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# Altitudinal variation of plant traits: morphological characteristics in *Fragaria vesca* L. (Rosaceae)

**E. Maliníková, J. Kukla, M. Kuklová, M. Balážová**

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**Abstract.** The relationships among ecological conditions, morphological characteristics and total flavonoid content in *Fragaria vesca* L. species growing from the beech (710 m a.s.l.) to dwarf pine altitudinal zone (1550 m a.s.l.) in the western part of the Chočské vrchy Mts. (Western Carpathians) were evaluated on 10 plots. Different habitats were studied using geobiocoenological typology system in order to investigate its ecology. It has been found out that *F. vesca* occurs in a variety of habitats with different trophic conditions (oligo-mesotrophic, mesotrophic, mesotrophic calciphile, nitrophilous calciphile and calciphile ranges) and as a rule reached significantly higher values of measured parameters (number of leaves, length of the longest leaf, dry weight and total flavonoid content) in the mesotrophic calciphile, mesotrophic and calciphile ranges of the 5$^{th}$ fir-beech and 8$^{th}$ dwarf pine altitudinal zones. On the other hand, average values of specific energy accumulated in strawberry leaves were significantly lower in calciphile conditions of the 4$^{th}$ beech and 8$^{th}$ dwarf pine altitudinal zones. From the measured parameters, mean number of leaves in strawberry rosettes and rosette weight were as a rule increasing from lower to higher altitudinal zones. The results of regression analysis confirm moderate positive linear relationship between these parameters and the altitude ($R$ = 0.33). The flavonoid contents were as a rule decreasing from lower to higher altitudinal zones. The correlation of the flavonoid contents and an altitude was strong ($R$ = 0.77). In the case of dependence rosette energy and length of the leaf on an altitude there were found out the regression relationships uncorrelated.
**Keywords** *Fragaria vesca* L., altitudinal gradient, ecological conditions, morphological characteristics.

**Authors.** Erika Maliníková (malinikova@ku.sk), Mária Balážová - The Catholic University, Faculty of Pedagogy, Department of Biology and Ecology, Hrabovská cesta 1, 034 01 Ružomberok, Slovak Republic; Ján Kukla, Margita Kuklová - Department of Soil and Plant Ecology, Institute of Forest Ecology of the Slovak Academy of Sciences, 960 53 Zvolen, Slovak Republic.
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## Introduction

*Fragaria vesca* L. is a perennial herb species with a short stalk and rounded leaves. It occurs in broadleaved and coniferous forests of Eurasia from lowlands up to the mountains where prefers thinner forest stands with favourable light conditions. The wild strawberry is hemi-heliophilous to heliophilous herbaceous species, hemi-cryptophyte with mesomorphic hibernal leaves remaining green over winter and withering in the spring period (Jurko 1990). In favourable conditions, the strawberry flowers from April to September. Its seeds are transported mainly by animals, human included. The propagation is mainly vegetative (by offshoots), facilitating the plant survival also in conditions unfavourable for generative reproduction. The species prefers moderately dry to moist humose soils rich in nutrients, and wholly avoids acid soils (Zlatník et al. 1970).

Wild strawberry is regarded as a medicinal herb species the effects of which were known already in Antiquity. The herb has special taste and represents an excellent remedy in natural treatments. The leaves of *Fragaria vesca* species contain in addition to tannins also flavonoids, a small amount of ascorbic acid and a very small amount of essential oil. Creasy (1974) reports that flavonoid content in plants culminates in autumn when the leaves loss chlorophyll and change their colour. Mohamed et al. (2001) reported higher concentration of flavonoid in fruit skin grown in full sun compared to those grown under shade.

Flavonoids are one of the most analyzed groups of secondary metabolites in higher plants because they are major constituents of plant pigments (Mol et al. 1998, Marais et al. in Grotewold 2006). The most common representant of flavonoids occuring in fruits and vegetables is quercetin (Hakkinen et al. 1999). The multiplicity of possible modifications of flavonoids result in more than 6000 different compounds and this number continues to increase (Harborne & Williams 2000).

The responses of plant species to a variety of environmental conditions as stand density, shade, forest structure, nutrients, have been reported previously (Willmot 1985, Laska 1996, Vacek et al. 1999, Kukla et al. 2004, Kuklová et al. 2006). Changes in composition and structure of plant communities in relation to the soil and snow cover variation along an altitudinal transect from the mountain-temperate forests to a woody shrub community and alpine meadows were analyzed by Doležal & Šrůtek (2002). The interest has been focused on assessment of the physiological and morphological responses of plant species under heavy metal stress (Michalak 2006, Mróz & Demczuk 2010) and on the growth of these species on soils contamined by toxic elements from industrial activities (Lăcătuşu et al. 2008, Gjoka et al. 2010). Many studies have shown knowledge about the chemical ecology of assimilatory organs of plants (Maciejewska-Rutkowska et al. 2007, Mróz & Demczuk 2010). Much information has been gained on the structures, chemical activities and biosynthesis of these compounds (Hollman & Katan 1999, Birt et al. 2001, Mudnic et al. 2009, Pawlaczyk et al. 2009, Vinay et al. 2010).

In last papers *Fragaria vesca* species provided excellent material for the studying interactions of anatomical structure and gas exchange in leaves under different environmental conditions (Chabot & Chabot 1977, Chabot 1978) and for the study of physiological and morphological responses of this plant growing in a heterogeneous substrates with contrasting quality (Hancock & Bringhurst 1978, Roiloa & Retuerto 2011).

In the research, we investigate the relationships among ecological conditions, morphological characteristics and total flavonoid content in *Fragaria vesca* species growing in different forest phytocoenoses, mostly carbonaceous substrates. It is based on Zlatník´s (1976a) geobiocenological differentiation of the landscape. Zlatník's theory is based on the types of permanent ecological conditions unifying the natural and human influenced communities.

The aim of the paper was to ascertain how the morphological parameters of the wild strawberry (1) vary with forest altitudinal zones (2) and between different edaphic-trophic ranges.

## Materials and methods

### Study site

The research plots are situated in forest phytocoenoses selected in the western part of the Chočské vrchy Mts (Table 1). The forest ecosystems situated in Chočské vrchy Mts are formed under influence of permanent ecologi-

**Table 1** Ecological characteristics of studied ecosystems

| Plot | Altitude (m) | Altitudinal zone | Stand canopy (%) | Parent rock | Soil subtype[1)] | Equivalent CaCO3(%) | Soil reaction in 0-5 cm | | Humus |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | pHH2O | pHKCl | (%) |
| P8 | 710 | 4th beech | 0-60 | Dolomitic Limestone | Lithic Rendzina (Lithi-Rendzic Leptosol) | 71.00 | 7.51 | 6.90 | 11.83 |
| P1 | 730 | 5th fir-beech | 80 | Dolomitic Limestone | Cambic Pararendzina (Calcaric Cambisol) | 0.08 | 6.06 | 5.35 | 12.84 |
| P6 | 780 | 5th fir-beech | 70 | Dolomitic Limestone | Cambic Pararendzina (Calcaric Cambisol) | 7.90 | 5.28 | 4.46 | 21.71 |
| P2 | 780 | 5th fir-beech | 60 | Ramsau Dolomite | Cambic Rendzina (Cambi-Rendzic Leptosol) | 62.00 | 7.38 | 7.10 | 14.00 |
| P5 | 800 | 5th fir-beech | 80 | Marl Limestone | Pararendzic Cambisol (Eutric Cambisol) | 0.00 | 5.46 | 4.56 | 11.89 |
| P13 | 1100 | 6th spruce-beech-fir | 70 | Ramsau Dolomite | Cambic Rendzina (Cambi-Rendzic Leptosol) | 10.00 | 7.67 | 7.19 | 32.15 |
| P35 | 1200 | 6th spruce-beech-fir | 70-90 | Guttenstein Dolomite | Cambic Rendzina (Cambi-Rendzic Leptosol) | – | – | – | – |
| P15 | 1270 | 7th spruce | 70 | Reinflinger Limestone | Skeli-Lithic Rendzina (Skeli-Rendzic Leptosol) | – | – | – | – |
| P11 | 1300 | 7th spruce | 50-60 | Guttenstein Limestone | Skeli-Lithic Rendzina (Skeli-Rendzic Leptosol) | 0.60 | 5.45 | 4.71 | 29.79 |
| P10 | 1550 | 8th dwarf pine | 100 | Ramsau Dolomite | Modal Rendzina (Hapli-Rendzic Leptosol) | 24.00 | 7.40 | 7.20 | 33.92 |

Note. [1)] according to Bedrna et al., (2000) and IUSS Working Group WRB (2006).

cal conditions and of result of inter-specific competition. The climate of studied region (600–1600 m a.s.l.) is moderately cold to cold, very moist, with average July air temperature below 16°C (Miklós 2002). The precipitation totals and temperature values depend in a large extent on the altitude and slope orientation. The July precipitation in Veľký Choč Mt. are due to rain shadow much lower (by 20–30%) on the south-oriented slopes than on the north-facing slopes (Plesník 1966). Vertical gradients in the Chočské vrchy Mts. calculated based on long-termed average annual temperatures and precipitation totals published by Petrovič (1972) are following: an average increase of precipitation by 60 mm per 100 m and an average decrease of temperature by 0.6°C per 100 m rise.

The soils of studied forest ecosystems were formed from Marl Limestone (Eutric Cambisol on plot P5), Dolomitic, Guttenstein and Reiflinger Limestones (Lithi-Rendzic Leptosol on plot P8, Skeli-Rendzic Leptosols on plots P11, P15, Calcaric Cambisols on plots P1, P6) and Ramsau and Gutenstein Dolomites (Cambi-Rendzic Leptosols on plots P2, P13, P35, Hapli-Rendzic Leptosol on plot P10). The soils are as a rule normally developed (with low to medium content of skeleton), with exception of shallow (less than 20-30 cm deep) or very stony soils on plots P8, P10 (calciphile range) and P11 (oligo-mesotrophic range). Soil-ecological characteristics of forest ecosystems are presented in Table 1.

The plant communities were selected in five altitudinal zones of the Chočské vrchy Mts (Western Carpathians), as follows: (i) 4$^{th}$ beech zone – by presence of *Carduus glaucinus* Holub, *Polygala amara* subsp. *brachyptera* (Chodat) Hayek species and mainly presence of *Prenanthes purpurea* L. in the surrounding forest ecosystems with normally developed deep soils (plot P8 – Pineta dealpina superiora); (ii) 5$^{th}$ fir-beech zone – by presence of *Cortusa matthioli* L., *Dentaria glandulosa* Waldst. et Kit. ex Willd., *Galium rotundifolium* L., *Rubus saxatilis* L., *Soldanella carpatica* L. and *Lonicera nigra* L. species, and/or by gradation of *Polygonatum verticillatum* (L.) All. and *Prenanthes purpurea* L. species (plots P1, P6 – Abieti-Fageta ulmi inferiora, P2 – Fagi-Acereta inferiora, P5 – Abieti-Fageta typica); (iii) 6$^{th}$ spruce-beech-fir zone – by presence of subalpine species *Adenostyles alliariae* (Gouan) A. Kern., *Doronicum austriacum* Jacq., *Luzula sylvatica* (Huds.) Gaudin and *Senecio hercynicus* Herborg (plot P13 – Abieti-Fageta piceae typica, P35 – Fagi-Acereta superiora); (iv) 7$^{th}$ spruce zone – by gradation of subalpine species and by physiognomy of spruce stands (lower stand density and height, canopy gaps, groups of trees), (plots P15, P11 – Sorbi aucupariae-Piceeta); (v) 8$^{th}$ dwarf pine zone – by presence of alpine species *Carex sempervirens* Vill. and *Festuca versicolor* Tausch, and by absolute dominance of *Pinus mugo* Turra species (plot P10 – Sorbi ariae-Pineta mugo rupestria).

Sampling and measurements. Macromorphological characteristics of soils were described according to Šály & Ciesarik (1991). The soil samples were air-dried and passed through a sieve with a mesh size of 2 x 2 mm. There was determined active and exchange soil reaction using a digital pH-meter, type 08 211/1, Radelkis (ratio of fine earth to water or 1 M KCl solution 1:2.5; in case of surface humus 1:10) and carbon content oxidimetrically, according to Ťurin. Determination and classification of soil units was made according to Bedrna et al. (2000) and IUSS Working Group WRB (2006).

The phytocoenological reléves were taken in 2006-2007. For the purpose of the study geobiocoenological typology was used (Zlatník 1976a). Based on present soil properties, bedrock, climate data and floristic composition, every plot was assigned to a correspondent altitudinal vegetation zone and trophic range. The classification of phytocoenoses was carried out in the sense of Zlatník (1976b). The names of plant taxa were given according to Marhold & Hindák (1998).

The plant material was obtained by random sampling from 10 representative plots in July. From each plot (400 $m^2$) 10 strawberry rosettes were sampled in 3-4 repetitions. The *Fragaria vesca* species as typical rosette plant is characterised by the clonal growth form (Klimeš et al. 1997). As plant individual was considered rosette of leaves. The values of following parameters in strawberry rosettes were recorded: number of leaves, length of the longest leaf (with a precision of 0.5 cm), dry weight (after 48-hours drying at a temperature of 80°C with a precision of 0.002 g). The air dried herb material was homogenised in a planetary micro mill (< 0.001 mm) and samples in amounts of 0.7–1 g dried up to a constant weight at 100°C pressed in form of brickettes and burnt in pure oxygen under a pressure of 3.04 MPa (Dykyjová 1989). The content of specific energy ($J.g^{-1}$ d. m.) was determined using an adiabatic calorimeter IKA C-4000 (software C-402, DIN 51 900).

The flavonoid content was determined by Pharmacopoeaia Slovaca 1 (Lehký et al. 1997-2004) using spectrophotometer Cintra 101 at 425 nm and converted to isoquercitrin.

The differences between ecological conditions and morphological parameters of the wild strawberry were analyzed by an ANOVA (Fisher-LSD test) and correlation relationships between morphological characteristics and flavonoid contents of *Fragaria vesca* L. rosettes on an altitude were evaluated with a regression analysis (Statistica 9 software).

## Results

### Morphological characteristics

Number of leaves in rosette. The research of *Fragaria vesca* L. species (Fig. 1) showed that the mean number of leaves in strawberry rosettes was as a rule increasing from lower to higher vegetation zones (the 5th fir-beech zone < the 6th spruce-beech-fir zone < the 7th spruce zone < the 4th beech zone < the 8th, gap in dwarf pine zone). This fact could be connected with more favourable light conditions in the stands having lower stand density and canopy. The exception was only the plot P8 in the 4th beech zone with extreme shallow soil and open stand.

The lowest average number of strawberry leaves was ascertained in nitrophilous calciphile conditions on the plots P2, P35 (3.0–3.7) and mesotrophic range on the plot P5 (3.9), while the highest ones (4.5) were in mesotrophic calciphile range on the plot P6 and calciphile range on the plot P10. The absolute lowest number of leaves (2) was found in some of miniplots established in mesotrophic calciphile (P1, P6), nitrophilous calciphile (P2) and mesotrophic (P5) conditions of the fir-beech zone, and the absolute highest number (9 leaves) was in oligo-mesotrophic range (P11) of the spruce-beech-fir zone.

Significantly lower compared with other studied phytocoenoses was the mean number of leaves found in strawberry rosettes growing in nitrophilous calciphile conditions on the plot P2 – the fir-beech zone (ANOVA, $F_{(9, 267)} = 5.027$, $p < 0.001$, Fisher-LSD test, Table 2), and also on the plot P35 – the spruce-beech-fir zone, however at significance level $p < 0.05$. The results of regression analysis confirm moderate positive linear relationship between number of leaves in *Fragaria vesca* L. rosettes and an altitude ($R = 0.328$), Table 3.

Rosette length. The mean length of the longest leave in rosettes of the *Fragaria vesca* species studied in the Chočské vrchy Mts varied between 8.8 and 14.9 cm (Fig 1). The smallest leaves (8.8–10.7 cm) were ascertained on the plots P13, P8 and P6, the greatest ones (13.7–14.9 cm) on the plots P10, P5 and P1. The absolutely shortest leaf (3 cm) in a rosette was found in one of miniplots established in mesotrophic range on the plot P13 in the 6th spruce-beech-fir zone and in oligo-mesotrophic conditions on the plot P11 (the 7th spruce zone), while the absolutely longest leaf

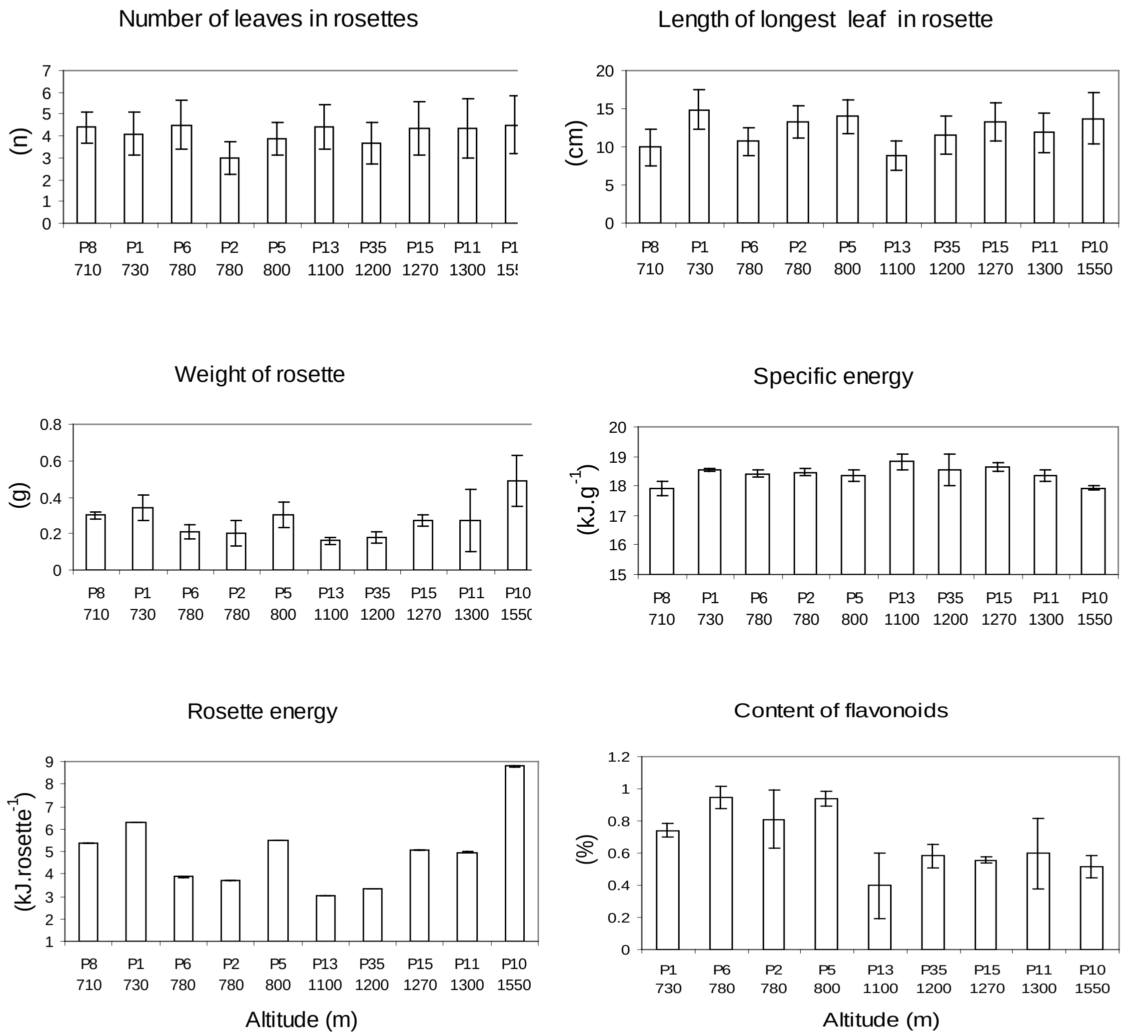


**Figure 1** Morphological characteristics and flavonoid contents of *Fragaria vesca* L. rosettes growing along the altitudinal gradient (mean ± standard deviation)

(21 cm) was ascertained in calciphile range on the plot P10 (the dwarf pine zone). Significantly longer leaves compared with other studied phytocoenoses grew in mesotrophic calciphile and mesotrophic ranges of the 5th fir-beech zone and in calciphile range of the 8th dwarf pine zone (ANOVA, $F_{(9, 267)} = 20.219$, $p < 0.001$, Fisher-LSD test; Table 2). The results of regression analysis confirm uncorrelated relationship between length of leaves of *Fragaria vesca* rosettes and an altitude ($R = 0.043$), Table 3.

Rosette dry weight. The dry weight of strawberry rosettes in the Chočské vrchy Mts varied between 0.16 and 0.49 g with maximum in calciphile range in the 8th altitudinal zone, Fig. 1. Significantly higher, compared with other studied phytocoenoses (ANOVA, $F_{(9, 25)} = 4.790$, $p < 0.001$, Fisher-LSD test; Table 2) was only the mean dry weight of strawberry rosettes growing in open stand of the calciphile phytocoenosis on the plot P10 (in the dwarf pine zone). Relatively lower mean weight of strawberry rosette (0.30 g) in ecologically similar calciphile phytocoenosis on the plot P8 (the 4th beech zone) was evidently caused by summer shortage of plant available water in shallow (only 20–30 cm deep) soil.

The rosette weight was as a rule increasing from lower to higher altitudinal zone. The

**Table 2** Significance of differences in mean values of the *Fragaria vesca* L. morphological characteristics and flavonoid content (Fisher-LSD test)

| Plot | P8 | P1 | P6 | P2 | P5 | P13 | P35 | P15 | P11 | P10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Altitude [m] | 710 | 730 | 780 | 780 | 800 | 1100 | 1200 | 1270 | 1300 | 1550 |
| Altitudinal zone | 4th beech | 5th fir-beech | | | | 6th spruce-beech-fir | | 7th spruce | | 8th dwarf pine |
| Trophic range | C | M/C | | N/C | M | | N/C | O/M | | C |
| Number of leaves in rosettes | | | | | | | | | | |
| N/C(P2) | 0.000* | 0.000* | 0.000* | - | 0.000* | 0.000* | 0.022 | 0.000* | 0.000* | 0.000* |
| Length of the longest leaf in rosette | | | | | | | | | | |
| M/C(P1) | 0.000* | - | 0.000* | 0.040 | 0.237 | 0.000* | 0.000* | 0.015 | 0.000* | 0.156 |
| M(P5) | 0.000* | 0.237 | 0.000* | 0.376 | - | 0.000* | 0.000* | 0.256 | 0.000* | 0.748 |
| C(P10) | 0.000* | 0.156 | 0.000* | 0.031 | 0.748 | 0.000* | 0.000* | 0.487 | 0.000* | - |
| Rosette weight | | | | | | | | | | |
| C(P10) | 0.003 | 0.024 | 0.000* | 0.000* | 0.004 | 0.000* | 0.000* | 0.002 | 0.002 | - |
| Specific energy | | | | | | | | | | |
| C(P8) | - | 0.000* | 0.006 | 0.002 | 0.013 | 0.000* | 0.000* | 0.000* | 0.018 | 0.972 |
| C(P10) | 0.972 | 0.001 | 0.009 | 0.004 | 0.018 | 0.000* | 0.002 | 0.000* | 0.035 | - |
| Flavonoid contents in leaves | | | | | | | | | | |
| M(P5) | - | 0.058 | 0.960 | 0.208 | - | 0.000* | 0.001 | 0.000* | 0.002 | 0.000* |
| M/C(P6) | - | 0.052 | - | 0.191 | 0.960 | 0.000* | 0.001 | 0.000* | 0.001 | 0.000* |

Note. Abbreviations: C - calciphile, N - nitrophilous, M - mesotrophic, O - oligo-, Significance levels: * $p < 0.001$.
$P_i$ - plot number.

**Table 3** Regression analysis – the relationships between morphological characteristics and flavonoid contents of *Fragaria vesca* L. rosettes on an altitude

| Characteristics | *F*-ratio | Probability level ($p$) | *R*-squared (%) | Correlation coefficient (*R*) | Standard error |
|---|---|---|---|---|---|
| Number of leaves in rosettes | 0.970 | 0.354 | 10.8 | 0.329 | 0.481 |
| Length of the longest leaf in rosette | 0.015 | 0.907 | 0.2 | 0.043 | 2.075 |
| Rosette weight | 1.001 | 0.346 | 11.1 | 0.333 | 0.096 |
| Specific energy | 0.018 | 0.897 | 0.2 | 0.047 | 302.164 |
| Flavonoid contents in leaves | 10.175 | 0.000 | 59.2 | 0.770 | 0.131 |

statistical evaluation of the obtained results confirms moderate positive linear relationship between rosette dry weight and an altitude ($R = 0.333$), Table 3.

Rosette energy. The average values of energy stored in strawberry rosettes ($J.rosette^{-1}$) in framework of the altitudinal zones create the same sequence as in a case of dry weights. The most energy was stored in strawberry rosettes growing in calciphile trophic conditions on the plot P10 (8,785 $J.rosette^{-1}$; the 8th altitudinal zone), the least one in the mesotrophic range on the plot P13 (3,011 $J.rosette^{-1}$; the 6th zone), Fig.1.

Rosette flavonoid content. The concentration of flavonoids ascertained in leaves of *Fragaria vesca* species growing in the Chočské vrchy Mts (Fig. 1) varied from 0.17% (absolutely minimum in mesotrophic conditions on the plot P13, the spruce-beech-fir zone) to 1.01% (absolutely maximum in the mesotrophic calciphile range on the plot P6, the fir-beech zone). The mean values ranged between 0.40 ± 0.21 and 0.94 ± 0.07%. Significantly higher flavonoid contents were found in strawberry rosettes growing in mesotrophic calciphile and mesotrophic ranges of the 5th fir-beech zone, compared to the phytocoenoses of the spruce-beech-fir and dwarf pine zones (ANOVA, $F_{(12, 24)} = 5.208$, $p < 0.001$, Fisher-LSD test; Table 2). The flavonoid content was as a rule decreasing from lower to higher altitudinal zone. The statistical evaluation of the obtained results confirms strong correlation relationship between flavonoid contents and an altitude ($R = 0.770$), Table 3.

## Discussion

The mean number of leaves in strawberry rosettes was as a rule increasing from lower to higher vegetation zone. The only exception (in case of the beech zone) was caused by very favourable light conditions in the open stand in the calciphile trophic conditions on the plot P8. This fact is in agreement with data of the Chabot & Chabot (1977), Jurik & Chabot (1986) according to which the light is the most significant factor for production and growth of wild strawberry compared with other ecological factors.

Similar number of leaves (3–5) ascertained in July 1994 and 1995 also Schieber and Kováčová (2002a) in rosettes of *Fragaria vesca* populations growing in mesotrophic beech forest of Kremnické vrchy Mts (density of stand treated with intensive regeneration cutting 0.3). A little higher, compared to our results were the mean numbers of leaves (4–7) found in strawberry rosettes growing in control beech stand (stand density 0.9). The absolute number of leaves in strawberry rosettes varied between 2 and 9, similarly as in a case of the Chočské vrchy Mts. On the other hand, the average number of leaves found by Angevine (1983) in rosettes of the *Fragaria vesca* populations growing on sandy alluvium varied in range of 2.8–4.2 and they were in a bottom part of the range (3–5) ascertained by us in the Chočské vrchy Mts. In a case of wet and dry localities the average numbers of leaves ranged between 4.3 and 5.1, i.e. in upper part of the mentioned range.

The average lengths of the longest leaves in strawberry rosettes ascertained by Schieber & Kováčová (2002b) in beech stands of the Kremnické vrchy Mts ranged between 10.3–14.2 cm (stand density 0.3), or were equal to 15 cm (control stand with density 0.9). These values are compatible with our results. However, the lengths of rosette leaves varied in wider interval (between 6 and 25 cm in stand with density 0.3 and from 13 to 19 cm in control stand with density 0.9), compared with our data. On the other hand, the average length of the longest leaf in *Fragaria vesca* species cultivated on sandy loam soil by Labokas & Bagdonaitë (2005) reached 7.98 cm and in comparison to our results was considerably shorter.

The mean dry weight of strawberry rosettes ascertained by Schieber & Kováčová (2002b) in beech phytocoenoses of the Kremnické vrchy Mts (0.12–0.41 g in stand with density 0.3 and 0.25–0.37 g on control plot with stand density 0.9) were a little lower, compared with our results. On the other hand, the mean weight of strawberry rosettes cultivated in a pots experiment by Littschwager et al. (2009) varied from 0.41–0.44 g (lower nitrogen level) to 0.59–0.75 g (higher nitrogen level). Consequently higher, in comparison with our results, were only the mean dry rosette weights of intensely fertilised.

Schieber and Kováčová (2003) ascertained in rosettes of strawberry populations growing in beech stands of the Kremnické vrchy Mts in average 17,865–18,352 $J.g^{-1}$ (stand density 0.3) and 17,537–17,570 $J.g^{-1}$ (control plot with stand density 0.9). These values are as a rule below lower limit of range determined by us in the Chočské vrchy Mts.

Concentration and distribution of flavonoids and other plant metabolites in the plant are not only a function of genetics, but also are found to be influenced by various environmental factors such as light, humidity and soil fertility (Warren et al. 2003). Zlatník et al. (1970) classify the *Fragaria vesca* species as humicolous. However, in the case of Chočské vrchy Mts the higher amount of flavonoids was found in strawberry leaves growing on soils with lower humus content (the fir-beech altitudinal zone).

## Conclusions

Different habitats were studied using geobiocoenological typology system in order to investigate their ecology. It has been found out that *F. vesca* occurs in a variety of habitats with different trophic conditions (from the oligo-mesotrophic through mesotrophic, mesotrophic calciphile and nitrophilous calciphile to calciphile) from the 4$^{th}$ beech to 8$^{th}$ dwarf pine altitudinal zone. The values of morphological characteristics of this species are considerably depended on quality of soil-ecological characteristics (pH reaction, humus content) and light conditions.

Significantly lower (by 22–33%) compared with other studied phytocoenoses was the mean number of leaves found in strawberry rosettes in nitrophilous calciphile conditions, only. Significantly longer leaves (by 14–40%) grew in the mesotrophic calciphile and mesotrophic ranges of the fir-beech zone and in calciphile range of the dwarf pine zone. Significantly the highest rosette weigth was ascertained in the calciphile range of the dwarf pine stand, only. Higher flavonoid contents reached this species in rosettes growing in the fir-beech zone (mesotrophic and mesotrophic calciphile conditions) and in compare with other phytocoenoses differences represented 40–59%. The average values of specific energy accumulated in strawberry leaves were significantly lower in the calciphile range.

The mean number of leaves in strawberry rosettes and rosette weight were as a rule increasing from lower to higher altitudinal zone. Values of correlation coefficients indicated a moderate positive relationship between measured parameters and an altitude. The correlation of the flavonoid content and an altitude was strong. In the case of dependence rosette energy and length of the leaf on an altitude there were found out non-linear relationships.

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