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STUDIES ON THE MAIZE COLD TOLERANCE TESTS IN THE MARTONVÁSÁR PHYTOTRON

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The climatic conditions in Hungary and in the countries to which seed is exported makes the study of maize cold tolerance and constant improvements in the cold tolerance of Martonvásár hybrids especially important. An improvement in the early spring cold tolerance of maize would allow it to be grown in more northern areas with a cooler climate, while on traditional maize-growing areas the profitability of maize production could be improved by earlier sowing, leading to a reduction in transportation and drying costs and in diseases caused by *Fusarium* sp. The recognition of this fact led Martonvásár researchers to start investigating this subject nearly four decades ago. The phytotron has proved an excellent tool for studying and improving the cold tolerance of maize. The review will give a brief summary of the results achieved in the field of maize cold tolerance in the Martonvásár institute in recent decades.

Key words: maize, cold tolerance, phytotron, *Fusarium*

Introduction

Nowadays maize production is one of the most important branches of crop production, both in Hungary and on a world scale. Its importance is proved by the fact that in recent decades the sowing area has moved ever further north in Europe. On the whole, the ecological conditions in Hungary are favourable for maize production. In the major maize-producing regions of the country, the only suboptimal temperature effects during the vegetation period of maize occur in the germination and early development stages. Maize yield averages are substantially influenced by resistance to abiotic stress, including chilling in early spring. The phytotron has proved an excellent tool for studying and improving the cold tolerance of maize. Reproducible, identical environmental conditions (low temperature, damp soil) can be ensured during germination and emergence. In nature, cold, wet springs only occur every 4–7 years, so under natural conditions selection can only be conducted with low efficiency.

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Materials and methods

The aim was to study the cold tolerance of Martonvásár maize genotypes. The genotypes were examined in E-15 and G-30 phytotron cabinets and PGB-96 phytotron units (Tischner et al., 1997). The data were evaluated using analysis of variance (Sváb, 1981).

Results and discussion

The first cold tolerance tests in Martonvásár were set up using the cold test method elaborated by Clark (1954) relying on the results of Tatum and Zuber (1943) and Neptune (1953). These trials were conducted mainly to study the cold tolerance of the inbred lines used at the time, applying temperatures of 6–8°C for ten days, followed by 14–16°C. The germination percentage was found to decrease even under sterile conditions as the length of the cold incubation increased (Kovács, 1961). Under field conditions the decrease in germinating ability was even greater due to the effect of pathogens (Table 1).

Herczegh (1970) recommended the use of a new climatic programme (10 days' incubation at 8°C followed by 20 days at 13.5°C) which made it possible to distinguish more clearly between the chilling tolerance levels of the genotypes. It was recommended that genotypes should be characterised by the ratio of the maximum germination percentage and the corresponding germination time, i.e. by the cold tolerance index. Herczegh (1983) evaluated a large number of breeding stocks belonging to different related groups on the basis of the number of days to emergence (Table 2). Lines belonging to the Lancester (A) group emerged nearly three days later than those of the Reid Yellow Dent (B) group. Stocks of European origin were similar to those of the Reid Yellow Dent group. Hybrids between European lines and those of the Reid Yellow Dent group had better cold tolerance than hybrids of lines from groups A and B. This is particularly important, because the yielding ability of these hybrids is also better than that of A × B hybrids.

When studying the cold tolerance of populations with different levels of heterozygosity it was found that the 0% (lines) and 100% (F_1 hybrids) heterozygotic forms had the lowest emergence percentage, whereas populations with a 50% rate of heterozygosity had the highest emergence percentage. The 50% and 100% heterozygotic forms had the shortest emergence time (Table 3). In the case of hybrids there was an increase in the germination percentage and a decrease in the time to emergence as the heterozygotic level of the female rose. An r = –0.87 to –0.90 correlation was found between the heterozygotic level of the female and the time to emergence, and r = 0.73–0.89 between the heterozygotic level of the female and the germination percentage of the hybrid (Szundy and Kovács, 1981a, b).

Table 1
Effect of length of cold treatment and germination medium on the "cold test" germination percentage of inbred lines (Kovács, 1961)

Length of cold treatment (days)	Soil from maize field	Germination medium sand	Sterilized sand
9	34.4	60.5	81.0
12	24.2	52.5	74.2
15	18.5	45.8	66.4
18	15.9	39.5	59.1

Table 2
Cold tolerance of breeding stocks belonging to various related groups (No. of days to emergence) (Herczegh, 1983)

Breeding stocks	"A" Lancaster	"B" Reid Yellow Dent	European origin
Elite lines	24.7	22.1	22.4
Populations	20.6	17.9	19.4

Table 3
Cold tolerance of populations with different levels of heterozygosity (Szundy and Kovács, 1981a)

Trait	Levels of heterozygosity				$LSD_{5\%}$
	0%	25%	50%	100%	
Days to emergence	20.1	18.0	17.0	17.0	0.51
Emergence (%) percentage	41.3	84.0	89.1	51.3	3.8

From the study of the cold tolerance of S_2 maize families it was concluded that there is sufficient variability for selection for improved cold tolerance both regarding the number of days to emergence and the emergence percentage (Quang and Szundy, 1989) (Table 4). A close, positive correlation was observed for the number of days to emergence between the S_1 and S_2 families. The correlation coefficient between the S_1 generation and the means of S_2 families originating from the same S_1 plant was r= 0.97, significant at the P=1% level. The correlation between the days to germination of the S_1 individuals and the S_2 families was also close (r=0.69) and significant at the P=1% level. The correlation between the numbers of S_1 and S_2 plants emerging from the cold soil was also close and significant. A close correlation (r=0.99) significant at the P=0.1 % level was observed between the germination percentages of the S_1 generation and the means of S_2 families originating from the same S_1 plant. The correlation coefficient between the germination percentages of the S_1 individuals and S_2 families (r=0.52), however, was only significant at the P=5% level. The results of the correlation studies revealed that the two most important indicators of cold tolerance investigated, the number of days to emergence and the germination percentage, were reliably inherited in the progeny generation.

Table 4
Cold tolerance of S_2 maize families (Quang and Szundy, 1989)

Characteristic	Mean	Extreme values	Deviation
Days to emergence	20.08	16.00–27.25	11.25
Emergence (%)	49.50	20.00–72.50	52.50

Under Hungarian conditions it is possible to produce high-yielding hybrids with longer vegetation periods, thus able to make better use of the ecological potential, provided hybrids with better chilling tolerance are bred and sowing is carried out at an earlier date (Marton et al., 1999). In the suboptimal temperature range substantial differences could be demonstrated between the genotypes in the rate of germination (Marton, 1990) and in the development of the young plants (Marton, 1991; Marton and Szundy, 1997).

The relationship between temperature and green mass can be described satisfactorily by linear regression. This means that a threshold temperature above which growth becomes faster cannot be determined for the growth stage and temperature range studied (Marton et al., 1990).

Marton and Kuti (2002) elaborated a new modified joint scaling test and found that the expansion of the joint scaling test to include the [fh] parameter makes it suitable for demonstrating the effect of the level of heterozygosity of the female parent, which can be expected to be felt mainly in characters scored at emergence or in the seedling stage.

At low temperatures pathogens play an important role in the disease infection and destruction of seedlings (Záborszky et al., 2002; Szőke et al., 2007). There are significant differences between various soil samples as regards their degree of infection with pathogens. Thus the results of consecutive cold tests deviate, making it difficult or impossible to compare the data.

Other investigations were aimed at determining which of the *Fusarium* species existing in Hungary are widespread and the degree to which they damage germinating seeds. A study on the hybrids and parent components of an 8 × 8 complete diallel revealed that *F. culmorum, F. poae* and *F. graminearum* caused a significant reduction in the emergence of infected genotypes, while infection with *F. oxysporum* hardly decreased the survival percentage of seedlings compared to the wet control (Table 5). Infection resulted in a much higher rate of destruction in inbred lines than in their hybrids. Whereas more than 50% of hybrids survived infection, in the case of lines this ratio was 20×25%. Thus, the survival percentage of the hybrids compared to the average of the parent lines, i.e. the degree of heterosis, is around 240–270% in the case of strongly pathogenic species compared to 104.8% in the control. Similar results were obtained for the time to emergence and the dry matter production of the seedlings. These data confirmed the effect of adaptive heterosis. The effect of seed infection with *Fusarium* depends to a large extent on the temperature at

which germination takes place. The degree of infection is also reflected to varying degrees by the characteristics studied. There is only a slight change in the time to emergence due to infection. Temperature hardly modifies the relationship between the time to emergence for infected and healthy seeds. The emergence percentage and CT value decrease significantly due to infection at low temperatures, but at higher temperatures these values improve significantly and approach the values recorded for healthy seeds. The most drastic reduction was observed for the dry matter production of emerged seedlings, which only increased slightly with an increase of temperature (Marton et al., 1988). Among the *Fusarium* species, infection with *F. culmorum* and *F. graminearum* caused the greatest decline in chilling tolerance (Marton et al., 2000).

Marton (1997) reported that the pathogens to be found in the germinating medium had a great influence on the results of cold tests. The extent of the cold tolerance determined in sterilised soil may be modified in infected soil as a result of the different levels of resistance to the pathogens found in the soil (Table 5). The genetic parameters estimated also depended to a considerable extent on the experimental conditions.

Table 5
Cold tolerance traits of inbred lines and their hybrids in different germinating media (Marton, 1997)

Germinating medium	Emergence				Cold tolerance index		Plant height (cm)	
	%		Days from planting					
	Hybrids	Lines	Hybrids	Lines	Hybrids	Lines	Hybrids	Lines
Sterilised soil	86.30	56.10	19.61	25.87	4.27	2.29	9.08	5.07
Infected soil	38.60	5.23	24.26	30.09	1.66	0.12	5.70	2.00
$LSD_{5\%}$	3.02		0.47		0.16		0.38	

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