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Frost resistance evaluation of the common millet (*Panicum miliaceum* L.) varieties

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The aim of this study was to determine the most sensitive growth stage of the common millet *(Panicum miliaceum* L.*)* to frost temperatures, and to evaluate differences in frost resistance among varieties. A modified field-laboratory approach method was used for the evaluation of four varieties. The lethal temperature (LT 50) was determined for all variants. The critical time for lethal temperature (LT 50) was determined in the stage of two secondary leaves. Millet is the most sensitive to frost temperature from the stage of two secondary leaves to the beginning of tillering. Differences among sensitivity of growth stages are influenced by environmental conditions. The lethal temperature of the common millet ranged from –1.5 to –4.1°C, depending on stage of development and growth conditions. Differences among varieties were significant in field conditions. Variety 'Hanacka Mana' was the most resistant from chosen varieties in field.

Key words: common millet, *Panicum miliaceum,* frost resistance, variety evaluation

INTRODUCTION

The common millet is one of the perspective and underutilised alternative crops. It can be used as animal feed and as tasty and nutritive food for humans. Husked millet has favourable nutrients ratio of proteins, lipids and carbohydrates, and has high content of vitamins A, B1 and B2.

The common millet is a thermophilic short-day crop. The short day restricts its vegetative growth and accelerates its flowering. The average sum of temperatures during the vegetative period of this crop is 23 °C. The optimal growth temperature is 18-24 °C (Jelagin 1981). At temperatures below 10 °C, the development of leaves and photosyntehsis are very slow at temperature under (Jašovskij 1987).

In the literature, have not much information about frost resistence of the common millet and opinions of autors are different. The germinated plants are sensitive to frost. Plants are frost sensitive in the stage of flowering too because frost can injure the developing reproductive organs (Jelagin 1981). Low temperatures considerably decrease the activity and exchange capacity of the root system, on which depend utilisation of nutrients from the soil. Low temperatures such as 2 °C have a negative influence on plant height, plant biomass and leaf area. The degree of this factor influence depends strongly on the time of action (Zauralov et al. 1994).

Each variety has specific temperature requirements, which are depending on genetic, physiological and biochemical characteristics. The varietal differences in frost sensitivity are very well known in common ceral species.

The main objectives of our experiments were to determine the most sensitive growth stage of the common millet to frost, the lethal temperature, the critical periods of action of lethal temperature for individual varieties, and evaluate differences in frost resistance among chosen varieties.

MATERIAL AND METHODS

A modified field-laboratory method according to Prášil (1989) was used in our experiments. Four varieties were tested ('Hanácká Mana', CZ; 'Uilskoe White', Russia; 'Veselopodolianskoe', Russia; 'Polyploid', Russia). Each variant included 3 x 20 plants. The field-grown plants were tested in the stage of two leaves, at the beginning of tillering and at the beginning of shooting at temperatures 0, -2, -4, -6 °C (during 6 hours). All varieties were exposed to lethal temperature during 2, 4 and 6 hours. The frost resistance of field-grown plants the stage of two secondary leaves (density of growth 350 per m^2, plot area 10 m^2, sowing 14th May 2001 and 7th May 2003, site České Budějovice - 380 m a.s.l., cambisol, sandy loam, pH 6.4, meteorological data are situated in Figure 1) and pot-grown plats (grown in constant laboratory condits 22-25 °C) in the same stage of development were compared. The lethal temperature and critical (lethal) time of action of lethal temperature were determined by the program LT 50 2.1, that uses logistic non-linear model developed for data associated with frost and hot injury (Janáček and Prášil 1991). An S-shaped response curve adequate described changes corresponding to a different frost temperature. The lethal temperature (LT 50) is the temperature at which 50 % of the tested plants are killed. Except an inflection point of

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the model function, which is LT 50, it is also possible compare the stepness of change from minimal to maximal injury (relative injury rate - RIR). The values of parametrs LT50 and RIR for different variants were compared by F- test in program LV 50 2.1. (Research Institute of Crop Production, Praha). The critical time of frost action (LT 50) is the time of treatment at a chosen temperature by which 50 % of plants are killed.

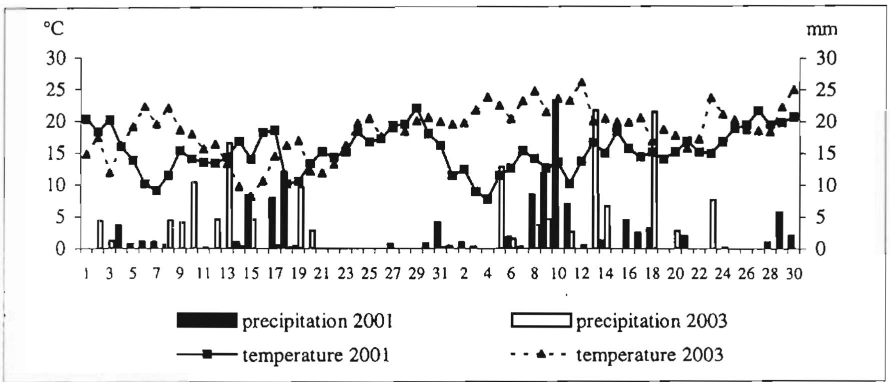

Fig. 1 Basic meteorological data – May and June 2001 and 2003 (period from sowing to beginning of shooting).

Table 1. Evaluation of frost resistance by millet (vitality %).

Temperature (°C)	0		-2						-4		-6	
Time (hour)	6		6		4		2		6		6	
Year	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003
Laboratory - two leaves												
Hanacka Mana	100	100	57.4	27.0	83.3	47.8	76.7	51.2	0	0	0	0
Polyploid	100	100	51.3	17.4	72.6	43.5	71.7	46.7	0	0	0	0
Veselopodolianskoe	100	100	52.4	31.6	71.4	34.7	76.9	40.0	0	0	0	0
Uilskoe White	100	100	39.7	23.8	75.6	31.2	76.7	45.0	0	0	0	0
Field - two leaves												
Hanacka Mana	100	100	60.0	100	100.0	100	100	100	0	11.0	0	0
Polyploid	100	100	33.1	100	91.7	100	100	100	0	20.0	0	0
Veselopodolianskoe	100	100	41.2	100	90.0	100	100	100	0	15.0	0	0
Uilskoe White	100	100	41.2	100	86.7	100	100	100	0	21.0	0	0
Field– beginning of tillering												
Hanacka Mana	100	100	66.0	53.3					0	0	0	0
Polyploid	100	100	47.4	23.1					0	0	0	0
Veselopodolianskoe	100	100	58.1	40.0					0	0	0	0
Uilskoe White	100	100	43.8	46.2					0	0	0	0
Field– beginning of shooting												
Hanacka Mana	100	100	82.7	100					0	52.1	0	0
Polyploid	100	100	74.1	100					0	58.9	0	0
Veselopodolianskoe	100	100	80.1	100					0	53.1	0	0
Uilskoe White	100	100	79.8	100					0	58.0	0	0

Table 2. Lethal temperature - LT50 (average, F-test).

Conditions	Laboratory				Field			
Growth stage	Two leaves		Two leaves		Beginning of tillering		Beginning of shooting	
Year	2001	2003	2001	2003	2001	2003	2001	2003
Hanacka Mana	-2.1 c	-1.4 b	-2.2 b	-3.7 c	-2.3 d	-2.1 d	-3.0 c	-4.0 a
Polyploid	-2.0 b	-1.5 b	-1.8 a	-3.5 b	-2.0 b	-1.7 a	-2.4 b	-4.1 a
Veselopodolianskoe	-2.0 b	-1.5 b	-1.9 a	-3.5 b	-2.1 c	-1.8 b	-2.5 b	-4.1 a
Uilskoe White	-1.8 a	-1.4 b	-1.9 a	-3.3 a	-1.9 a	-1.9 c	-2.5 a	-4.1 a
Average	-2.0	-1.5	-2.0	-3.5	-2.1	-1.9	-2.6	-4.1

RESULTS

The common millet was found to be more sensitive to frost temperature in the stage of two leaves and at the beginning of tillering than at the stage of the beginning of shooting (Table 1). The most resistant variety in field conditions was 'Hanácká Mana'. In the laboratory, we found statistically significant differences among varieties only in 2001. The most resistant variety was 'Hanácká Mana'. During the other year, the differences were not significant.

The average LT 50 in stage of two leaves was – 2 °C in the first year of our experiment, year 2001 (Table 2). On these results basis we chose the temperature of -2 °C for determination of the critical time of frost action. However, we were not able to use this temperature in the test of field-grown plants in the year 2003. We had to use lower temperature (-4 °C) because of their higher frost resistance.

The critical time of exposition to the temperature of – 2 °C was 5.8 hours in field conditions and 6.2 hours in laboratory conditions (Table 3). In both years, we found the significant influence of variety on this parameter in laboratory conditions.

Table 3. Critical time of frost action - LT50 (average, F- test).

	Laboratory		Field	
Year	2001 (-2 °C)	2003 (-2 °C)	2001 (-2 °C)	2003 (-4 °C)
Hanacka Mana	6.9 a	2.6 a	6.2 a	5.3 a
Polyploid	6.1 a	2.6 a	5.5 b	5.4 b
Veselopodolianskoe	6.1 a	2.6 a	5.7 b	5.5 c
Uilskoe White	5.5 a	2.0 a	5.7 c	5.0
Average	6.2		5.8	

The lethal temperature and critical time of frost action was influenced by year of cultivation. Plants were the most resistant in the stage of two leaves and of the beginning of tillering in year 2001, and at the beginning of tillering in year 2003.

Any significant differences were found in the parameter RIR (relative injury rate).

DISCUSSION

The frost resistance was influenced, among others, by variety. Resistance differences among varieties of the common millet plants in the stage of emerging were also established by Zauralov and Lukatkin (1997). In our experiment, the variety 'Hanácká Mana' was the most resistant. This variety was selected from the old regional Czech variety 'Sede hanacke' in 1940. It is possible that this variety adapted to environmental conditions. This adaptation could be a result of natural selection pressure, accomulation of mutations and/ or genetic recombinations (common millet is a partly allogamous plant).

After Jašovskij (1987) plants in stage of tillering are less sensitive to freezing and temperatures to – 4.5 °C injure only top parts of plants. In our experiments, we did not found increase of frost resistance in the stage of tillering, and the temperature of – 4 °C caused injuries on all plants.

The differences among lethal temperatures and critical time of frost action in different years of our experiment are probably a result of diverse environmental conditions (soil and climatic conditions), mainly water supplementation. The injury of plant tissues results from the formation of ice crystals in cells or intersellular spaces. The ice has a mechanical influence but it causes a dehydration of colloids too and that gets to changes in structure of membrane system (Prochazka et al. 1998). In year 2003, the time of sampling (in the stage of two leaves and shooting) was poorer regarding precipitation when compared with 2001 (Fig. 1). Due to this reason, the frost resistance of plant in these stages was probably higher in year 2003. The plants growing in the laboratory were not stressed with low temperatures therefore they had lower frost resistance.

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