Sjemenarstvo 16(99)1-2

UDK: 633.111;631.524.86(045)=020
Izlaganje na znanstvenom skupu

EVALUATION OF WHEAT RESISTANCE TO FUSARIUM HEAD BLIGHT (Fusarium graminearum Schw.) THROUGH GRAIN YIELD PER PLANT UNDER THE CONDITIONS OF ARTIFICIAL AND NATURAL INFECTION

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SUMMARY

Aware of the fact to what extent possible diseases can affect grain yield of wheat and in order to preserve high-yield stability, Bc Institute has focused its breeding programs on developing high-yielding varieties with satisfactory grain and flour quality, as well as genetic resistance to the most important diseases like black stem rust, powdery mildew, and more recently to septoria and especially to *fusarium* on spikes.

The program of incorporating wheat resistance to *fusarium* head blight is very complex, because it means dealing with a facultative parasite. Under favourable conditions for its growth and development, it can cause considerable damages. In breeding for resistance to *Fusarium graminearum* Schw. (more recently also to *Fusarium moniliforme* var. *subglutinans*) tests were made with lines derived from mutually crossed sources of resistance. The lines were tested both in natural and artificial conditions (*Fusarium* nursery).

Grain yield per plant is a complex wheat characteristic and is the result of a number of influencing factors. How much damage *Fusarium graminearum* may cause in a certain wheat growing region is difficult to determine precisely without conducting exact field trials. Effect of *Fusarium graminearum* on fulfill yield capacity was estimated on the basis of resistance of initial sources of resistance and their crosses.

Yield reduction may be achieved if severe infection is duplicated after applying artificial infection in adequate climatic conditions. In our investigations it was successful. Initial sources of resistance (parents) were compared for resistance to *Fusarium graminearum* Schw. with their single and double crosses from F_1 and F_1x F_1 generations in two field trials in artificial and natural (control) infection.

Key words: *Fusarium graminearum* Schw., *Fusarium moniliforme* var. *subglutinans*, wheat breeding, evaluation of resistance, grain yield per plant, field trials, artificial and natural infection.

* This paper was presented at 10th Congress of the Mediterranean Phytopathological: UNION, June 1st-5th, 1997, Montpellier - Le Corum, France.

INTRODUCTION

Generally speaking, wheat diseases caused by fungi are one of the yield limiting factors. It this case we are dealing with fusarium head blight which is, most frequently, caused by *Fusarium graminearum* Schw. Program of incorporating wheat resistance to *fusarium* on spikes is very complex. To wit, pathogens of the genus *Fusarium* (*Fusarium gramienarum* Schw. most often) are permanently present in the soil and as saprophytes they have very limited requirments in nutrients. As a contrast, parasites cause considerable damages on crops under conditions favourable for their development (Tomasović, 1981). Increased damages caused by *fusarium* head blight, more severe attack of which was first reported in 1975 in Croatia, were the main reason why the Institute for Breeding and Production of Field Crops in Zagreb initiated a breeding program for developing resistant varieties to this disease (Milatović et al., Vlahović, Tomasović, 1982; Vlahović and Milatović, 1983).

MATERIALS AND METHODS

In the period from 1976 to 1996 over 20.000 wheat genotypes of both local and foreign origin were tested applying both types of infection. However, among the tested material, 25 wheat varieties and lines, primarily from Brazil, China, Japan, Rusia and France distinguished by their level of resistance and superior agronomic traits.

In 1990, 7 genotypes among the 25 were selected for crossing in 1991. In order to accumulate resistance genes in wheat (frequency of the favourable genes) to Fusarium graminearum Schw., in 1991, mutual crossings were made among the 7 selected sources of resistance using the semi-diallel scheme. In 1992, mutual crossings of F_1 were made. 34 combinations of double crossings were made, with 4 different parents in each combination, assuming that there is a greater possibility for accumulation of the favourable resistance genes in this way.

In 1993, 4 trials were laid (two under artificial infection and two under natural with space isolation of 200 m). Each trial consisted of respective combinations of double crossings (F_1x F_1 crosses), their F_1, combinations of crossings, and parents (sources of resistance). The trials were laid in the following way:

Trial 1		7 parents
		13 F_1 combinations of crossing
		17 F_1x F_1 combinations of crossing
	TOTAL	37 entries x 5 replications (artificial and natural infection)

Trial 2		7 parents
		11 F_1 combinations of crossing
		17 F_1x F_1 combinations of crossing
	TOTAL	35 entries x 3 replications (artificial and natural infection)

RESULTS

Trial 1

Effect of *Fusarium graminearum* Schw. on yielding potential was evaluated based on reaction of the tested genotypes and their crosses to this disease by measuring yield. In trial 1 effect of *Fusarium graminearum* Schw. on grain yield per plant (g) tested in several sources of resistance in comparison with their single and double crosses of F_1 and F_1x F_1 generation under artificial and natural (check) conditions in 1993 (Table 1). It is evident from the table, that the sources of resistance achieved different grain yields per plant (g). It is probably the result of difference in productivity among the genotypes. Attack of *Fusarium graminearum* Schw. under artificial conditions was very severe because of which grain yield per plant was substantially lower than the yields produced in natural infection.

In single crosses of the F_1 generation higher grain yield per plant was achieved relative to the parents. Yield produced under artificial conditions were lower as compared to those under natural infection.

In double crosses of the F_1x F_1 generation higher grain yield per plant was produced in comparison with single crosses of the F_1 generation and the parents.

Likewise, grain yields were also lower under artificial conditions as compared to natural conditions.

Trial 2

F-test was significant under artificial infection, however not significant under natural infection (Table 2). Similar to trial 1, yields were considerably lower as compared to those produced under natural infection.

In single crosses of the F_1, generation higher grain yield per plant was produced relative to the parents and again higher yields were obtained under natural infection. In double crosses of the F_1x F_1 generation higher grain yield per plant was produced in comparison with single crosses of the F_1 generation and parents. The differences were statistically significant.

Table 1. Effect of Fusarium graminearum Schw. on grain yield per plant in some wheat sources of resistance in comparison with their single and double crosses of the F_1, and F_1x F_1, generation in 1993.

Trial 1

Parents and F_1, crosses	Artif. infect.	Natur infect.	Grain yield reduction per plant (%)	Average reduction (%) x	F_1x F_1 crosses	Artif. infect.	Natur infect.	Grain yield reduction per plant (%)	Average reduction (%) x
	Grain yield per plant (g)								
1. TOROPI (Trp)	11,83	14,99	21,0		1. /(TrpxBzl)x(M-808xPnc)/	10,35	12,08	14,3	
2. ROAZON (Rzn)	12,53	13,52	7,3		2. /(TrpxBzl)x(BlcxPnc)/	16,36	17,30	5,4	
3. ENCRUZILHADA (Ecr)	7,85	8,04	2,4		3. /(RznxEcr)x(BzlxPnc)/	3,31	15,05	11,6	
4. BIZEL (Bzl)	10,56	10,87	2,9		4. /(RznxEcr)x(M-808xBlc)/	11,67	15,62	25,3	
5. MIRONOVSKAYA 808 (M-808)	9,25	11,27	17,9	11,8	5. /(RznxEcr)x(M-808xPnc)/	12,70	14,44	12,0	
6. BALAYA-CERKOV (Blc)	10,01	12,08	17,1		6. /(RznxBzl)x(M-808xPnc)/	12,51	15,59	19,8	
7. PONCHEAU (Pnc)	10,17	11,86	14,2		7. /(RznxBzl)x(M-808xPnc)/	15,30	15,76	2,9	
1. (Trpx Ecr)	15,38	17,00	9,5		8. /(RznxBzl)x(BlcxPnc)/	13,47	14,51	7,2	12,8
2. (Trpx Bzl)	13,30	13,47	1,3		9. /(RznxM-808)x(TrpxBzl)/	11,18	15,99	30,0	
3. (Rznx Ecr)	12,12	12,88	5,9		10. /(RznxBlc)x(BzlxM-808)/	13,69	16,78	18,4	
4. (Rznx Bzl)	12,17	14,35	15,2		11. /(RznxBlc)x(M-808xPnc)/	10,91	11,75	7,2	
5. (Rznx M-808)	11,73	12,58	6,8		12. /(BzlxM-808)x(RznxEcr)/	13,25	13,39	1,0	
6. (Rznx Blc)	13,14	14,46	9,1	7,9	13. /(BzlxM-808)x(RznxPnc)/	15,95	16,27	2,0	
7. (Rznx Pnc)	14,20	14,36	1,1		14. /(BzlxM-808)x(BlcxPnc)/	14,94	18,04	17,2	
8. (Bzlx M-808)	12,50	14,27	12,4		15. /(BzlxBlc)x(M-808xPnc)/	16,19	17,10	5,3	
9. (Bzlx Blc)	11,50	13,61	15,5		16. /(BzlxPnc)x(M-808xBlc)/	11,22	17,40	35,5	
10. (Bzlx Pnc)	13,24	13,55	2,3		17. /(M-808xBlc)x(TrpxEcr)/	14,25	14,75	3,4	
11. (M-808x Blc)	12,20	13,21	7,6						
12. (M-808x Pnc)	13,39	14,34	6,6						
13. (Blcx Pnc)	15,20	16,93	10,2						

LSD 0,05 = F-test not significant
LSD 0,01 = F-test not significant

Table 2. Effect of Fusarium graminearum Schw. on grain yield per plant in some wheat sources of resistance in comparison with their single and double crosses of the F_1, and F_1x F_1, generation in 1993

Trial 2

Grain yield per plant (g)									
Parents and F_1, crosses	Artif. infect.	Natur infect.	Grain yield reduction per plant (%)	Average reduction (%) x	F_1x F_1 crosses	Artif. infect.	Natur infect.	Grain yield reduction per plant (%)	Average reduction (%) x
1. TOROPI (Trp)	11,25	22,17	49,2		1. /(TrpxBzl)x(RznxEcr)/	15,24	23,88	36,2	
2. ROAZON (Rzn)	9,21	17,91	48,6		2. /(RznxEcr)x(BlcxPnc)/	17,25	22,17	22,2	
3. ENCRUZILHADA (Ecr)	9,88	17,26	42,8		3. /(RznxBzl)x(TrpxEcr)/	18,05	27,00	33,1	
4. BIZEL (Bzl)	10,29	14,14	27,2	41,4	4. /(RznxBzlx(RznxPnc)/	15,89	19,33	17,8	
5. MIRONOVSKAYA 808 (M-808)	9,61	15,27	37,0		5. /(RznxBzlx(BzlxPnc)/	16,06	29,00	44,6	
6. BALAYA-CERKOV (Blc)	9,87	17,35	43,1		6. /(RznxM-808)x(BzlxBlc)/	14,60	17,45	16,3	
7. PONCHEAU (Pnc)	9,54	16,42	41,9		7. /(RznxM-808))x(BzlxPnc)/	14,00	15,33	8,7	
1. (Trpx Ecr)	12,13	19,61	38,1		8. /(RznxM-808)x(BlcxPnc)/	11,74	17,75	33,9	32,0
2. (Trpx Bzl)	11,72	17,85	34,3		9. /(RznxBlc)x(TrpxBzl)/	14,69	24,67	40,4	
3. (Rznx Ecr)	12,72	21,07	39,6		10. /(RznxPnc)x(TrpxEcr)/	13,12	31,73	58,7	
4. (Rznx Bzl)	14,00	19,78	29,2		11. /(RznxPnc)x(TrpxBzl)/	15,93	23,83	33,1	
5. (Rznx M-808)	9,62	14,78	34,9		12. /(RznxPnc)x(BzlxBlc)/	15,03	15,68	4,1	
6. (Rznx Blc)	10,00	11,33	11,7	28,0	13. /(RznxPnc)x(M-808xBlc)/	17,39	28,00	37,9	
7. (Rznx Pnc)	13,15	15,58	15,6		14. /(RznxPnc)x(BzlxPnc)/	8,89	29,67	70,0	
8. (Bzlx Blc)	8,41	14,58	42,3		15. /(BzlxBlc)x(RznxEcr)/	15,62	26,33	40,7	
9. (Bzlx Pnc)	13,90	15,65	11,2		16. /(BzlxPnc)x(TrpxEcr)/	17,94	25,08	28,5	
10. (M-808x Blc)	10,50	16,00	34,4		17. /(M-808xBlc)x(TrpxBzl)/	16,89	20,92	19,3	
11. (Blcx Pnc)	12,03	14,50	17,0						

LSD 0,05 6,06 = F-test not significant
LSD 0,01 7,99 = F-test not significant

DISCUSSION

According to the obtained results in 1993 from trial 1 and 2, the most resistant sources did not produce the highest grain yield. On the contrary, the poorest sources of resistance to *Fusarium graminearum* Schw. (Balaya-cerkov, Toropi, and especially Roazon) produced the highest grain yield. Later, in crossing involving the above mentioned susceptible sources of resistance to *Fusarium graminearum* Schw. through gene recombinations, selection and testing (artificial and natural infection) wheat lines with improved resistance and high yielding ability were developed. This can be compared with the variety Sumai 3, the best available Chinese sources of resistance to Fusarium head blight in the world, which was presumably developed as a result of transgressive segregation in crossing two susceptible varieties - Funo and Taiwan-xiomai (Liu, 1984; Chaofei et al. 1986; Wu, 1986).

To determine the level of wheat resistance by the effect *Fusarium graminearum* Schw. has on grain yield is not always reliable. To wit, direct measurements of yield per square unit did not always give objective results both under artificial and natural infection. By conducting field trials under artificial infection, and by using adequate statistical methods of calculation it was possible to determine the real effect of *Fusarium graminearum* Schw. on yielding ability in general and for each variety (crosses). Its effect on reduced yielding ability can also be expressed through yield reduction. In trial 1, reduction in grain yield under artificial infection as compared to natural infection averaged 11,8% in parental lines. In single crosses of the F_1 generation this reduction was 7,9% on the average, while in double crosses of the F_1x F_1, generation grain yield reduction under artificial infection in comparison with the natural averaged 12,8%. However, in trial 2 under artificial infection as compared to the natural, reduction in grain yield of the parental lines was as high as 41,4%. In single crosses of the F_1, generation it was 28,0% on the average, and in double crosses of the F_1x F_1, generation it averaged 32,0%.

PROSUDBA OTPORNOSTI PŠENICE NA FUZARIJSKU PALEŽ KLASA (*Fusarium graminearum* Schw.) PUTEM URODA ZRNA PO BILJCI U UVJETIMA UMJETNE I PRIRODNE ZARAZE

SAŽETAK

Spoznavši koliki je mogući utjecaj bolesti na urod zrna pšenice, a u svrhu očuvanja stabilnosti visokog uroda, Bc Institut je programe oplemenjivanja usmjerio na stvaranje sorata visokog uroda, zadovoljavajuće kakvoće zrna i brašna, te genetske otpornosti na najvažnije bolesti: crnu žitnu hrđu i pepelnicu, a u novije vrijeme septorioze i posebice fuzarioze klasa.

Program unašanja otpornosti pšenice na fuzarijsku palež klasa vrlo je složen, jer se radi o fakultativnom parazitu. U uvjetima povoljnim za rast i razvoj on može učiniti velike štete. U tijeku

selekcije pšenice na otpornost na *Fusarium gramienarum* Schw. (u novije vrijeme i na *Fusarium moniliforme* var. *subglutinans*) testirane su linije izvedene iz međusobno križanih izvora otpornosti. Linije su ispitivane u uvjetima prirodne i umjetne zaraze (rasadnik *Fusariuma*).

Urod zrna po biljci je kompleksno svojstvo i rezultat je djelovanja niza činilaca. Kolike štete *Fusarium graminearum* Schw. može prouzročiti u nekom uzgojnom području teško je točno utvrditi bez egzaktnih ispitivanja u polju. Utjecaj *Fusarium graminearum* Schw. na realizaciju kapaciteta rodnosti ocjenjivan je na osnovi otpornosti ispitivanih početnih izvora i njihovih križanaca na tu bolest. Smanjenje uroda može se ostvariti ako se pomoću umjetne zaraze i odgovarajućih klimatskih prilika postigne jaka infekcija, što je u našim istraživanjima u potpunosti uspjelo. Početni izvori (roditelji) uspoređivani su po otpornosti na *Fusarium graminearum* Schw. s njihovim jednostrukim i dvostrukim križancima F_1 i F_1x F_1 generacije u dva poljska pokusa u uvjetima umjetne i prirodne zaraze (kontrola).

Ključne riječi: *Fusarium graminearum* Schw., *Fusarium moniliforme* var. *subglutinans*, oplemenjivanje pšenice, procjena razine otpornosti, urod zrna po biljci, poljski pokusi, umjetna i prirodna zaraza

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Primljeno – Received:
17. 06. 1999.