The soil temperature at Pohořelice station during the years 1961 to 2000

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Abstract: Out of the agroclimatological stations of the Czech Hydrometeorological Institute, the soil temperature is measured by the mercurial soil bent thermometers with range from $-30°$ C to $+45°$ C for low depth (5, 10, 20 cm) and in-depth mercurial thermometer with range of $-25°$ C to $+35°$ C, which is used for measuring soil temperature in 50 cm and 100 cm. The evaluation of measurement for the period of 1961 to 2000 at the Pohořelice station, where the soil is formed by chernozems, has brought the following results. On average the soil temperature drops bellow 0° C in depth of 5 cm from 4th January to 7th February, i.e., 35 days and in 10 cm from 10th January to 6th February, i.e., 28 days. The absolute maximum of soil temperature during the observed period (12.8° C was reached on 30th March 1973 at depth 5 and 100 cm and absolute minimum of soil temperature ($-9.5°$ C) was measured in 5 cm on 2nd and 3rd February 1963. The data were processed by Surfer 8.0. By the aid of this software the values of soil temperature were interpolated for the whole vertical profile (5 to 100 cm) on the basis of data at depth (5, 10, 20, 50, 100 cm).

Key words: soil temperature, thermometer, agroclimatological stations

1. Introduction

In moderate climatic zone, as well as in temporally subtropical and subarctic zones and in areas with vertical zoning of mountain climate, the decline of air temperature in winter is accompanied by degressivity of the

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soil temperature. The temperature character of winter is mostly evaluated according to air temperature and number of frost, ice and arctic days. It can be evaluated by ice index, which was completed by verbal value of "winter severity" for the conditions of central Europe (*Sládek, 1988).* For appreciation of temperature character of winter it is possible to use the depth of soil freezing. The depth of soil freezing depends on air temperature, depth and density of snow cover, vegetation cover, soil moisture, soil type and exposition of terrain. The soil compared to air has higher heat capacity and persistence. During the decline of soil temperature under 0° C the liquid phase and solid phase of water coexist together producing variations in the distribution of soil water (*Stähli, 1997).*

The knowledge of the soil environment is significant from the climatological, technical and biological point of view. For plants, soil is an environment from which they get nutriments and water The soil supports them and creates conditions for wintering (*Hejduk and Kasprzak, 2004).*

From the biological viewpoint, it is a part of the period of vegetation rest, however for wintering plants, mainly agricultural crops, it can have a negative impact. During high values of temperature decrease a damage or complete annihilation of plant organs occurs (freezing-out). This happens especially when temperatures below and above zero alternate, when the breaking of roots occurs *(Petr, 1991; Slavíková, 1986* and others).

According to *Kurpelová et al. (1975)* it is very important to know the wintering conditions of cultural plants not only for their further development, for the creation of bases for their next crop, but also from the point of view of the economy of growing a certain culture. The wintering of winter crops is influenced by two main factors. These are external factors, such as the influence of weather, and internal factors, peculiar to plants, species and sorts, also known as biological factors. Out of the external weather factors, which can influence wintering the most, both in the positive and negative sense, the following are most important: autumn, pre-spring and spring frosts, snow cover and precipitation overall, thaws and frosts, moisture under the snow cover, alternate freezing and thawing of soil (especially of surface layers), wind, and soil moisture in the autumn.

Among the internal biological factors that influence wintering of winter crops are: the balance and bulk of the stand, the development stage of the plants before wintering, the degree of hardiness (frost-proofness) of plants, species, or sort. After quoting at least the basic external and internal factors, which influence wintering, we shall further be more concerned only with external meteorological wintering conditions. It is necessary to realise, that these external factors, such as frosts, snow cover of different thickness, wetted soil surface, temperature fluctuation, ice crust, wind, winter and pre-spring drought, etc., do not make themselves felt in isolation, but mostly act in a complex manner, in more combinations at the same time.

In some areas the frost-heaving of the stands arrives on in 2 or 3 years per 10 years. It might occur in different periods of winter and thus it is not possible to say when it is the most frequent. The frost-heaving is not evocate just by low temperature, but is a difficult physiological process.

The most cold stable winter crop is winter rye, if it is in good condition before wintering stands temperature -25 to $-30°$ C. Winter wheat well prepared for wintering stands minimal temperature -23 to $-28°$ C, but more often just $-17°$ C. The critical minimal temperature for winter barley is $-10°$ C to $-12°$ C and for the most of lucerne varieties -23 to $-25°$ C. Trefoil dies at $-16°$ C to $-20°$ C. Those temperatures were measured in ground layer of air or in surface soil layer eventually at the depth of the coleoptile. In those temperatures the plants at most perish, but their damage occurs at higher temperature. In the *Climate of CSSR – Tables (1961)*, we find average monthly temperatures at depths of 10, 20, 50 and 100 cm for the period of 1924–1953 or shorter for 17 stations, and maximum and minimum temperatures from 11 stations on the territories of the Czech Republic (CR) and the Slovak Republic (SR) with similar data for depths of 15, 30, 60 and 100 cm. In the *Climate of CSSR - Collective Study (1969)*, in the chapter "Soil temperature", there are average monthly soil temperatures and periods with temperatures equal to or lower than 0° C quoted for the stations of Čáslav-Filipov, Havlíčkův Brod, Klatovy, Rožnov pod Radhoštěm, Hurbanovo and Starý Smokovec.

Many authors have studied soil temperatures in our conditions (*Možný, 1991; Němec, 2001; Němeček et al., 1990).* For Brno soil temperatures they were analysed by *Lednický (1979).* A publication *(Coufal et al., 1993)* is devoted to soil temperatures in the cold part of the year (October to March), where the statistical analysis of the time series has been carried out for stations of Cheb, Doksany, Havlíčkův Brod, Olomouc and Pohořelice, and map processing has been carried out for 35 stations predominantly for the monitoring period of 1961–1990. For the evaluation of soil freezing in this work, we use mainly data on the absolute minima of soil temperatures, which are negative down to the depth of 50 cm. The coldest winter in the evaluated 30-years period was the winter of 1962–1963, with the most pronounced manifestations at the station of Doksany, where the temperature of 0° C was measured at depth under 100 cm. The station of Pohořelice has only a table with soil temperatures for 5 cm, so there it is not possible to compare our results. The soil temperatures at the Pohořelice station for the period of 1956–1985 were analysed by *Rožnovský (1990).*

Data on freezing of soil were published by *Boušková (1961)*, who, however, derived soil freezing from soil temperatures, or from the course of the average temperature of soil of 0° C.

2. Material and methods

Data on soil temperature were acquired by means of measurements at the climatological station Pohořelice (elevation 184 m a.s.l., latitude 48°59′ North, longitude 16°41′ East), where soil temperature is measured by thermometer . The station is a part of a network of climatological stations of the Czech Hydrometeorological Institute. From available literature (*Climate of CSSR – Tables, 1961; Climatic Atlas of CR, 1958* and others) it is possible to say that our territory lies in the temperate zone, which is at the same time a region of transitional central-European climate. The climate of south Moravia is significantly influenced by circulation and geographical conditions. According to the split into climatic regions, it is a warm region, dry sub-region, ward A2, which is characterized as warm, dry, with temperate winter, with shorter duration of sunshine. Within the framework of agroclimatic zoning, it is an agroclimatic warm macroregion, mostly warm region, mostly dry subregion, agroclimatic ward with relatively temperate winter. The processed period was 1961–2000. In Czech Republic the soil temperature is measured at depths of 5, 10, 20, 50, 100 cm. The most often used are special mercurial or electric thermometers. Mercurial soil thermometers have been sorted out to two type: bent thermometer with range from −30° C to +45° C for low depth are permanent placed in the soil. They are constructed mainly for depths of 5, 10 and 20 cm. In-depth mercurial thermometer with range of −25° C to +35° C, which is used for measuring soil temperature in 50 cm and 100 cm in CHMI stations. Hours of observation are 7, 14, 21 h of mean local time. For the purpose of this paper the daily averages of soil temperature were used. The results were processed by MS Excel 2000 and Surfer 8.0.

3. Results and discussion

In long-term average the soil temperature drops bellow 0° C in depth of 5 cm from 4^{th} January to 7^{th} February, i.e., 35 days and in 10 cm from 10^{th} January to 6^{th} February, i.e., 28 days. The maximal average value (Fig. 1, Table 1) in 5 cm was reached on 31^{st} March, in 10 cm on 3^{rd} November, in 20 cm on 3^{rd} November, in 50 cm on 1^{st} November and in 100 cm on 1^{st} November. The minimal average value in 5 cm was reached on 18^{th} January, in 10 cm 18^{th} January, in 20 cm on 21^{st} January – 23^{rd} January, in 50 cm on 23^{rd} January – 8^{th} February and in 100 cm on 8^{th} February, 11^{th} February to 25^{th} February.

The absolute minimum of soil temperature drops bellow 0° C in depth of 5 cm from 6^{th} November to 27^{th} March, i.e., 136 days, permanently from 17^{th} November to 27^{th} March, i.e., 131 days. Minimal value for depth 5 cm occurs on 2^{nd} and 3^{rd} February, for 10 cm on 3^{rd} February, for 20 cm on 3^{rd} February, for 50 cm 5^{th} February and for 100 cm on 28^{th} January and 5^{th} – 10^{th} March. Maximal value in depth of 5 cm occurs on 31^{st} March, in 10 cm on 31^{st} March, in 20 cm on 2^{nd} November, in 50 cm 1^{st} November and in 100 cm on 1^{st} November (Fig. 2, Table 2).

The absolute maximum of soil temperature does not drop bellow 0° C in any day. Minimal value for depth 5 cm occurs on 15^{th} January, for 10 cm on 22^{nd} January, for 20 cm on 21^{st} January, for 50 cm on 13^{th} – 16^{th} February and for 100 cm 17^{th} – 20^{th} February. Maximal value in depth of 5 cm occurs on 31^{st} March, in 10 cm on 30^{th} March, in 20 cm on 31^{st} March, in 50 cm on 4^{th} November and in 100 cm on 1^{st} and 2^{nd} November (Fig. 3, Table 3).

The real observed minimum of soil temperature was reached in the period of 1963–1964. The soil temperature drops bellow 0° C in depth of 5 cm from 10^{th} December to 23^{rd} March, i.e., 108 days, 10 cm from 9^{th} December to 12^{th} March, i.e., 104 days, 20 cm from 17^{th} December to 26^{th} March, i.e.,

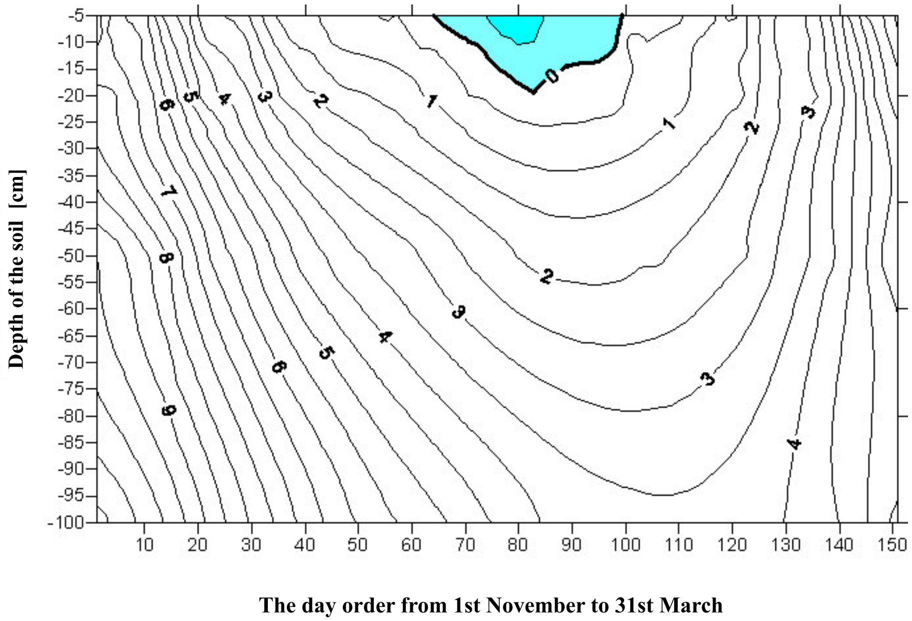

Fig. 1. Long-term average of soil temperature in the period of 1st November to 31st March during the years of 1961 to 2000.

Table 1. Statistical parameters of long-term average value of soil temperature in the period of 1st November to 31st March

Long-term average					
		AVERAGE	**MAXIMUM**	**MINIMUM**	**STANDARD DEV.**
Depth of the soil [cm]	**5**	1.9	7.3	-0.9	2.35
	10	2.1	7.2	-0.6	2.23
	20	2.4	7.7	0.0	2.16
	50	4.0	9.5	1.8	2.17
	100	5.7	11.2	3.6	2.26

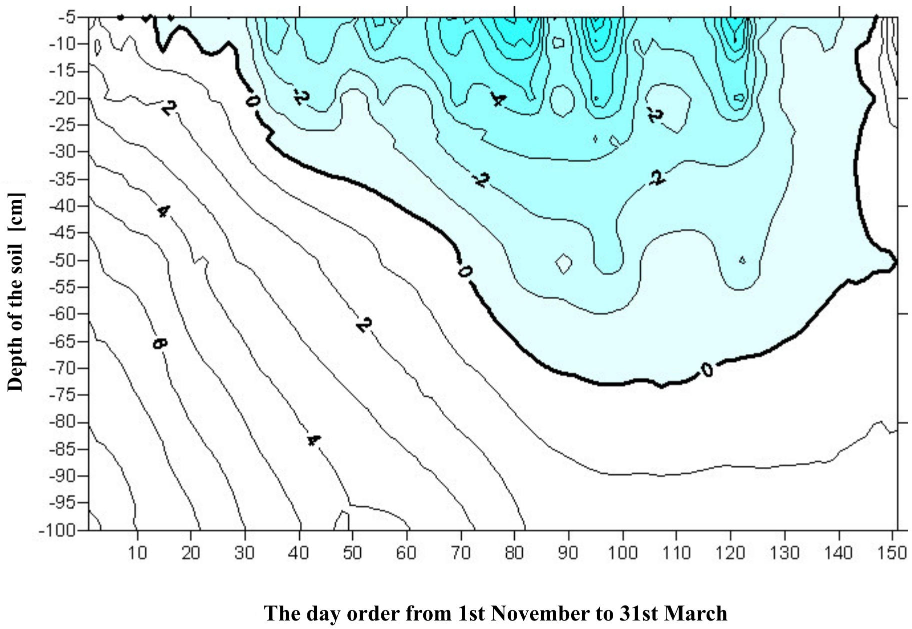

Fig. 2. Absolute minimum of soil temperature in the period of 1st November to 31st March during the years of 1961 to 2000.

Table 2. Statistical parameters of absolute minimum value of soil temperature in the period of 1st November to 31st March during the years of 1961 to 2000

Absolute minimum					
		AVERAGE	MAXIMUM	MINIMUM	STANDARD DEV.
Depth of the soil [cm]	5	-3.2	3.7	-9.5	2.74
	10	-2.6	3.8	-8.1	2.60
	20	-1.5	3.2	-6.3	2.19
	50	0.9	7.0	-2.7	2.32
	100	3.6	9.4	1.3	2.42

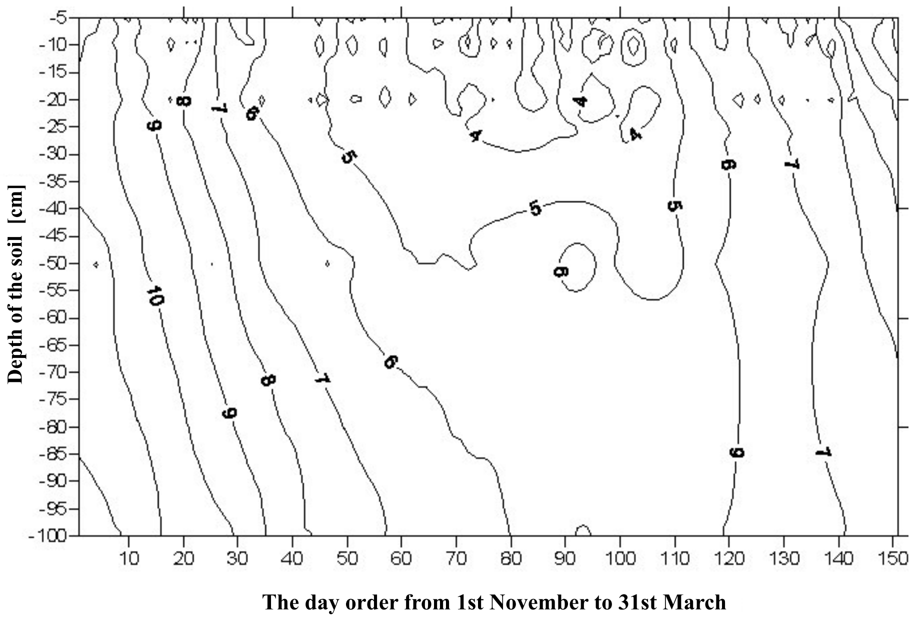

Fig. 3. Absolute maximum of soil temperature in the period of 1st November to 1st March during the years of 1961 to 2000.

Table 3. Statistical parameters of absolute maximum value of soil temperature in the period of 1st November to 31st March during the years of 1961 to 2000

Absolute maximum					
		AVERAGE	MAXIMUM	MINIMUM	STANDARD DEV.
Depth of the soil [cm]	5	6.4	12.6	2.5	2.53
	10	6.3	12.8	2.2	2.47
	20	6.0	10.7	2.4	2.24
	50	6.8	12.3	4.5	1.86
	100	7.6	12.6	5.2	2.07

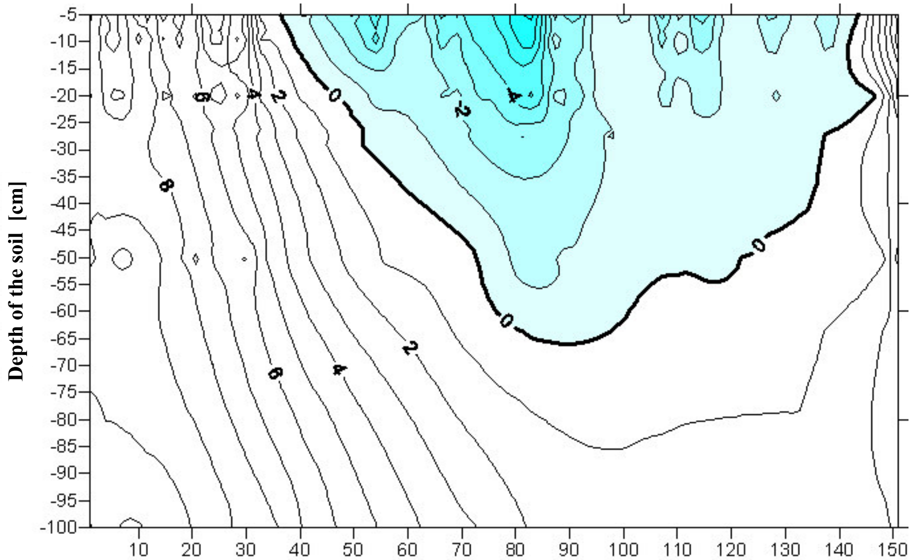

Fig. 4. Real minimum of soil temperature in the period of 1st November to 31st March during the years of 1961 to 2000.

Table 4. Statistical parameters of real minimum value of soil temperature from 1st November to 31st March during the years of 1961 to 2000

		Real minimum			
		AVERAGE	MAXIMUM	MINIMUM	STANDARD DEV.
Depth of the soil [cm]	5	-0.2	10.7	-7.6	4.11
	10	0.3	10.8	-7.0	4.01
	20	0.8	10.4	-5.2	3.68
	50	2.2	10.5	-2.0	3.49
	100	4.4	11.1	1.3	3.77

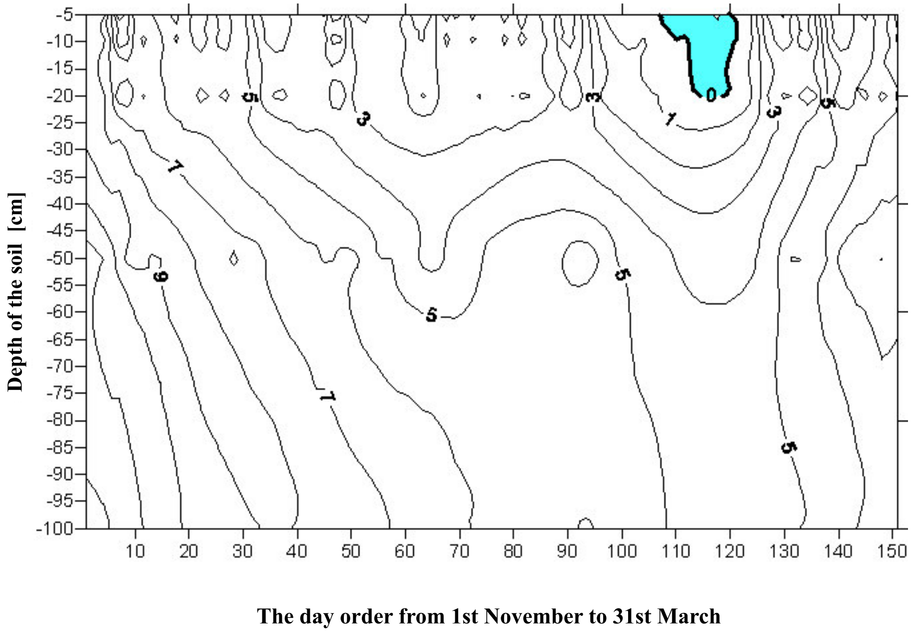

Fig. 5. Real maximum of soil temperature in the period of 1st November to 31st March during the years of 1961 to 2000.

Table 5. Statistical parameters of real maximum value of soil temperature from 1st November to 31st March in the cool period 1982–83

		Real maximum			
		AVERAGE	MAXIMUM	MINIMUM	STANDARD DEV.
Depth of the soil [cm]	5	3.3	8.8	-1.3	2.45
	10	3.5	9.0	-0.6	2.32
	20	3.4	9.0	-0.1	2.16
	50	6.1	11.6	3.3	1.84
	100	7.0	12.6	4.2	2.19

100 days, 50 cm from 12th January to 5th March, i.e., 52 days. Minimal value for depth 5 cm occurs on 2nd and on 3rd February, for 10 cm on 3rd February, for 20 cm on 3rd February, for 50 cm on 5th February. For depth 100 cm soil temperature drops bellow 0° C not once. Minimal value in depth of 5 and 10 cm were observed on 21st January, in 20 and 50 cm on 22nd January and in 100 cm on 28th January. Maximal value in depth 5, 10 and 20 cm occurred on 6th November, in 50 cm on 7th November and in 100 cm on 1st and 8th – 11th November (Fig. 4, Table 4).

The real observed maximum of soil temperature was measured in period of 1982–1983. The soil temperature drops bellow 0° C in depth of 5 cm from 15th February to 27th February, i.e., 13 days, 10 cm from 18th February to 2nd March, i.e., 13 days (permanently from 21st February to 28.2., i.e., 8 days), 20 cm just on 24th February. In depth 50 and 100 cm the soil temperature does not drop bellow 0° C. Minimal value in depth of 5 cm was measured on 26th February, 10 cm on 25th and on 26thFebruary, in 20 cm on 24th February, 50 cm on 28th February and 100 cm on 25th February – 8th March. Maximal value for every depth occurred on 1st November (Fig. 5, Table 5).

The variation in course of soil temperatures is represented by the decrease with depth. At the end of the observed period (second decade of February) the heating of soil is coming on. In the beginning of the third decade of March the temperature of every layer is balanced. Later the temperature in shallow layer is higher than in the deeper ones (Fig. 6).

4. Conclusion

The absolutely maximal depth, in which the temperature was not higher than 0° C was about 73 cm from 2nd February to 20th February during the period 1961–2000, regardless of real years (Fig. 2). From the point of soil temperature the coldest period was 1963–1964, when the maximal depth of temperature equal or lower than 0° C was 66 cm on 28th January to 30th January 1964 (Fig. 4). In this year the greatest depth of frozen soil was also recorded during the monitored years, when freezing started on the 8th December 1963, and reached the maximum of 74 cm during the days of 26th January to 30th January 1964. (*Rožnovský and Pokladníková,*

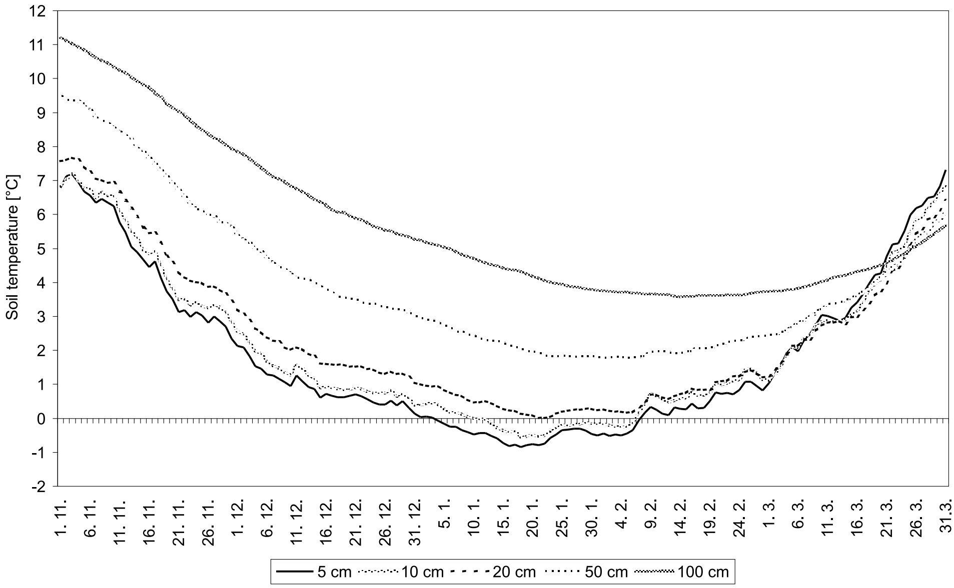

Fig. 6. Course of average soil temperature from 1st November to 31st March during the years 1961–2000.

2005). Regardless of years the minimal temperature (2.2° C) was measured on 22nd January (Fig. 3). The warmest period from the viewpoint of soil temperature was 1982–1983, were the temperature of 0° C or lower reached maximally 20 cm on 26th to 28th February 1983 (Fig. 5). The course of freezing of the soil in this winter, when minimum depths of soil freezing have been recorded, testifies about the basic influence of air temperature, more accurately of circulation and therefore of advection of warm or cold air on our territory. In the course of March 1983, a significant phenomenon occurs, when changeable freezing of the surface occurs as late as 30th March (*Rožnovský and Pokladníková, 2005*)

The data processed by Surfer 8.0. On the basis of data at measuring depth (5, 10, 20, 50, 100 cm) the values of soil temperature were interpolated for whole vertical profile (5 to 100 cm) by the aid of this software.

Acknowledgments. The authors are grateful to the Ministry of Education, Youth, and Sports of the Czech Republic (grant No. 2B06101) for the partial support of this work.

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