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# WHEAT RESISTANCE TO SCAB (*FUSARIUM* HEAD BLIGHT)

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## SUMMARY

The paper gives a brief account of wheat breeding for resistance to fusarium disease on spikes (head blight). Causes of more severe incidence of this disease are presented, with a special reference on growing semi-dwarf high-yielding wheat varieties applying intensive cultural practices. The beginning of the breeding program is outlined. Cooperation with countries from worldwide is commented on collecting sources of resistance and the exchange of breeding materials among the breeders in developing new lines or varieties resistant to head fusarium, mainly caused by *Fusarium graminearum* Schw. in our wheat growing areas. Methods of crossing and breeding used in development of resistant varieties to head blight are given. Also, phytopathological part of the work is presented, with an emphasis laid on methods of artificial infection to our growing conditions.

Key words: winter wheat, resistance, sources of resistance, fusarium head blight (FHB), artificial infection.

## INTRODUCTION

In wheat breeding, considerable results have been achieved until now, i.e. varieties with high genetic yielding potential and very good adaptability have been developed. However, this genetic potential is not being fully realized in production because of some negative factors adversely affecting yield, grain and flour quality. One of the direct adverse factors affecting yield is *Fusarium* head blight caused most often by *Fusarium graminearum* Schw. Weak or severe, attack of *Fusarium graminearum* Schw. on wheat has long been known in Croatia. Last few years, this disease has been reported in our wide agricultural practice increasingly affecting wheat spikes, especially in seasons when high temperatures prevail at anthesis, accompanied with high relative air humidity. *Fusarium* head blight is a disease of high-productive wheat genotypes grown under very intensive cultural practices.

Wheat head blight is known to be caused by several *Fusarium* species. *Gibberrella zeae* (Schw.) Petch. (*Fusarium graminearum* Schw.) is the most widely spread cause of maize diseases in production. Because of short rotation one could assume that the same *Fusarium* species would be also the most widely spread pathogen of scab, which was proved by our investigations (Milatović et al., 1982).

Breeding wheat for resistance to *Fusarium graminearum* Schw. is a continuous process in which efforts are made to transfer genes of resistance from the wheats-carriers of resistance into our new lines. The new lines are being developed following our programmed ideotype, applying breeding methods of crossing and selection. Sources of resistance are being collected on the basis of exchange with breeders from worldwide. Sources of resistance (test-assortment) and a part of breeding materials (both earlier and later generations) are tested under conditions of artificial infection.

## SOURCES OF RESISTANCE TO *FUSARIUM* DISEASES ON SPIKES

Given the high importance of sources of resistance to *Fusarium*, contacts were established already during 1976 and 1977 with the centers from worldwide, where wheat breeding to *Fusarium* spp. was conducted (The Netherlands, China, Japan, Australia, the USA and others).

After the year 1980, the cooperation with the centers working on *Fusarium* diseases on wheat was further broadened and contacts were made with Hungary, France, Germany, Bulgaria, Mexico (CIMMYT), Chile, Argentina, Canada, South Corea and some other.

The obtained sources are tested in experimental nursery of the Institute at Botinec under conditions of both artificial and natural infection to this as well as to other diseases, and for other important agronomic and biological traits. In breeding sources of resistance (after the most resistant ones have been selected), they are crossed among themselves in order to increase level of resistance, and then taken as sources of resistance to scab (*Fusarium graminearum* Schw.) for developing high-yielding wheat varieties resistant to this disease. For that reason, sources of resistance need to be first improved through "pre breeding" in order to raise the level of resistance, at the same time eliminating negative factors. The obtained progenies are then tested under conditions of artificial infection in $F_2$, $F_3$, $F_4$ and later generations, to screen the most resistant genotypes. Their progenies are first grown following ear-to-row method and then like other breeding materials using a pedigree-method with continued and discontinued individual selection of spikes.

## NEW IMPROVED SOURCES OF RESISTANCE

Inheritance of resistance to *Fusarium* spp. is controlled by multiple genes (polygenic inheritance). In breeding for resistance to *Fusarium*, back-crossing seems to be very effective. Diallel crossing and recurrent selection appears to be the most effective method for increasing frequency of resistance genes for the above pathogen (Tomasović, 1981).

Breeding sources of wheat resistance to *Fusarium* head blight was initiated as far back as 1981, to improve resistance of wheat to *Fusarium* by applying recurrent selection. Throught those investigations, a problem arose to test the following:

1. Improvement of selected wheat sources of resistance to *Fusarium* diseases
2. Attaining the above improvement of resistance through recurrent selection, in this case the most suitable method.

The aim of the investigations is to determine reaction of the selected sources of resistance by applying partial diallel crossing and recurrent selection for getting guidelines to be used in breeding programs for resistance to Fusarium diseases. Seven sources of resistance were selected based on as broad genetic variability of the parents as possible (France, USSR, Brazil). Among the selected genotypes (sources), 21 combinations of single crosses were made following the scheme of partial diallel. In 1982, crosses between $F_1$ generations were made ($F_1$x $F_1$) forming $F_1$ generation of double crosses, i.e. $F_2$ derived generation.

In order to achieve frequency of desirable genes of sources of resistance to *Fusarium* as high as possible, 34 combinations of double-crosses were made. In 1983, four trials were set, i.e. two trials with five replications (17 combinations $F_1$ x $F_1$, 13 $F_1$, and seven parents (sources of resistance), and the other two trials in three replications because of the seeds available (17 combinations of double-crosses ($F_1$ x $F_1$), 11 $F_1$, and seven parents (sources of resistance). Two trials were subjected to artificial infection, and the other two were conducted under conditions of natural infection following randomized block design. Trials were seeded with space isolation to allow spore transmission (most often *Fusarium gramienarum* Schw.).

In 1983, two trials were artificially inoculated, estimates taken and six most resistant combinations selected for the 1st cycle of recurrent selection. In 1984, 15 $F_1$ combinations were made with them (partial-diallel), and in 1985, 105 combinations of $F_1$ generations as the final step of the experiment. Results are already being used in the program of breeding wheat for resistance to *Fusarium graminearum* Schw.

## LABORATORY TESTING OF *FUSARIUM GRAMINEARUM* FUNGUS

Phytopathological investigations within wheat breeding for resistance to scab, caused most often by *Fusarium graminearum* Schw. fungus comprise the following:

a) Isolation of the pathogen from the samples of infected spikes and its growing in pure culture.

b) Testing the pathogen in laboratory conditions on PDA substrate.

c) Testing virulence of *Fusarium graminearum* Schw.

d) Testing wheat for resistance to *Fusarium graminearum* under conditions of artificial infection in adult stage in field, which is a part of laboratory testing of the fungus.

e) Collecting samples of infected wheat plants (spikes) as the begining of laboratory work.

Identification of the species from genus *Fusarium* is made in laboratory from pure culture grown on PDA supstrate originating from different locations. Isolates from pure culture are then grown on media to determine their virulence, i.e. the speed at which they develop colonies, the speed and quantity of sporulation. Only the isolates with speedy and abundant sporulation are used for making inoculum for artificial infection. Suspension of spores or populations of isolates with different virulence of the above pathogen is made.

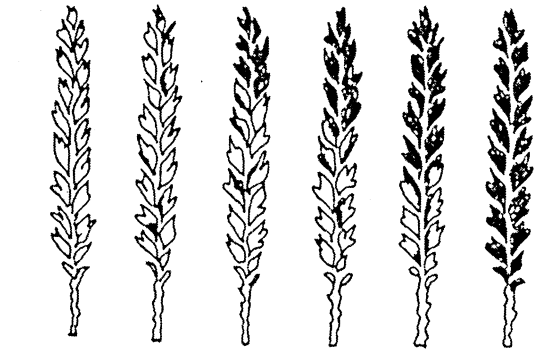
Artificial infection is made at anthesis using a "spray-method". Ratings are taken 15 days later by an 0-5 scale (Table 1, Fig. 1, 2). During the growing season, samples of infected spikes are collected from naturally infected plants, which will serve for investigations in the following year. The following materials are tested under conditions of artificial infection:

1. Sources of resistance
2. Parental components for crossing
3. $F_2$, $F_3$, and later generations
4. Materials from preliminary testing (plot size 7,5 $m^2$)
5. Materials from comparative small-scale trials and other.

*Table 1. Rating scale for attack of wheat* Fusarium *head blight (*Fusarium graminearum *Schw.)*

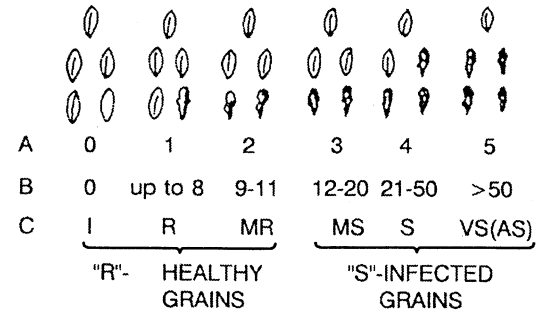
| Degree (Infection severity) | Reaction | % Spike infection | % Kernel infection |
|---|---|---|---|
| 0 | Imune | 0 | 0 |
| 1 | R | 1-5 | up to 8 |
| 2 | MR | 5-25 | 9-11 |
| 3 | MS | 25-50 | 12-20 |
| 4 | S | 50-75 | 21-50 |
| 5 | AS | >75 | >50 |

*Figure 1. Rating scale for attack of wheat fusarium head blight* (Fusarium graminearum Schw.)




A = DEGREE (INTENSITY OF ATTACK)
B = PERCENT OF INVOLVED INFECTION OF HEAD
C = REACTION OF RESISTANCE (R) RESPECTIVELY SUSCEPTIBILITY (S) OF WHEAT HEADS

*Figure 2. Rating scale for attack of wheat fusarium head blight by counting of infected grains* (Fusarium graminearum Schw.)

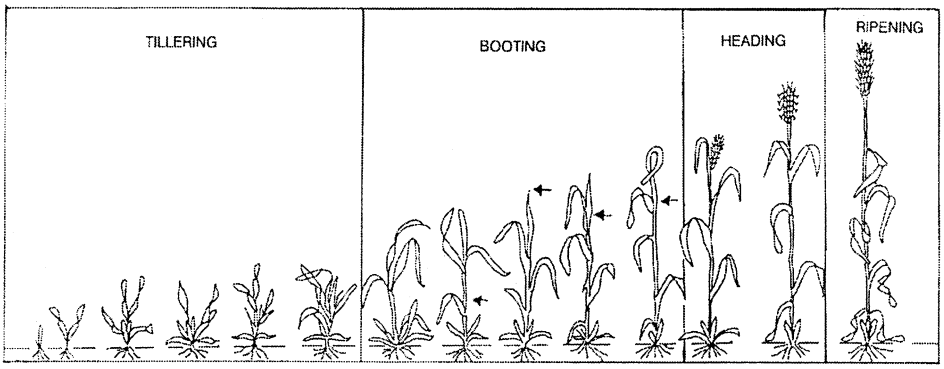



A = DEGREE (INTENSITY OF INFECTION)
B = PERCENT OF INFECTED GRAINS
C = REACTION OF RESISTANCE (R) RESPECTIVELY SUSCEPTIBILITY (S) THROUGH THE PERCENT OF INFECTED GRAINS

## SCALE FOR ESTIMATING ATTACK OF *FUSARIUM* HEAD BLIGHT IN WHEAT (*Fusarium graminearum* Schw.)

The fungus attacks wheat spikes as soon as they emerge and at anthesis the attack is most dangerous. That stage of growth presents the best moment for infection, especially if high temperatures (over 25 °C) prevail, accompanied by high relative air humidity (over 85%). Pinkish hyphae of mycelium are especially manifested at milk stage and early dough stage (Feekes stage 11.1 and 11.2) (Keller and Baggiollini, 1954; Large, 1954; Zadoks et al., 1974; Fig. 3). That is the best moment for estimating attack severity, because the manifestation of the pathogen is most clearly expressed.

*Figure 3. Developmental stages of wheat*




SCALLES:

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10,1 | 10,2 | 10,5 | 11 |
| B | 10-13 | 21 | 25 | 29 | 30 | 31 | 32 | 37 | 39 | 49 | 51-55 | 59-69 | 71-92 |
| C | A-D | E | F | G | H | I | J | K | L | M | N | O-P | R-W |

A= FEEKES LARGE, B= ZADOKS ET ALL., C= KELLER-BAGGIOLINI

A unique 0-5 scale is used in which 0 = no infection, 5 = over 75% of diseased spikes.

Used in estimating spikes, the scale 0-5 is as follows: (Figure 1):

0 - healthy spike

1 - several spikelets in a spike infected

2 - 1/4 of the spike surface infected (the tip)

3 - 1/2 the spike infected

4 - 3/4 of the spike surface infected

5 - entire spike surface infected

In estimating disease attack, one should assess the intensity of attack, i.e., % of a spike's surface infected. Based on these two estimates, reaction

behaviour of the material is given, or estimates on whether the material is resistant (R) or susceptible (S). Estimates of the infection are shown in Table 1.

*Fusarium* head blight appears most frequently at anthesis or milk stage, affecting parts of spikes, individual spikelets or the entire spike which will die if the top internode gets infected. Infected spikes develop kernels with various degrees of filling (from normal to completely empty). A rating scale for grain infection is shown in Figure 2.

Affected spikelets are light reddish to red. In extreme cases the spikes become "dead". When the spores carried by wind land on a spike, the fungus develops and the symptoms of spike *Fusarium* become evident within 3 days at 25-30 °C and high humidity.

*Fusarium* head blight is unually estimated at milk stage by taking samples from a large number of places (4 x 100 spikes) in one crop. Infection is rated on each spike by the percent of spike area affected. Based on the percentages obtained, a disease index is calculated (Marić, 1983).

## OTPORNOST PŠENICE NA FUZARIJSKU PALEŽ KLASA (*Fusarium graminearum* Schw.)

SAŽETAK

U radu je dat kratki prikaz na oplemenjivanju pšenice na otpornost prema fuzariozama klasa (palež klasa). Iznijeti su razlozi jače pojave bolesti s osobitim osvrtom na uzgoj novih polupatuljastih visokorodnih sorti pšenice, uz vrlo intenzivnu agrotehniku. Iznosi se početak rada na oplemenjivačkom programu. Daje se osvrt na suradnju u svijetu u vezi sakupljanja izvora otpornosti, te razmjene selekcijskog materijala među selekcionerima u svijetu, u stvaranju novih linija odnosno sorti otpornih na fuzarioze klasa, a čiji je glavni uzročnik patogen *Fusarium graminearum* Schw. u našem uzgojnom području pšenice. Daje se prikaz metoda križanja i selekcije u stvaranju sorti otpornih na palež klasa. Iznosi se također i fitopatološki rad s naglaskom na metodu umjetne infekcije modificiranu prema našim uvjetima proizvodnje.

Ključne riječi: ozima pšenica, otpornost, izvori otpornosti, fuzarijska palež klasa (*Fusarium graminearum*)

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