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Morphometric analysis of Polish members of the *Potentilla* subsect. *Collinae* in Poland

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Abstract: Methods of numerical taxonomy, i.e. Cluster Analysis, Principal Component Analysis (PCA), Discriminant Function (DF) and Correspondence Analysis (CA), have been used to analyse 132 Operational Taxonomic Units of *Potentilla* subsect. *Collinae*. Among 53 morphological characters (20 quantitative and 33 qualitative), the most useful appeared following: bent inflorescence, flower diameter**,** width of epicalyx segments, length and width of petal, length ratio of calyx to petals, length ratio of calyx to epicalyx segments, shape of carpel style, presence of basal leaves during flowering, number of leaflets on basal leaves, upper and lower surfaces of leaf blades, pattern of pubescence of calyx, nervation of leaves as well as number and size of teeth of the central leaflet. The following taxa were distinguished in the investigated subsection: *P. collina* Wibel s.str.; *P. thyrsiflora* Hülsen ex Zimmeter; *P. silesiaca* R. Uechtr.; *P. wimannania* Günther et Schummel; *P. leucopolitana* P.J. Müll.; *P. karoi* R. Uechtr. ex Zimmeter; *P. schultzii* P.J. Müll. ex F. W. Schultz; *P. koernickei* R. Uechtr. ex Zimmeter; *P. leucopolitanoides* Błocki; *P.* ×*sholziana* Callier; *P. leucopolitana* P.J. Müller × *P. incana* P. Gaertner, B. Meyer & Scherb.); *P.* ×*tynieckii* Błocki*(P. argentea* L. × *P. leucopolitana* P.J. Müll.).

Key words: *Potentilla collina*; *Rosaceae*; morphometric analysis; Poland

Introduction

The *Potentilla* sect. *Terminales* subsect. *Collinae* Juz. was divided into many units of various rank. Differences in the number of distinct species were related to varying concepts of species as such. In Flora Europaea (Ball et al. 1968) *P.* subsect. *Collinae* is treated as the numbered species *P. collina* (s. lato), under which 12 taxa are listed without numbering and at the species level. On the other hand, Gerstberger (2002) lists 12 taxa within the *P.* subsect. *Collinae* (including one – as a possible "*P. collina*-Sippe"), while Kurtto et al. (2004) lists 14 species in Europe.

In Poland five species, four varieties and forms of the *P.* subsect. *Collinae* have been identified, i.e. *P. collina* Wibel; *P. thyrsiflora* Hülsen ex Zimmeter; *P. silesiaca* R. Uechtr; *P. wimannania* Günther & Schummel; *P. leucopolitana* P.J. Müller; *P. l.* var. *karoi* (Zimmeter) Ascherson et Graebner; *P. l.* var. *schultzii* (P.J. Müller ex F.W. Schultz) T. Wolf, *nom. illeg.* (Art. 32.1 of the Code); *P. l.* var. *schultzii* (*nom. illeg.*) f. *koernickei* (Zimmeter) T. Wolf (Wolf 1908; Szafer & Pawłowski 1955; Mirek et al. 2002; Gerstberger 2002; Kurtto et al., 2004).

Identification of most of the taxa from *P.* subsect. *Collinae* is based on the length ratio of calyx to petals, the number of leaflets on basal leaves, the pattern of pubescence of upper and lower surfaces of leaf blades (Wolf 1908; Ascherson & Graebner 1904–1905; Juzepczuk 1941; Ball et al. 1968; Borhidi & Isépy 1965; Soják 1995). Moreover, in the recent years the morphology of achenes (Kołodziejek & Gabara 2007) in addition to anatomy of leaves (Kołodziejek & Gabara 2003) has been a useful tool in their identification.

However, apart from descriptions of anatomy of achenes and leaves, no morphological studies of *P.* subsect. *Collinae* have been carried out in Poland. Therefore, the aim of the present paper was to analyse in detail the morphological variability of *P.* subsect. *Collinae*, to distinguish and characterise the individual taxa.

Material and methods

Plants of *Potentilla* subsect. *Collinae* originated from the following herbaria in Poland: BP, BREM, KRA, KRAM, KTU, LBL LE, LOD, POZ, PR, PRC, TRN, WA, WSRP, WRSL – for abbreviations see Holmgren et al. (1990). Plants collected in natural environment in Poland were also the object of the present study.

Analysis of 53 morphological characters (20 quantitative and 33 qualitative) described in Table 1 was performed on dried material from 132 individuals.

In numerical analysis, individuals were regarded as Operational Taxonomic Units (OTUs). Some of them were binary (zero-one) and some quantitative or qualitative multistate (Stace, 1989). Leaf dimensions were defined according to description in Fig. 1.

The morphometric analyses of all characters were performed in the following order:

Quantitative characters:

1. Cluster Analysis with Ward's Minimum Variance Cluster method based on City-block (Manhattan) distance.

Table 1. The list of studied characters; binary (two-state) characters are coded as 0 or 1; the values used for qualitative multi-state characters are separated by a semicolon (;) * – quantitative characters.

Number	Characters	Abbreviations
	Shoot	
1	basal leaves during flowering – absent (0), present (1)	BASLEAV
2	shoot branched – below the middle (0); in the middle (1); above the middle (2)	SHOOBR
3*	length of the shoot (in cm)	SHOOLEN
4	inflorescence paniculate-racemose – absent (0), present (1)	INFLORPR
5	inflorescence bent – absent (0), present (1)	IINFLORBE
	Flower	
6*	diameter of flower (in mm)	FLOWDIA
7*	length of petal (in mm)	PETALLEN
8*	width of petal (in mm)	PETALWID
9*	length of calyx (in mm)	CALYXLEN
10*	width of calyx (in mm)	CALYXWID
11	calyx and epicalyx segments – equal (0), calyx twice longer (1)	CALEPIC
12	petals – slightly longer than calyx (0), twice longer (1)	PET
13	epicalyx segments – obtuse (0), acute (1)	EPIC
14*	length of epicalyx segments (in mm)	EPICLEN
15*	width of epicalyx segments (in mm)	EPICWID
16	hairiness of calyx and epicalyx segments – slight (0), hairy (1), dense (2)	SEHAIR
17	carpel style – narrowing towards the stigma (0), not narrowing towards the stigma (1)	CARSH
18	pedicels – raised (0), bent (1)	PED
	Cauline leaves	
19*	length of central leaflet (in mm)	LFLENCAUL
20*	width of central leaflet (in mm)	LFWIDCAUL
21	number of teeth of central leaflet – 2 (0); 3 (1); 4 (2); 5 (3)	TEENCLEA
22	teeth – acute (0), obtuse (1)	TEENCLEA
23	central tooth – smaler in size than lateral (0); equal (1); protruding (2)	CTOOCLEA
24*	length of central tooth of central leaflet (in mm)	CLCTLENC
25*	width of central tooth of central leaflet (in mm)	CLCTWIDC
26*	length of lateral tooth (on the right side) (in mm)	TOOTLLENC
27*	width of lateral tooth (on the right side) (in mm)	TOOTLWIDC
28	edges of leaves – flat (0), curved down (1)	EDCLEA
29	nervation of the lower side of leaves – indistinct (0), distinct (1)	NERCLEA
	Basal leaves	
30	number of leaflets on basal leaves – 5 (0); 5–6 (1); 5–7 (2)	RLEANU
31*	length of central leaflet (in mm)	LFLENBAS
32*	width of central leaflet (in mm)	LFWIDBAS
33	size of teeth – similar (0), different (1)	TEESI
34	teeth directed forward – absent (0), present (1)	TEEDIR
35	teeth – acute (0), obtuse (1)	TBBLEA
36	central leaflet divided – absent (0), present (1)	CLDBLEA
37	central tooth – smaler in size than lateral (0); equal (1); protruding (2)	CTOOBLEA
38	number of teeth on the central leaflet – 2 (0); 3 (1); 4 (2); 5 (3); 6 (4)	TEENBLEA
39	teeth on the central leaflet – irregular (0), regular (1)	CLTEE
40	lower teeth curved downwards – absent (0), present (1)	LTEED
41*	length of central tooth of central leaflet (in mm)	CLCTLENB
42*	width of central tooth of central leaflet (in mm)	CLCTWIDB
43*	length of lateral tooth (on the right side) (in mm)	TOOTLLENCB
44*	width of lateral tooth (on the right side) (in mm)	TOOTLWIDB
45	leaflet upper side – green (0); grey (1); white sericeous (2)	LEAUPPS
46	leaflet lower side – green (0); grey (1); white sericeous (2)	LEALOWS
47	hairiness of upper side of leaflet – slightly hairy (0); hairy (1); densely hairy (2)	LEAUPSH
48	stellate hairs of upper side of leaflet – absent (0), present (1)	LEAUPSST
49	stellate hairs of the lower side of leaflet – absent (0), present (1)	LEALOSST
50	edges of leaves – flat (0), curved down (1)	EDBLEA
51	nervation of the lower side of leaves – indistinct (0), distinct (1)	NERBLEA
52	falcate teeth – absent (0), present (1)	FTBLEA
53	cuneate base of leaves – absent (0), present (1)	CBLEA

The aim of this analysis was preliminary segregation of the material to distinguish groups of studied OTUs.

2. Principal Component Analysis (PCA) based on the correlation matrices for taxa.

3. Discriminant Analysis (DA) classification matrix to evaluate the correctness of *a priori* distribution of OTUs within respective taxa.

Qualitative characters:

4. The qualitative characters were separately analysed with the method of Correspondence Analysis (CA) for the selection of best characters differentiating taxa.

The software package STATISTICA PL. ver. 5 (STATSOFT INC., 1997) was used for all mentioned numerical analyses.

Results

Cluster analysis

On the basis of Cluster Analysis, two main clusters divided into several subclusters were distinguished within the *P. collina* group (Fig. 2). The major OTU cluster on the left-hand side of the graph encompasses tall plants with big flowers (more than 12 mm in diameter), with basal leaves with long, narrow and irregular teeth. The central tooth of basal leaves protrudes further than the lateral teeth. Pubescence of upper leaf surface is weak. In this cluster, starting from left, are included the following taxa: *P. thyrsiflora*, *P. wimannania* and hybrid *P. argentea* × *P. leucopolitana*.

On the other hand, the major cluster on the right-hand side includes shorter plants, with flowers less than 12 mm in diameter and with basal leaves with short, regular teeth. The central tooth of these leaves is equal to or shorter than the lateral teeth. This group includes, starting from right, the following taxa: *P. collina*, *P. leucopolitana*, *P. leucopolitana* × *P. incana, P.* ×*sholziana* and *P. silesiaca*.

Within the *P. leucopolitana* taxa, conspicuous phenetic groups are distinguished which can be classified to the following varieties: *P. karoi*, *P. schultzii* and *P. leucopolitanoides*.

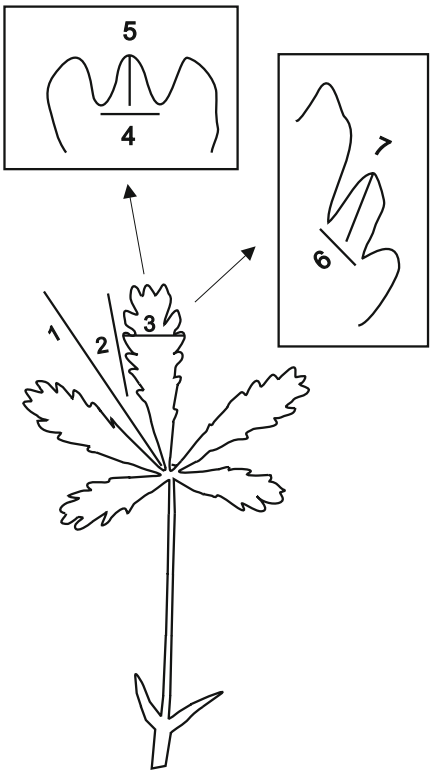

Fig. 1. Method of leaf measurement: 1 – length of central leaflet; 2 – number of teeth; 3 – width of central leaflet; 4 – width of central tooth; 5 – length of central tooth; 5 – width of lateral tooth (on the right side); 7 – length of lateral tooth (on the right) side.

Principal Component Analysis (PCA)

On the basis of PCA, a group of 8 quantitative characters was selected which were most useful to establish differences between studied OTUs (Table 2). The best separation of groups is achieved along PC1 and PC2 axes (Fig. 3). The three component axes, i.e. PC1, PC2 and PC3, explain properly 61% of the total variance: the first component – 31% of the variation, the second – 19% and the third one – 11%. The highest loading value for the first principal component was diameter of flower, length and width of petal; for the second principal component – width of central tooth of central leaflet and length of lateral teeth of basal leaves; while for the third – length and width of epicalyx segments and length of lateral teeth of cauline leaves (Table 2 and Fig. 3).

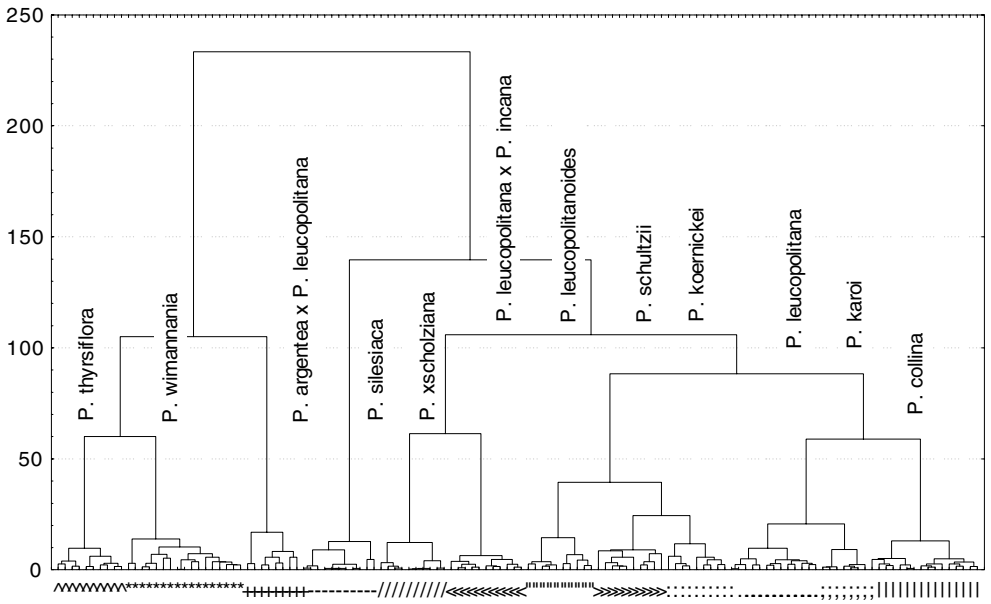

Fig. 2. Phenogram of 132 OTUs (Ward's Minimum Cluster method based on City-block distance) of *P.* subsect. *Collinae* in Poland.

Table 2. Results of the principal component analysis (PCA) for individuals from *P.* subsect. *Collinae* as OTUs – cumulative variance and the loadings of 20 characters for the three first principal components (PC1–PC3). Values given in boldface are the loadings for the characters, which were highly correlated ($r \geq 0.7$) with principal components; see Table 2 for abbreviations of characters.

Principal component	PC1	PC2	PC3
Cumulative variance (%)	30.78	50.08	61.54
Characters (no.)		loadings	
SHOOLEN (3)	0.37	0.24	0.48
FLOWDIA (6)	**0.86**	−0.05	0.26
PETALLEN (7)	**0.92**	−0.04	0.23
PETALWID (8)	**0.86**	0.13	0.36
CALYXLEN (9)	0.56	0.36	0.09
CALYXWID (10)	0.56	0.22	−0.26
EPICLEN (14)	0.37	−0.06	**0.81**
EPICWID (15)	0.31	−0.19	**0.85**
LFLENCAUL (19)	−0.59	0.32	0.31
LFWIDCAUL (20)	−0.23	0.52	0.01
CLCTLENC (24)	0.19	0.39	0.64
CLCTWIDC (25)	−0.22	0.67	0.37
TOOTLLENC (26)	0.07	0.37	**0.75**
TOOTLWIDC (27)	−0.1	0.47	0.22
LFLENBAS (31)	0.44	0.63	0.03
LFWIDBAS (32)	0.12	0.84	−0.06
CLCTLENB (41)	0.01	0.58	0.3
CLCTWIDB (42)	0.03	**0.73**	0.04
TOOTLLENCB (43)	0.12	**0.78**	0.05
TOOTLWIDB (44)	0.13	0.64	−0.1

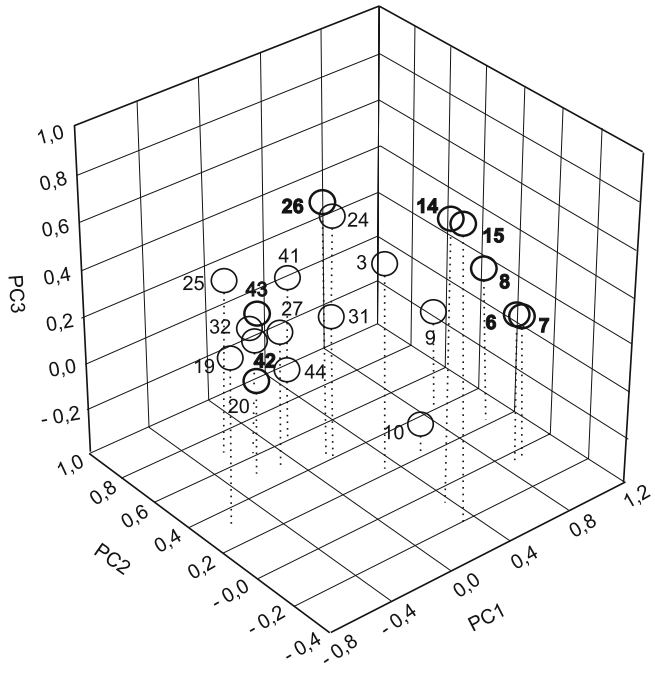

Fig. 3. Principal Component Analysis (PCA) – scatter diagram of 20 quantitative characters along the three first principal components (PC1–PC3). See Table 1 for abbreviations of characters.

Discriminant Function (DF)

Application of discriminant analysis after comparing the observed and predicted classifications using classification matrices (Table 3) has shown significant phenetic coherence of individual OTUs. The percentage consistence in these comparisons equalling 85–100% attests to the high phenetic coherence of taxa. The group of most distinct taxa includes *P. thyrsiflora*, *P. silesiaca* and *P.* ×*sholziana* – for all of them the percentage of correctly classified specimens was 100%. On the other hand, highest variability was shown by the hybrid *P. argentea* × *P. leucopolitana* (71.4% of correctly classified OTUs).

The ordination of OTUs along the first three DFs (Fig. 5a, b) is in concordance with the results of classification. Discriminant Function DF1 differentiates two major groups: 1/ on the left-hand side includes *P. wimanniana*, *P. thyrsiflora* and *P. argentea* × *P. leucopolitana*, while 2/ on the right-hand side – the remaining 7 taxa.

DF2 in its turn represents the phenetic distinctiveness of *P. collina* which is a taxa of high phenetic coherence which reaches a value of 93.75% correctly classified OTUs in the investigated material, while DF3 represents the phenetic distinctiveness of *P. leucopolitana* × *P. incana* with 100% phenetic coherence in the investigated material (Table 3).

Correspondence Analysis (CA)

On the basis of the correspondence analysis, 14 characters of shoot, flower, cauline and basal leaves useful for differentiation and description of variability within morphological groups were selected.

Lack of basal leaves during flowering (which appear later) is a character which distinguishes *P. collina* from all remaining taxa. A bent inflorescence and basal leaves with 7 leaflets are characteristic for *P. silesiaca.* In *P. wimannania*, the calyx is twice longer than the epicalyx, while in the remaining taxa the calyx and the epicalyx are nearly equal in length. Distinct nervation of leaves is characteristic for P. *argentea* × *P. leucopolitana* and *P.* ×*sholziana*, while inconspicuous nervation – for *P. collina*, *P. thyrsiflora*, *P. silesiaca* and *P. leucopolitana.* A trait which distinguishes *P. thyrsiflora* and *P. wimanniana* from other taxa is the arrangement of teeth on leaflets. In *P. thyrsiflora* the lower teeth are curved downwards, while in *P. wimannania* – they are directed forward. The number of teeth on the leaflets proved to be most reliable. The leaflets of *P. silesiaca* and *P. thyrsiflora* have 3 to 7 pairs of teeth, whereas those of *P. leucopolitana*, *P. collina* and *P. wimannania* – 2 to 4 pairs. Furthermore, densely sericeous pubescence on leaf blade and calyx as well as central teeth of basal leaves shorter than lateral teeth are distinguishing characters for *P. leucopolitana.* The graphical presentation of variability for individual characters obtained from this analysis is presented in Fig. 4.

Discussion

In the present paper the apomict microspecies (pseudogamous apomict) concept was adopted. The microspecies, i.e. a small, isolated genetically, localized

Table 3. Discriminant Function Analysis (DFA) classification matrix of 132 OTUs from the *P.* subsect. *Collinae* in Poland; observed classification based on a priori grouping, predicted – on DFA.

Discriminant Analysis	Classification matrix – observed vs. predicted classification													
Taxon	correctly classified (%)	1	2	3	4	5	6	7	8	9	10	11	12	Total (observed)
1. *P. collina*	93.75	15	0	0	0	0	0	0	0	0	0	0	1	16
2. *P. thyrsiflora*	100.00	0	8	0	0	0	0	0	0	0	0	0	0	8
3. *P. silesiaca*	100.00	0	0	11	0	0	0	0	0	0	0	0	0	11
4. *P. wimannania*	85.71	0	0	0	24	0	0	0	0	0	0	0	4	28
5. *P. leucopolitana*	90.91	0	0	0	0	10	0	0	0	0	0	0	1	11
6. *P. karoi*	89.47	0	0	0	0	2	17	0	0	0	0	0	0	19
7. *P. schultzii*	90.00	0	0	0	0	1	0	9	0	0	0	0	0	10
8. *P. koernickei*	100.00	0	0	0	0	0	0	0	3	0	0	0	0	3
9. *P. leucopolitanoides*	85.71	0	0	0	0	0	0	0	0	6	0	0	1	7
10. *P. leucopolitana* × *P. incana*	100.00	0	0	0	0	0	0	0	0	0	6	0	0	6
11. *P.* ×*scholziana*	100.00	0	0	0	0	0	0	0	0	0	0	4	0	4
12. *P. argentea* × *P. leucopolitana*	71.43	1	0	0	0	0	1	0	0	0	0	0	5	7
Total (predicted)	92.25	16	8	11	24	13	18	9	3	6	6	4	12	130

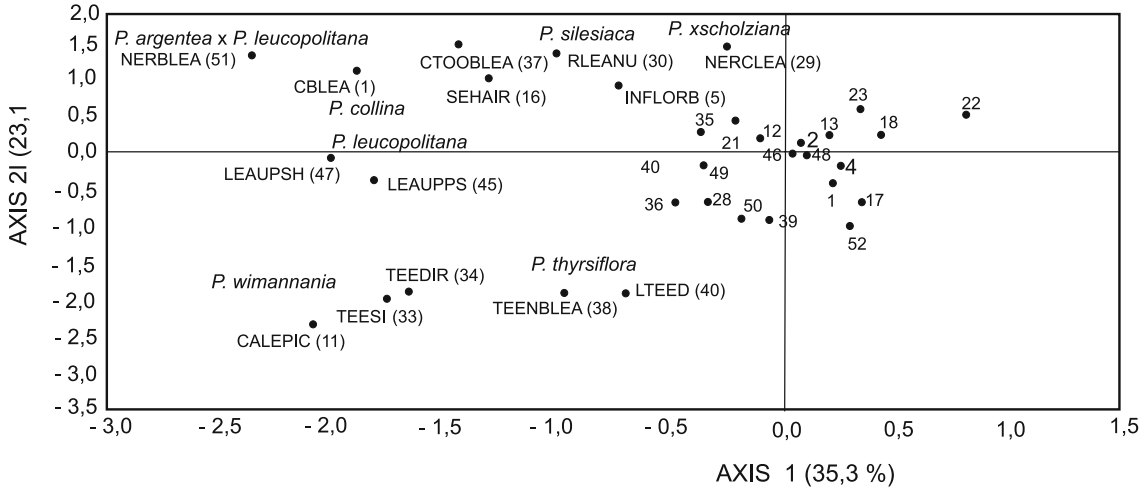

Fig. 4. Correspondence Analysis (CA) – scatter diagram of *P.* subsect. *Collinae* and selected qualitative characters along the first and second axis. See Table1 for abbreviations of characters.

species population that is clearly differentiated from related taxa, is treated as 'taxonomic" species. The circumscribing of a given microspecies relies mainly on mode of reproduction criterion, supplement (and also verified) by other criteria, as morphological, geographical, cytogenetical and molecular.

As a result of the numerical analysis conducted on 132 specimens from *P.* subsect. *Collinae* as well as critical review of taxonomic concepts, the following taxa from this group may be distinguished in Poland: *P. collina* Wibel s.str.; *P. thyrsiflora* Hülsen ex Zimmeter; *P. silesiaca* R. Uechtr.; *P. wimannania* Günther et Schummel; *P. leucopolitana* P.J. Müll.; *P. karoi* R. Uechtr. ex Zimmeter; *P. schultzii* P.J. Müll. ex F. W. Schultz; *P. koernickei* R. Uechtr. ex Zimmeter; *P. leucopolitanoides* Błocki; *P.* ×*sholziana* Callier; *P. leucopolitana* P.J. Müller × *P. incana* P. Gaertner, B. Meyer & Scherb.); *P.* ×*tynieckii* Błocki *(P. argentea* L. × *P. leucopolitana* P.J. Müll.). Only *P. leucopolitana* P.J. Müller × *P. incana* P. Gertner, B. Meyer & Scherb has not been found in the territory of Poland yet.

Among the above-mentioned taxa, the most variable is *P.* leucopolitana s. lato (incl. *P. karoi*, *P. schultzii* and *P. leucopolitanoides*). The number of leaflets in basal leaves, arrangement of leaflet teeth and strongly sericeous hairiness of leaves are determinant characters for this taxa. *P. karoi* has 2–3 characteristically short and obtuse teeth, while *P. schultzii* has longer, narrower and more pointed teeth than *P. leucopolitana* var. *karoi*.

A very interesting and questionable taxa is *P. koernickei* Uechtritz ex Zimmeter. Plants belonging to this taxa were found for the first time in 1863 by Körnicke near Królewiec (Königsberg). Using seeds collected on this occasion, Uechtritz cultivated plants which he identified (not knowing the wild-growing parent plant) as *P. koernickei* Uechtritz Herb. (Wolf 1908). Morphologically similar plants were collected by Hohefeldt in 1885 on a railway embankment in Czarna Woda (Schwarzwasser). Plant specimens originating both from Królewiec and Czarna Woda, presenting leaf blade teeth that are long, typical for *P. schultzii*, and

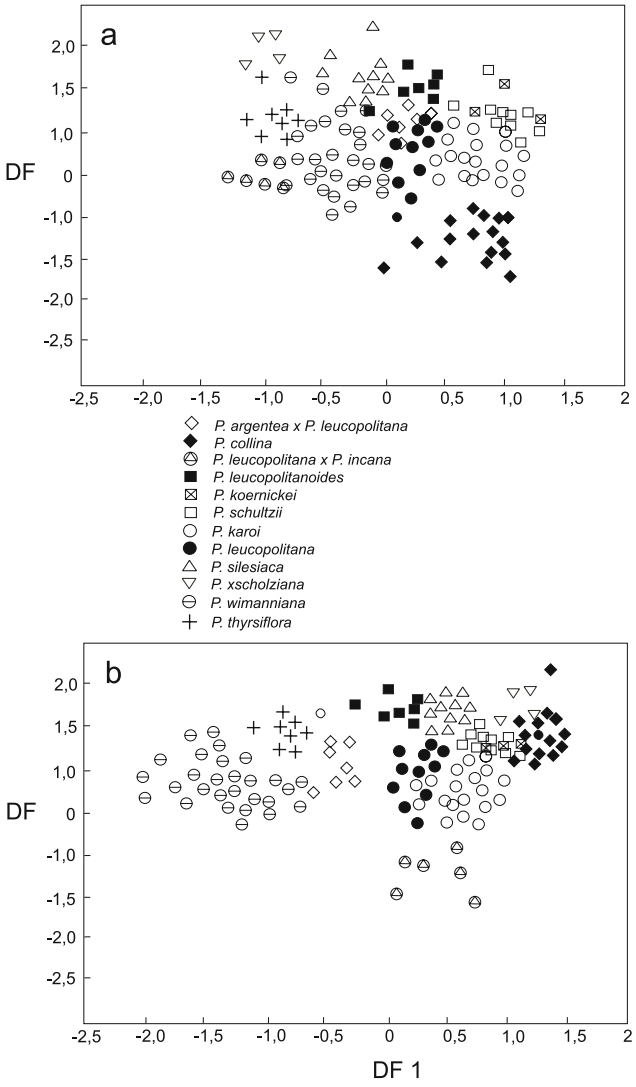

Fig. 5. Numerical analysis of 132 OTUs of *P.* subsect. *Collinae*: a – Discriminant Function 1 – DFs1 and DFs2; b – DFs1 and DFs3.

obtuse, typical for *P. karoi*, seem to be an intermediate form between these two species (Wolf 1908). However, based on numerical analysis, the specimens (OTUs) originating from Czarna Woda as well as ones collected by the author of the present study (see Appendix) were identified as a separate species – *P. koernickei.*

Potentilla vockei P.J. Müll. ex F.W. Schultz is a source of taxonomic problems. The taxa collected by A. Vocke in 1857 (cf. Vocke 1857) in the vicinity of Nieborów near Łowicz was identified by P.J. Müller as P. *leucopolitana* var. *schultzii*, while Schultz (1858) in his Herbarium norm. Cent. 3 described this taxon as *P. vockei* (number 254) or *P. schultzii* (number 255b). After analysing plants, described from the *locus classicus* in Nieborów (collected by Vocke in 1857), originally determined as *P. vockei* (PRC, BP 165441) and as *P. schultzii* (BP 165442, 165443), due to the lack of characters typical for *P. vockei*, i.e. 7–leaflet basal leaves with a divided central leaflet. In my opinion they belong to *P. schultzii.*

A relatively weakly variable taxa is *P. thyrsiflora* which may be distinguished from the closely related *P. leucopolitana, P. wimanniana* and *P. silesiaca* by its branched paniculate-racemose inflorescence and especially by its large, oblong, wedge-shaped leaflets with slightly downward-curved teeth. Furthermore, in *P. thyrsiflora* the leaf blade which is intensely green in colour is also nearly naked on the top surface.

The conducted numerical analysis made it possible to additionally distinguish hybrid taxa (nothotaxa), i.e. *P.* ×*sholziana* (*P. argentea* × *P. silesiaca*), *P. argentea* × *P. leucopolitana* and *P. leucopolitana* × *P. incana*. The emergence of nothotaxa between the taxa from the *P. argentea* and *P. incana* and taxa from the *P.* subsect. *Collinae* is confirmed by experiments carried out by the author (Kołodziejek, unpbl.). However, artificial hybridisation did not result in obtaining plants morphologically similar to taxa from the *P.* subsect. *Collinae*, in accordance with results by other authors (Müntzing 1928, 1958; Asker 1966, 1967, 1970). Natural hybrids between taxa in the investigated *P.* subsect. *Collinae* are also infrequent (Wolf 1908). The limiting factor for their emergence may be the low percentage of viable pollen grains in the anthers of taxa from this subsection (Kołodziejek & Gabara, unpbl.) as well as the geographical isolation of individual taxa which prevents an unrestrained exchange of genes (Kołodziejek, unpbl.).

The hybrid which occurs most frequently in Poland is *P. argentea* × *leucopolitana*. The size of leaves and irregular teeth on leaflets with a distinctly protruding central tooth makes these plants similar to *P. argentea*. On the other hand, hairs which occur abundantly in this hybrid make it similar to *P. leucopolitana*. Individuals found in the Częstochowa Upland where they grew among *P. leucopolitana* and *P. incana* were determined to be hybrids between these taxa since they have intermediate characters between them. Their strong sericeous pubescence makes them similar to *P. leucopolitana*, while their short central tooth, numerous stellate hairs and prostrate shoots resemble *P. incana*.

According to literature, the petals of *P. wimannania* and *P. thyrsiflora* are twice as large as the sepals, while those of *P. leucopolitana* are only slightly larger than the calyx (Zimmeter 1884; Wolf 1908). However, the ratio of calyx to petals is not constant. There are also *P. thyrsiflora* forms with smaller petals and *P. leucopolitana* forms with larger flowers (Borhidi & Isépy 1965).

The analysis presented in this paper indicates that the most variable characters in the *P.* subsect. *Collinae* are height of plants and size of leaves, therefore these traits cannot be of much use in taxonomy. On the other hand, characters such as flower size, plant pubescence, leaf shape, teeth arrangement on the leaf blade (number and shape of teeth), are only slightly subject to the influence of growth environment and are therefore strongly dependent on the genotype.

In summary, it can be concluded that the most useful characters appeared to be characters were found to be: bent inflorescence, flower diameter, width of epi-

calyx segments, length and width of petal, length ratio of calyx to petals, length ratio of calyx to epicalyx segments, shape of carpel style, presence of basal leaves during flowering, number of leaflets on basal leaves, pattern of pubescence of upper and lower surfaces of leaf blades, pattern of pubescence of calyx, nervation of leaves as well as number and size of teeth of the central leaflet.

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Appendix

***Potentilla collina* Wibel s. str.**

[BD17]* Ludwikowo pod Poznaniem, zbocze nad Jeziorem Góreckim, za restauracją, 24.5.1930 and 21.5.1933, F. Krawiec (POZ ?). – [BD43] W lesie sosnowym k. Olejnicy powiat Wolsztyn, 14.6.1932, J. Paczoski (POZ ?). – [BE84] Mościsko powiat Dzierżoniów, łąka na północ od wsi, 28.5.1964, E. Kuźniewski (KRAM 288644). – [DD76] Łódź-Julianów, łąka, 15.6.1968, B. Trzepałkowska (LOD ?). – [DE18] Lubiaszów powiat Piotrków Trybunalski, śródleśna łąka, 7.10.1972, W. Walkiewicz (LOD 001492). – [DE23] Uroczysko Łęczna, gmina Sulejów, bór mieszany sosnowy świeży, 20.5.1977, G. Piwowarska (LOD 032031). – [DE52] Zalesiaki koło Działoszyna, suche, piaszczyste przydroże na skraju boru sosnowego (licznie), 3.6.1966, R. Sowa (LOD ?). – [DE62] Wapienne wzgórze na północ od Łobodna gmina Kłobuck, 25.5.1957, J. Śledziona (KTU 041358). – [DE73] Kłobuck-Smugi 50°46′31″N/19°16′15″E, 20.5.2000, J. Kołodziejek (LOD ?). – [DE84] Rez. "Zielona Góra", skałki, 14.5.1983, A. Sendek (KRAM 343471). – [DF17] Ogrodzieniec pow. Zawiercie, 20.6.1974, K. Rostański (KTU 027927). – [DF22] Rogoźnik powiat Będzin, trawnik przy ośrodku rekreacyjnym, 25.5.1974, K. Jędrzejko (KTU 041358); [DF35] Stare Elaszki k. Sosnowca, murawa piaszczyskowa, 24.5.1977, A. Sendek (KRA 0138358). – [DF60] Żory k. Rybnika, mokradło nad Śmieszkiem, 19.6.1931, J. Gałuszka (KTU 033788). – [ED22] Wilanów pod Warszawą, 19.5.1882, K. Łapczyński (WA 060005). – [ED35] Pęcice k. Pruszkowa, 18.5.1963, M. Gęgała (WA 063693).

***Potentilla thyrsiflora* Hülsen ex Zimmeter**

[BC68] Flora von Posen 6667, Oborniki, Kiejernwalde bei Reisen, 8.6.1895, ?. (POZ ?). – [BD56] Fl. Silesiaca Exs. no. 1042, Lissa: Kiejernwalde bei Reisen (*P. leucopolitana* var. *pliodonta* T. Wolf, *rev.* J. Kołodziejek), 20.7.1894, A. Callier (BP 167321). – [DF17] Ogrodzieniec, wypasane murawy na skalistym zboczu wapiennym, 15.6.1953, B. Pawłowski (KRAM-Pawłowski 117757). – [DF22] Wojkowice Komorne-Żychcice, murawa kserotermiczna k. torów kolejowych, 22.6.1976, A. Sendek (KRA 0138354, KTU 034430). – [DF24] Ostra Góra k. Siewierza 50°25′37″N/19°08′57″E, alt. 345 m, xerothermic grass, 25.5.1999, J. Kołodziejek (LOD ?). – [DF27] Cisowa k. Pilicy 50°26′56″N/19°42′23″E, murawa kserotermiczna, 5.6.2001,

J. Kołodziejek (LOD ?). – [EE63] Polonia: in arenosis (Juniperalis) inter opp. Kielce et Bialogon, (*P. thyrsiflora* subsp. *leucopolitanoides*(Błocki) Borhidi & Isépy, *rev.* J. Kołodziejek), 13.8.1927, G. Moesz (BP 165388).

***Potentilla silesiaca* R. Uechtr.**
[AE48] Löwenberg in Silesia: H. Siegfriedii Exsiccatae Potentillarum spontanearum culturamque. Planta culta exsicc. no. 134, 5.6.1889, H. Siegfried (BREM ?); E. F. Dresler 19.5.1888 (B 1001892). – [BD86] Prov. Posen: bei Bojanovo: "Grüner Garten", Sandhuegel, ?.5.1884, C. Scholz (LE ?). – (BE36) Breslau, Spitzberg: Nimkau und Nippern, etwa 150 m, C. Baenitz, Herbarium Europaeum 7416, 26.5.1893, C. Baenitz (KRAM 139681); H. Siegfriedii, Exsiccatae Potentillarum spontanearum culturamque. Planta spontanea exsicc. no. 134a, 28.6.1863, R. Uechtritz (PR); C. Baenitz Herbarium Europaeum no. 7416, 12.5.1893, C. Baenitz (B ?, KRAM 139681, KRA 47880); Callier Fl. Siles. Exs. no. 347, 5.6.1891, A. Callier (B ?); Flora von Breslau, 6.1969, A. Engler (KRA 47882); 5.1866; R. Uechtritz (PR ?).

Potentilla wimanniana Günther et Schummel
[BD85] W rowie przy szosie, ok. 0.8 km na pd.-wsch. od wsi Luboszyce powiat Góra Śląska, 1.6.1967, J. Mądalski (KRAM 487312). – [BE11] Haynau: Michelsdorf, 19.5.1910, T. Schube (PR). – [BE48] C. Baenitz Herbarium Europaeum, Oder bei Breslau, 25.5.1892, C. Baenitz (PR ?); C. Baenitz, Herbarium Europaeum, Oder bei Breslau, 25.5.1893, C. Baenitz (BP 167782); Fl. Siles. Exs. no. 192; Breslau bei Carlovitz, ?.5.1890, A. Callier (BP 167787); F. Schultz Herb. norm. Cent. 7 (bis), Oder bei Breslau, 28.5.1861, E. Fiek (BP 16786); Flora von Schlesien, Oder bei Breslau, ?.5.1866. R. Uechtritz (PR); F. Schultz. Herb. norm. Cent. 5, Breslau, Günther (BP 167795); H. Siegfriedii Exsiccatae Potentillarum spontanearum cultarumque, Planta spontanea exsicc., Silesia: locis graminosis siccis ad 'Carlovitz" prope Vratislaviensis, 21.5.1894, A. Callier (BP ?). – [BE83] Friedland: sonnige Abhange bei Langwaltesdorf, in collibus arenosis, 16.6.1875, E. Fiek (BP 167775, BP 167800). – [BE88] Księginice powiat Strzelin, 19.5.1970, J. Mądalski (KRAM 487308). – [CA79] Flora der Provinz Westpreussische, Danzing, 16.6.1854. Klinsmann (TRN ?). – [CB89] Chełmno: Schemlau, 11.7.1901, Fr. A. Ahlfvengren (TRN ?). – (CC16) Na skraju lasu koło Rynkowa, na północ od Bydgoszczy, 25.5.1931, F. Krawiec (POZ ?). – [CC39] Westpreussiche Provinzial Museum, Toruń, 20.5.1894, C. Scholz (TRN ?). – [CC80] Dziewicza Góra pod Poznaniem, młody zagajnik sosnowy na północny-zachód od leśniczówki wojskowej, 10.5.1934, W. Alkiewicz (POZ ?). – [CE50] Czechnica k. Wrocławia: trawiaste zbocze wału przeciwpowodziowego nad rzeką Oławą, 12. 6.1970, E. Kozioł (POZ 1005, WA 069890, KRAM 211482, WRSL ?). – [CE72] Gierszowice powiat Brzeg, śmietnisko i wykop na północny-wschód od wsi tuż przy szosie, 16.5.1963, M. Ciaciura (KRAM 288943, det/rev. Th. Gregor). – [DA92] Luszkówko k. Pruszcza Gdańskiego, 6.1891, G. Grütter (TRN ?). – [DE73] Wyżyna Częstochowska: Kusięta 50°46′09″N/19°15′16″E, murawa kserotermiczna, 11.5.2000, J. Kołodziejek (LOD ?). – [DE95] Wyżyna Częstochowska: Zaborze k. Olsztyna 50°40′81″N/19°20′00″E, alt. 362 m, murawa kserotermiczna, 28.6.2002, J. Kołodziejek (LOD ?). – [DF06] Wyżyna Częstochowska: Mirów 50°37′37″N/19°28′44″E, alt. 415 m, murawa kserotermiczna, 22.6.2002, J. Kołodziejek (LOD ?).

***Potentilla leucopolitana* P.J. Müller**
[CA49] Flora der Provinz Westpreussische, Puck, 15.6.1895, Schraebner (TRN ?). – [CC16] Maksymilianów k. Bydgoszczy 53°51′94″N/18°06′47″E, alt. 155 m, 23.7.2002, J. Kołodziejek (LOD ?). – [DF06] Skałki Kroczyckie k. Kroczyc, 15.6.1953, B. Pawłowski (KRAM-Pawłowski 322241). – [DF27] Podzamcze gm. Ogrodzieniec, murawy naskalne, 10.10.1989, A. Sendek (KRAM 364074). – [DF27] Cisowa k. Pilicy (*P. collina* Wibel, *rev.* J. Kołodziejek), murawa naskalna, 5.8.1980, A. Sendek (KRAM ?). – [DF49] Okolice Ojcowa, dolina Prądnika (*P. collina* Wibel, *rev.* J. Kołodziejek), murawa *Origano-Brachypodietum*, 17.8.1964, S. Michalik (KRAM 454444). – [ED28] Falenica k. Warszawy (*P. argentea* L., *rev.* J. Kołodziejek), łąka, 3.10.1972, E. Sypniewska (LOD ?). – [ED30] Rudzienko k. Otwocka, 20.6.1996, M. Makos (WSRP 078645). – [EE38] Pakosław koło Iłży, wzgórze na skraju torfowisk koło dworca, 15.6.1953, B. Pawłowski (KRAM-Pawłowski 329751). – [EF62] Puszcza Niepołomicka, Grodkowice, 21.5.1953, J. Staszkiewicz (KRAM 407677). – [EG30] Szaflary, wzgórze wapienne (z krzyżem) trawiaste, krzaczaste zbocze, 03.07.1952, B. Pawłowski (KRAM-Pawłowski). – [GF15] Lubelszczyzna, pow. Tomaszów Lubelski, Jarczów, miedza, (*Potentilla argentea* L., *rev.* J. Kołodziejek), 16.7.1957, T. Kuszpit (LBL ?).

Potentilla karoi R. Uechtr. ex Zimmeter
[AD17] Łagów k. Świebodzina, 31.5.1870, J. Golenz (BP 165710). – [AE38] Lwówek Śląski, 19.5.1888, E.F. Dresler (BP ?, POZ ?). – [BD19] Kórnik, 1885, H. Poeverlein (POZ ?). – [CA49] Flora der Provinz Westpreussische, Puck, 15.6.1895, Klinggraeff (TRN ?). – [CB15] Flora der Provinz Westpreussische, Kościerzyna, 21.5.1915, Kolkreuth (TRN ?). – [CC90] Herbarium der Provinz Posen no 6649, Biskupice k. Gniezna, 1885, H. Poeverlein (POZ ?). – [CD75] Herbarium der Provinz Posen no 6671, Kórnik, 1885, H. Poeverlein (POZ ?). – [DA70] Flora der Provinz Westpreussische, Gdańsk, 31.5.1922, W. Wangein (TRN ?). – [DA80] Gdańsk Ginsterberge zwischen Brentau und Pietzhendorf, 31.05.1922, W. Wangein (TRN ?). – [DB52] Flora der Provinz Westpreussische, Kwidzyn, 5.6.1874, W. Klinggraeff (TRN ?). – [DE74] Z flory Królestwa Polskiego, Krzyżowa Góra k. Częstochowy, 18.6.1876, F. Karo (BP 165412). – [DE83] Closter Częstochowa, 18.6.1874, F. Karo (WA 060016). – [EB52] Olsztyn, 1922, R. Kobendza (WA 060000). – [ED25] Warszawa, park w Aninie, 20.6.1986, Skowrońska (WA 1279). – [ED39] Celestynów k. Warszawy, 21.7.1925, H. Juraszkówna (WA 060023). – [GD00] Łosice k. Siedlec, 5.5.1873 and 1894, F. Karo (PR ?, BP ?). – [GE65] Czantoria k. Grabowca, słoneczne zbocza, 9.5.1973, D. Fijałkowski (LBL ?).

***Potentilla schultzii* P.J. Müll. ex F.W. Schultz**
[BC46] Herbarium der Provinz Posen no. 6659, Czarnikau, 1886, Pfuhl (POZ ?). – [CC39] Westpreussiche Provinzial Museum, Thorn: Stadtwald, 20.5.1894, C. Scholz (TRN ?). – [DA70] Flora der Provinz Westpreussischen, Gdańsk, suche skraje lasów koło Oliwy, 28.5.1883, Wacker (TRN ?). – [DF49] Okolice Ojcowa: dolina Prądnika, k. odgałęzienia szosy do Skały, murawa naskalna *Festucetum pallentis*, 10.7.1959, S. Michalik (KRAM 454445). – [ED30] F. Schultz Herb. norm. Cent. 3. no. 255, dans les sables au bord d'une foreţ de pins sur le diluvium pręs de Niebarow (Nieborów) arrondissement de Lowic (Pologne), 3 juin et 25 juillet 1857, A Vocke (PRC ?, BP 165431, BP 165442, BP 165443). – [ED35] Pęcice, murawa w parku, 30.7.1968, K. Nowak (WA 076255).

***Potentilla koernickei* R. Uechtr. ex Zimmeter**
[CB47] Westpreussichen Provinzial Museum, Kr. Stargard, Schwarzwasser, am Bahndamm (*P. wimanniana*, *rev.* J. Kołodziejek), 9.6.1885, Hohefeldt (TRN ?); Czarna Woda k. Czerska, nasyp kolejowy przy dworcu kolejowym 53°51′56″N/18°06′27″E, 12.8.2004, J. Kołodziejek (LOD ?).

***Potentilla leucopolitanoides* Błocki**
[BD08] Herbarium der Provinz Posen 6652, Poznań, 27.6. 1897, H. Poeverlein (POZ ?). – [BD56] Callier Fl. Siles. Exs., Lissa prov. Posen: Kiejernwalde bei Reisen, 20.7.1894, (BP 167321). – [CA69] Westpreussiche Provinzial Museum, Neustadt: Abhange bei Pogorsh,16.6.1882; Westpreussiche Provinzial Museum, Neustadt: Adlershorst, 3.6.1883, W. Klinggraeff (TRN ?). – [DF06] Wyżyna Częstochowska: Kroczyce, murawa kserotermiczna, 23.7.2001 and 24.7.2001, J. Kołodziejek (LOD ?). – [EE16] Herbarium T. Tischevsky, Flora Polonica, Powonkowzkij Poligon, w lesie sosnowym przy szosie, 13.5.1912, P. Tischevsky (LE ?).

***Potentilla* ×*scholziana* Callier (*P. argentea* L. × *P. silesiaca* R. Uechtr.)**
[BD56] Reisen bei Lissa, 13.6.1894, C. Scholz (LE ?). – [BD86] "Grünen Garten", Sandhügel bei Pakowko, 6.1891 (LE, KRAM). – (BE36) Spitzberg: Nimkau und Nippern, 26.5.1893, C. Baenitz (LE ?).

***Potentilla* ×*tynieckii* Błocki (*P. argentea* L. × *P. leucopolitana* P.J. Müll.)**
[DF06] Mirów 50°37′29″N/19°28′34″E, murawa kserotermiczna, 27.7.2003, J. Kołodziejek (LOD ?). – [DF17] Krzywopłoty k. Olkusza, 30.7.1981, A. Sendek (KRAM 296926). – [ED25] Warszawa (*P. col*lina Wibel, *rev.* J. Kołodziejek), 6.5.1978, B. Sudnik (WA ?). – [ED39] Celestynów, słoneczne zbocze wydmy, 20.07.1925, H. Juraszkówna (WA ?). – [EE77] Łagów powiat Opatów, suche zbocza na wapieniu, 5.6.1964, H. Piękoś and A. Jasiewicz (KRAM 420039). – [EG00] Beskid Wyspowy Czarny Dział, Mszana Dolna, alt. 600 m, 11.5.1968, B. Pawłowski (KRAM-Pawłowski 338329). – [GE63] Czantoria k. Grabowca (*P. collina* Wibel, *rev.* J. Kołodziejek), 9.5.1973, D. Fijałkowski (LBL ?).

***Potentilla leucopolitana* P.J. Müller × *P. incana* P. Gaertner, B. Meyer & Scherb.**
DE95] Częstochowska Upland: Jaroszów near Żarki 50°39′ 21″N/19°21′33″E, alt. 315 m, xerothermic grassland, 28.5. 2003, 12.6.2004, J. Kołodziejek (LOD ?); Zaborze near Żarki 50°40′31″N/19°20′00″E, alt. 333 m, xerothermic grassland, 3.6.2003, 17.7.2007, 14.6.2004, 30.6.2004, J. Kołodziejek (LOD ?).

* – cartographic square in Poland – ATPOL (Zając, 1978); ? – no data