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Soil chemistry of *Thymus* species stands in Carpathians and Pannonia.

PAVOL MÁRTONFI, ANTON GREJTOVSKÝ & MIROSLAV REPČÁK

Department of Experimental Botany and Genetics, Faculty of Science, P. J. Šafárik University, Mánesova 23, SK-04154 Košice, Slovakia

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ABSTRACT: Nine soil chemistry characters (pH, carbonate content, oxidisable carbon content, total nitrogen content and the content of available mineral nutrients P, K, Ca, Mg, Na) were studied for 10 *Thymus* species from Carpathians and Pannonia. The species were characterised from the point of view of their relation to soil chemistry and on the basis of multivariate analysis three groups of taxa with different demands were delimited.

KEYWORDS: *Thymus*, *Lamiaceae*, soil chemistry, autecology, Carpathians, Pannonia

Introduction

While in cultivated plant species their demands from the point of view of soil properties are quite well-known, in wild species there are not too many data available on the soil properties (for example ELLENBERG & al. 1991, ZÓLYOMI & al. 1967, HADAČ 1988, HROUDOVÁ & al. 1992, SIMON 1992), some of them are obtained only indirectly and from the point of view of soil chemistry they are only partial (soil reaction, nitrogen content). A survey of the data concerning soil reaction in the genus *Thymus* found in the papers of ELLENBERG & al. (1991), SIMON (1992) with reagard to ZÓLYOMI & al. (1967), and HADAČ (1988) are given in the Tab. 1. Nitrogen content in the habitats of *Thymus praecox*, *T. pulegioides* a *T. serpyllum* is according to ELLENBERG & al. (1991) very low for all the above species. Detailed data on soil chemistry for *T. pulegioides* can be found in the paper MÁRTONFI & al. (1994), which deals with chemotype pattern differentiation on different substrates.

Tab. 1. Selected literature data concerning soil reaction of *Thymus* species.

Species	ELLENBERG (1991) [indicative values]	SIMON (1992) [indicative values]	HADAČ (1988)
T. alpestris	–	–	pH 4.3 (average)
T. froelichianus (sub *T. pulegioides* ssp. *carniolicus*)	between weak alkaline to alkaline	–	–
T. glabrescens	–	almost neutral	–
T. pannonicus	–	weak alkaline	–
T. praecox	between weak alkaline to alkaline	alkaline	–
T. praecox ssp. *polytrichus*	between weak alkaline to alkaline	–	–
T. pulegioides	indifferent to soil reaction	almost neutral	pH 4.4–4.9(avg)–7.3
T. serpyllum	medium acid	almost neutral	–

Material and methods

Soil samples were collected from the rhizosphere of 10 *Thymus* species in each of the 50 localities in Carpathians and Pannonia (except for loc. 24; for details see Appendix). The following analyses were made for each sample: pH was measured in 1 M KCl electrometrically, and carbonate content ($CaCo_3$) by decomposition of the soil sample with diluted HCl (3:1). Organic matter was determined as oxidisable carbon (C_{ox}) by oxidation with $K_2Cr_2O_7$ and H_2SO_4 according to the method of Tjurin (in HRAŠKO et al. 1962). Total N was determined by mineralization of soil samples with H_2SO_4 and selene catalyzer, according to the method of MEDVEĎ (1988). Available mineral nutrients (P, K, Ca, Mg, Na) were determined by use of the Mehlich II method (DAMAŠKA 1992).

Statistical methods: for each data set studied selected statistic characteristics were calculated (average, coefficient of variation; while calculating averages for pH we respected the logarithmic scale) and principal component analysis (PCA) and cluster analysis (UPGMA method; dissimilarity coefficient: Euclidean distances) from the NTSYS-pc package, ver. 1.80 (ROHLF 1993) were used for the determination of data structure.

Results and discussion

General notes

The survey of the results obtained is given in Tab. 2. The results correspond with certain expectations in the species where dependency on certain soil substrata is known. This substrata then influence soil reaction and also the content of available mineral nutrients. A typical example is species *T. serpyllum*, which is limited to sandy substrata and these ones are characterized, in average, by a very low value of carbonate content (0.23 %) and content of total nitrogen (0.08%) and also generally low content of available mineral content (especially K, Ca, Mg). The content of available phosphorus is also low to very low, however, it is not in contrast with the results for other species and generally low available phosporus content seems to be, with one exception (locality 21) one of the common characteristics for soils of all species of the genus *Thymus.* Further case of the limitation to a substratum is *T. pulcherrimus,* the species limited to limestone habitats. In one case (locality 25) the value obtained reached 91.2% of carbonate content in soil. For further, rather rare or vene endemic species of the genus (*T. alpestris, T. alternans, T. bihoriensis a T. comosus*) brief information obtained from soil sample taking in several localities is given. The range of the values obtained is, as a rule, rather wide and does not allow us to make unambiguous conclusions about species limitation to soil conditions. We dealt in detail with four species, which are distributed in Carpathians and Pannonia quite in a good measure. This species are following: *T. glabrescens, T. pannonicus, T. praecox a T. pulegioides*.

Thymus glabrescens. This species grows on habitats with neutral to basic soil reaction (KCl), in one case only weak acid value (locality 12 - pH 5.77) was found. At the same time, this locality proved to be with low carbonate content (0.25 % carbonate content only), other habitats are with medium to high carbonate content, in some cases they are limestone (localities 17 and 18 - carbonate content 76.8 and 87.4 %). Content of oxidisable carbon varies much, however, medium to high humous soil prevail. As for the content of total nitrogen in the soil samples studied, there are not peculiarities. Available phosphorous content is rather low, available potassium varies from very low to very high values, available calcium and magnesium content is usually high (Tab. 2).

Thymus pannonicus. The situation is similar for *T. pannonicus*, because this species occupies habitats similar to the previous species. Soil reaction of the habitats is very well balanced with a very narrow range of the values obtained from pH (KCl) 6.5 to pH 7.64, i. e. neutral reaction prevails. Only two of the values can be regarded extreme for this species - the sample 13 with strong acidity - pH 4.14 and the sample 39 with basic reaction - pH 8.02. From the point of view of carbonate content *T. pannonicus* occurs in soils with different carbonate content - from carbonate-free to limestone ones. Content of oxidisable carbon and total nitrogen is shifted to higher values (e. g. the sample from the locality 35: CO_x content 10.0 %, N_t content 1.2 %). Available mineral nutrients content varies and does not differ substantially from the data for *T. glabrescens* (Tab. 2).

Thymus praecox. This species also occupies predominantly the habitats with neutral soil reaction, weak acidity (locality 31, pH_{KCl} 6.34) was recorded only in one case and in two cases (locality no. 22 pH 7.76, locality no. 46 pH 7.45) the reaction was alkaline. *T. praecox* is bound mainly to the habitats with medium carbonate content, only in two cases lower carbonate content was found (locality no. 31 - $CaCO_3$ content 0.84 %, locality no. 47 - $CaCO_3$ content 0.53 %) and one case with higher carbonate content (locality no. 30 - $CaCO_3$ content 50.93 %). Content of oxidisable carbon is shifted to the

Tab. 2. Results of soil analyses for *Thymus* species from Carpathians and Pannonia. Abbreviations according to methods; labels: x - average, v - coefficient of variation, min - minimum, max - maximum.

Taxon; number of samples		pH $_{KCl}$	pH $_{H2O}$	Co_x [%]	N_t [%]	$CaCO_3$ [%]	P [mg. kg^{-1}]	K [mg. kg^{-1}]	Ca [mg. kg^{-1}]	Mg [mg. kg^{-1}]	Na [mg. kg^{-1}]
	min	6.48	6.79	6.31	0.46	7.86	6.08	227.71	6942	894	68.58
T. alpestris	x	6.49	6.97	14.67	1.07	9.72	10.06	309.60	8237	1402	99.37
n=2	max	6.49	7.28	23.04	1.67	11.58	14.03	391.49	9532	1911	130.15
	v	0.11	5.15	80.59	80.09	27.06	55.91	37.41	22.23	51.28	43.81
	min	3.56	4.67	1.03	0.14	0.08	traces	99.70	786	339	32.74
T. alternans	x	3.67	4.82	1.52	0.20	0.16	0.22	109.48	1193	752	41.82
n=3	max	3.84	4.88	2.36	0.29	0.23	0.66	125.90	1516	1470	46.89
	v	3.90	3.06	48.38	40.41	47.19	173.13	13.06	31.20	83.01	18.85
	min	7.07	7.47	0.61	0.08	0.53	0.33	38.34	2731	92	43.86
T. bihoriensis	x	7.44	7.83	1.50	0.14	26.77	1.19	65.18	6748	215	75.05
n=4	max	8.18	8.32	2.83	0.23	75.10	1.75	90.11	10130	307	93.76
	v	6.87	4.82	63.55	48.55	125.75	55.74	33.54	56.09	41.78	31.06
	min	4.23	5.23	0.61	0.08	0.26	1.68	38.34	399	25	32.92
T. comosus	x	4.53	5.53	1.05	0.10	3.95	3.78	57.52	5264	58	63.34
n=2	max	8.18	8.32	1.49	0.12	7.64	5.88	76.69	10130	92	93.76
	v	80.81	50.73	59.76	28.01	123.11	78.57	47.15	130.71	81.79	67.92
	min	5.77	6.12	0.43	0.04	0.25	1.92	28.08	4783	77	20.13
T. glabrescens	x	6.62	6.99	3.28	0.33	33.24	19.92	150.82	5411	601	66.10
n=11	max	8.02	8.44	8.65	1.10	87.44	109.74	334.54	9432	1445	97.30
	v	12.04	11.94	86.26	102.81	88.66	169.58	66.94	51.77	63.61	38.58

Tab. 2 - continued

Taxon; number of samples		pH $_{KCl}$	pH $_{H2O}$	Co_x [%]	N_t [%]	$CaCO_3$ [%]	P [mg. kg^{-1}]	K [mg. kg^{-1}]	Ca [mg. kg^{-1}]	Mg [mg. kg^{-1}]	Na [mg. kg^{-1}]
	min	4.14	4.85	0.57	0.06	0.09	1.92	64.94	1805	77	29.13
T. pannonicus	x	5.29	5.98	4.36	0.46	14.98	18.82	244.65	6021	525	67.26
n=15	max	8.02	8.44	10.00	1.25	87.44	109.74	506.70	11521	1445	101.66
	v	30.31	24.36	69.98	83.98	156.69	157.51	53.99	52.23	76.39	35.53
	min	6.34	6.68	0.43	0.04	0.53	0.33	28.08	1685	77	28.22
T. praecox	x	6.83	7.32	6.10	0.73	13.18	11.36	222.61	7502	314	71.43
n=10	max	7.76	8.27	13.32	1.74	50.93	58.41	410.33	11522	1033	99.20
	v	6.33	6.74	69.94	78.57	121.32	149.45	60.36	46.38	95.34	34.89
	min	6.48	6.79	4.53	0.25	7.86	2.46	64.15	9532	74	130.15
T. pulcherrimus	x	6.84	7.14	11.39	0.89	58.92	10.76	201.51	18111	699	159.45
n=3	max	7.32	7.72	23.04	1.68	91.16	15.79	391.49	28607	1911	211.29
	v	7.62	7.32	89.07	80.71	75.91	67.30	84.31	53.45	150.04	28.24
	min	3.56	–	0.49	0.04	0.02	traces	63.00	785	73	32.74
T. pulegioides	x	4.44	–	1.61	0.21	10.66	7.16	128.45	5335	641	39.29
n=13	max	7.63	–	6.27	0.64	73.15	29.2	241.00	35751	1555	45.83
	v	44.40	–	94.53	71.22	208.49	111.19	47.47	174.36	73.56	23.56
	min	3.8	4.63	0.85	0.07	0.06	0.55	31.95	151	29	32.32
T. serpyllum	x	4.22	5.07	0.86	0.08	0.23	2.43	35.97	456	55	35.72
n=3	max	5.63	6.55	0.87	0.09	0.54	3.81	39.21	722	75	39.99
	v	25.91	23.61	1.31	16.01	116.91	69.44	10.27	62.96	42.84	10.94

soil categories with higher content. It can be, however, in some cases, the result of presence of organic fragments which are difficult to remove. Total nitrogen content consistently copies pattern of CO_x and gives a proof of humus content in the soil. Similar to previous two species, the content of available mineral nutrients is usually high, with exception of phosphorus, where it is very low (in the case of locality no. 47 it is only 0.33 mg. kg^{-1}) (Tab. 2).

***Thymus pulegioides*.** For this species, several important differences were found when compared with the previous species. Soil reaction (KCl) includes all of the range of possibilities, from strong acid to basic. Also from the point of view of carbonate content, soil habitats belong mainly to the soils with very low to low carbonate content, but opposite extremes occur as well, e. g. locality 4 can be classified as limestone. When compared with the previous species, the content of oxidisable carbon in soil is lower as well (average 1.61 %). The content of particular available mineral nutrients varies significantly, the content of available phosphorus is very low with the extreme case of the locality 48, where it was recorded only in traces (Tab. 2).

Multivariate analysis

With regard to all of the studied features of soil chemistry for 10 species of the genus *Thymus* from Carpathians and Pannonia we tried to define ecological similarity of habitats for the particular species. We must mention that no conclusions about relationship between certain taxa have been made, only the soil chemistry similarity is concerned. A representation of PCA results is given in the Fig. 1, which comprises 77.8 % of primary data variability. Cluster analysis (UPGMA method) allowed more exact definition of similarity of particular taxa from the point of view of their relations to soil chemistry conditions.

The similarity of the habitats of *T. glabrescens, T. pannonicus a T. praecox* can be included among the most important similarities (Fig. 2). Generally these species tolerate various parameters of soil chemistry quite well, but predominantly they occupy soils with neutral soil reaction, usually with high content of oxidisable carbon and corresponding higher content of total nitrogen. From the point of view of carbonate contents the species tolerate low as well as high carbonate content in soil, however, they prefer soils with higher carbonate content. The content of available mineral nutrients K, Ca, Mg can vary substantially in the soils, as well as the content of available P, however, the species grow also well if its values are low. The demands of these taxa resemble those of an endemic taxon from Romania, *T. bihoriensis*, which prefers habitats with rather alkaline soil reaction (average pH_{KCl} 7.62, which is the highest value when particular species of the genus are compared.

The second cluster of taxa of similar demands is formed by *T. alternans, T. pulegioides, T. comosus* and *T. serpyllum*. These species are characteristic by a tolerance to rather acid soil reaction. The soils of these species are characterized also by low content of oxidisable carbon (in averages 0.86-1.61 %) and total nitrogen as well. Carbonate content varies in this group in various ways, but there is also a shift to lower

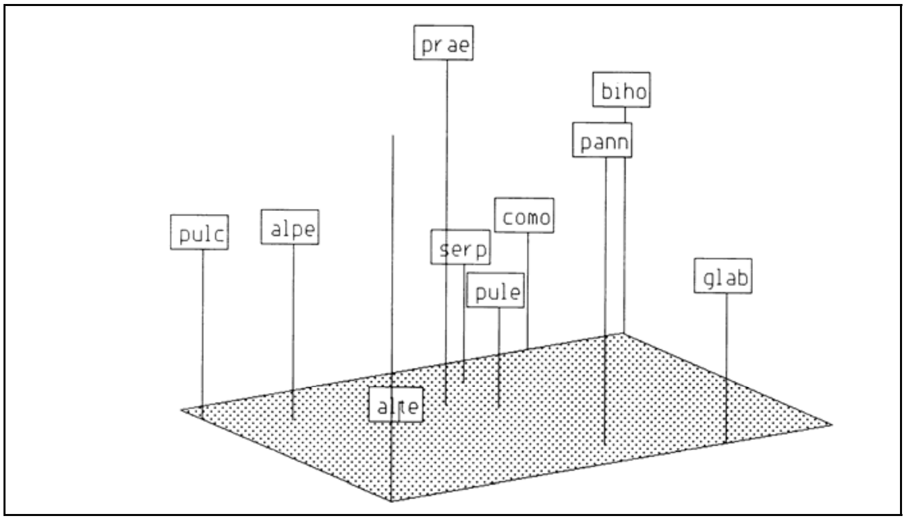

Fig. 1. Projection of species onto the first three principal components. First three axes represent 77.8 % of the total variation. Labels represent first letters of *Thymus* species names.

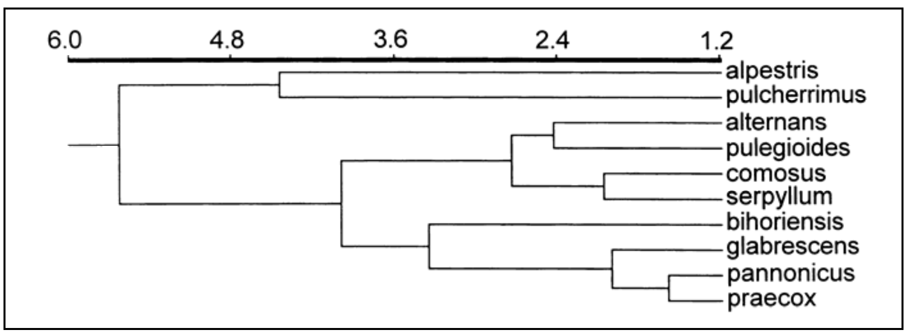

Fig. 2. Dendrogram of UPGMA method on the base of soil chemistry data for *Thymus* species studied.

values there, which is the most conspicious in *T. serpyllum*. Content of available mineral nutrients also varies, but phosporus content reaches the lowest, sometimes even trace values in this group of taxa.

When compared with the above two taxa of groups, the cluster of two mountain taxa, *T. alpestris* a *T. pulcherrimus* differs mainly by a limitation of these taxa to soils with high content of oxidisable carbon, as well as to total nitrogen content (see Tab. 2). Soil reaction is neutral to weak alkaline, carbonate content is shifted to higher values. The range of available mineral nutrient (P, K, Ca, Mg, Na) does not differ substantially from the situation in the previous two clusters.

A comparison with literature data

As it was already mentioned in the introduction, there are not many data on the soil chemistry concerning the genus *Thymus* available. Several partial results for *T. pulegioides* (MÁRTONFI & al. 1994) were included also in this paper. Other data can be compared only when total nitrogen content and soil reaction. ELLENBERG & al. (1991) gives very low indicative values of nitrogen content in the habitats of all the species mentioned (Tab. 1), however, our results point out possible tolerance of the species to the higher nitrogen content in soil. The most of the literature data concern to soil reaction. When the data in the Tab. 1 and 2 are compared, we can state, that literature data corresponds, more or less, with our results. To compare further results we have no literature data available.

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Appendix: List of localities.

Given are: serial number of the locality; description of the locality; date of soil sample collection; species of *Thymus* collected on locality and voucher specimen identification. All the samples, except for the locality no. 24, were collected by P. MÁRTONFI.

1. Slovakia, Slovinky, pasture, west of the village; 16 July 1992; *T. pulegioides,* KO sine no. **2.** Slovakia, Poráč, meadow, south of the village; 16 July 1992; *T. pulegioides,* KO sine no. **3.** Slovakia, Kavečany - Suchá dolina, bushy slope around the road between Košice and Kavečany; 18 July 1992; *T. pulegioides,* KO sine no. **4.** Slovakia, Muráň, meadow, foot of the „Cigánka" hill (935 m); 24 July 1992; *T. pulegioides,* KO sine no. **5.** Slovakia, Muránska Lehota, meadow, north of the village; 24 July 1992; *T. pulegioides,* KO sine no. **6.** Slovakia, Medzev, bushy hillside, northeast of the village, pasture; 26 July 1992; *T. pulegioides,* KO sine no. **7.** Slovakia, Nižná Jedľová, boundary of pasture, northeast of the village; 29 July 1992; *T. pulegioides,* KO sine no. **8.** Slovakia, Kapišová, meadow near th forest, south of the village; 29 July 1992; *T. pulegioides,* KO sine no. **9.** Slovakia, Nová Ľubovňa, pasture, west of the village; 30 July 1992; *T. pulegioides,* KO sine no. **10.** Slovakia, Kolačkov, sands near the „Kolačkovianka" brook; 30 July 1992; *T. pulegioides,* KO sine no. **11.** Slovakia, Skrabské, meadow, north of the village; 7 August 1992; *T. pulegioides,* KO sine no. **12.** Slovakia, Zemplínska Šírava - Kamenec; estate of cottage; 21 May 1993; *T. pannonicus,* KO sine no. **13.** The same as 12; *T. glabrescens,* KO sine no. **14.** Slovakia, Zemplínska Šírava - Klokočov; west of the village; 21 May 1993; *T. glabrescens,* KO sine no. **15.** Slovakia, Košice - Kavečany, below the road to Kavečany; 30 May 1993; *T. pannonicus,* KO 8846; *T. glabrescens,* KO 8848. **16.** The same as 15; *T. glabrescens,* KO 8842. **17.** Slovakia, Košice - Kavečany, slope around the road; 30 May 1993; *T. glabrescens,* KO 8840. **18.** The same as 17; *T. glabrescens,* KO 8830; *T. pannonicus,* KO 8844. **19.** The same as 17; *T. pannonicus,* KO 8835. **20.** Hungaria, Balatonfüred, Tamas-hegy hill, north of Balaton; 29 June 1993; *T. pannonicus,* KO 9245, KO 9260. **21.** Hungaria, Balatonaracs, part of Balatonfüred, Koloska valley, north of Balaton, 29 June 1993; *T. glabrescens,* KO 9253; *T. pannonicus,* KO 9252, KO 9255. **22.** Hungaria, Keszthely, near the road, north-east of the village, 30 June 1993; *T. praecox,* KO 9256, KO 9257; *T. glabrescens*, KO 9264. **23.** Hungaria, Keszthely, „Fagyoskereszt", 30 June 1993; *T. praecox,* KO sine no. **24.** Czech Republic, between Býkev and Cýtov villages, near the railway, 6 July 1993; *T. pannonicus,* KO 9266 (leg. P. Mráz). **25.** Slovakia, Hrabušice, Suchá Belá gorge, 31 July 1993; *T. pulcherrimus*, KO 9247. **26.** Slovakia, Kláštorisko, towards to Malý Kyseľ gorge, 31 July 1993; *T. alpestris,* KO 9246. **27.** Slovakia, Smižianska Maša, limestone rock, 31 July 1993; *T. pannonicus,* KO 8851. **28.** Slovakia, Ladmovce, Šomoš hill (215,7 m), east of the village, 25 August 1993; *T. praecox,* KO 9240, KO 9241. **29.** Slovakia, Ladmovce, on the slope of Šomoš hill, east of the village, 25 August 1993; *T. praecox*, KO 9243, KO 9244. **30.** Slovakia, Zádiel, Zádielsky kameň hill, 7 May 1994; *T. praecox,* KO 9115. **31.** Slovakia, Turňa nad Bodvou, slope of Turniansky hradný vrch hill, 7 May 1994; *T. praecox,* KO 9151. **32.** Slovakia, Nízke Tatry Mts., Demänovská dolina valley, ca. 850 m s. m., at the foot of Siná Mt., 8 September 1994; *T. pulcherrimus,* KO 9153. **33.** Slovakia, Nízke Tatry Mts., north of the Sedlo pod Sinou saddle, ca. 1310 m s. m., 8 September 1994; *T. pulcherrimus,* KO 9154; *T. alpestris*, KO 9156. **34.** Slovakia, Nitra, forest-steppe on the slope of Zobor hill, 2 June 1995; *T. praecox,* KO 9915; *T. pannonicus,* KO 9950. **35.** Slovakia, Nitra, forest-steppe, east of the Plieška (393 m) hill, 2 June 1995; *T. praecox,* KO 9923; *T. pannonicus*, KO 9972; *T. glabrescens,* KO 9969. **36.** Slovakia, Nitra, Žibrica hill, 3 June 1995; *T. praecox,* KO 9903; *T. pannonicus,* KO 9895; *T. glabrescens,* KO 9880. **37.** Slovakia, Nitra, saddle below the Žibrica hill, 3 June 1995; *T. glabrescens,* KO 9876. **38.** Slovakia, Plešivec, Plešivecká planina plateau, ca. 500 m s. m., 8 June 1995; *T. pannonicus,* KO 9863; *T. glabrescens,* KO 9857. **39.** Slovakia, Plešivec, slope of the Plešivecká planina plateau, ca. 410 m s. m., 8 June 1995; *T. pannonicus,* KO 9853; *T. glabrescens,* KO 9852. **40.** Czech Republic, south Moravia, sands near the railway station Bzenec-Přívoz, 2 July 1995; *T. serpyllum,* KO sine no. (PM 1912). **41.** The same as 40; *T. serpyllum,* KO sine no. (PM 1913). **42.** Slovakia, sands near the Sekule village, 4 June 1995; *T. serpyllum,* KO sine no. (PM 1918). **43.** Romania, Munții Cindrelui Mts., near the Păltiniş, 15 July 1995; *T. comosus,* KO sine no. (PM 1950). **44.** Romania, Apuseni, Munții Bihorului, calcareous rocks between the Albac and Scărişoara, 16 July 1995; *T. comosus,* KO sine no. (PM 1951); *T. bihoriensis,* KO sine no. (PM 1963). **45.** The same as 44; *T. bihoriensis,* KO sine no. (PM 1966) **46.** The same as 44; *T. bihoriensis,* KO sine no. (PM 1967) **47.** The same as 44; *T. bihoriensis,* KO sine no. (PM 1968). **48.** Slovakia, path near the Runina village, 31 July 1995; *T. alternans,* KO sine no. (PM 2026); *T. pulegioides,* KO sine no. (PM 2027). **49.** Slovakia, meadow, west of the Runina village; *T. alternans,* KO sine no. (PM 2025); *T. pulegioides,* KO sine no. (PM 2028). **50.** The same as 48; *T. alternans,* KO sine no. (PM 2024).

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