Resistance of Maize Inbreds and their Hybrids to *Fusarium* Stalk Rot

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Abstract: The resistance of 35 inbred lines and their 70 hybrids with two testers to stalk rot is described and the results of natural and artificial stalk infection are compared. A mixture of *Fusarium* spp. spores was used for artificial infections. The disease was scored for two years. Inbreds and hybrids differed significantly in resistance and infection types in both years. Generally, disease scores of hybrids were lower than of inbreds. No close association was found between lines and their testcross hybrids (r = –0.06 to 0.29) and between hybrids with the two testers (r = –0.04 to 0.38). The correlation coefficients of disease scores after natural and artificial infection were in inbreds and in hybrids highly significant (r = 0.45–0.87). The results suggest, that *Fusarium* stalk rot resistance should be tested in both inbreds and hybrids. We recommend for maize breeding, that tests with artificial infection should be followed by tests under natural infection.

Keywords: maize; *Fusarium* stalk rot; inbreds; hybrids; resistance of maize

Stalk rot is one of the most destructive maize diseases in Croatia. The disease is caused by a complex of pathogenic fungi, predominantly *Fusarium* species (*F. graminearum, F. moniliforme* and *F. subglutinans*). Stalk rot reduces yield directly by affecting the physiological activity of the plants and finally results in lodging, which is the main cause of economic losses. Different stress conditions such as drought, heavy cloudiness, high plant density, leaf diseases and corn borer attack favour stalk rot because of decreased photosynthesis (Dodd 1983). The wide range of environments, pathogens and plants affects the occurrence and expression of stalk rot symptoms, making screening for resistance difficult. Several authors (Russell 1961; Hooker 1973; Hooker & Draganić 1980) recommended artificial stalk infection in breeding for resistance. However, artificial infection may not result in symptoms typical for natural infection (Koehler 1960; Palaveršić 1983).

Stalk rot resistance is an important criterion for selecting better inbred lines, but more important is the resistance of hybrids in testcrosses. A relation between stalk rot resistance of inbred lines and their hybrids would be helpful, since susceptible lines could be then discarded before testing. Investigations by Russell (1961), Palaveršić (1989), Rojc *et al*. (1990), and Vragolović *et al*. (1997) showed that resistance of inbred lines to stalk rot can differ from the resistance of its testcross hybrid. The objectives of this investigation were to test the resistance of maize inbreds and their hybrids to natural and artificial stalk infection with *Fusarium* spp. and to compare the response of inbreds and their testcross hybrids to the pathogen.

MATERIALS AND METHODS

The material included 35 inbred lines and their 70 hybrids with two inbred testers. Inbred lines 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 23, 24, 25 and 30 trace back to the Lancaster Sure Crop variety, while the inbreds 3, 18, 19, 20, 26, 27, 28, 29, 31 are of Reid Yellow Dent origin (mostly Io dent). The lines 21, 22, 32, 33, 34, 35 were from single crosses. Testers were the inbred lines Os 24-48 (Harkovska 46 × B73) and Os 438-95 (KI411SCSEV400/86) with good general combining ability (GCA) for yield and resistant to *Fusarium* stalk rot. Although both testers are of Reid Yellow

Dent origin (BSSS), they cause heterosis in crosses with lines of similar origin (about heterotic patterns more in Hallauer *et al*. 1988).

The trials were conducted in Osijek (Croatia) in 1998 and 1999 using a lattice design with three replications. Inbreds and hybrids were placed in separate adjacent trials. Each entry was planted in two rows, the first row for artificial stalk infection and the second row for natural infection. A mixture of three *Fusarium* species (*F. graminearum, F. moniliforme* and *F. subglutinans*) grown on potato dextrose agar (PDA) and carnation leaf agar (CLA) was used for inoculation. The inoculation was performed by injecting 1 ml of inoculum with approx. 60 000 spores per ml into the first elongated internode, 6–8 days after silking of 50% of plants in a plot. Disease symptoms were evaluated after 6 weeks on splitted stalks, using a 1–6 scale (Hooker 1956). The degree of *Fusarium* stalk rot after natural infection was estimated at harvest using the FAO 1–9 scale. In both scales the score 1 represents plants with no symptoms. In the first step of statistical analyses, data from each environment were analysed separately as lattice designs according to Cochran and Cox (1957). Adjusted entry means and effective error mean squares from individual analyses were used in the combined analyses of variance.

RESULTS AND DISCUSSION

Scores for natural stalk rot infection differed significantly among inbreds and among hybrids in both years. Inbreds had usually higher mean scores and showed more variability than hybrids (Figures 1 and 2). The background origin of inbred lines had an effect on resistance. The most resistant inbreds were those of the Iodent group. This confirms the findings of Sokolov *et al*. 1996. Hybrids between the most susceptible inbreds (2, 22, 24, 32 and 33) and the testers had a very low level of stalk infection. These results confirmed the findings of Hooker and Draganić (1980), suggesting that one resistant inbred parent is sufficient for obtaining a hybrid resistant to stalk rot. Analyses of variance (Table 1) revealed a highly significant effect of years in inbreds, but not in hybrids. Although the effect of genotype was highly significant for both inbreds and hybrids, much higher mean squares were found in inbreds. Significant genotype × year interaction confirmed the importance of environment in the expression of natural maize *Fusarium* stalk rot in

Table 1. Analysis of variance for natural *Fusarium* stalk rot infection for maize inbred lines and their respective testcross hybrids

Sources of variation	Inbreds			Hybrids		
	df	MS	*F*	df	MS	*F*
Years (Y)	1	4.13	**	1	0.01	ns
Genotypes (G)	34	2.12	**	69	0.05	**
GY	34	0.49	**	69	0.03	**
Error	118	0.07		236	0.01	

** significant at $P < 0.01$

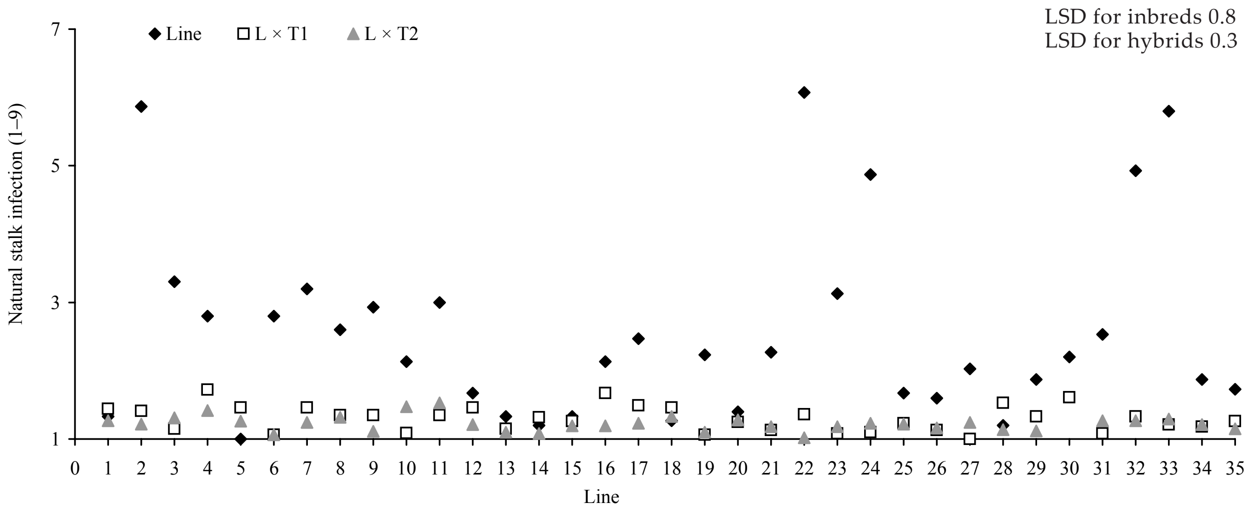

Figure 1. Reaction of maize inbred lines and their testcross hybrids to natural *Fusarium* stalk rot infection in 1998

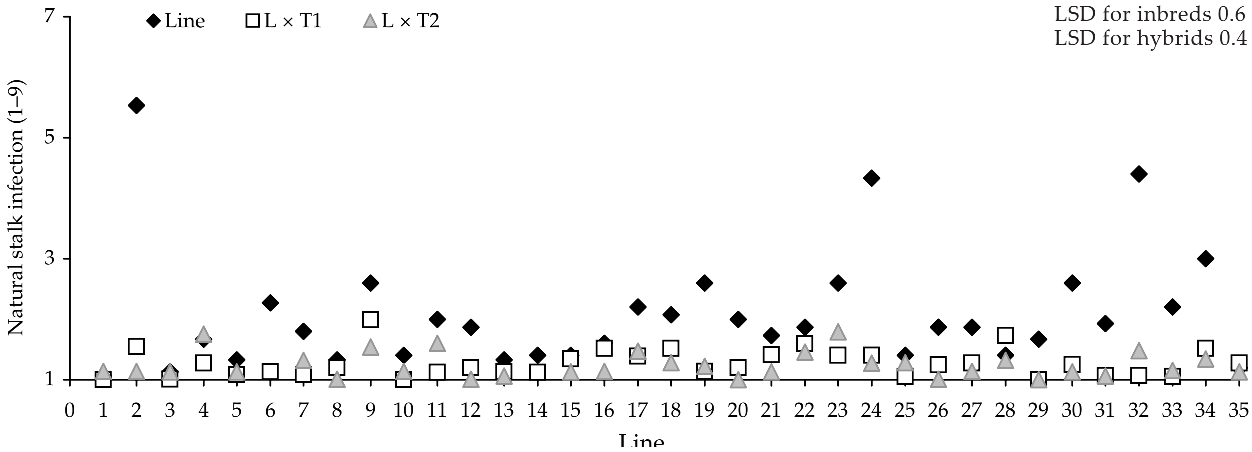

Figure 2. Reaction of maize inbred lines and their testcross hybrids to natural *Fusarium* stalk rot infection in 1999

inbred and hybrid genotypes. The effect of years on the resistance of some lines (e.g. 22) can be seen in Figures 1 and 2.

In terms of artificial *Fusarium* stalk rot infection, significant differences among inbreds as well as among hybrids in both years (Figures 3 and 4) were obtained. All hybrids showed low level of stalk rot infection regardless of the resistance of parents. However, some inbreds showed lower disease scores than the corresponding testcross hybrids. A possible reason could be the difference in kernel sink capacity between some inbreds and their testcross hybrids (Dodd 1979).

Table 2. Combined analysis of variance for artificial *Fusarium* stalk rot infection for maize inbred lines and their respective testcross hybrids

Sources of variation	Inbreds			Hybrids		
	df	MS	*F*	df	MS	*F*
Years (Y)	1	0.35	ns	1	0.02	ns
Genotypes (G)	34	0.77	**	69	0.17	**
GY	34	0.20	**	69	0.05	**
Error	118	0.03		236	0.03	

** significant at $P < 0.01$

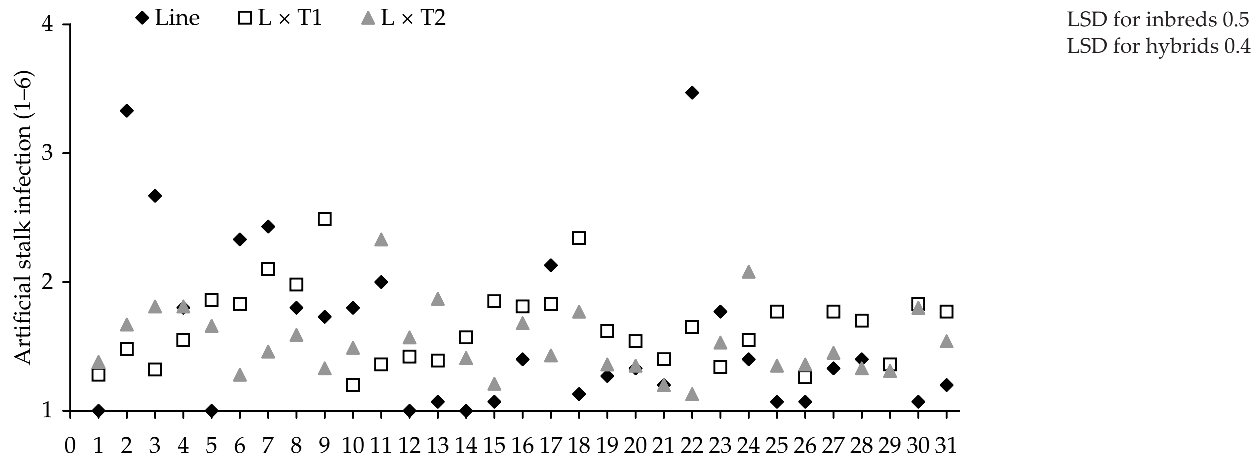

Figure 3. Reaction of maize inbred lines and their testcross hybrids to artificial *Fusarium* stalk rot infection in 1998

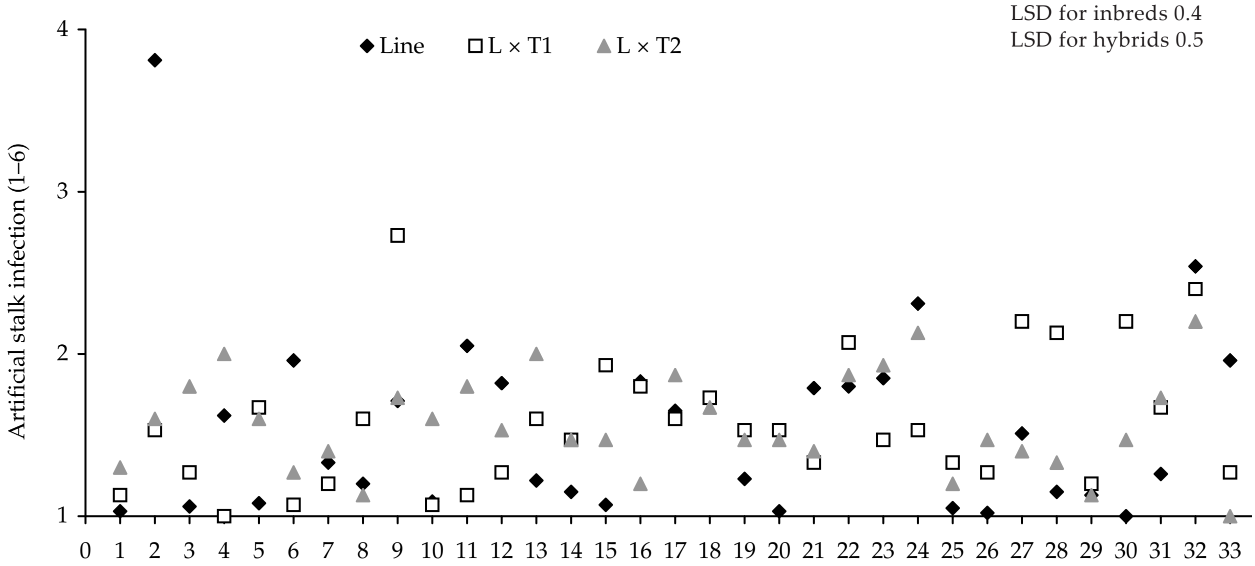

Figure 4. Reaction of maize inbred lines and their testcross hybrids to artificial *Fusarium* stalk rot infection in 1999

Table 3. Correlation coefficients between natural and artificial *Fusarium* stalk infection for maize inbred lines and their respective testcross hybrids

	1998	1999
Inbred lines	0.87**	0.81**
Hybrids	0.45**	0.55**

** significant at $P < 0.01$

Analysis of variance showed significant effects of genotype and genotype × year interactions for both inbreds and hybrids (Table 2). Year effects were not significant. The inbred line 33 had the largest difference in scores between years after artificial infection: 4.4 (susceptible) in 1998 but 2.0 (resistant) in 1999.

Although some authors did not find the same symptoms after artificial and natural stalk rot infection (Koehler 1960; Palaveršić 1983), we have found a significant correlation between the results of natural and artificial infection. The association was closer in inbreds than in hybrids, but in both groups the correlation coefficients were highly significant (Table 3). The lower correlation in hybrids was partly due to very low variation in natural infection, that caused erratic and inconsistent ranking of the hybrids. Some genotypes differed markedly in their response to natural and artificial infection (inbred 24).

The correlation between scores of lines and hybrids with both testers was low and non-significant in both years for both natural and artificial infection (Table 4) and mostly also between scores

Table 4. Correlation coefficients for *Fusarium* stalk rot resistance between maize inbred lines (L) and their respective testcrosses (L × T1, L × T2) and between testcrosses with the lines and two different testers in 1998 and 1999

Traits	L – L × T1	L – L × T2	L × T1 – L × T2
1998			
Stalk rot after natural infection (1–9)	–0.06	0.04	0.05
Stalk rot after artificial inoculation (1–6)	0.13	0.06	–0.04
1999			
Stalk rot after natural infection (1–9)	0.29	0.24	0.38*
Stalk rot after artificial inoculation (1–6)	0.08	0.29	0.18

* significant at $P < 0.05$

of hybrids with a different tester. This suggests, that stalk rot resistance was highly specific for the genotype, in spite of the resistance of both testers and of different ways of infection. This indicates a possibility, that genetic resistance to stalk rot is controlled also by non-additive gene action, as stressed by HOOKER and DRAGANIĆ (1980), and NAGY and CABULEA (1996).

Our results suggest that testing for *Fusarium* stalk rot resistance needs to be conducted in both inbreds and hybrids, since hybrid resistance could not be safely predicted from line resistance. However the use of resistant parental lines led generally to resistant hybrids. Artificial stalk rot infection followed by a natural infection test can be recommended in maize resistance breeding, since artificial infection can generate larger variation, that can be used for selection.

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Abstrakt

LEDENČAN T., ŠIMIĆ D., BRKIĆ I., JAMBROVIĆ S., ZDUNIĆ Z. (2003): **Rezistence inbredních linií kukuřice a jejich hybridů vůči fusariové hnilobě stonků**. Czech J. Genet. Plant. Breed., **39**: 15–20.

V práci je popsána odolnost 35 inbredních linií kukuřice a jejich 70 hybridů s dvěma testery vůči fusariové hnilobě stonků a srovnány výsledky umělé a přirozené infekce. Pro umělou infekci byla použita směs spor *Fusarium* spp. Symptomy choroby byly hodnoceny po dva roky. Inbrední linie i hybridy se v obou letech průkazně lišily v odolnosti a v infekčním typu. Hybridy byly celkově odolnější než inbrední linie. Nebyla nalezena úzká souvislost mezi odolností inbredních linií a jejich hybridů v testcrossu (r = –0,06–0,29) ani mezi hybridy s oběma testery (r = –0,04–0,38). Koeficienty korelace mezi hodnotami napadení po přirozené a umělé infekci byly vysoce průkazné (r = 0,45–0,87). Z výsledků vyplývá, že odolnost vůči fusariové hnilobě stonků by měla být testována jak u inbredních linií, tak u hybridů. Odolnost hybridů může být přibližně předpovídána z odolnosti inbredních linií. Doporučujeme pro šlechtění kukuřice provádění testů s přirozenou infekcí po předchozích testech s umělou infekcí.

Klíčová slova: kukuřice; fusariová hniloba stonků; inbrední linie; hybridy; odolnost kukuřice

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