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A possible connection between macroclimate and shell morphometry of *Granaria frumentum* (Draparnaud, 1801) (Gastropoda: Chondrinidae)

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Abstract: We measured 726 specimens of *Granaria frumentum* (Draparnaud, 1801) from Szársomlyó and Oltárkő, and this was completed with earlier data from Kereszteskő. We aimed to show the relationship between macroclimatic factors and shell morphometry of *Granaria frumentum.* We found differences among the populations came from the three different localities according to the macroclimatic trend. Correlation between mode of height of the shells in the populations and mean temperature is positive, correlation between mode of height of the shells in the populations and the ammount of precipitation is negative.

Introduction

The first Hungarian paper in shell morphometry and variability was written by M. Rotarides in 1927. He urged on studying and conparing mollusc populations with statistical methods from numerous locality in order the aquaintance of the relationship between shell parameters and geographical elements. Domokos studied the mesoclimatic differences of the geographical clines of *Chondrula tridens* (O.F. Müller, 1774) (Domokos 1982–83). Later Domokos – Fűköh (1984) investigated the connection between microclimate and the shell morphometry of *Granaria frumentum* (Draparnaud, 1801). The connection was well detectable in micro scale environment in Uppony Valley (the study was recently repeated). They found that higher mean temperature promoted the development of higher and wider shells within the studied temperature range (19,7–22,8 ºC).

In this paper we present a possible connection between macroclimatic data and morphometrical features of *G. frumentum* populations from three different localities.

Materials and methods

Granaria frumentum is mostly a xerophilous species living in rocky and short grasses (Soós 1943). Agócsi (1961) considers the species as very variable with a big geographical range occuring several macroclimatic areas of Hungary.

The malacological matter of the paper is came from three different localities. Equal volumed soil samples (1 l samples from or 20 cm * 20 cm quadrats where it was possible) were taken from the Szársomlyó (Villány Hills) in order to calculate relative abundances. The sampling areas were the following: steppe grassland (2), rocky grassland (3, 9), shrub-grassland mosaic (5–8). The numbers of the areas are the same as in Sólymos (1996) and Sólymos – Nagy (1997) what contains quantitative data in details. This material contained both living and dead individuals. Single individuals of *G. frumentum* were collected from Oltárkő (Nagy-oldal, Aggtelek Karst Area) and from the surrounging of a bauxite mine tunnel. We used earlier data of Domokos–Fűköh (1984) accured from Kereszteskő (Uppony Valley) as well (quantitative data in details: Fűköh 1980). Every sampling areas are rocky grasslands with some shrubs and clumps of trees exposed to the south.

We used full-blown and entire shells for measuring. The height (H) and width (W) of shells were measured directly in mm with 0,1 mm precision (max 5% measuring error) (Fig. 1.). We calculated elongation index (H/W) for each height-width data pairs, arithmetic mean (AM), mode (MO), median (ME), standard deviation (SD), minimum value (Min), maximum value (Max) and range of measuring (d) for each samples concerning H, W and H/W values (Table 1.). On the graphs we used 0.3 mm interclasses for the height and 0,1 mm interclasses for the width values (open at the lower end) to avoid hiatuses of the curves.

Domokos (1982) gives 30 for the minimal number of cases which is representative for the derived data. The optimal number of cases is about 50–60 (Fig. 2.) which is representative both for the derived values and for the distribution of the interclass values.

The sampling of the recent material was carried out in different times (1978: Kereszteskő, 1996–97: Szársomlyó, 1997: Oltárkő) and this temporal deviation can lead to inconsistences. On the contrary Fig. 3. shows that we can expect well reproducible results in short term surveys.

Fig. 1. Picture of a living Granaria frumentum with the measured shell parameters. H: height, W: width

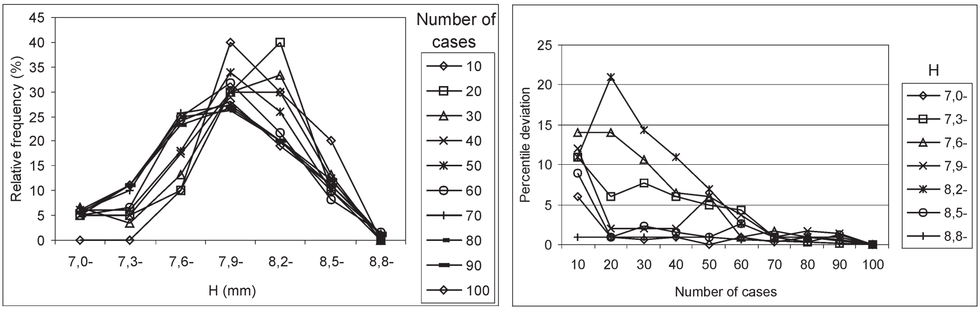

Fig. 2. Distribution curves of height (H) according to the number of cases (B1 sample from Szársomlyó). Percentile deviation means the deviation from the values where the number of cases is maximal (N=100)

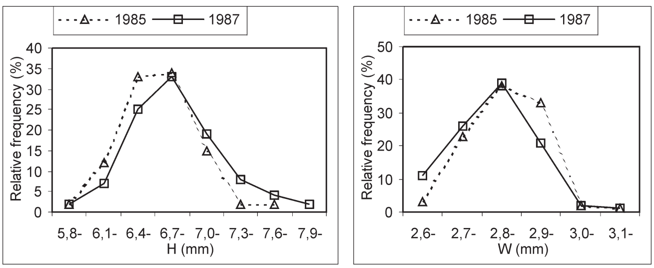

Fig. 3. Size distribution of a Granaria frumentum population from Balatonszárszó sampled in 1985 and 1987. H: height, W: width

Table 1.: Size characteristics of the sampled Granaria frumentum populations. The state of existance was determined according to Domokos (1995). H: height, W: width, H/W: elongation index, AM: arithmetic mean, MO: mode, ME: median, SD: standard deviation, Min: minimum value, Max: maximum value, d: range of measuring, BMT: bauxite mine tunnel.

Locality		Nagyoldal		Szárnysomlyó										
Sampling area		Oltárkő		2	3	3	5	6	6	6	7	8	9	BMT
State of existence		E2	E2-E4	E2-E4	E2-E4	E2-E4	E2-E4	E2-E4	E2-E4	E2-E4	E2-E4	E2-E4	E2-E4	E1
Number of cases		46	100	20	100	80	40	10	10	10	80	60	60	110
Relative abundance (%)		–	–	46.49	77.14	66.77	35.62	16.43	15.20	19.23	37.80	70.15	21.04	–
H (mm)	AM	7.5	7.8	8.8	7.9	7.9	8.4	8.6	8.1	8.4	7.6	7.5	7.4	7.7
	MO	7.4	7.7	8.9	7.9	7.8	8.7	8.0	7.7	8.1	7.4	7.4	7.1	7.5
	ME	7.4	7.7	8.9	7.9	7.9	8.6	8.7	7.9	8.2	7.6	7.4	7.4	7.7
	SD	0.48	0.56	0.61	0.41	0.51	0.57	0.50	0.68	0.57	0.50	0.48	0.53	0.39
	Min	6.7	6.2	7.8	7.0	6.1	7.1	7.8	7.4	7.7	6.4	6.5	6.2	7.0
	Max	9.1	9.0	10.2	8.9	9.0	9.7	9.3	9.3	9.3	8.8	8.7	8.5	9.0
	D	2.4	2.8	2.4	1.9	2.9	2.6	1.5	1.9	1.6	2.4	2.2	2.3	2.0
W (mm)	AM	3.1	3.1	3.3	3.0	3.1	3.2	3.3	3.3	3.2	3.0	3.0	3.0	3.1
	MO	3.1	3.2	3.3	3.0	3.0	3.2	3.2	3.1	3.2	3.0	3.1	3.0	3.0
	ME	3.1	3.1	3.3	3.0	3.1	3.2	3.3	3.3	3.2	3.0	3.1	3.0	3.1
	SD	0.11	0.11	0.13	0.09	0.10	0.11	0.15	0.16	0.09	0.11	0.10	0.10	0.12
	Min	2.9	2.8	3.1	2.9	2.9	3.0	3.1	3.1	3.0	2.9	2.8	2.9	2.8
	Max	3.3	3.3	3.7	3.2	3.4	3.4	3.5	3.5	3.3	3.4	3.2	3.3	3.6
	D	0.4	0.5	0.6	0.3	0.5	0.4	0.4	0.4	0.3	0.5	0.4	0.4	0.8
H/W	AM	2.42	2.50	2.67	2.60	2.56	2.60	2.61	2.48	2.64	2.51	2.46	2.44	2.51
	MO	2.31	2.61	2.70	2.63	2.69	2.72	2.50	–	–	2.50	2.47	2.37	2.50
	ME	2.44	2.48	2.66	2.61	2.57	2.62	2.57	2.45	2.62	2.50	2.47	2.45	2.50
	SD	0.144	0.149	0.153	0.135	0.166	0.155	0.145	0.170	0.192	0.149	0.150	0.173	0.134
	Min	2.03	2.07	2.41	2.28	2.03	2.09	2.44	2.24	2.41	2.06	2.013	2.06	1.94
	Max	2.84	2.87	2.94	2.90	2.90	2.87	2.87	2.71	3.00	2.84	2.77	2.83	2.90
	D	0.81	0.80	0.53	0.62	0.87	0.78	0.43	0.46	0.59	0.77	0.60	0.77	0.96

Linear regression analysis was used to investigate the connection between the parameters of the sampled populations and the macro scale environmental factors. For these purposes annual mean temperature, July mean temperature and annual ammount of precipitation were used after Marosi–Somogyi (1990) and Pécsi et al. (1989) (Table 2.).

Table 2.: Macroclimatic features of the different sampling areas. AMT: annual mean temperature, JMT: July mean temperature, AAP: annual ammount of precipitation (after Marosi–Somogyi 1990, Pécsi et al. 1989).

Locality	AMT (ºC)	JMT (ºC)	AAP (mm)
Szársomlyó	10.5	20.8	680
Oltárkő	8.5	19.0	695
Kereszteskő	7.3	18.0	800

Results

During our work we concentrated only on climatic factors and we put aside other abiotic and biotic factors, which might be also relevant to the size distribution of *G. frumentum* populations. We considered the ammount of $CaCO_3$ and vegetation cover the same for each sampling areas because those are located on limestone base rocks and the vegetation is rocky grassland with shrubs in southern exposure. Biotic interactions are similar to each other (Fig. 4.) and it is interesting that the relationship between size characteristic and relative abundance of *G. frumentum* is not linear. The moderately dense populations have bigger probability to contain higher shells than very dense populations. This may be caused by intra- or/and interspecific competition and the bigger heterogenity of the habitats as well. In our oppinion the heterogenity is bigger on Szársomlyó than on Uppony Valley.

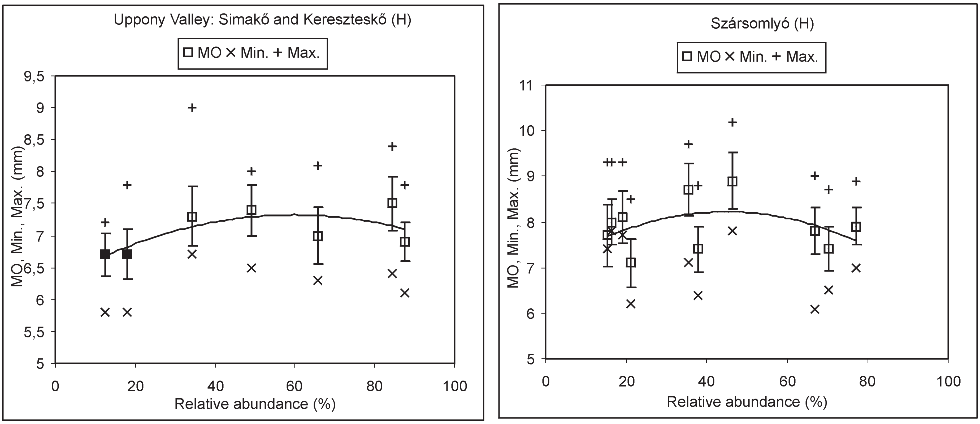

Fig. 4. Modes (MO), minimum (Min) and maximum (Max) values of height (H) of Granaria frumentum populations from Szársomlyó and Uppony Valley (filled squares: Simakő exposed to the north, empty squares: Kereszteskő exposed to the south) according to the relative abundances of the soil samples. Standard deviation ranges are connected to the modes

According to the microclimatic variability of the micro-habitats we can find big differences among the size distribution curves came from the same locality. Comparing Szársomlyó to Kereszteskő the deviation is so wide that the curves overlap one another (Fig. 5.). The macroclimatic differences of the different localities are hided behind the microclimatic overlap. Macroclimate is the average of several mesoclimates which are the average of microclimates. Alike to the calculation of the annual mean temperature of a region we can draw the populations of the same locality together and than we get the average of the distribution curve. Delineating the average curves in the same graph we find differences among the areas belonging to different macroclimates (Fig. 6.). Szársomlyó is influenced mainly by submediterranean climate, the mean temperature values are the highest in this region. Kereszteskő and Oltárkő are influenced by mountainy Carpathian climatic effects which reflects in the lower mean temperatur values (Table 2.). The modes of the size (height) distribution curves follow the macroclimatic ternd. On Szársomlyó we can find relatively higher shells than on Oltárkő and Kereszteskő, and we can find the relatively smallest shells on Kereszteskő (Fig. 6.).

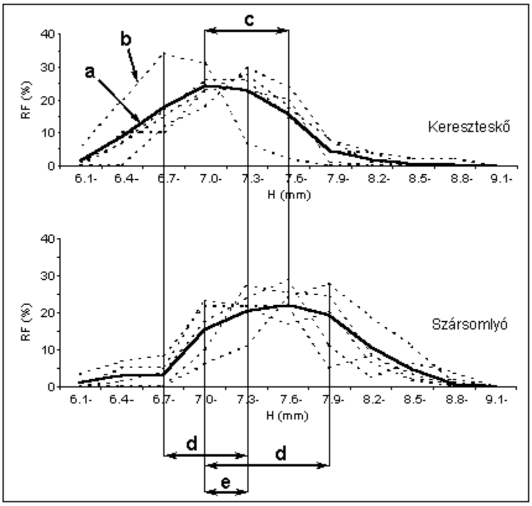

Fig. 5. The height (H) distribution of the Granaria frumentum populations from Kereszteskő and Szársomlyó.
a: average curve after drawing the curves of the sampled populations together, b: curves of the sampled populations, c: macroclimatic difference, d: microclimatic deviation, e: microclimatic overlap

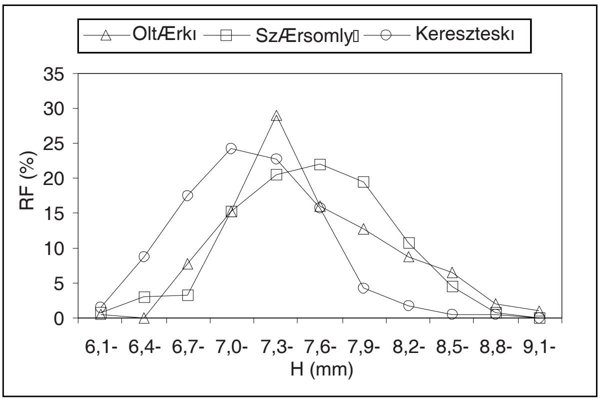

Fig. 6. Average curves of the three areas after drawing the curves of the sampled Granaria frumentum populations together

The modes of height (Table 1.) and macroclimatic data (Table 2.) were used for the linear regression analysis. We did not calculate significance of the regression line because of our sparse data. Statistical testing of the relationship needs more data from other localities (eg. Bükk, Transdanubian Midmountains). The correlation between modes of height and annual and July mean temperature is positive, the correlation between modes of heights and annual ammount of precipitation is negative (Fig. 7.). It is similar to the trend confirmed in micro scale by Domokos–Fűköh (1984).

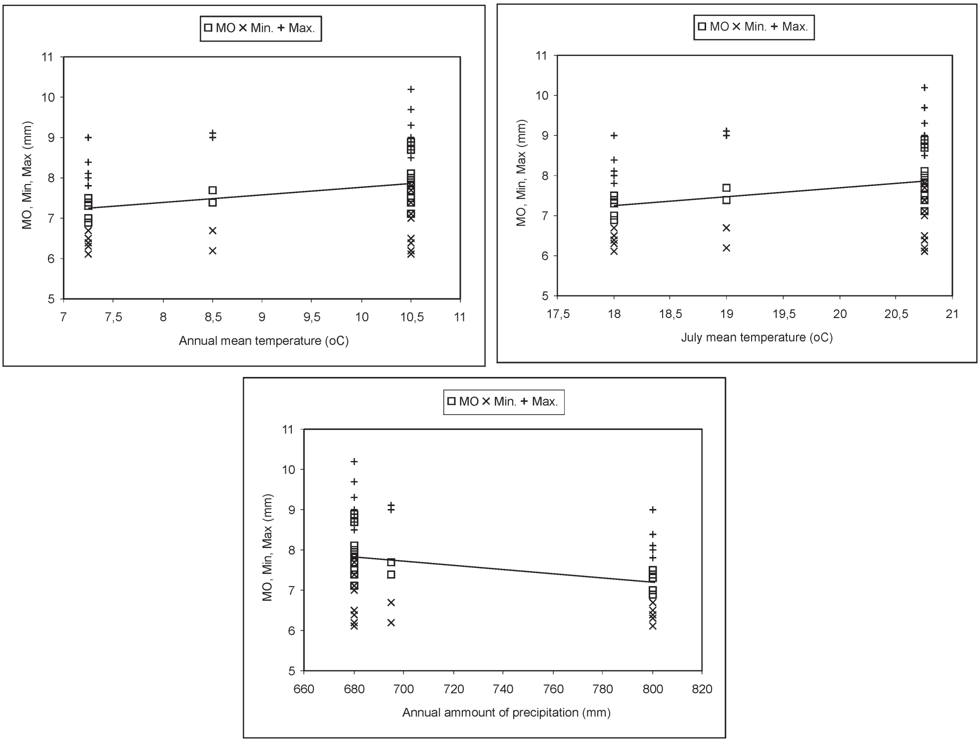

Fig. 7. Connection between macroclimatic factors (see Table2) and modes of height (MO) of the *Granaria frumentum* populations from the three sampling areas (Szársomlyó, Oltárkő, Kereszteskő)

Discussion

Here we applied a very reduced model of the relationship between *G. frumentum* populations and their environment where we concentrated only some factors that we thought relevant a *priori.* For the comparison we chose areas that are similar to each other in base rocks, exposure and vegetation structure but differ to each other in their macroclimatic features. We found a possible connection between macroclimatic factors and shell morphometry of *G. frumentum.* Giving this relationship precise is difficult and needs more data of similar habitats of numerous different localities. Our further aim is to carry on investigating the above interpreted relationship.

Domokos–Fűköh (1984) proposed the "morpho-thermometer", and Domokos (1985) used it for the palaeoenvironmental reconstruction of Horváti Cave in Uppony where he applied the micro scale relationship demonstrated by Domokos–Fűköh (1984). Rotarides wrote in his paper in 1931 that ”if we had many recent and fossil populations, their statistical comparison would enable us to draw conclusions as to the climatic conditions of the loess period". These words are true even nowadays. If we had more recent data we could draw the palaeoenvironment more accurate in the cases of *G. frumentum* containing time horizons using the connection between the macroclimate and shell morphometry according to the above (Sümegi, P.–Sólymos, P. 1999).

Összefoglalás

Domokos–Fűköh (1984) a *Granaria frumentum* házának morfometriai jellemzői és a mikroklíma között kapcsolatot mutatott ki. Jelen dolgozat célja igazolni a kapcsolat meglétét makroklimatikus léptékben is. A különböző élőhelyek, ahonnan a vizsgált *G. frumentum* populációk származnak, igen nagy mikroklimatikus variabilitást mutatnak, ami a mikroléptékű kapcsolatnak megfelelően a házak morfometriájában is tükröződik. Mivel egy adott terület makroklímájának jellemzésére szolgáló mutatók (évi és júliusi középhőmérséklet, évi csapadékmennyiség stb.) több mérőállomás adatainak átlagai, így a *G. frumentum* populációk esetében is hasonlóan járhatunk el. Az egy területről származó adatokat összevonva és az így kapott eredményeket összehasonlítva különbségek mutathatók ki az eltérő makroklímával jellemezhető területeken élő populációk között. Ez a kapcsolat azonban csak alapkőzet, növényzeti fedettség és kitettség tekintetében megegyező élőhelyek esetén mutatható ki, mert így a populációk méreteloszlására ható tényezők közel azonosnak tekinthetők. Eredményeink alapján a házak mérete az évi és júliusi átlaghőmérséklettel pozitív, az évi csapadékmennyiséggel negatív kapcsolatban áll.

A kimutatott kapcsolat reményeink szerint felhasználható paleoökológiai rekonstrukciók során az őshőmérséklet becslésére, más módszerekkel kapott adatok kiegészítése, alátámasztása is.

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