THE *FUSARIUM* ATTACK ON SOME WINTER WHEAT VARIETIES IN CORELATION WITH NITROGEN FERTILIZATION

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Abstract

In the lasts decades, the Fusarium head blight become the most damaged disease of wheat, especial during the rainy springtime. The year 2010 was one of these types, especial in western Romania. It was an opportunity for us to study this disease, in natural infection conditions.

Our results stand out the superior resistance of some varieties (Josef, Kristina, Apache and Litera), appreciate by fervency, intensity and attack degree. By the correlation method, we determined that the varieties with great spike densities are more affected by the attack. Also, the attack parameters correlate in variants fertilized and unfertilized with nitrogen, demonstrating that, even the attack is greater in fertilized variant, the susceptible varieties have the same reaction with low nitrogen fertilization. Information confirmed in this experiment is that the quality of seeds (wet gluten, total proteins and sedimentation index) are depending of fusarium attack intensity.

Key words: fusarium head blight, wheat, variety, resistance.

INTRODUCTION

Wheat is most important cereal crop in Europe, being cultivated on over 16 million ha and yielding over 88 million metric tons per year (Ruckenbauer and all, 2007). The wheat quality and consumer safety is threatened by *Fusarium* Head Blight (FHB) caused by *Fusarium culmorum, Fusarium graminearum and Fusarium avenaceum.* Most of the winter wheat varieties cultivated today in Europe are susceptible to this disease.

Post–flowering infections may have a low impact on crop yield, infected and DON-contaminated plump kernels are likely to contribute to the final mycotoxin levels in mature grains (Del Ponte et. al., 2003).

The *Fusarium* susceptibility of most Europeans cultivars is the basic cause of the irregularly occurring severe epidemics. Beside yield and quality loss, the toxin contamination is the major threat (Mesterházy, 2001).

In Romania, after 1975 when intensive cultivation of wheat varieties begun, the damages frequently exceeded 50% in large areas, where the fungus *Giberella zeae (*Schw. Petch.), conidian form *Fusarium graminearum* Schw met optimal climate conditions (Bunta Gh. and Bunta A., 1992). In Crisana county, the disease caused great damages in 1970, 1985, 1987 (Bunta Gh., 2003) and more recently in 2010, its emergence and intensity being very irregular.

The researches regarding the breeding of wheat for resistance to this disease have been very difficult, the major causes being:

- the existence of a great number of *Fusarium* species and varieties, with large adaptability capacities;
- the inexistence of a standardized method for evaluation of resistance;
- the variable reaction of genotypes to disease attack, depending on the year and areas;
- the genetic source of immunity to *Fusarium* head blight has not been identified so far;
- the fungus is not necessarily parasitic since it is able to survive as saprophytic on dead leaves and culms like mycelium, conidia, ascosporous.

For this reason, some researchers tried to create some methods based on artificial infection with *Fusarium* (Mesterházy, 1984; Bunta Gh. and Bunta A., 1992; Mesterházy, 1995). As an argument, Mesterházy established that dwarf genotypes were more severely infected by head blight than tall genotypes under natural conditions, but they were similarly susceptible after artificial inoculations.

The development of a florecasting system has been suggested as an important tool to be integrated into FHB management to effectively use fungicides in conjunction with other management strategies (Xu, 2003; Mc Mullen et. al., 1997).

A mechanistic model for estimating an infection index of FHB was developed by Del Ponte et. al.(2005). The model is process-based driven by rates, rules and coefficients for estimating the dynamics of flowering, airborne inoculum density and infection frequency, as well as the function of temperature during an infection event, which is defined based on a combination of daily proportion of susceptible tissue available, infection frecvency and spore cloud density.

Another dynamic simulation model for FHB that produces daily infection risks for disease development and mycotoxin accumulation in infected tissues was elaborated by Rossi et. al (2003).

The project FUCOMYR was developed in the European Union in conjunction with 6 countries. Three genomic regions were found to be significantly associated with *Fusarium* head blight (FHB) resistance: the most prominent effect was detected on the short arm of chromosome 3B, explaining up to 60% of the phenotypic variance for type II resistance. A further QTL was located on chromosome 5A and a third one on 1B (Ruckenbauer and all, 2007). These results indicate that FHB resistance is under control of a few major QTL's operating together with an unknown number of minor genes.

The FHB resistance QTL region of wheat chromosome 2DS flanks the reduced height gene Rht 8, which might influence initial infection of FHB under the field conditions (Handa and Ban, 2008). However, it is suggested the existence of other potential resistance genes within this QTL region.

The most favorable scenario for integration is the incorporation of FHB 1 from Asian cultivars into adapted material with good native resistance, high yield and tested weight, with superior milling and backing quality (Guedira and all, 2008). The highly resistant materials solve all problems, including DON (deoxynivalenol), the very dangerous toxin for animals and human health (Mesterházy, 2001).

The sources for resistance to *Fusarium* head blight (FHB) present in the breeding line RCATL 33 (realized from Tamburic-Ilincic et. al., 2005) were Sumai 3 from China and Frontana from Brasil. This line is tall (120 cm) and it is lacking a high yield potential, so it can not be registered as a cultivar, but it is useful for FHB resistance breeding. Another well known resistant genotype is Nobeoka Bozu (from Japan).

A new source of resistance to FHB, realized recently in Canada, is a series of four synthetic hexaploid spring wheat (x*Aegilotriticum* sp.) lines (Berzonsky and all, 2003). They broaden the genetic base of resistance to *Fusarium.* The breeding synthetic lines are available now to breeders as a source to resistance.

Our present study tries to identify the possible sources of resistance to FHB and to explain some interactions between it and other diseases and plant characteristics.

MATERIAL AND METHODS

The experiments were conducted in the experimental field of Agricultural Research and Development Station Oradea during the years 2009-2010 and they consisted in 25 winter wheat varieties, Romanian (18), Hungarian (2), Serbian (1), Austrian (2) and French (2). This kind of experiments is common in our country, aiming to establish the best cultivar for each area.

Regarding the climate conditions, we must underline the extremely rainy spring and summer, when the sum of precipitation was of 118.9 mm in May and 82.8 mm in June. The rain fall exceeded the normal average during the months of April, May and June, thus facilitating the apparition and speeding of life and ear diseases. It is significant that the sum of precipitations from August to July exceeded 840 mm, unusual for our region. In addition, the relative humidity of air varied between 74% and

96% and the sun shone for only 185 hours in May. In these conditions, the diseases had high intensity.

The 25 variants (varieties) were tested in a Lattice square balanced method, in 6 replications, three fertilized and the other three unfertilized with nitrogen (100 kg active substance/ha). The results were statistically processed by ANOVA (analyze of variance) and LSD (limit standard difference), correlations and regressions methods.

The attack of diseases was appreciated by notes, in FAO system, by percents (fervency, intensity and attack degree).

RESULTS AND DISCUSSION

The results regarding yield potential of variants, well ensured with nitrogen, are presented in table 1.

Table 1

Grain yield of some winter wheat varieties tested at Oradea in 2009/2010. (Fertilized)

Class.	Variety	Yield (kg/ha)	Relative yield (%)	Differences to experimental average (kg/ha)	Significance of differences
1	Apache	9027	127.0	+1921	***
2	Ciprian	8568	120.6	+1462	***
3	Litera	7735	108.9	+629	
4	Izvor	7669	107.9	+563	
5	Faur	7647	107.6	+541	
6	Glosa	7450	104.8	+344	
7	Serina	7365	103.6	+259	
8	Kristina	7334	103.2	+228	
9	Capo	7312	102.9	+206	
10	Miranda	7301	102.7	+195	
11	Romulus	7219	101.6	+113	
12	Boema	7191	101.2	+85	
13	Dropia	7113	100.1	+7	
Experimental average		**7106**	**100.0**	**0**	**-**
14	Flamura 85	7102	99.9	-4	
15	Renesansa	7101	99.9	-5	
16	Kiskun Gold	6921	97.4	-185	
17	Lovrin 34	6883	96.9	-223	
18	Ardeal	6805	95.8	-301	
19	Alex	6680	94.0	-426	
20	Delabrad	6791	95.6	-315	
21	Gruia	6613	93.1	-493	
22	Crisana	6108	85.9	-998	o
23	Briana	6059	85.3	-1047	o
24	Ariesan	5946	83.7	-1160	oo
25	Josef	5709	80.3	-1397	oo

$LSD_{5\%}$ = 780 Kg/Ha; $LSD_{1\%}$ = 1057 Kg/Ha; $LSD_{0,1\%}$ = 1415 Kg/Ha.

The level of yields is higher than usual. The results are statistically ensured, the cultivars Apache and Ciprian being very significant, better in comparison to experimental average (7.106 kg/ha). The good results led to four new Romanian cultivars (Litera, Izvor, Faur and Glosa), with yields up to 7450 kg/ha. Without nitrogen fertilization, the levels of yields are lower with more than 1400 kg/ha (table 2), but the varieties that have good performances are the same (Apache, Ciprian).

The relative great values of LSD are caused by the fall of plants, caused especially by the fact that they were 10-15 cm taller than the previous year, the explanation being the excess of rain during springtime (April, May and the beginning of June). We have the mention that the best yielding varieties were the lowest in the quality parameters (wet gluten, total protein, sedimentation index).

The density of ears was good, with values between 512 (Kristina) and 760 (Capo), with an average of 624 ears/square meter. In terms of this big density, the number of ears affected by *Fusarium* head blight is, in absolute values, big, the experiment average being 159.7/ m^2 (table 3).

The least affected were the varieties Josef, Kristina, Apache, Briana and Serina, with values below 100 affected ears. The most affected were the varieties Boema, Miranda, Capo and Ariesan, with values up to 250 ears affected.

Appreciating the *Fusarium* attack by notes (FAO system), the most resistant varieties were Apache, Josef and Kristina, respectively the most susceptible were Lovrin 34, Gruia and Capo.

The frequency of ears affected by *Fusarium* attack was very big in the case of the varieties Dropia, Boema, Faur and Romulus, but the intensity of attack was different. With the highest intensity values of attack were: Apache, Miranda, Kiskun Gold, Capo, Romulus, and Ariesan.

The degree of attack, being a synthetic indicator, is more important than the other two. According to this, the varieties with good reaction to *Fusarium* attack are: Josef, Kristina, Apache and Litera, with values under 10%.

Table 2

Grain yield of some winter wheat varieties tested at Oradea in 2009/2010.
(No fertilized)

Class.	Variety	Yield (kg/ha)	Relative yield (%)	Differences to experimental average (kg/ha)	Significance of differences
1	Apache	7519	132.2	+1832	***
2	Ciprian	6912	121.5	+1225	***
3	Capo	6419	112.9	+732	*
4	Renesansa	6342	111.5	+655	*
5	Kiskun Gold	6074	106.8	+387	
6	Litera	6032	106.1	+345	
7	Serina	5992	105.4	+305	
8	Izvor	5955	104.7	+268	
9	Ariesan	5889	103.6	+202	
10	Lovrin 34	5786	101.7	+99	
11	Faur	5750	101.1	+63	
12	Boema	5717	100.5	+30	
Experimental average		**5687**	**0.0**	**0**	**-**
13	Glosa	5606	98.6	-81	
14	Miranda	5579	98.1	-108	
15	Dropia	5475	96.3	-212	
16	Romulus	5414	95.2	-273	
17	Delabrad	5402	95.0	-285	
18	Flamura 85	5364	94.3	-323	
19	Kristina	5250	92.3	-434	
20	Ardeal	5198	91.4	-489	
21	Briana	5173	91.0	-514	
22	Gruia	4950	87.0	-737	o
23	Alex	4879	85.8	-808	o
24	Crisana	4812	84.6	-875	o
25	Josef	4688	82.4	-999	oo

$LSD_{5\%}$ = 651 Kg/Ha; $LSD_{1\%}$ = 882 Kg/Ha; $LSD_{0,1\%}$ = 1181 Kg/Ha.

Table 3

Results regarding the *Fusarium* head blight in fertilized variant
(Oradea, 2010)

Variety	**Total ears /m²**	**Ears with FHB / m²**	***Fusarium* head blight**			
			Notes	**Frequency (%)**	**Intensity (%)**	**Degree of attack (%)**
Flamura 85	568	152	4	26.7	40	10.7
Lovrin 34	664	220	5	33.1	65	21.5
Ariesan	704	256	6	36.4	55	20.0
Dropia	536	152	4	28.4	35	9.9
Alex	664	160	2	24.1	60	14.5
Ardeal	640	160	2	25.0	75	18.7
Romulus	536	188	6	35.1	80	28.1
Boema	696	260	5	37.4	72	26.9
Delabrad	668	248	3	37.1	38	14.1
Faur	520	156	3	30.0	35	10.5
Glosa	624	200	4	32.1	40	12.8
Gruia	644	112	3	17.4	40	7.0
Izvor	688	216	3	31.4	70	22.0
Ciprian	704	224	3	31.8	55	17.5
Briana	520	60	4	11.5	68	7.8
Serina	688	88	3	12.8	65	8.3
Capo	760	256	5	33.7	72	24.3
Apache	636	80	2	12.6	43	5.4
Josef	624	20	2	3.2	18	0.6
Kristina	512	40	3	7.8	48	3.7
Kiskun Gold	692	116	3	16.8	66	11.1
Renesansa	696	156	4	22.4	77	17.2
Crisana	528	108	3	20.5	50	10.2
Litera	488	108	4	22.1	25	5.5
Miranda	600	256	6	42.7	70	29.9
Averages	**624**	**159.7**	**3.68**	**25.3**	**54.5**	**14.3**

In the variant with no nitrogen fertilization (table 4), all the values are less than in the variant with 100 kg/ha nitrogen (active substance). Even the values of attack are less, the classification of varieties is the same. That means that the resistance to *Fusarium* attack is under genetic control.

Table 4

Results regarding the *Fusarium* head blight in no fertilized variant
(Oradea, 2010)

Variety	Total ears $/m^2$	Ears with FHB $/ m^2$	*Fusarium* head blight			
			Notes	Frequency (%)	Intensity (%)	Degree of attack (%)
Flamura 85	492	68	4	13.8	60	8.3
Lovrin 34	428	136	6	31.8	62	19.7
Ariesan	596	112	5	18.8	72	13.5
Dropia	444	144	4	32.4	50	16.2
Alex	456	76	3	16.7	45	7.5
Ardeal	388	68	3	17.5	70	12.2
Romulus	452	176	5	38.9	78	30.3
Boema	536	200	5	37.3	66	24.6
Delabrad	468	112	4	23.9	45	10.8
Faur	444	144	3	32.4	40	13.0
Glosa	420	100	5	23.8	44	10.5
Gruia	464	36	6	7.8	25	1.9
Izvor	532	104	3	19.5	62	12.1
Ciprian	648	124	4	19.1	46	8.8
Briana	528	32	4	6.1	27	1.6
Serina	588	76	3	12.9	67	8.6
Capo	496	76	6	15.3	72	11.0
Apache	600	36	2	6.0	80	4.9
Josef	524	56	2	10.7	27	2.9
Kristina	444	24	2	5.4	62	3.3
Kiskun Gold	504	72	4	14.3	73	10.4
Renesansa	484	88	4	18.2	56	10.2
Crisana	488	52	3	10.7	40	4.3
Litera	420	64	4	15.2	38	5.8
Miranda	368	76	5	20.7	72	14.9
Averages	**488.5**	**90.1**	**4**	**18.8**	**55**	**10.7**

Trying to understand the implications of *Fusarium* attack on yield and its quality, we calculated the correlations between the elements of attack and yields of grains, grains damage and seeds germination (table 5). The varieties with great densities had the highest degree of intensity and attack. Like evidence, intensity, frequency and attack degree correlate very strongly. The seed germination is negatively affected by the frequency of attack. The percent of diseased grains is strongly dependent on the attack degree. In comparison to the unfertilized variant, the correlation indexes are positive and significant.

Table 5

The correlations between FHB and grain yield.
Oradea, 2010, fertilized.

	Character	2	3	4	5	6	7	8	Unfertilized
1	**Total ears**	0.255	0.414*	0.409*	0.070	0.099	0.041	-0.001	0.434*
2	**Frequency**	-	0.323	0.838***	-0.441*	0.200	0.049	0.115	0.725**
3	**Intensity**		-	0.731**	-0.116	0.153	0.069	0.019	0.580**
4	**Attack degree**			-	0.207	0.310	0.169	0.708**	0.952**
5	**Germination**				-	-0.010	0.020	-0.057	0.078
6	**Total grains yield**					-	-0.009	0.671**	0.495*
7	**Healthy grains yield**						-	-0.822**	-0.540**
8	**Grain damage %**							-	0.265

R5% = 0,39; R1% = 0,51.

In the table 6, (which presents the correlations between FHB and grain yield in no fertilized situation), there is a new different significant correlation between ears density and frequency of attack.

Table 6

The correlations between FHB and grain yield.
Oradea, 2010, no fertilized.

	Character	2	3	4	5	6	7	8
1	**Total ears**	-0.256	0.097	-0.181	0.060	0.554**	0.553**	-0.408*
2	**Frequency**	-	0.216	0.908**	-0.186	-0.123	0.091	-0.022
3	**Intensity**		-	0.537**	-0.138	0.390*	0.377	-0.254
4	**Attack degree**			-	-0.200	0.150	0.125	-0.065
5	**Germination**				-	0.041	0.057	-0.084
6	**Total grains yield**					-	0.985**	-0.730**
7	**Healthily grains yield**						-	-0.835**
8	**Grain damage %**							-

R5% = 0,39; R1% = 0,51.

In the climatic conditions previously described, other diseases were present: powdery mildew, septoria and leaf rust (Table 7). All the FHB indicators correlated significantly with powdery mildew. That means that the varieties susceptible to FHB are susceptible to *Erisiphe graminis*, too. The same climatic conditions facilitate the apparition and evolution of both diseases.

Table 7

The correlations between FHB and other diseases.
Oradea, 2010, fertilized.

	Character	Precocity	Powdery mildew	Septoria	Leaf rust	FHB notes
1	**Frequency**	-0.202	0.426*	-0.346	-0.246	0.642**
2	**Intensity**	-0.060	0.485*	-0.010	-0.086	0.374
3	**Attack degree**	-0.067	0.513**	-0.188	-0.246	0.669**
5	**FHB notes**	-0.331	0.181	-0.218	-0.132	-
6	**Leaf rust**	-0.068	0.229	-0.200	-	
7	**Septoria**	0.095	-0.182	-		
8	**Powdery mildew**	0.035	-			

R5% = 0,39; R1% = 0,51.

In the unfertilized variant (table 8), the results suggest that the precocious varieties were more affected by FHB and leaf rust, too. In opposition, the most attacked varieties by septoria were the less attacked by *Fusarium*.

Table 8

The correlations between FHB and other diseases.
Oradea, 2010, unfertilized.

	Character	Precocity	Powdery mildew	Septoria	Leaf rust	FHB notes
1	**Frequency**	-0.043	-0.110	-0.039	0.164	0.411*
2	**Intensity**	0.360	-0.032	-0.509*	-0.380	0.081
3	**Attack degree**	0.046	-0.061	-0.111	0.001	0.453*
5	**FHB notes**	-0.531**	0.097	0.135	0.343	-
6	**Leaf rust**	-0.565**	-0.246	0.134	-	
7	**Septoria**	-0.188	0.030	-		
8	**Powdery mildew**	-0.161	-			

R5% = 0.39; R1% = 0.51.

As an expression of genetic control of resistance to FHB and to the stability reaction, the regression line between attacks in the two conditions is very suggestive (figure 1). The general trend is the same, but at a different level.

In figure 2, the linear regression between the intensity attack and the sedimentation index explained in a clear manner the effect of depreciating the quality of yield.

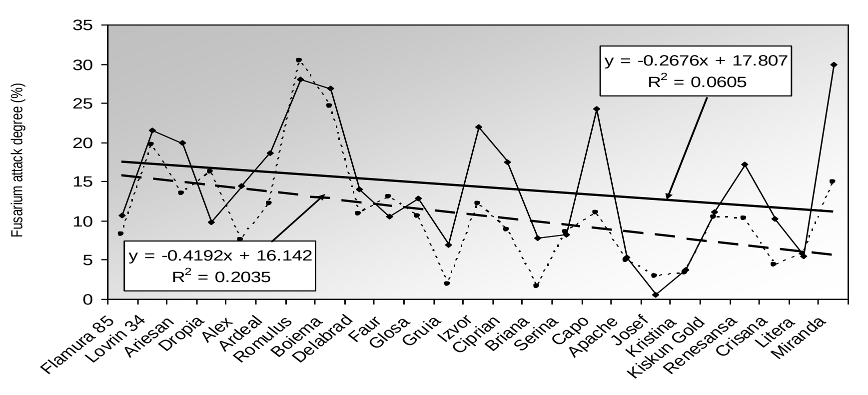

Fig. 1. Regression between Fusarium degree attack in fertilized and unfertilized conditions

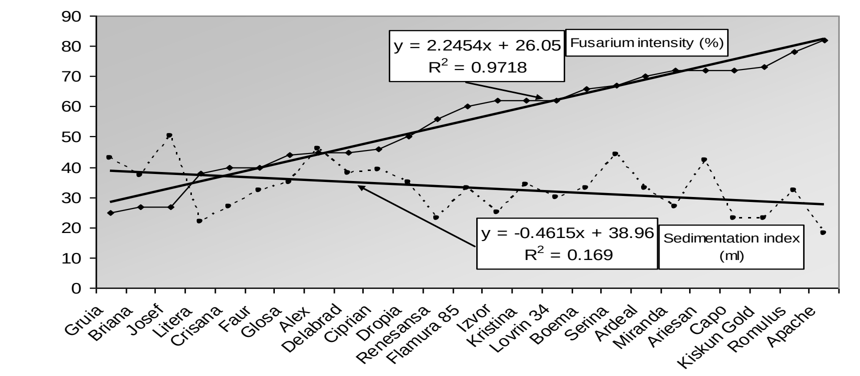

Fig. 2. Regression between Fusarium intensity attack and sedimentation index (unfertilized)

CONCLUSIONS

1. The least affected varieties by FHB were: Josef, Kristina, Apache, Briana and Serina and the most affected were: Boema, Miranda, Capo and Ariesan.
2. The nitrogen fertilization affects the level of attack, but not the varieties classification of resistance. This suggests a strong genetic control of resistance to *Fusarium*.
3. The attack frequency and intensity are facilitated by a big ears density.
4. The quality of yield, like seed germination and sedimentation index, are strongly affected by FHB attack.
5. The reaction of varieties to *Fusarium* attack is similar for powdery mildew, but not for septoria sp.

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