CHARACTERIZATION OF WHEAT RUST AND POWDERY MILDEW POPULATIONS IN TRANSYLVANIA AND IMPLICATIONS IN BREEDING FOR RESISTANCE

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ABSTRACT

The dynamics of virulence in the local populations of wheat rusts and powdery mildew has been supervised at A.R.D.S. Turda since 1974, by growing special national and international disease nurseries. The resistance genes and trap varieties from these nurseries have been observed in the field, on the adult plant stage under natural or artificial infections with a mixture of local virulences of the studied pathogens. The results obtained during 1994-2001 are presented, with a highlight on the resistance genes and the sources that are still effective. The results are considered from the viewpoint of both pathogen-population structure and weather conditions specific to every year, which could influence the manifestation of the attack. The genes which maintained their efficiency for powdery mildew (*Erysiphe graminis* f.sp. *tritici*) resistance, are *Pm2 + Pm6*, *Pm5 + Pm* (MK 983), *Pm17* (Amigo), plus several adult plant resistance sources (like the cultivars Transilvania, Turda 95, Flamura 85, Fundulea 4, Ardeal). The effective genes for yellow rust (*Puccinia striiformis* f.sp. *tritici*) are *Yr1* (Chinese 166), *Yr3, Yr3c, Yr5* (*T. spelta album*), *Yr11*, *Yr14*, *Yr12, 3a, 4a, Yr13,1,3a,4a, Yr17, So, Sd, Sp*, and the cultivars *Almus, Norda, Remus*. The genes still effective against leaf rust (*Puccinia recondita* f.sp. *tritici*) are *Lr9, Lr19, Lr21* (WGCR 15), *Lr22, Lr22a, Lr24, Lr29, Lr32, Lr36, Lr38, Lr39, Lr40, Lr41, Lr42, Lr43, Lr44l*, as well as certain adult plant resistance sources: Turda 195, Turda 81, Transilvania, Ardeal, Flamura 85, Gabriela. The experimental results have contributed to wheat breeding for rust and powdery mildew resistance. They allowed the identification of new resistance sources, the control of their efficiency into time and their inclusion in the breeding material.

Key words: breeding, resistance genes, leaf rust, powdery mildew, yellow rust

INTRODUCTION

The climatic conditions specific to wheat cropping area of Transylvania favoure the occurrence and development of many pathogens which lead to quantitative and qualitative yield losses.

Wheat rusts and powdery mildew, diseases which affect mainly the foliage, reduce the photosynthetic area with negative effects on yield and grain composition.

One of the most important targets of wheat breeding is the development of cultivars resistant to diseases. The utilization of host plant resistance as an efficient method for disease prevention has many advantages for farmers. Growing resistant cultivars does not require supplementary interventions and expenses for disease control and is not harmful to environment. However, the host plant resistance could become in the long time less efficient or even inefficient because of possible occurrence of new virulences or their frequency modification within the pathogen population. The so-called „loss of resistance", is taking place (Bayles, 1998). That is why breeders should develop cultivars with durable resistance to diseases.

The resistance sustainability increases through the development and maintenance of genetic diversity at the level of both new cultivars and their structure by the utilization of oligogene and polygene combinations and of horizontal and vertical resistance types (Ceapoiu et al., 1977, 1983, 1984; Botezan et al., 1982; Johnson, 1988; Ittu et al., 1989).

This strategy supposes a good knowledge of changes occurring in local pathogen populations by early detection of both new virulences and modifications regarding the virulence frequency (McIntosh, 1988; Rajaram et al., 1988; Roelfs, 1988; Stubbs, 1988; Moldovan et al., 1994; Bayles, 1998; Rabinovich et al., 2001).

The observation on changes of rust and powdery mildew local populations at A.R.D.S. Turda started in 1974 and was conducted on collections of differential cultivars and near- isogenic lines from national and international survey programmes (Figure 1).

Although these nurseries had a limited duration in time, the respective collections were maintained and the observations on these genotypes were performed every year because, in Mesterhazy's et al. (2000) opinion, regarding the wheat leaf rust, a circulation of races in European populations could not be demonstrated till now, many countries (regions) having their own local races.

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The aim of this paper is the characterization of wheat rust (*Puccinia* spp.) and powdery mildew (*Erysiphe graminis* f. sp. *tritici*) local populations based on observations performed in gene collections, identification of new resistance sources and of modifications occurring in these source efficiency, aiming at introduction of valuable sources into new breeding material in order to breed wheat cultivars with durable disease resistance.

National collection for rust and powdery mildew study
- coordinator: A.R.D.I. Fundulea
- cooperating centers in Romania: Fundulea, Turda, Podu-Iloaiei, Lovrin
- period: 1974-1985

Uniform nursery for survey of rust and powdery mildew virulences in East-European countries
- coordinator for Romania: A.R.D.I. Fundulea
- cooperating centers in Romania: Fundulea, Turda, Podu-Iloaiei, Lovrin
- period: 1976-1989

COST 817 - First working group – survey of virulence and aggressiveness
- coordinator for Romania: A.R.D.I. Fundulea
- cooperating centers in Romania: Fundulea, Turda, Podu-Iloaiei, Oradea
- period: 1998 - …

Figure 1. Nurseries for studying virulences in rust and powdery mildew populations

MATERIAL AND METHODS

The biological material tested regarding the behaviour to rust and powdery mildew attack included:

- near-isogenic differential lines, obtained from the participation to COST 817 (1998-2000) activity, and tested as adult plants under natural infection, in the field (Table 1);

- differential cultivars originating from the International collection for study of rust and powdery mildew (1976-1989) as part of the "Uniform nursery for survey of wheat rust and powdery mildew virulences in East-European countries", tested under natural and artificial infection;

- wheat cultivars and lines originating from the breeding programme, tested as adult plant under artificial inoculation, in the field.

The inoculum used for artificial infections was obtained by collecting mixture of parasite fungus spores from naturally infected plants in the breeding field. The spores were kept in lyophilized ampoules, under vacuum, in a refrigerator at 4°C - 10°C.

Infection methods. In some nurseries the wheat reaction to leaf and yellow rust was also observed under artificial inoculation. For this, the infection was performed in field by pulverization of wet plants with a spore + talc powder mixture and their isolation 48 hours (yellow rust) and 24 hours (leaf rust) in order to ensure the incubation conditions. The infection with yellow rust spores was achieved during tillering stage and for leaf rust, the plants were infected during shooting stage.

The first symptoms were observed after 14 days from infection.

The scoring methods. The genotype reaction was estimated by Cobb modified scoring system (intensity/reaction type) or FAO system, in which, 1 = very resistant; 9 = very sensitive.

Having in view that the experiments were performed under field conditions, the results were influenced by the climatic factors specific to the analyzed period. Table 2 presents the tempera-

Table 1. Genes for resistance to diseases (rust and powdery mildew), identified till present in wheat*

Pathogens	Genes identified and denominated		Genes identified with provisional name		Genes tested at Turda (2001)
	Denomination**)	Number	Denomination	Number	Number
Puccinia recondita f. sp. *tritici*	*Lr 1 -Lr 49* and 9 alleles	58	*Lr*	5	54
Puccinia graminis f. sp. *tritici*	*Sr 2 -Sr 49* and 11 alleles	48	*Sr*	15	16
Puccinia striiformis f. sp. *tritici*	*Yr 1 -Yr 28* and 5 alleles	33	*Yr*	25	25
Erysiphe graminis f. sp. *tritici*	*Pm 1 -Pm 8* and 13 alleles	41	*Pm*	15	16

*) McIntosh, 1988; McIntosh et al., 1996-2000;
**) *Lr* = Leaf rust; *Sr* = Stem rust; *Yr* = Yelow rust; *Pm* = Powdery mildew

Table 2. Climatic conditions (temperature and rainfall) at A.R.D.S. Turda, during 1993-2001 (Turda meteorological station)

Month / Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	Multiannual average (°C)
TEMPERATURE (°C)										
March	1.9	6.7	4.9	-0.8	2.8	1.5	4.8	3.5	7.3	3.9
April	8.8	11.1	9.0	10.0	5.4	11.3	10.2	12.9	10.1	9.4
May	17.2	14.7	14.3	17.1	15.4	14.0	14.3	16.9	15.6	14.5
June	18.5	18.1	18.2	19.7	18.1	18.5	19.7	19.2	17.0	17.4
July	18.7	21.4	22.3	18.0	18.3	19.7	21.2	19.7	20.4	18.5
Annual average (°C)	8.6	10.5	9.2	8.7	8.4	8.8	9.3	9.9	9.3	8.6
RAINFALL (mm)										
March	41.7	13.7	2.9	21.9	13.8	11.0	10.7	17.8	35.7	24.2
April	52.5	48.8	16.6	20.4	58.4	40.7	73.6	14.6	55.5	48.2
May	14.5	67.0	65.9	84.4	41.8	57.5	109.7	32.5	64.1	71.3
June	49.3	111.7	114.4	73.9	91.7	181.5	134.8	37.4	82.7	75.7
July	57.6	68.7	8.0	43.8	81.4	57.6	68.4	66.9	103.1	70.8
Annual sum (mm)	460.2	500.6	378.8	513.8	495.0	580.7	628.3	259.7	609.6	509.2

tures and rainfall registered at Turda meteorological station during March-July, 1993-2001.

RESULTS AND DISCUSSION

Wheat powdery mildew (*Erysiphe graminis* D.C. f.sp. *tritici* Marchal, syn. *Blumeria graminis* f.sp. *tritici*)

The observations performed during 1994-2001, regarding the powdery mildew attack on trap varieties emphasized the fact that under natural infection conditions, the attack was middle to strong, excepting 1999 when the attack was weak.

Regarding the reaction to powdery mildew of trap varieties, a variability was observed from one year to another, as a result of both modifications in virulence structure of pathogen local population and climatic conditions which could differently influence the attack manifestation from year to year. The Fakir and Kenya Civet cultivars had relatively constant resistance reaction. The Diplomat and Mironovskaia 808 varieties have proved to be constantly medium-resistant. Also, one can ascertain the Halle St 13471 (*Pm2* + *Mld*) line which from resistant to medium-resistant became susceptible (in 2000 and 2001). This line was noticed in Hungary as a partial resistance source (Szunics et al., 2001) (Table 3).

The observations performed on resistance gene collection received from the COST 817 programme emphasized some changes in virulence of *Erysiphe graminis* f.sp. *tritici* local population. Thus, in 2001 the attack was observed on *Pm3a*, *Pm3c* and Kenya Civet, while in 2000 they were completely resistant. In 2001 the attack on *Pm17* (Amigo), *Pm2* + *Pm6*, *Pm5* + *Pm* (MK 983) lines was not observed (Table 4).

Yellow rust *(Puccinia striiformis* West. f.sp. *tritici)*

The manifestation of yellow rust {*Puccinia striiformis* West. [*P. glumarum (*Schm.) Erikss.

Table 3 . Manifestation of powdery mildew on trap varieties under natural infection conditions at A.R.D.S. Turda, during 1994-2001

Cultivar	1994	1995	1996	1997	1998	1999	2000	2001
Alcedo	30M	20M	60S	60S	40S	10S	40S	40S
Diplomat	20M	30M	10M	30M	10M	0	20M	10M
Fakir	5R	0	0	5R	uR	5M	10M	10M
Mironovskaia 808	30S	30M	30M	30M	0	0	30M	20M
Salzmunder 14/44	30M	80S	70S	80S	60S	40S	70S	60S
Axminster	50S	60S	60S	70S	40M	0	40S	30M
Ulka	50S	80S	80S	80S	40M	0	40S	50S
Chul	50S	60S	70S	70S	20M	0	60S	40S
Hope	40S	50S	30M	70S	30M	0	50S	40S
Kenya Civet	5R	30M	0R	5R	0R	0	0R	10M
Halle St. 134712	10M	40M	30M	5R	10M	0	50S	40S
Transec	30S	80S	60S	80S	20M	0	50S	30M

Scoring in Cobb modified scale (intensity in % and reaction type)
Reaction type: R = resistant; M = middle; S = susceptible

Table 4. Manifestation of powdery mildew in resistance gene collection – COST 817 programme – at A.R.D.S. Turda, during 2000-2001

Resistance genes with recorded matching virulence		Resistance genes without recorded virulence	
2000	2001	2000	2001
Pm1, Pm2, Pm2+, Pm3b, Pm4, Pm5, Pm6, Pm7, Pm8, ***Pm17*** (Amigo), ***Pm5* + *Pm*** (MK 983)	*Pm1, Pm2, Pm2+,* ***Pm3a****, Pm3b,* ***Pm3c****, Pm4, Pm5, Pm6, Pm7, Pm8,* **Kenya Civet**	***Pm3a****,* ***Pm3c****, Pm2+ Pm6,* **Kenya Civet**	***Pm17*** (Amigo), *Pm2+ Pm 6*, ***Pm 5+Pm*** (MK 983)

Note: the recorded modifications are emphasized by bold letters

et Henn f.sp. *tritici* Eriksss.]} virulence was observed on trap varieties under natural infection and artificial inoculation. During 1994-2001, the attack level under natural conditions was low and in 2000 was absent, this year being characterized as an excessively dry one (Table 2). The yellow rust attack was constantly very high on Fundulea 29 and Turda 81 cultivars, which possess *Yr9* gene (Ittu et al., 1989). On Heines Peko, Lee, Compaire, Clement, Heine VII, Vilmorin 23, Hybrid 46, Remus cultivars, the yellow rust attack was recorded during some years. In 2001, under natural conditions, the yellow rust attack was recorded on Heine VII (5M), Heines Peko (uR), Lee (40S), Compaire (40M), Clement (10M), Moro (5M), Almus (uR), Remus (uR), Fundulea 29 (70S), Turda 81 (50S) cultivars. In all eight years, the yellow rust attack was not observed on cultivars Chinese 166, *Triticum spelta album*, Norda, and Saladin.

The artificial infection conditions were more favourable for the manifestation of virulence of the local yellow rust population. Almus and *Triticum spelta album* cultivars did not show any yellow rust attack. The Moro, Norda, Saladin cultivars presented an attack with very low intensity and middle to resistant reaction type in very few years. Constantly, the utilized inoculum provoked infection on Heines Peko (*Yr2*, *Yr6*), Lee (*Yr7*), Compaire (*Yr8*), Fundulea 29 (*Yr9*), Turda 81 (*Yr9*), Vilmorin 23 (*Yr3a*) and Heine VII (*Yr2*) (Table 5). In 2001, among the resistance genes observed under natural infection conditions, *Yr1*, *Yr3*, *Yr3c*, *Yr5*, *Yr11*, *Yr12,3a, 4a*, *Yr13,1,3a,4a*, *Yr14*, *Yr17*, as well as Almus, Norda, Remus, So, Sd, and Sp, proved to be efficient. In 2001, the recording of yellow rust symptoms on *Yr2* (Heine VII), *Yr6 + 7* (Pavon 76), *Yr9* (Riebesel), *Yr10* (Moro) genes could mean the occurrence of a new virulence in the pathogen population (Table 6).

Table 5. Manifestation of yellow rust on trap varieties, under natural and artificial infection conditions, at A .R.D.S. Turda, during 1994-2001

Cultivar	1994		1995		1996		1997		1998		1999		2001
	Natural infection	Artificial inoculation	Natural infection	Artificial inoculation	Natural infection	Artificial inoculation	Natural infection	Artificial inoculation	Natural infection	Artificial inoculation	Natural infection	Artificial inoculation	Natural infection
Chinese 166	0	30M	0	0R	0	0R	0	0R	0	5R	0	0R	0
Heine VII	30M	40S	0	uM	0	uR	0	uR	0	5M	0	5M	5M
Vilmorin 23	5M	20M	5M	10M	0	10M	0	10R	0	0R	0	20M	0
Hybrid 46	30M	40S	0	20M	0	0R	0	0R	0	10M	0	0R	0
Triticum spelta album	0	0R	0	0R	0	0R	0	uR	0	0R	0	0R	0
Heines Peko	30M	20M	0	30M	0	-	0	0R	5M	10M	0	0R	uR
Lee	60S	80S	0	80S	0	100S	5M	60S	10M	80S	0	60S	40S
Compaire	30M	20M	0	30M	0	-	0	0R	5M	10M	0	0R	40M
Clement	5M	0R	0	uM	0	uR	0	10R	0	5R	0	0R	10M
Moro	0	5R	0	uR	0	uR	0	0R	0	0R	0	0R	5M
Almus	0	0R	0	0R	0	0R	0	0R	0	0R	0	0R	uR
Norda	0	0R	0	0R	0	uM	0	0R	0	5R	0	0R	0
Remus	5M	5M	0	0R	0	0R	0	10R	0	0R	0	0R	uR
Saladin	0	5R	0	0R	0	0R	0	0R	0	0R	0	0R	0
Fundulea 29	70S	90S	40S	100S	30S	80S	60S	90S	60S	80S	-	60S	70S
Turda 81	70S	90S	40S	90S	-	80S	60S	100S	30S	80S	-	80S	50S

Scoring in Cobb modified scale – intensity in % and reaction type
Reaction type: R = resistant; M = middle; S = susceptible; U = traces

Table 6. Manifestation of yellow rust in resistance gene collection (COST 817 programme), at A.R.D.S. Turda, during 1998-2001

Resistance genes with recorded matching virulence		Resistance genes without recorded virulence	
1998	2001	1998	2001
Yr3a (Heine VII/Selpek):	***Yr2***(Heine VII): *Yr3a*:	*Yr1* (Chinese spring):	*Yr1*: *Yr3*: *Yr3c*: *Yr5*:

Leaf rust (*Puccinia recondita* Rob. ex Desm. f.sp. *tritici* Erikss. et Henn.)

Based on observations regarding the leaf rust reaction of trap varieties during 1994-2001, under natural infection, one can see that the strongest attack took place in 2001. In the year 2000, the leaf rust attack was inexistent, due to totally unfavourable for diseases climatic conditions (Table 2). In the eight years of testing, no attack on *Lr9* and *Lr19* was registered. Leaf rust symptoms were observed with different intensities on Martonvasari 8, Timpaw, Tiszatay, *Lr10*, *Lr16*, Penjamo, and Pembina cultivars. Under artificial inoculation, no attack on *Lr9* and *Lr19* was observed and the reaction was different from one year to another on Purdue 6234, Flevina, Ns 720, Penjamo, and Pembina cultivars (Table 7).

Based on observations performed under natural infection on resistance genes received from the COST 817 programme, one can conclude that the leaf rust local population suffered a few modifications in the virulence structure in the year 2001, as compared to 1999 (in 2000 the leaf rust attack was not present).

Thus, in 2001, leaf rust attack on *Lr1*, *Lr2a*, *Lr2b*, *Lr12*, *Lr13*, *Lr26*, and *Lr44 III* genes was recorded. The genes *Lr9*, *Lr19*, *Lr21* (WGCR 15), *Lr22*, *Lr22a*, *Lr24*, *Lr29*, *Lr32*, *Lr36*, *Lr38*, *Lr39*, *Lr40*, *Lr41*, *Lr42*, *Lr43*, *Lr44* remained efficient (Table 8).

The genes *Lr9*, *Lr19* and *Lr24* were also recorded by other authors, as extremely efficient genes with strong resistance effect in Europe (Mesterhazy et al., 2000). In 2001, the lines *Lr23* and *Lr37* were not tested. Also the authenticity of the *Lr25*, *Lr29* and *Lr35* lines is questionable.

The observed attack differences under artificial inoculation could be caused by weather conditions, and/or pathogen population structure. Under these conditions the observations performed on trap varieties under artificial inoculation offer an image of the annual fluctuations in virulence structure of the local population of each rust. Such fluctuations were recorded by other authors, too (Mesterhazy et al., 2000).

Implications in breeding for resistance

Table 7. Manifestation of leaf rust on trap varieties under natural and artificial infection conditions, at A.R.D.S. Turda, during 1994-2001

Cultivar	1994		1995		1996		1997		1998		1999		2001
	Natural infection	Artificial inoculation	Natural infection	Artificial inoculation	Natural infection	Artificial inoculation	Natural infection	Artificial inoculation	Natural infection	Artificial inoculation	Natural infection	Artificial inoculation	Natural infection
Purdue 6234	0	40M	0	0R	0	5R	0	20M	0	0R	0	20M	**60S**
Flevina	0	20M	0	5R	0	0R	0	uR	0	0R	0	uR	10S
Martonvasari 8	30S	60S	40M	60S	0	60S	10 M	40S	0	80S	30S	40M	60S
Ns 720	0	40S	uR	60S	0	20 M	uM	20M	0	-	0	60M	-
Timpaw	uR	20M	30M	40M	0	40 M	uM	20M	0	80S	5M	60M	80S
Tiszatay	uR	20M	0	40M	5S	40 M	5M	20M	5M	-	5M	40M	40S
Lr9	0	0R	0	0R	0	0R	0	0R	0	0R	0	0R	0
Lr10	0	60S	20S	100S	0	40S	40 M	80S	0	80S	10S	40S	40S
Lr16	0	60S	20M	100S	0	40S	40 M	80S	uM	80S	10M	60S	40S
Lr19	0	0R	0	0R	0	0R	0	0R	0	0R	0	0R	0
Penjamo	0	0R	0	60R	0	5R	0	0R	0	60M	uM	0R	20M
Pembina	uM	80S	uR	100S	0	40 M	40 M	40M	0	0R	5M	0R	20M

Scoring in Cobb modified scale (intensity in % and reaction type)
Reaction type: R = resistant, M = middle, S = susceptible, U = traces

Table 8. Manifestation of leaf rust in resistance gene collection – COST 817 programme, at A.R.D.S. Turda during 1999-2001

Resistance genes with recorded matching virulence		Resistance genes without recorded virulence	
1999	2001	1999	2001
Lr2; Lr2c, Lr3, Lr3-3ka, Lr3-Bg, Lr10, Lr11,	***Lr1***, *Lr2*, ***Lr2a***, ***Lr2b***, *Lr2c, Lr3, Lr3-3ka, Lr3-3Bg, Lr10, Lr11,*	***Lr1***, ***Lr2a***, ***Lr2b***, *Lr9*, ***Lr12***, ***Lr13***, *Lr19*,	*Lr9, Lr19, Lr21 (WGCR 15),*

The distribution of reaction types of the tested breeding material regarding the reaction to powdery mildew, yellow and leaf rust attack considers both the changes registered in pathogen population structure and at the level of resistance to diseases of biological material released and tested at A.R.D.S. Turda (Figures 2, 3 and 4).

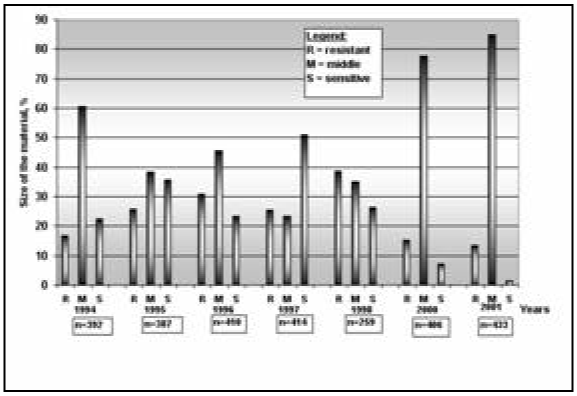

Figure 2. The breeding material tested to powdery mildew attack and its distribution on reaction types. Turda, 1994-2001

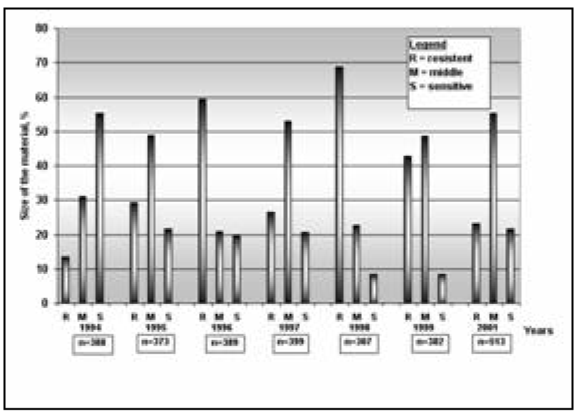

Figure 3. Breeding material tested to yellow rust attack and its distribution on reaction types. Turda, 1994-2001

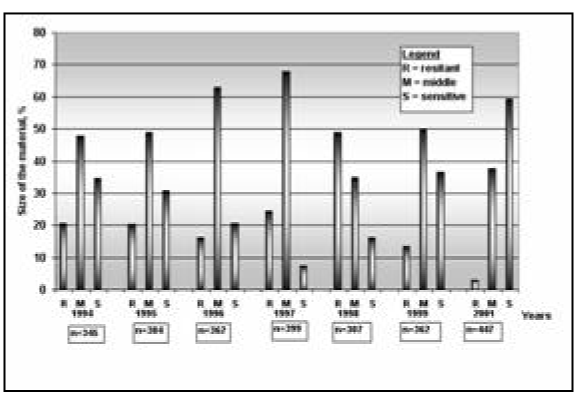

Figure 4. Breeding material tested to leaf rust attack and its distribution on reaction types. Turda, 1994-2001

The analysis of these distributions allows the estimation of future targets in breeding works for resistance. Thus, for powdery mildew selection was preponderantly achieved for partial resistance which ensures a low infection level during a long period. The genotypes with middle reaction type had a greater weight in almost all experimental years. In the years 2000 and 2001 the genotypes with middle reaction were of over 70% and 80% respectively. Also, the resistant genotypes represented over 10% of the total breeding material under testing (Figure 2).

The efficient total or partial resistance sources from collection have been introduced in genotypes under different breeding stages. A series of partial resistance sources, cultivars and lines developed by the breeding centers from Romania (Fundulea, Turda, Suceava) and abroad were intensely utilized. Some of them are present in the genealogy of lines under preliminary or registration official testing networks or even in released cultivars (Table 9).

In the case of yellow rust, during the last years, the weight of resistant and middle resistant genotypes increased, as a consequence of the utilized breeding strategy (Figure 3).

In order to diversify the genetic basis of resistance to yellow rust, with effect on its durability, efficient resistant sources to this pathogen were used. Adult plant resistance sources were utilized, some of which being already present in the genealogy of cultivars grown on farms. In advanced stages, under testing in official networks, there are lines which have both adult plant resistance sources and total resistance originating from the national breeding programme (A.R.D.I. Fundulea) or abroad. More recently, several new total or partial resistance sources, have been introduced in breeding and are present in lines in initial stages of selection (Table 10).

The current strategy applied in breeding for resistance to leaf rust is based on combining the total resistance given by major genes with partial field resistance which ensures, as a rule, a greater resistance durability. This fact results from the analysis of distribution of reaction types of the breeding material during eight years. In most

Table 9. Introduction stage of resistance sources to powdery mildew in wheat breeding programme at A.R.D.S. Turda, in 2001

Source	Initial material F_1- F_2	Selection and control nurseries	On station yield trials	Official trials	Farms
Pm2 + Pm6; Pm5 + Pm; Pm17 (Amigo)	X				
Dropia, Ardeal, Fundulea lines	X	X	X		
APR with satisfactory levels (Transilvania, Turda 81, Turda 95, Flamura 85, Fundulea 4, Aniversar)	X	X	X	X	X
Sources: Ukraine, Russia	X	X	X	X	
Czech Republic, Slovakia	X	X	X		
Hungary	X	X	X		
Bulgaria	X	X	X		
Yugoslavia, Croatia	X	X	X		
Germany, France	X	X			
England	X	X			
USA	X	X	X		
CIMMYT	X	X			

APR = Adult plant resistance

Table 10. Introduction stage of resistance sources to yellow rust in wheat breeding programme at A.R.D.S. Turda, in 2001

Source	Initial material F_1- F_2	Selection and control nurseries	On station yield trials	Official trials	Farms
Yr1 (Chinese 166)					
Yr5 (*Triticum spelta album*)					
Yr11 (Joss Cambier), ***Yr14*** (Moulin)	X				
Yr12, 3a, 4a (Bounty)	X				
Almus	X				
Fundulea lines	X	X	X	X	
Sources APR (Tansilvania, Apulum, Ariesan, Turda 95)	X	X	X	X	X
Sources: Ukraina, Russia	X	X	X	X	
Czech Republic, Slovakia	X	X	X	X	
Hungary	X	X	X		
Yugoslavia, Croatia	X	X	X		
Germany, France	X	X	X		
England	X	X	X		
USA	X	X	X		
CIMMYT	X	X			

APR = Adult plant resistance sources

years, the weight of resistant and middle resistant genotypes is dominant. In 2001, a year with changes in virulence manifestation, almost 60% of the tested genotypes presented a susceptibility reaction (Figure 4).

This is the result of the intensive utilization as parents of some sources with low resistance during the last years. So, the genotypes which presented a resistance reaction even under conditions of the year 2001 could be considered as valuable sources. Such sources are introduced into lines which have been promoted in yield trials, and they are intensively used as parents. The parents which contain *Lr13* and other genes which give durable resistance, such as *Lr37*, have been intensively utilized. Also, the *Lr9*, *Lr19*, *Lr24* genes are already introduced into breeding initial material, progenies and lines in yield trials (Table 11).

Table 12 presents the characterization of reaction to rusts and powdery mildew attack of some winter wheat lines released by AR.D.S. Turda and which are under official preliminary and registration testing. Thus, during 1997-2001, the lines with middle reaction to powdery mildew attack were predominant. Many of them (T 95-97, T 64-98, T 53-97, T 13-99, T 35-99, T 69-99, T 98-99) present resistance reaction.

Table 11. Introduction stage of resistance sources to leaf rust in wheat breeding programme at A.R.D.S. Turda, in 2001

Source	Initial material F_1- F_2	Selection and control nurseries	On station yield trials	Official trials	Farms
)*Lr9*** (*Ae. umbellulata*) - Chinese spring, Transfer, Arthur 71, Riley 67,	X	X	X		
)*Lr19*** (*Th. Ponticum*) - Agatha, Agrus, Oasis 86	X	X	X		
)*Lr24*** (*Th. Ponticum*) - Agent	X				
)*Lr37*** (*Ae. ventricosa*) - VPM 1	X	X	X		
Fundulea lines	X	X	X	X	
Sources with durable resistance: ***Lr13***, ***Lr34*****)- cultivars from Argentina, Bezostaia 1, Romania (Lv 32, Lv 34, Lv 41, Fl 85)	X	X	X	X	X
*)Adult plant resistance-type Skorospelka, T 195	X	X	X	X	X
*)Adult plant resistance-type Fiorello, Transilvania, T 81	X	X	X		X
*)Adult plant resistance-type Doina	X				
Sources : Ukraine, Russia	X	X	X		
Hungary	X	X	X		
Bulgaria	X	X	X		
Yugoslavia, Croatia	X	X	X		
Czech Republic, Slovakia	X	X	X		
Switzerland, France, Germany	X	X	X		
England	X	X	X		
U.S.A.	X	X	X		
CIMMYT	X	X	X		

*) Ionescu-Cojocaru, 1984, 1985 APR = Adult plant resistance
**) Rabinovich et al., 2001

Table 12. Reaction of some winter wheat lines to rusts and powdery mildew attack under artificial infection conditions, at A.R.D.S. Turda, during 1997-2001

Line	Leaf rust (*Puccinia recondita* f. sp. *tritici*)	Yellow rust (*Puccinia striiformis* f. sp. *tritici*)	Powdery mildew (*Erysiphe graminis* f. sp. *tritici*)
T 137 - 96	M - S	R	M
T 51 - 97	M - S	R - M	M
T 53 - 97	M	M - S	R - M
T 95 - 97	M - S	M	R
T 100 - 97	M - S	R - M	M
T 14 - 98	M	R	M
T 34 - 98	M	M	M
T 64 - 98	S	M	R
T 66 - 98	M - S	R	M
T 95 - 98	M	M	M
T 103 - 98	M	R - M	M
T 13 - 99	S	R	R - M
T 22 - 99	M - S	M	M
T 35 - 99	M	R	R - M
T 69 - 99	S	R	R - M
T 98 - 99	S	R	R - M

R = resistant, M = middle, S = susceptible

During all period of testing, the lines T 137-96, T 14-98, T 66-98, T 13-99, T 35-99, T 69-99, T 98-99 were resistant to yellow rust. Also, a few of long-tested lines had a middle reaction. The reaction of long-tested lines to leaf rust, during 1997-2001 was middle or susceptible. The genealogy of these lines includes sources of durable resistance (*Lr13, Lr34*) or adult plant resistance (Skorospelka type) which were not efficient under

Table 13. Reaction of some winter wheat cultivars to rusts and powdery mildew attack under artificial infection conditions at A .R.D.S. Turda, during 1997-2001

Line	Leaf rust (*Puccinia recondita* f. sp. *tritici*)	Yellow rust (*Puccinia striiformis* f. sp. *tritici*)	Powdery mildew (*Erysiphe graminis* f. sp. *tritici*)
Transylvania	M	M	M
Turda 81	R-M	S	M
Ariesan	M	R - M	R - M
Apulum	M - S	R - M	M
Turda 95	M - S	R - M	R - M
Turda 2000 (T 20-94)	M	R - M	M
Fundulea 29	M	S	M
Flamura 85	M	R - M	R - M
Fundulea 4	M	R - M	R - M
Ardeal	R-M	R - M	R - M
Aniversar	R-M	M	M
Gabriela	M	R - M	R - M

R = resistant, M=middle, S=s usceptible

conditions of 2001. Accordingly, many lines with middle reaction became susceptible to leaf rust. The lines T 14-98, T 34-98, T 95-98, T 103-98, T 35-99 presented a good or middle resistance reaction (field resistance).

Many of the released cultivars such as Transilvania, Ariesan, Turda 2000, Flamura 85, Fundulea 4, Ardeal, Aniversar, Gabriela, maintained a field resistance to all three diseases during 1994-2001. The cultivars Turda 81 and Fundulea 29 are susceptible to yellow rust while Apulum and Turda 95 presented a middle to sensitive reaction to leaf rust during the eight years of testing (Table 13).

CONCLUSIONS

The observations performed during 1994-2001, at A.R.D.S. Turda, emphasized modifications of the local rust and powdery mildew populations virulence spectrum.

The changes observed in 2001 indicate the occurrence of new virulences:

- for powdery mildew (*Erysiphe graminis* f. sp. *tritici*) on both *Pm3a*, *Pm3c* genes and Kenya Civet source;

- for yellow rust (*Puccinia striiformis* f. sp. *tritici*) on *Yr2, Yr6+7, Yr9* (Riebesel), *Yr10* (Moro) genes;

- for leaf rust (*Puccinia recondita* f. sp. *tritici*) on *Lr1*, *Lr2a*, *Lr2b*, *Lr12*, *Lr13*, *Lr26*, *Lr39*, *Lr44III* genes.

The following sources maintained their efficiency:

- for powdery mildew, the *Pm2+Pm6*, *Pm5+Pm* (MK 983), *Pm17* (Amigo) genes and Transilvania, Turda 95, Flamura 85, Fundulea 4, Ardeal (adult plant resistance sources);

- for yellow rust, the *Yr1* (Chinese 166), *Yr3*, *Yr3c*, *Yr5* (*T. spelta album*), *Yr11*, *Yr14*, *Yr12,3a,4a*, *Yr13,1,3a,4a*, *Yr17*, *So*, *Sd*, *Sp* genes and Almus, Norda, Remus cultivars;

- for leaf rust, the *Lr9*, *Lr19*, *Lr21*(WGCR 15), *Lr22*, *Lr22a*, *Lr24*, *Lr29*, *Lr32*, *Lr36*, *Lr38*, *Lr40*, *Lr41*, *Lr42*, *Lr43*, *Lr44I* genes and Tuda 195, Transilvania, Turda 81, Ardeal, Flamura 85, Gabriela (adult plant resistance sources).

The resistance sources which maintained their efficiency to the new virulences have been included in the breeding material and are present in different selection generations.

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Table 1

Average yield of experiments with winter wheat cultivars, under irrigation and dry-land in six localities from the South of Romania (2002)

Locality	Average yield under:		Yield percentage diminution
	irrigation (kg/ha)	dry-land (kg/ha)	
Caracal	8560	5601	34.6
Marculesti	4716	3075	34.8
Teleorman	5963	3594	39.8
V. Traian	6941	3794	45.3
Fundulea	4858	1918	60.5
Simnic	(8560)	380	95.6

Table 2

Percentage diminution of some plant features under water stress conditions as compared to irrigation

Locality	Plant number	Plant height	Grain filling period	Spike number	Grain/ear	TKW	Test weight
Caracal	0	14,9	15,0	7,9	10,2	14,1	0,9
Teleorman	0	10,0	19,2	12,0	12,0	11,9	1,0
V.Traian	34,9	21,0	16,9	42,5	12,2	2,9	8,1
Fundulea	4,9	28,8	24,9	6,9	28,9	29,5	3,9
Simnic	27,6	61,7	30,0	65,0	64,5	53,1	10,7
Media	13,5	27,3	21,2	26,9	25,6	22,3	4,9

Table 3

Minimum, maximum and average yields registered at Fundulea in 2002 in international trials WWEERYT with genotypes grouped depending on the originating country

Source	Average yield of the tested genotypes (kg/ha)	Maximum yield of the tested genotypes (kg/ha)	Minimum yield of the tested genotypes (kg/ha)
Romania	2368	2953	2073
Russia	2327	2453	1980
Ukraina-Odessa	2224	3013	1287
Hungary	2181	2780	1320
Ukraina-Mironovka	2108	2753	1500
Moldova	1927	2560	1293
Bulgaria	1898	2873	1313
Turkey	1893	2420	1487
Azerbaidjan	1460	1553	1367
Kazahstan	1422	1833	853
LSD 5%	243	275	

Table 4

Correlations between yield under water stress conditions and different traits

Locality	Average yield diminution because of water stress (%)	Correlation coefficients between yield under water stress conditions and:						
		yield under irrigation	plant height under stress conditions	plant height under irrigation	heading time	spike/m²	grain/ear	TKW
Caracal	34,6	**0,48**	0,29	-0,31	-0,12	0,20	0,11	-0,30
Teleorman	39,8	**0,80**	0,35	0,31	**-0,85**	**0,58**	-	-
Valu Traian	45,3	0,04	0,33	0,20	**-0,40**	**0,42**	**0,40**	0,22
Fundulea	60,5	0,00	**0,46**	-0,31	**-0,46**	**0,52**	0,30	-0,17
Simnic	95,6	-0,01	**0,41**	**-0,62**	-0,04	**0,40**	**0,50**	0,15

The bold characters are significant at the probability level of 0.05

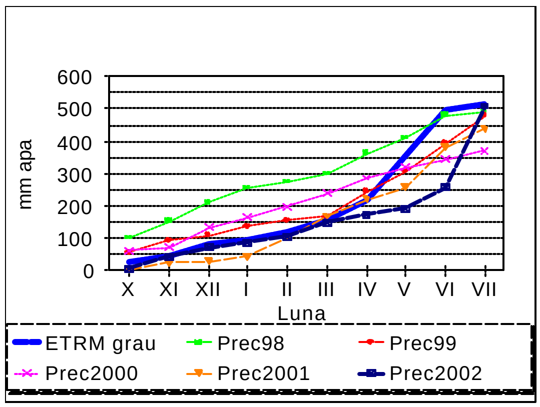

Figure 1. Average evapotranspiration and rainfall during 1999-2002 at Fundulea (mm water; month; wheat evapotranspiration; rainfall)

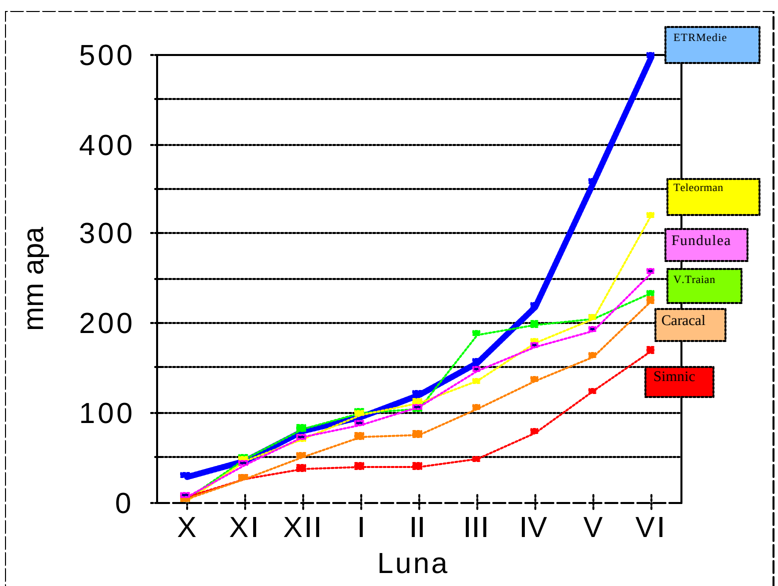

Figure 2. Average evapotranspiration and rainfall during the vegetation period in six locations of Southern of Romania in 2001-2002 year (mm water; month).

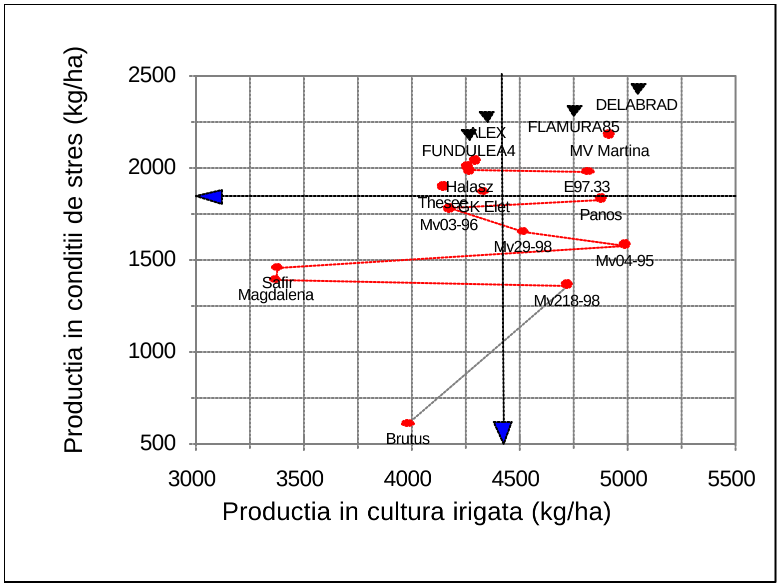

Figure 3. Yield obtained by some Romanian and foreign cultivars under irrigation and non-irrigation, in 2002 at Fundulea (arrows indicate the experiments average yield)(Yield under stress conditions; yield under irrigation).

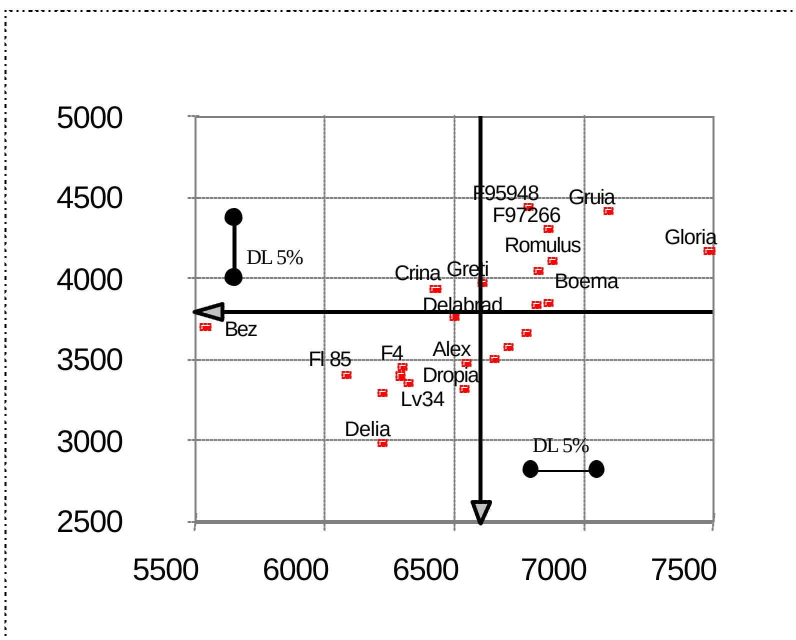

Figure 4. Average yields in four locations, obtained in 2002 by Romanian new lines and cultivars under irrigation and non-irrigation (arrows indicate experiments average yield)(Yield under non-irrigation; Yield under irrigation; LSD).