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EFFECT OF S_1 RECURRENT SELECTION ON THE OCCURRENCE OF STALK, EAR AND ROOT ROT (*FUSARIUM GRAMINEARUM*) IN THE SYNTHETIC CORN POPULATION NSB

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A study has been conducted to assess the effect of S_1 recurrent selection on the occurrence of stalk, ear and root rot *(Fusarium graminearum)* in the synthetic corn population NSB. After five cycles of S_1 recurrent selection, a significant increase was registered in the stalk resistance to the agent of stalk rot. The percentage of lodged plants was reduced from 57.7 to 41.6%. The largest reduction in the number of lodged plants occurred in cycle C_5. In all selection cycles, lower percentages of plants infected by stalk rot occurred in the locations of Ada and Sombor, in conditions of natural infection, than in the locations Rimski Šančevi and Srbobran, in conditions of inoculation.

Key words: corn, S_1 recurrent selection, infection index

INTRODUCTION

Recurrent selection can be described as a cyclic selection process because it involves the development of progenies, evaluation of progenies in replicated trials and recombination of superior progenies for the next cycle of selection

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(HALAUER and MIRANDA, 1988). Choice of recurrent selection method depends on breeding objective and material available. Recurrent selection methods based on inbred progenies are most efficient for improvement of populations *per se* (MOLL and SMITH, 1981). The S_1 or S_2 recurrent selection method has been developed to exploit the effects of additive genes in eliminating undesirable recessive alleles that occur in progenies immediately after selfing (HALLAUER, 1988). One should be aware, however, that S_1 or S_2 recurrent selection lowers genetic variability within the population, thus lowering the efficiency of selection (CHOO and KANNENBERG, 1979; TANNER and SMITH, 1987; HELINS *et al.*, 1989).

Corn is attacked by a large number of diseases and pests that cause considerable damage and corresponding yield reductions. Perspectives of corn breeding lie in the use of materials possessing high yield potential and high disease resistance (LAMBERT and WHITE, 1997). Resistance to stalk rot is mostly controlled by additive genes (MARTIN and RUSSEL, 1984). The method of S_1 recurrent selection is most frequently used for increasing corn resistance to diseases and pests.

The objectives of this study were to assess the efficiency of five cycles of S_1 recurrent selection for resistance to the agent of stalk rot, *Fusarium graminearum,* and to determine components of variance and genetic parameters, linear regression and genetic gain from selection.

MATERIAL AND METHODS

The object of study was NSB, an early synthetic corn population, FAO maturity group 200-300, with standard quality of the flint-type grain. Comparative field trials were established using the Nested design (COCHRAN and COX, 1957) in 1997, in the following four locations: Rimski Šančevi, Srbobran, Sombor and Ada. Fifty-four families were sown within each cycle of S_1 selection (C_0, C_1, C_3 and C_5).

The experimental design of each cycle included the following elements: 3 sets with 18 families per set (54 in total), two replications per set, 16 plants per replication, a basic plot size of 2.8 m^2, stand density of 57,142 plants/ha.

Disease index was calculated in plants inoculated by the toothpick method.

The toothpick method was used in two locations, Rimski Šančevi and Srbobran. In the other two locations, Sombor and Ada, corn plants were grown in conditions of natural infection, in order to detect the eventual presence of resistance to *Fusarium graminearum.*

Infection intensity was measured at the stage of physiological maturity. Basal parts of corn stalks were cut longitudinally and the intensity of infection rated on the scale from 0 to 5. Material free of disease symptoms and material with symptoms exhibited on less than one fourth of the inoculated internode were considered as resistant. Material in which the infection spread over one-fourth to half of the internode was treated as medium resistant. Infection spread over half to three-quarters of the internode was treated as medium susceptibility. Genotypes with conspicuous symptoms and those in which the infection had spread over the entire internode, or extended to adjacent internodes, were pronounced susceptible. The assessment data were used for the calculation of disease index by the formula of McKINEY (1923). The formula gives the mean value of disease intensity over a certain area:

$$I = \frac{\sum(n \cdot k)}{(N \cdot K)} \cdot 100,$$

where:

I = disease index, n = plant number per rating category, k = number of rating categories, N = number of plants tested, K = number of categories.

RESULTS AND DISCUSSION

Average values of disease index for *Fusarium graminearum*. - Under the pressure of S_1 recurrent selection for resistance to the agent of stalk, ear and root rot, the average disease index was reduced from 57.7% to 41.6% from C_0 to C_5. MOSTAFA *et al.* (1988) reported that three cycles of simple recurrent selection for an agent of stalk rot *(Gibberella zeae)* reduced the infection intensity in six corn synthetics by 31%. The infection rate was higher under the conditions of inoculation than under the conditions of natural infection (64.5% and 37.8%, respectively). On the other hand, the percentage of infection in the fifth cycle was reduced by 13.4% in the inoculated plants and by 19.2% in the naturally infected plants. Similar results were reported by MOSTAFA *et al.* (1990) for a BS_5 population tested in conditions of natural infection by *Gibberella zeae.* In our study, the highest infection intensity was registered in Srbobran and the lowest in Ada (65.6% and 35.1%, respectively; Table 1).

Table 1. Average values, standard error, minimum and maximum values of disease index for Fusarium graminearum (%) in corn

Cycle	RŠ	SR	SO	ADA	Values for all locations		
	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x} \pm SEX$	min	max
C_0	67.0	69.4	48.9	45.5	57.7 ± 0.716	20.0	100.0
C_1	69.1	72.1	46.0	38.6	56.4 ± 0.661	20.0	95.0
C_3	63.1	65:9	36.5	30.4	49.0 ± 0.500	20.0	90.0
C_5	54.8	54.8	31.2	25.7	41.6 ± 0.416	20.0	70.0
$\bar{x}$	63.5	65.6	40.6	35.1			

Locations: RŠ - Rimski Šančevi, SR - Srbobran, SO - Sombor and ADA - Ada

Broad variation intervals observed in all five cycles of selection indicated the presence of genetic differences among the tested S_1 progenies.

Analysis of variance for disease index. - Significant values of mean squares for variation sources in the analysis of variance are indicative of the presence or absence of significant differences among locations, sets, families and replications as well as of their interactions.

Mean squares for disease index per location were highly significant for all cycles of selection of the population NSB. This may be due to the specific agroecological conditions of the experimental locations. Although the significance of differences among sets was taken as a factor for dividing the tested genotypes into sets, significant differences for this variation source in the S_1 progenies were found only in cycles C_3 and C_5. The absence of significant differences in cycles C_0 and C_1 may be due to the random choice of families during the forming of the sets, which in its turn is a prerequisite for the application of the random model of the Nested design. WAITERS *et al.* (1991), studying four synthetics (BSSSC_0, BS13 (S) C3, BSSS(R) C9 and C_3 x C_9) in six different locations, found significant differences in mean squares for the genotypes and for genotype x location interactions for root rot (%) and stalk breakage (%).

The interactions location x set for the S_1 progenies of the synthetic NSB were highly significant in cycles C_0, C_1 and C_5. The differences between replication per set and per location were not significant. This is an indication that the experiment was conducted correctly and that the results obtained may be interpreted objectively. The mean squares of families per set were highly significant in all cycles of S_1 recurrent selection. Further informations on the effect of location on the expression of other characteristics are provided by mean squares of interactions of families and locations per set (Table 2). The selection for resistance to *Fusarium graminearum* was found to have caused changes in the other characteristics.

Table 2. Mean squares of ANOVA for disease index in the S_1 families of the population NSB

Source of variation	Degrees of freedom	C_0	C_1	C_3	C_5
Location (L)	3	6027.8**	10863.9**	12534.6**	9158.0**
Set (S)	2	117.6	40.5	189.1**	297.0**
L x S	6	611.3**	200.9**	7.49	34.7**
Pon./S/L	12	12.0	15.0	16.6	3.5
Fam./S	51	441.3**	195.1**	116.9**	65.6**
F x L/S	153	45.2**	35.5**	20.2**	13.9**
Error	204	10.2	8.7	8.9	7.1

* $p<0.05$; ** $p<0.01$

Components of variance, heritability and coefficients of variation for disease index. - Significant reductions in the genetic and phenotypic variance occurred in the corn synthetic NSB over the five cycles of S_1 recurrent selection. Progenies with highest resistance to stalk rot were selected for each subsequent cycle. As the genetic variance became narrower, the frequency of desired resistance genes kept increasing. The calculated values of genetic variance between cycles C_1 and C_3 and between cycles C_3 and C_5 were significant. The differences between C_0 and C_3, C_0 and C_5 and C_1 and C_5 were highly significant (Table 3).

Table 3. Components of variance, heritability and coefficients of variation for disease index

Cycle	C0	C1	C3	C5
Vg	123.7	51.9	32.1	18.1
SEvg	26.8	12.4	7.6	4.45
Vf	137.6	63.7	38.8	22.7
SEvf	26.8	12.5	7.6	4.5
h2 (%)	89.9	81.5	82.6	79.4
SEh	0.19	0.19	0.19	0.20
CVg (%)	19.3	12.8	11.6	10.2
CVf(%)	20.3	14.1	12.7	11.4
		(0:1)**	(0:3)**	(0:5)**
$\Delta\sigma_g^2$			(1:3)*	(1:5)**
				(3:5)*

* $p<0.05$; * * $p<0.01$; $\Delta\sigma^2_g$ significance of differences in genetic variance

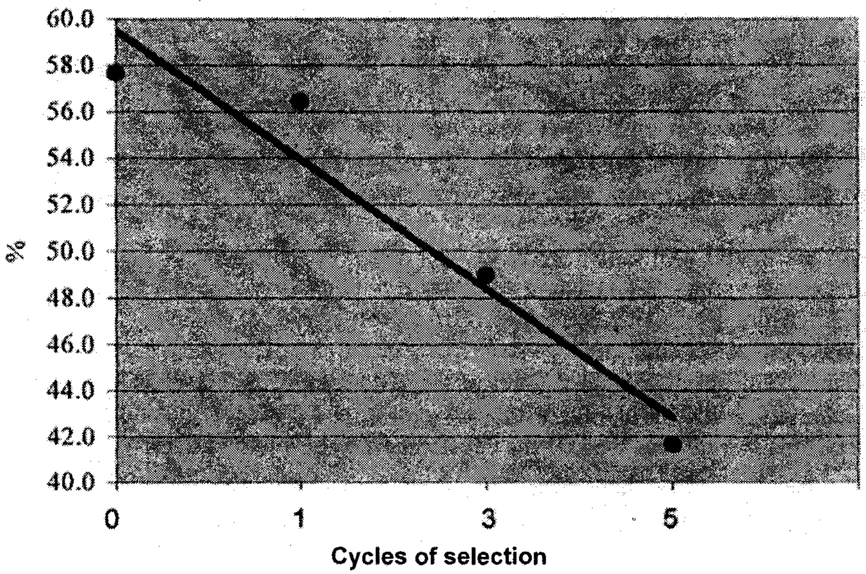

Fig. 1. Line of regression for disease index per cycle of S_1 recurrent selection

The values of wide-sense heritability for disease index were high in all five cycles of S_1 recurrent selection. The highest heritability for disease index was found in cycle C_0 and the lowest in cycle C_5 (89.9% and 79.4%, respectively). The coefficients of genetic and phenotypic variation were highest in cycle C_0 and lowest in cycle C_5, indicating a high level of variability for disease index in the synthetic NSB. The coefficients of phenotypic variation (CVf) were higher than the corresponding coefficients of genetic variation (CVg), because the former include both genetic and environmental variance. WALTERS *et al.* (1991) observed reductions in genetic variance and heritability for root rot and stalk rot in four populations of Iowa Stiff Stalk Synthetic (Table 3).

Linear regression and genetic gain from selection. - The coefficient of linear regression *b* for disease index was significant, -5.56, i.e., the reductions in the occurrence of *Fusarium graminearum* ear, stalk and root rot were 5.56% in each cycle of S_1 recurrent selection (Fig. 1). Coefficients of linear regression in two early populations, BS_5 and Cornell Early Composite, grown in conditions of natural infection were negative and highly significant, showing a linear trend of improvement in the resistance to the agent of stalk rot (-7.2** and -4.6*, respectively; MOSTAFA *et al.*, 1988 and 1990).

The genetic gain per cycle of selection was -5.56%, i.e., plant resistance to *Fusarium graminearum* increased by 5.56% per cycle of S_1 recurrent selection. Similar results were reported by STOJAKOVIĆ *et al.* (1998). After five cycles of S_1 recurrent selection, disease index was reduced on average by 6% in a synthetic population tested *per se*.

CONCLUSION

In consequence to S_1 recurrent selection, resistance to *Fusarium graminearum* ear, stalk and root rot in the corn synthetic NSB was increased.

Disease intensity was much higher in conditions of inoculation than in conditions of natural infection. The five cycles of S_1 recurrent selection reduced the percentage of infected plants by 5.6% per cycle.

The genetic and phenotypic variances for disease index kept decreasing from the initial to the final cycle of selection. The narrowing of the genetic and phenotypic variances was due to selection and inbreeding, i.e., due to the selecting of progenies possessing improved resistance to stalk rot and their inclusion in subsequent selection cycles.

The results obtained confirm the efficiency of S_1 recurrent selection for increasing corn stalk resistance to *Fusarium graminearum.* Populations improved in this manner may be used for the development of new inbred lines.

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REFERENCES

CHOO M.T. and L.W. KANNENBERG (1979): Relative efficiencies of population improvement methods in corn: A simulation study. Crop.Sci., *19*, 179-185.

HALLAUER A.R. and J.B. MIRANDA (1988): Quantitative genetics in maize breeding (second edition). Iowa State University Press, Ames.

HALLAUER A.R., W.A. RUSSELL, and K.L. LAMKEY (1988): Corn breeding:463-564. *In*: Sprague, G.F. and J. W. Dudley: Corn and corn improvement. Agron. Monogr. (third edition). ASA, CSSA and SSSA Madison, WI.

HELMS T.C., A.R. HALLAUER, and O.S. SMITH (1988): Genetic variability estimates in improved and nonimproved "Iowa Stiff Stalk Synthetic" maize populations. Crop Sci., *29*, 959-962.

LAMBERT R.J. and D.G. WHITE (1997): Disease reaction changes from tandem selection for multiple disease resistance in two maize synthetics. Crop Sci., *37*, 66-69.

MARTIN M.J. and W.A. RUSSELL (1984): Response of a maize synthetic to recurrent selection for stalk quality. Crop Sci., *24*, 331-337.

MOLL R.H. and O. SMITH, 1981: Genetic variances and selection responses in an advanced generation of a hybrid of widely divergent populations of maize. Crop Sci., *21*, 387-391.

MOSTAFA M.A.N., J.G. COORS, and P.N. DROLSOM (1988): Selection for resistance to stalk rot in maize caused by *Gibberella zeae* (SCHW.) petch. Maydica, *23*, 15-26.

MOSTAFA M.A.N., J.G. COORS, and P.N. DROLSOM (1990): Correlated changes in grain yield and agronomic traits from selection for resistance to stalk rot in maize caused by *Gibberella zeae* (SCHW.) petch. Maydica, *35*, 253-258.

STOJAKOVIĆ M., Đ. JOCKOVIĆ, G. BEKAVAC, B. PURAR, A. NASTASIĆ, and N. Vasić (1998): Changes of agronomic traits in corn under the effect of S_1 recurrent selection for resistance to stalk rot (*Fusarium graminearum*). 2nd Balkan Symposium on Field Crops. 117-121.

TANNER A.H. and O.S. SMITH (1987): Comparison of half-sib and S_1 recurrent selection in the Krug yellow dent maize populations. Crop Sci., *27*, 509-513.

WALTERS S.P., W.A. RUSSELL, and K.R. LAMKEY (1991): Performance and genetic variance among S_1 lines and testcrosses of Iowa Stiff Stalk synthetic maize. Crop Sci., *31*, 76-80.

EFEKAT S_1 REKURENTNE SELEKCIJE NA TRULEŽ STABLA, KLIPA I KORENA (*FUSARIUM GRAMINEARUM*) KOD SINTETIČKE POPULACIJE KUKURUZA NSB

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Izvod

U radu je ispitivan uticaj S_1 rekurentne selekcije na trulež stabla, klipa i korena *Fusarium graminearum* u sintetičkoj populaciji kukuruza NSB. Nakon pet ciklusa S_1 rekurentne selekcije, došlo je do značajnog povećanja otpornosti stabla prema prouzrokovaču truleži *Fusarium graminearum*. Procenat poleglih biljaka je smanjen sa. 57,7% na 41,6%. Najveće smanjenje procenta poleglih biljaka je utvrđeno u C_5 ciklusu. Lokaliteti Ada i Sombor, u uslovima prirodne infekcije imali su manji procenat truleži stabla po ciklusima, nego lokaliteti Rimski Šančevi i Srbobran, u uslovima veštačke inokulacije.

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