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Shell morphological studies on *Granaria frumentum* (Draparnaud, 1801) populations from rock ledges (Romania: Apuseni and Poiana Ruscă Mountains)

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Abstract. I present morphometric results for some population of the *Granaria frumentum* from Munții Apuseni and Munții Poiana Ruscă . I set side by side July mean temperatures according to weather references and temperatures calculeted with arithmetic and graphic morpho-thermometer method. I showed the difference at best is 0.6°C according to Sólymos & Sümegi method and 3.2°C if the Domokos & Fűköh method is applied. Moreover arithmetic mean of *Granaria frumentum* height and temperature calculeted with morpho-thermometer method of Sólymos & Sümegi is increasing southward.

Keywords: shell variability, shell morphometry, macroclimate, microclimate, morpho-thermometer method

Introduction

The very first Hungarian work on shell morphometry and variability was published by M. Rotarides in 1927. He studied the relationship between shell parameters (H: height, W: width, H/W: elongation, see Fig. 1) and environmental factors (climate, habitat) using correlative statistical techniques. Subsequently Agócsy 1962,1963 and Fűköh 1980 investigated the effect of climatic factors on the shell parameters and their distributions for molluscs species. With time quantitative atti-

tude in shell-morphometric studies became standard and the use of morphometric results in climate reconstruction soon followed (Domokos 1982, 1982-1983, 1987, 2001, 2002; Domokos & Fűköh 1986; Sümegi 1989, 1996; Sólymos & Nagy 1997; Sólymos & Domokos 1999; Sólymos & Sümegi 1999; Sólymos et al. 2002; Bába & Domokos 2002).

Granaria frumentum is mostly a drought resistant species living in short grassland and rocky periphery, it is a very variable species (Soós 1943). Among others Gittenberger 1984, Bank 2007, Sólymos et al. 2003 studied taxonomical problem of *Granaria frumentum frumentum*. In Romanian territory Grossu 1993 distinguished six *Granaria frumentum* forms: *curta, elongata, illyrica (= hungarica)*, *cylindracea, minor, castanea.* Fehér et al. 2010 differentiated five morphotypes within the eastern part of the species range : *hungarica* (M. Kimakowicz 1890), *illyrica* (Rossmässler 1835), *atracta* (Pilsbry 1918), *subaii* (Fehér 2010) (Fig. 2). Fehér et al. (2010) mentions two subspecies from Romania: *Granaria frumentum frumentum* and *Granaria frumentum hungarica*, the latter with its cervical swelling absent-weak and weak palatal plicae. *Granaria frumentum* subspecies are not differentiated in this study because the sampled populations are likely to belong to the *frumentum* subspecies, and the two Romanian subspecies are likely to interbreed.

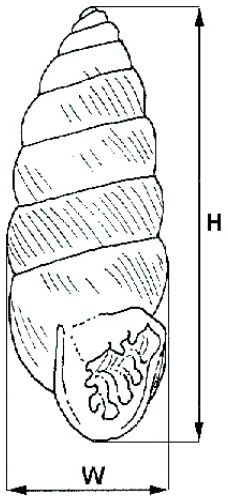

Fig. 1 – The measurement of shell parameters in *Granaria frumentum*. H: height, W: width.

In this paper I compare predicted temperature values by the different shell morpho-thermometer methods (Domokos & Fűköh 1986; Sólymos & Domokos 1999; Sólymos & Sümegi 1999; Sólymos 2002) based on *Granaria frumentum* populations collected from rock ledges.

The shell morpho-thermometer is based on the relationship between the shell morphometry (mode or arithmetic means of height ─ Fig.3.) and macroclimate factors, such as temperature and humidity (Fig.3─5.). Two methods are, one graphic and one arithmetic, have been proposed by Domokos & Fűköh 1986, Sólymos & Domokos 1999, Sólymos & Sümegi 1999.Temperature can be calculeted by the aid of diagrammatic read of from Fig. 3. or by equation of the regression line (Fig. 5.), wich has the following equation: **PT1= (AM–2,1747) / 0,2824**
where PT1 is the temperature calculeted with morpho-thermometer method, AM is arithmetic mean of height measurements.The correlations between modes of height and annual temperature (Sólymos & Domokos 1999) and July mean temperature was positive (Fig. 3., 5.). On the other hand the correlation between modes of height and relative humidity (Fig.4.) or annual amount of precipitation was negative (Sólymos & Domokos 1999).

Fig. 2 – Schematic distribution map of Granaria frumentum roughly indicating the ranges of subspecies, wich are mentioned in Fehér et al. 2010 study (empty area→*frumentum*, very rarely dotted→doubtful, rarely dotted→*apennina*, grated→*illyrica*, frequently dotted→*hungarica*, vertically lined→*atracta*, horizontally lined→*subaii*).

Materials and methods

The author sampled populations from rock ledge in different dates from the following locations (Fig. 6): Torda, Cheile Turzii, south exposition (1982: Munții Gilăului- Muntele Mare); Hunedoara, front of Cetate Corvineștilor, south exposition (1982: Munții Poiana Ruscă); Vadu Crișului, Defileul Crișul Repede, west exposition(2004: Munții Padurea Craiului); Sighiștel Pass, northwest and southeast exposition (2010: Munții Bihor). Sample size of the *Granaria frumentum* populations in were 57, 28, 32; 40, 32, 62, respectively (Table 1 and 2).

I used full-grown and intact shells for the measurements of the height (H) and width (W) of shells in mm with 0.1 mm accuracy.Thereafter I drew height and width distribution curves of the different populations with 0.3 mm interclass intervals (Fig.7—10) as well as made two tables with size distribution characteristics (N: number of cases, H: height, W: width, AM: arithmetic mean, Mo: mode, SD: standard deviation, Min: minimum, Max: maximumm value, d: range, Tm: July mean temperatures, PT: temperatures calculeted with morpho-thermometer method, ΔT: difference between Tm and PT.

July mean temperatures shown in Tables 1 and 2 are according to Csűrös 1973, Bleahu 1978, and Monografia Carstului Munții Pădurea Craiului, as well as Atlas Republica Socialistă România.

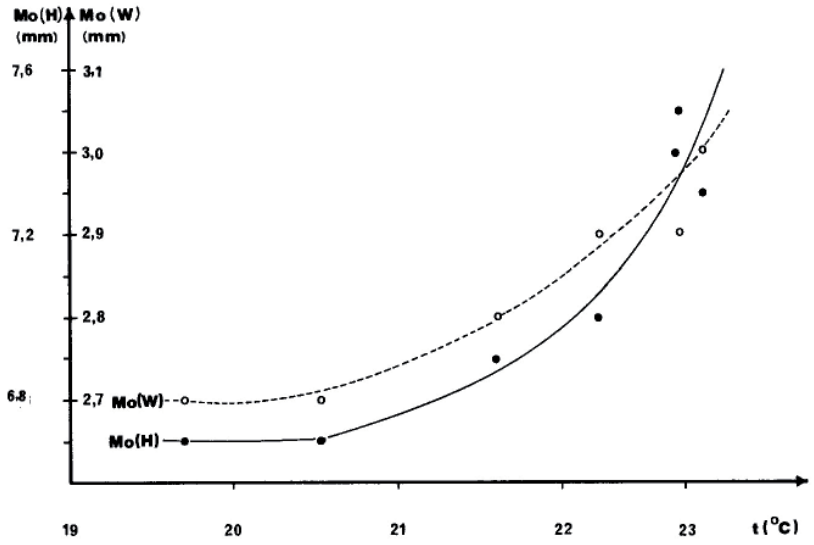

Fig. 3 – Relationship between height and width modes (MO) of *Granaria frumentum* and July mean temperature in Uppony Valley (Domokos & Fűköh 1986).

Results and discussion

On the basis of size distribution curves (Fig. 7—8) and size distribution parameters it can be ascertained that the climatic factors varied in the Pass of Sighiștel. In NW1 biotope a mixture of *Granaria frumentum* sample was found with

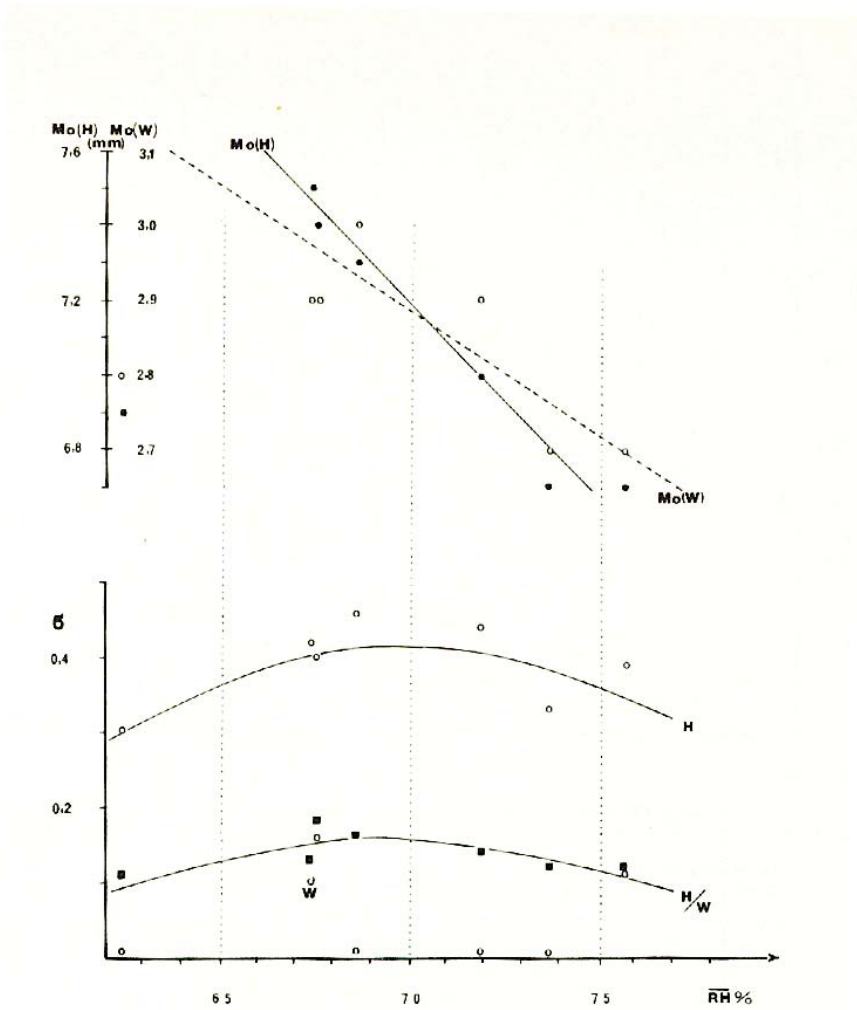

Fig. 4 – Relationshop between modes (MO) of Granaria frumentum as well as standard deviation (σ) and relative humidity (RH) in Uppony Valley (Domokos & Fűköh 1986)

and M-shaped distribution. It is likely that some specimens were washed down from higher and warmer rock ledges and led to the M-shaped mixture distribution.

Due to the climate conditions, firstly exposition to sun and washing down height orders of arithmetic mean is following: NW1—8.0 mm (PT1: 20.6°C); SE—7.9

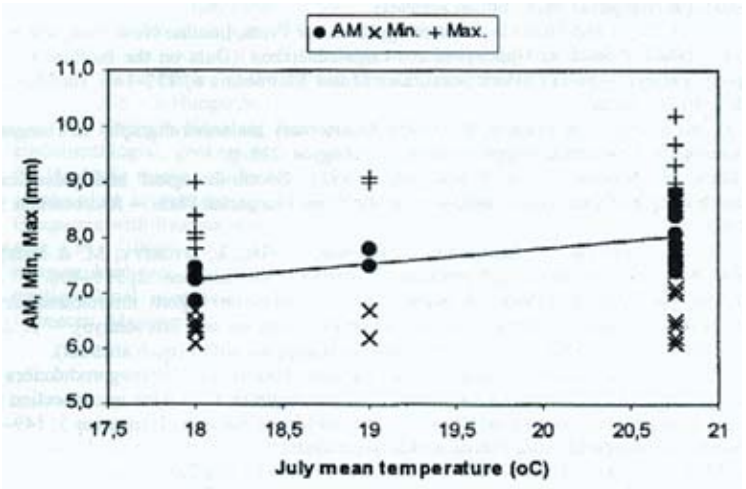

Fig. 5 – Connection between July mean temperature (°C) and means of height (AM), minimum (Min) and maximum (Max) of Granaria frumentum populations from three sampling areas: Kereszteskő, Oltárkő (Mid-Mountain Range, N Hungary), Szársomlyó (Villány Hills, S Hungary) (Sólymos & Sümegi 1999).

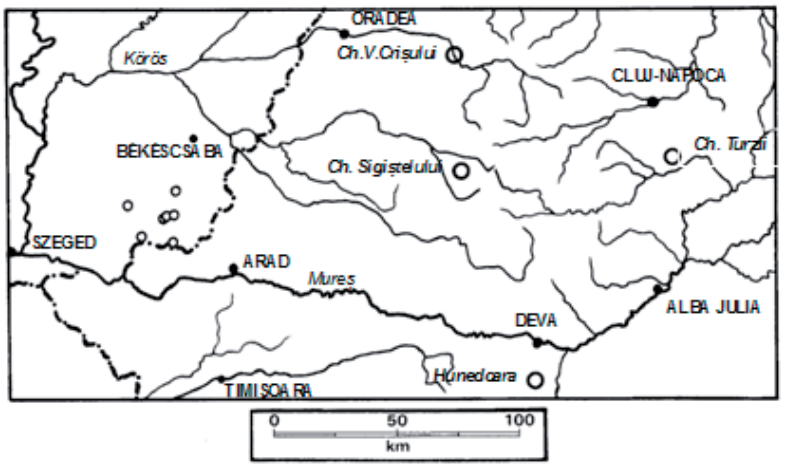

Fig. 6 – Hydrographic sketchmap of the sampling sites in Hungary (smaller empty circles) and Romania (larger empty circles).

mm (PT1: 20.3 °C); NW2–7.6 mm (PT1:19.2°C). Results indicate that predicted temperatures calculeted from morpho-thermometer-method (Sólymos & Sümegi 1999) are more precise. The difference is approximatelly +2.0 °C (Table 1). Relative positions and modes of the frequencies distribution curves of width (W) shows similar order (Fig.8).

Temperature calculeted with morpho-thermometer method (Domokos & Fűköh 1884) was found to be less precise with a difference of +5.4°C between July mean temperature and morpho-thermometer method (Table 2.). This value is approximately double of the one gained by equation of the regression line (Sólymos & Sümegi 1999). Contrary to this, results from southeastern part of the Hungarian Lowlands showed opposite tendency with respect to precision of the predictions (Domokos & Sólymos 2013).

The following group of samples consists of three sites. Between these (Cheile Vadu Crișului, CheileTurzii, Hunedoara) the distances were relatively large.

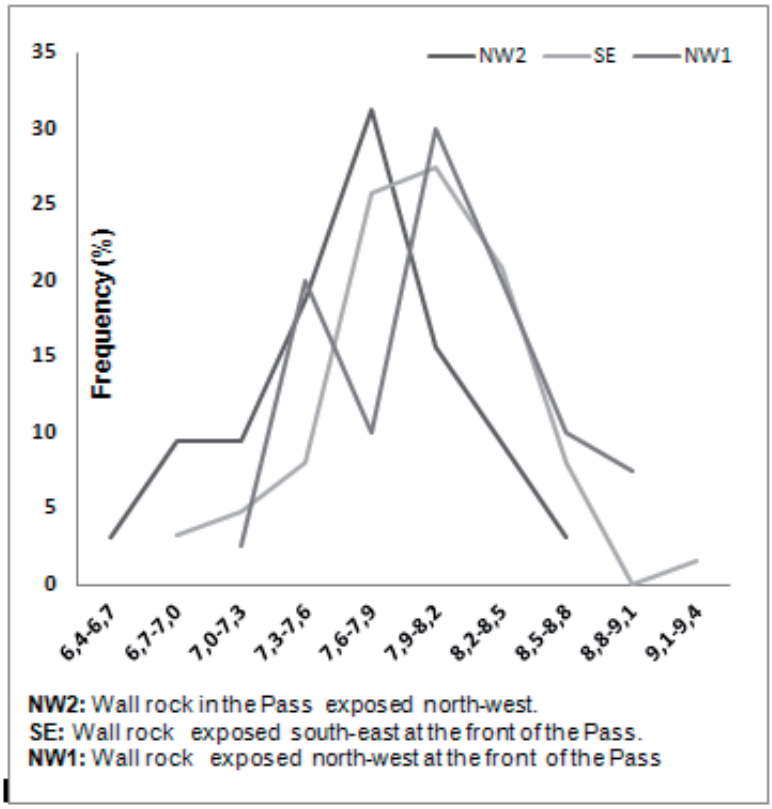

Fig. 7 – Frequency distribution curves of height in the Pass of Sighiștel (2010).

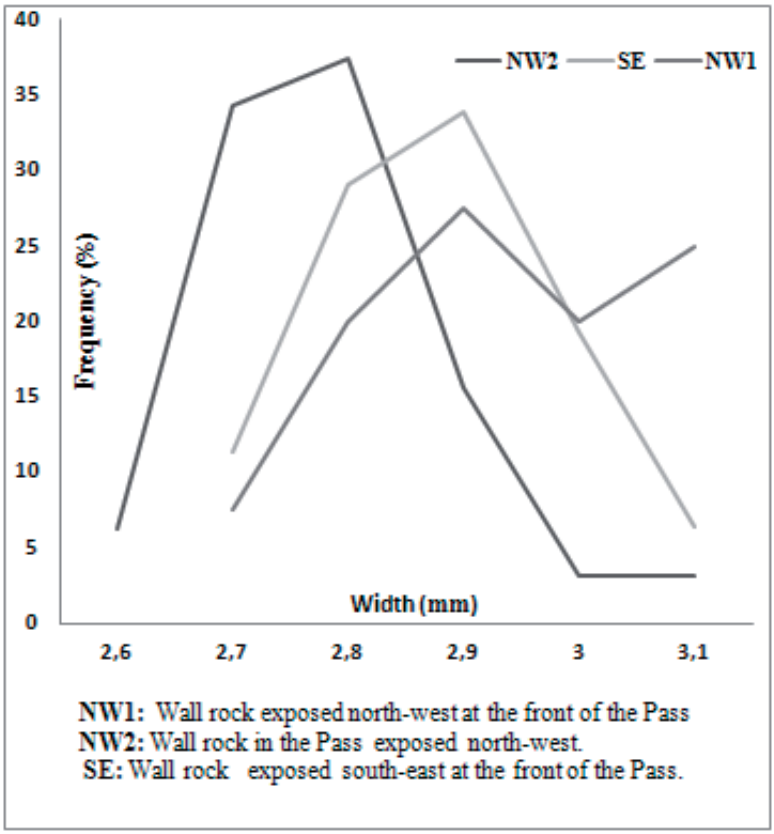

Fig. 8 – Frequency distribution curves of width in the Pass of Sighiștel (2010).

Cheile Turzii approximately 50 km, however Honedora approximatelly 125 km in a southerly direction (south component) from Vadu Crișului (Fig.5). According to expectations, the arithmetic mean of *Granaria frumentum* height (H) and PT1 was increasing southwards (6.9 mm ─16.7°C → 7.1 mm ─17.4°C → 7.8 mm ─19.9°C). A significant difference (─2.3 °C) was found between July mean temperature and morpho-thermometer method (Sólymos & Sümegi 1999) in Cheile Vadu Crișului. It is likely that habitat specific microclime greatly caused the deviation from the macroclimate based expectation. Difference between PT an PT1 values are significant in this group of samples too.The Tm and PT values in Cheile Turzii were especially different (18.0 °C and 22.3°C).

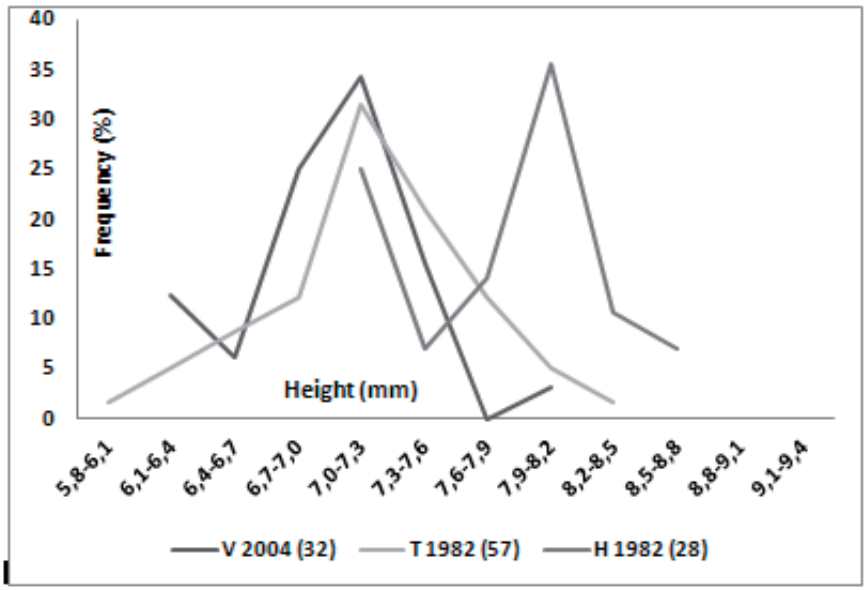

Fig. 9 – Frequency distribution curves of height [V= Vadu Crişului, T= Cheile Turzii, H= Hunedoara; (number of individuals)].

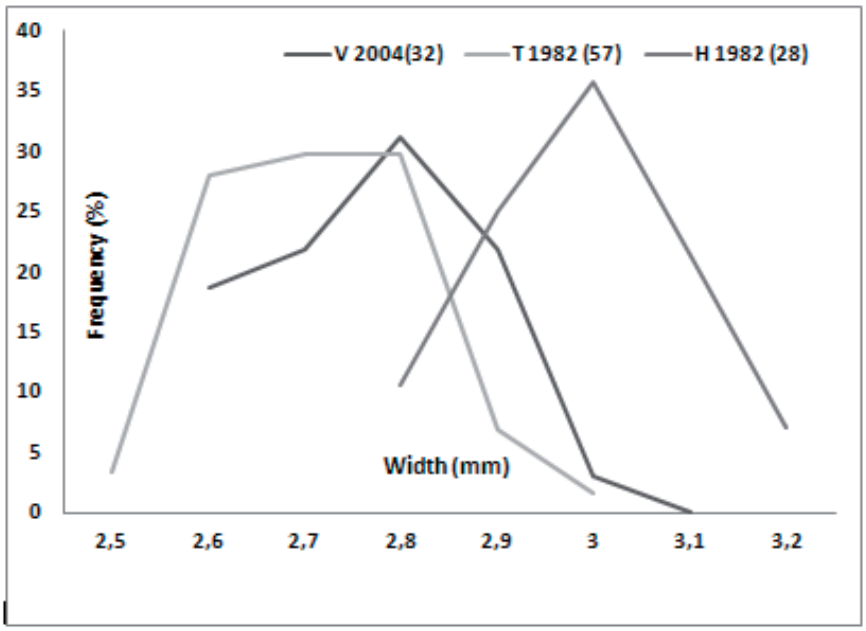

Fig. 10 – Frequency distribution curves of width [V= Def. Vadu Crişului, T= Cheile Turzii, H = Hunedoara; (number of individuals)].

Table 1. Size distribution parameters of H (height) of the measured *Granaria frumentum* populations. (N: number of cases, AM: arithmetic mean, MO: mode, SD: standard deviation, Min: minimum value, Max: maximum value, d: range of measuring, Tm:July mean temperatures according to references. PT1: temperatures calculeted with morpho-thermometer method (Sólymos & Sümegi 1999), Δt: difference between Tm and PT1.

Sampling sites	Exposure	N	AM	MO	SD	Min	Max	d	Tm (°C)	PT1 (°C)	ΔT (°C)
Sighiștel	1. NW1	40	8.0	8.0	0.48	7.1	8.8	1.7	18.0	20.6	2.6
	2. NW2	32	7.6	7.8	0.48	6.6	8.7	2.1		19.2	1.2
	3. SE	62	7.9	–	0.45	6.9	9.1	2.2		20.3	2.3
Vadu Crișului	W	32	6.9	7.1	0.42	6.1	7.9	1.8	19.0	16.7	2.3
Cheile Turzii	S	57	7.1	7.1	0.48	6.0	8.0	2.0	18.0	17.4	0.6
Hune-doara	S	28	7.8	–	0.48	7.0	8.7	1.7	20.6	19.9	0.7

Table 2. Size distribution parameters of height (H) of the measured *Granaria frumentum* populations. (PT: temperatures calculeted with morpho-thermometer method (Domokos & Fűköh 1986), further parameters are explained in Table1).

Sampling sites	Expo-sure	N	AM	MO	SD	Min	Max	d	Tm (°C)	PT (°C)	ΔT (°C)
Sighiștel	1. NW1	40	8.0	8.0	0.48	7.1	8.8	1.7	18.0	–	–
	2. NW2	32	7.6	7.8	0.48	6.6	8.7	2.1		23.4	5.4
	3. SE	62	7.9	–	0.45	6.9	9.1	2.2		–	–
Vadu Crișului	W	32	6.9	7.1	0.42	6.1	7.9	1.8	19.0	22.3	3.2
Cheile Turzii	S	57	7.1	7.1	0.48	6.0	8.0	2.0	18.0	22.3	4.3
Hune-doara	S	28	7.8	–	0.48	7.0	8.7	1.7	20.6	–	–

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