Evaluation of frost resistance in varieties of common buckwheat (*Fagopyrum esculentum* Moench)

J. Kalinová, J. Moudrý

Faculty of Agriculture, University of South Bohemia in České Budějovice, Czech Republic

ABSTRACT

The aim of this study was to determine the most sensitive growth stage of common buckwheat to frost temperatures and evaluate differences in frost resistance among varieties. A modified field-laboratory method was utilised for the study on four varieties of common buckwheat. The lethal temperature (LT_{50}) was determined for all variants. The critical time of frost action (Lt_{50}) was determined for the lethal temperature and for the most sensitive growth stage. Buckwheat is most sensitive to frost temperature from the stage of primary leaves to the stage of two secondary leaves. Differences among the growth stages developed with plant hardening during the growth. The lethal temperature of buckwheat was in the range –1.3 to –2.9°C depending on the stage of development and growing conditions. The critical time of frost action (temperature – 2°C) was in the range 4.3 to 5.9 hours. Varieties Pyra and Emka were most resistant from chosen varieties.

Keywords: common buckwheat; frost resistance; variety

Common buckwheat belongs to perspective alternative crops for its unpretentiousness on growing conditions. It is a typical low input crop (Kreft 1989). It is tolerant of poor, acid soil, it has a good adaptability to cultivation in higher altitudes and has also a short vegetation period (3–4 months). These are assumptions for extension of its cultivation in areas with a higher altitude (Joshi and Rana 1995). Widening of the range of rational nutrition products and its nutrition composition also play a role as factors in an increasing interest in its cultivation (Skrabanja and Kreft 1998).

In comparison to cereals common buckwheat belongs to less improved crops, indicators of insufficient breeding are mainly undetermined growth and low yield of grain (Babůrková et al. 2000). Some authors reported that yield has linearly decreased by late time of sowing (Gubbels et al. 1990, Aufhammer et al.1994, Kneževič et al. 1994). Early sowing provides a sufficient amount of soil humidity during the flowering stage and during the beginning of achene formation (Gubbels 1977). The term of sowing is limited by acceptable temperature for germination (optimal 10°C) and overcoming of late spring frosts (Jakimenko 1982). These are the reasons why in our climatic conditions the sowing is possible only in the first decade of May.

Frost resistance (tolerance) has not been widely studied in common buckwheat and opinions on lethal temperature are different. Aufhammer et al. (1994) reported that temperature –2°C caused severe damage to the plants and temperature –4°C caused total frost disruption of analysed plants. On the contrary Jakimenko (1982) reported partial damage at temperature –1°C and total disruption at –2°C. Gaberčik et al. (1986) found that leaves of buckwheat were frozen at –2 to –3°C.

The aim of our experiments was to determine the most sensitive growth stage of buckwheat to frost temperatures, the lethal temperature and the critical time of frost 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 et al. (1989) was utilised in our experiments. 3 × 20 plants from every variant were evaluated. The summary of used varieties is in Table 1. The plants were tested in the stage of primary leaves, two secondary leaves and beginning of branching at temperatures 0, –2, –4, –6°C. All varieties were exposed to the lethal temperature for 2, 4 and 6 hours. The frost resistance in more sensitive growth stage of plants grown in the field (density of growth 200 achenes per m^2, plot area 10 m^2, sowing May 8, 2000 and May 10, 2001, site České Budějovice – 380 m above sea level, cambisol, gleying, sandy loam, pH 6.4, meteorological data are situated in Figure 1) and the frost resistance of plants grown under the constant laboratory conditions (22–25°C, year 2001 and 2003) were compared.

The lethal temperature and the critical (lethal) time of frost action of lethal temperature were determined in program LT_{50} 2.1, which uses a logistic non-linear model developed for data of frost and hot injury in many studies (Janáček and Prášil 1991). An *S*-shaped response curve

This study was supported by the Ministry of Education, Youth and Sports of the Czech Republic, grant No. MSMT 122200002/2.

Table 1. Characterisation of varieties

Variety	Origin	Year of registration	Ploidy level	Length of vegetation period
Emka	Poland	1996	4*n*	moderate late
Hruszowska	Poland	1957	2*n*	moderate late
Krupinka	Ukraine	1994	2*n*	moderate early
Pyra	CR	1990	2*n*	moderate early

adequately described changes corresponding to a different frost temperature. The lethal temperature (LT_{50}) is the temperature at which 50% of plants are killed. Except the inflection point of the model function, which is LT_{50}, it is possible to compare also the steepness of the change from a minimal to maximal injury (relative injury rate – RIR). The values of parameters LT_{50} and RIR for different variants were compared by *F*-test in program LV_{50} 2.1. The critical time of frost action (Lt_{50}) is the time of treatment at chosen temperature by which 50% of plants are killed.

RESULTS

Buckwheat was more sensitive to the frost temperature in the stage of primary and two second leaves than in the stage of beginning of branching (Table 2). These differences were statistically significant.

The most resistant varieties in field conditions were varieties Pyra and Emka. We found statistically significant differences among varieties cultivated in laboratory conditions in the year 2003 too.

Average LT_{50} of buckwheat for the more sensitive growth stage was –1.8°C in the field and –1.6°C in the lab (Table 3). On these results basis we chose temperature –2°C for the determination of the critical time of frost action.

The critical time of exposition to temperature – 2°C was 5.6 hours in field conditions and 4.6 hours in laboratory conditions (Table 4). We did not find any significant influence of variety in laboratory conditions. And there were not found any significant differences in the param-

Table 2. Evaluation of frost resistance by buckwheat (vitality %)

Temperature (°C)	0		–2						–4		–6	
Time (hour)	6		6		4		2		6		6	
Year*	1	2	1	2	1	2	1	2	1	2	1	2
Laboratory – primary leaves												
Emka	100	100	21	30	66	76	88	87	0	0	0	0
Hruszowska	100	100	20	31	65	60	90	89	0	0	0	0
Krupinka	100	100	19	25	57	63	85	88	0	0	0	0
Pyra	100	100	30	38	56	67	90	90	0	0	0	0
Field – primary leaves												
Emka	100	100	47	39	97	90	100	92	0	0	0	0
Hruszowska	100	100	33	34	87	81	100	100	0	0	0	0
Krupinka	100	100	43	32	83	78	100	90	0	0	0	0
Pyra	100	100	46	37	90	86	100	93	0	0	0	0
Field– two second leaves												
Emka	100	100	50	48					12	0	0	0
Hruszowska	100	100	43	39					0	0	0	0
Krupinka	100	100	46	46					0	0	0	0
Pyra	100	100	50	46					10	0	0	0
Field– beginning of branching												
Emka	100	100	76	70					20	3	0	0
Hruszowska	100	100	50	71					0	1	0	0
Krupinka	100	100	51	68					0	0	0	0
Pyra	100	100	63	75					15	5	0	0

* 1 = in field and laboratory conditions year 2001, 2 = in field conditions year 2000, in laboratory conditions 2003

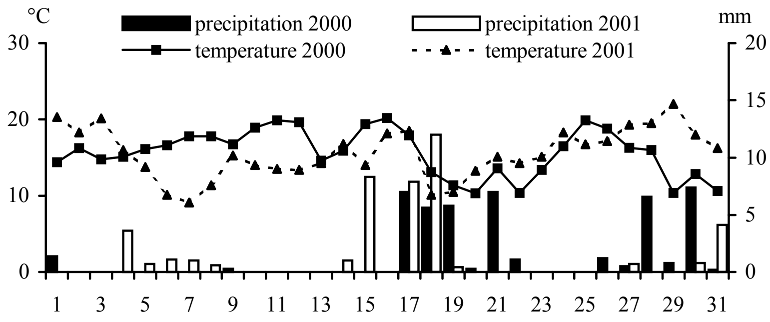

Figure 1. Basic meteorological data, May 2000 and 2001 (period from sowing to beginning of branching)

eter RIR (relative injury rate) also as result of only very small differences among analysed varieties. We found statistically significant differences in Lt_{50} between plants cultivated in the field and in the lab.

The influence of cultivation year on the lethal temperature and critical time of frost action was not statistically significant.

DISCUSSION

Plants cultivated in laboratory conditions are not exposed to the stress caused by low temperatures and it is the reason for their lower resistance. The differences between the growth stages originate in the period of hardening during their growth. According to Zauralov and Židkin (1982) the cooling increases the abscisic acid content, which is important for the adaptation. It is in agreement with our findings that the highest sensitivity to low (frost) temperatures is in the beginning of buckwheat vegetation. Jefimenko and Barabáš (1990) reported that green plants are most sensitive 2–3 days after sprouting. These authors also explained the buckwheat sensitivity to low temperatures as a result of high water content in young leaves. The frost resistance also depends on the variety. Differences among different variet-

Table 3. Lethal temperature LT_{50} (average, *F*-test)

Conditions	Laboratory		Field					
Growth stage	primary leaves		primary leaves		two second leaves		beginning of branching	
Year*	1	2	1	2	1	2	1	2
Emka	−1.7 a	−1.5 b	−2.0 b	−1.8 b	−1.8 a	−2.0 a	−2.9 c	−2.4 c
Hruszowska	−1.7 a	−1.5 b	−1.8 a	−1.6 ab	−1.9 a	−1.8 c	−2.0 a	−2.3 b
Krupinka	−1.6 a	−1.3 c	−1.9 a	−1.6 ab	−1.9 a	−1.9 b	−2.0 a	−2.3 a
Pyra	−1.8 a	−1.7 a	−1.9 b	−1.7 b	−2.1 a	−2.0 ab	−2.5 b	−2.5 d
Average	−1.7	−1.5	−1.8	−1.7	−1.9	−1.9	−2.4	−2.4

* 1 = in field and laboratory conditions year 2001, 2 = in field conditions year 2000, in laboratory conditions 2003

Table 4. Critical time of frost action Lt_{50} (average, *F*-test)

	Laboratory		Field	
Year*	1	2	1	2
Emka	4.6 a	5.2 a	5.9 a	5.7 a
Hruszowska	4.6 a	4.5 a	5.5 c	5.4 bc
Krupinka	4.3 a	4.6 a	5.7 b	5.2 c
Pyra	4.6 a	5.0 a	5.9 a	5.5 ab
Average	4.5	4.7	5.7	5.5

* 1 = in field and laboratory conditions year 2001, 2 = in field conditions year 2000, in laboratory conditions 2003

ies are reported by Jefimenko and Barabáš (1990). Pyra and Emka were the most resistant varieties in our experiments. Variety Pyra, which was selected from old regional cultivars, manifested the adaptation to different conditions of cultivation. The higher resistance of tetraploid variety Emka is also reported by Aufhammer et al. (1994). Generally, tetraploid varieties belong to the group of varieties that are demanding and more sensitive to cultivation conditions. The further study will be focused on the basis of frost resistance – whether the frost resistance is caused by an adaptation ability of variety or by its slower development.

The inconclusive influence of the cultivation year on the lethal temperature and critical time of frost action probably resulted from very analogous meteorological conditions during the growth of buckwheat plants (mean May temperature: 2000 = 15.7°C, 2001 = 15.6°C; May precipitation: 2000 = 45 mm, 2001 = 42 mm).

REFERENCES

Aufhammer W., Esswein H., Kübler E. (1994): Zur Entwicklung und Nutzbarkeit des Kornertragspotentials von Buchweizen (*Fagopyrum esculentum*). Bodenkultur, *45*: 37–47.

Babůrková M., Jůza J., Moudrý J., Pejcha J. (2000): Vliv genotypu a agrotechniky na strukturu výnosových prvků pohanky. Rostl. Výr., *46*: 225–230.

Gaberčik A., Martinčič A., Kajfež-Bogataj L., Kreft I. (1986): Possibility of laboratory determination of resistance of buckwheat plants to freezing. Fagopyrum, *6*: 10–11.

Gubbels G.H. (1977): Interaction of cultivar, sowing date and sowing rate on lodging, yield and seed weight of buckwheat. Can. J. Plant Sci., *57*: 317–321.

Gubbels G.H., Campbell C.G., Zimmer R.C. (1990): Interaction of cultivar seeding date and downy mildew infection on various agronomic characteristics of buckwheat. Can. J. Plant Sci., *70*: 949–954.

Jakimenko A.F. (1982): Grečicha. Kolos, Moskva.

Janáček J., Prášil I. (1991): Quantification of plant frost injury by nonlinear fitting of an *S*-shaped funkcion. Cryo-Lett., *12*: 47–52.

Jefimenko D.J., Barabaš G.I. (1990): Grečicha. Agropromizdat, Moskva.

Joshi B.D., Rana R.S. (1995): Buckwheat (*Fagopyrum esculentum*). In: Cereals and pseudocereals, London: 85–222.

Knežević M., Jurić I., Baketa E. (1994): Influence of planting date and variety on some characteristics of buckwheat plants in Easter Croatia. Fagopyrum, *14*: 55–58.

Kreft I. (1989): Breedding of determinate buckwheat. Fagopyrum, *9*: 57–60.

Prášil I. et al. (1989): Testování mrazuvzdornosti pšenice na vybraných pracovištích ČSSR. Genet. a Šlecht., *25*: 79–86.

Skrabanja V., Kreft I. (1998): Resistant starch formation following autoclaving of buckwheat (*Fagopyrum esculentum* Moench) groats. An *in vitro* study. J. Agr. Food Chem., *46*: 2020–2023.

Zauralov O.A., Židkin V.I. (1982): Effect of chilling on auxin and abscisic acid content of proso plants. Fiziol.-Rast., *29*: 605–607.

Received on October 25, 2002

ABSTRAKT

Porovnání mrazuvzdornosti vybraných odrůd pohanky seté (*Fagopyrum esculentum* Moench)

Cílem pokusu bylo stanovit nejcitlivější růstové stadium pohanky vůči záporným teplotám a posoudit rozdíly v mrazuvzdornosti mezi odrůdami. Studie byly provedeny upravenou polně laboratorní metodou u čtyř odrůd pohanky seté. Byla stanovena letální teplota (LT_{50}) u všech variant a kritická doba působení mrazu (Lt_{50}) pro letální teplotu a nejcitlivější růstové stadium. Pohanka je nejcitlivější k záporným teplotám ve fázi děložních až dvou pravých lístků. Rozdíly mezi růstovými stadii pohanky se vytváří otužováním během růstu. Letální teplota pohanky byla v závislosti na vývojovém stadiu a podmínkách pěstování –1,6 až –2,9°C. Letální doba působení – 2°C se pohybovala od 4,3 do 5,9 hodin. Ze zkoušených odrůd byla nejodolnější odrůda Pyra a Emka.

Klíčová slova: pohanka setá; mrazuvzdornost; odrůda

Corresponding author:

Ing. Jana Kalinová, Ph.D., Zemědělská fakulta, Jihočeská univerzita v Českých Budějovicích, Sludentská 13, 370 05 České Budějovice, Česká republika
tel.: + 420 387 772 430, fax: + 420 385 300 122, e- mail: janak@zf.jcu.cz