100	100
Lr2c	0	75.2	100	0	65.5	81.4	0	100	100
Lr3	100	100	100	100	100	100	100	100	100
Lr3ka	100	100	100	100	100	100	100	100	100
Lr3bg	100	100	100	100	100	100	100	100	100
Lr9	0	0	0	0	0	0	0	0	0
Lr10	100	100	100	100	100	100	100	100	100
Lr11	100	100	100	100	100	100	100	100	40.6
Lr12	100	100	100	100	100	100	100	100	100
Lr14a	100	100	100	100	100	100	100	100	80.2
Lr14b	100	100	100	100	100	100	100	100	80.3
Lr15	100	100	100	100	100	100	100	100	100
Lr16	100	100	100	100	100	100	100	100	12.6
Lr17	100	100	100	100	100	100	100	100	41.5
Lr18	100	100	100	100	100	100	100	100	6.7
Lr19	0	0	0	0	0	0	0	6.2	0
Lr20	100	100	100	100	100	100	100	100	100
Lr21	100	100	100	100	100	100	100	100	65.2
Lr22a	100	100	100	100	100	100	100	100	80.2
Lr23	100	50.2	0	100	65.2	100	100	100	50.7
Lr24	0	0	0	0	0	0	0	0	0
Lr25	0	0	0	0	0	0	0	0	0
Lr26	75.5	100	72.2	0	52.7	100	100	100	35.5
Lr27+Lr31	50.2	55.4	34.0	52.2	50.9	71.4	46.2	91.5	5.7
Lr28	0	0	0	0	0	0	0	0	0
Lr29	0	0	0	0	0	0	0	0	0
Lr30	100	100	100	100	100	100	100	100	100
Lr32	100	100	100	100	100	100	100	100	35.7
Lr33	100	100	100	100	100	100	100	100	100
Lr34	100	100	100	100	100	100	100	100	100
Lr35	100	100	100	100	100	100	100	100	1.6
Lr36	100	100	100	100	100	100	100	100	12.8
Lr37	100	100	100	100	100	100	100	100	8.2

* Races were identified according to Johnston and Browder's (Johnston and Browder, 1964) international register of wheat leaf rust races. ** Field plots were inoculated 17-20 days before heading with a mixture of races typical of the natural population Puccinia triticina in the Khuzestan province of Iran. *** Seedlings of the near-isogenic lines were tested in the greenhouse against 20 isolates each of races 57, 64, 84, 143, and 167 and against 8-10 isolates of the other races. **** New races not listed in Johnston and Browder's (Johnston and Browder, 1964) international register of wheat leaf rust races.

It has been noted that the greatest effectiveness of resistance to leaf rust in wheat can be attributed to resistance genes derived from wild relatives of wheat rather than from genes originating from *Triticum aestivum* (Goel and Saini 2001; Menon and Formar 2001; Leonard et al., 2005). For example, Lr9 was transferred to wheat from *Triticum umbellulatum*, *Lr19, Lr24* and *Lr29* are from *Agropyron elongatum*, *Lr21, Lr22* and *Lr32* genes are from *Triticum tauschi*, and *Lr28, Lr35* and *Lr37* are from *T. speltoides*. Our results confirm that *Lr9, Lr19, Lr24, Lr28*, and Lr29 are still effective against all or nearly all leaf rust races found in Iran. Our field inoculations also show that *Lr32, Lr35* , and *Lr37* were effective under field conditions against a broad mixture of leaf rust races in Iran. These resistance genes will be valuable to wheat breeders in developing future leaf rust resistant varieties. On the other hand, genes such as Lr2c*, Lr3, Lr3ka, Lr10, Lr16, Lr30* and *Lr34* are no longer effective in Iran and should be withdrawn from breeding programs or supplemented with more effective resistance genes. This is also true for *Lr23*, which formerly provided valuable resistance in Iran, but now is ineffective in the Khuzestan region. If cultivars are widely grown throughout the Khuzestan region, then selection of *P. triticina* isolates with virulence to resistance genes in wheat cultivars will occur at a faster rate. Effective leaf rust resistance may be prolonged by diversification of resistance genes in wheat cultivars that are commonly grown in this region. The use of these resistance genes in combination with adult plant resistance genes is expected to be a useful method to control leaf rust disease. This shows that continued regional surveys of virulence in *P. triticina* are necessary to support programs of breeding wheat varieties with effective leaf rust resistance in Iran.

ACKNOWLEDGMENTS

I thank Dr. Kurt J. Leonard from Department of Plant Pathology University of Minnesota St. Paul, USA for his discussions with me and suggestions, and for providing certain materials for the study. Financial support and the provision of facilities from the Islamic Azad University, Shushtar Branch for this research is gratefully acknow-ledged.

REFERENCES

Abdel HTM, EL-Sherif NA, Bassiouny AA, Shafik EL, Dauadi Y (1980). Control of wheat leaf rust by systemic fungicides. Proceedings of the Fifth European and Mediberranean Cereal Rusts Conference. Bari, Italy, pp. 255-266.

Afshari F (2005). Monitoring of virulence factors of Puccinia triticina Eriksson, the causal Agent of wheat Leaf Rust in Iran During 2002-2004. Iran. J. Nohal Bazr. 21(4): 485-500.

Afshari F (2006). Protein Marker Assisted Identification of Yr9, Lr26 and Sr31Genes in a Group of Iranian Wheat Cultivars. J. Agric. Sci. Technol. 8: 265-268

Afshari F (2008). Prevalent pathotypes of *Puccinia striiformis* f. sp. *tritici* in Iran. J. Agric. Sci. Technol. 10: 67-78.

Bamdadian A (1973). Physiological Races of Puccinia recondita in Iran. Cereal Rust Bull. 1: 45-47.

Bamdadian A (1997). A Genetic Study of Plant Resistance to Brown (Leaf) Rust in Bread Wheat. Iran. J. Agric. Sci. 36(2): 363-373

Beyhan A, Nusret Z, zzet O (2008). Field Resistance of Wheat (*Triticum aestivum* L.) Genotypes from Different Countries to Leaf Rust (Puccinia triticina). Turk. J. Agric. For. 32: 479-486.

Elyasi-Gomari S, Lesovaya GM (2009). Harmfulness of wheat leaf rust in Eastern part of forest-steppe of Ukraine. Arch. Phytopathol. Plant Protect. 42(07): 659-665.

Elyasi-Gomari S, Panteleev VK (2006). Virulence polymorphism of *Puccinia recondita* f. sp. *tritici* and effectiveness of Lr-genes for leaf rust resistance of wheat in Ukraine. Plant Dis. 90: 853-857.

Gilla BS, Huang L, Kuraparthy V, Raupp WJ, Wilson DL, Friebe B (2008). Alien genetic resources for wheat leaf rust resistance, cytogenetic transfer, and molecular analysis. Austr. J. Agric. Res. 59: 197-205.

Goel RK, Saini RG (2001). Effectiveness of Triticum tauschii (Aegilops squarossa) derived Lr genes in conferring resistance to Indian races of leaf rusn (Puccinia recondita tritici) of wheat . Wheat Inf. Ser. 93: 19-21.

Johnson T (1956). Physiologic races of leaf rust of wheat in Canada 1931 to 1955. Can. J. Agric. Sci. 36: 323-332.

Johnston CO, Browder LE (1964). Seventh revision of the international register of physiologic races of Puccinia recondita f. sp. tritici. Plant Dis. Reprod. 50: 756-760.

Johnston CO, Caldwell RM, Compton LE, Browder LE (1968). Physiologic races of *Puccinia recondita* f. sp. *tritici* in the United States from 1926 through 1960. USDA Tech. Bull. 1393: 1-18.

Kolmer JA, Long DL, Hughes ME (2007). Physiological specialization of *Puccinia triticina* on wheat in the United States in 2005. Plant. Dis. 91: 979-984.

Kolmer JA, Long DL, Hughes ME (2009). Physiologic specialization of Puccinia triticina on wheat in the United States in 2007. Plant Dis. 93: 538-544.

Leonard KJ, Anikster Y, Manisterski J, Long DL (2005). Resistance to leaf rust, stripe rust, and stem rust in *Aegilops* spp. in Israel. Plant Dis. 89: 303-308.

Mahdian S, Dehghani M (2004). Identication of wheat Leaf Rust (*Puccinia recondite* f. sp. *Tritici*) pathotypes in Mazandaran and Gorgan province. Iran. J. Plant Pathol. 72: 29-37

Mains EB, Jackson HS (1926). Physiologic specialization in the leaf rust of wheat Puccinia triticina Erikss. Phytopathol. 16: 89-120.

McIntosh RA, Wellings CR, Park RF (1995). Wheat rusts: An atlas of resistance genes. CSIRO Publications, East Melbourne.

Menon MK, Formar SM (2001). Transfer of Agropyron elongatum – derived rust resistance genes Sr24 and Lr24 into some Indian bread wheat cultivars. Wheat Inf. Ser. 93: 20-24.

Mikhailova LA, Kvitko KV (1970). Laboratory methods of cultivation of brown rust pathogen in wheat, P. recondita Rob. et Desm. f. sp. tritici Erikss. Mikologiya i fitopatologiya (Leningrad). 3: 269-273.

Peterson RF, Campbell AB, Hannah AE (1948). A diagrammatic scale for estimating rust intensity of leaves and stems of cereals. Can. J. Res. Sect. C 26: 496-500.

Starakhov TD (1951). Otsenka sortov pshenytsi po immunosti I porazhayemosti boroj listovoj rzhavchynoj P. recondita Rob. et Desm. f. sp. *tritici* Erikss. (methodology -appendix). – Kharkov: publisher, pp. 11. (In Ukrainian)

Torabi M, Mardouchi W, Nazari K, Golzar H, Kashani AS (1995). Effectiveness of Wheat Yellow Rust Resistance Gene in Different Parts of Iran. Cereal Rust Powdery Mildew Bull. 23: 9-12.

Torabi M, Nazari K, Afshari F (2001). Genetics of pathogenicity of *Puccinia recondite* f.sp. *tritici* , the causal agent of leaf rust of wheat. Iran. J. Agric. Sci. Abstract in English, 32: 635.

Waterhouse WL (1952). Australian rust studies. IX. Physiologic race determination and surveys of cereal rusts. Proc. Linn. Soc. N.S.W. 77: 209-258.