Taxonomic reliability of leaf and fruit morphological characteristics of the *Pyrus* L. taxa in Slovakia

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ABSTRACT: A population of 1,149 pear individuals from Slovakia is analysed according to their morphological characteristics of fruits and leaves. Three basic taxa were identified – *Pyrus pyraster*, *Pyrus amphigenea* and *Pyrus nivalis*. Qualitative traits (shape of leaf blade, fruit shape, type of leaf or fruit base, etc.) allowed the exact identification of a particular taxon only in some cases. Quantitative characteristics of leaves proved to be more suitable for the identification of analysed taxa. Statistically significant differences were found between all studied taxa in the values of leaf length and width, and also in the values of relative characteristics that described the leaf shape. Exceptionally the length of leaf petiole had very variable values ($S_{x\%}$ = 25.70–29.75%), therefore it was impossible to classify the species according to this character. Generally, fruit shapes and dimensions are less representative for taxonomy use although significant differences between all studied taxa were found in the values of fruit length. The correct taxonomic classification of pears cannot be done according to one characteristic. It is important to consider a few of them (shape and length of leaf blade or its slenderness, shape quotients and also the shape and length of fruits) for the appropriate classification of pear individuals.

Keywords: *Pyrus* L.; taxa; classification; leaves; fruits; morphological characteristics

In the last decade in European countries attention was already paid to rare woody plants in connection with expected changes of global climate. These were such woody plants that are able to grow in rather warm and arid environmental conditions. Wild pear (*Pyrus* L.) is one of these woody plants. It is a significant but scattered component of rural landscape and of woodland communities (ROLOFF 1998).

In 1994–1999, 64 experimental plots were established in Slovakia where pear occurred more frequently. A comparatively large scope of problems was studied on obtained data: pear requirements for environmental conditions (PAGANOVÁ 2003a), its growth abilities (PAGANOVÁ 2001), production qualities of pear populations and occurrence of lower taxa of this genus (PAGANOVÁ 2003b).

This material allowed to evaluate statistical significance of the morphological characteristics of leaves and fruits within the taxonomic identification of *Pyrus pyraster* (L.) BURGSD., *Pyrus nivalis* JACQ. and *Pyrus* × *amphigenea* (DOMIN, DOSTÁL in DOSTÁLEK 1989). These taxa were found in the territory of Slovakia. Great attention has been paid to the evaluation of generative pear progenies within the data collection.

Scope of problems

Three lower taxa of the genus *Pyrus* L. are mentioned according to PENIAŠTEKOVÁ (1992) in Slovakia: *Pyrus nivalis* JACQ., *Pyrus pyraster* (L.) BURGSD. and *Pyrus communis* L.

Among the mentioned taxa, *Pyrus nivalis* JACQ. is quite easily identified according to the morphological characteristics of leaves. Its leaves are elongate obovate, elliptic or even lanceolate, with entire leaf margin. They have the acute leaf base and in maturity they are white pubescent (PENIAŠTEKOVÁ 1992; TERPÓ 1960; KRÁLIK 1994).

In some cases it is rather difficult to identify wild pear *Pyrus pyraster* (L.) BURGSD. and common pear *Pyrus communis* L. emend. BURGSD.

WAGNER (1995) compiled all known and published information, results of research work, measured data and experiences of experts from various institutions. He elaborated a table of characteristics that are suitable for the identification of vegetative organs, fruits, shoots, leaves and also blooms of both these pear taxa.

Identification is complicated due hybridisation between cultivated pear sorts and wild pear (*Pyrus pyraster*). Progenies or half-cultivated individuals of hybrid origin are called naturalised pears. Such additional multi-hybridisation induces certain variability of plant habit, leaf shape and fruits of *Pyrus pyraster*. It is possible to study a conversion of wild pear to cultivated pear sorts within this morphological variability. Therefore it is more and more complicated to identify a bondary between cultivated pear sorts, naturalised plants and wild pear (TERPÓ 1960). In the Czech territory DOMIN (1944) described pear hybrids (*Pyrus communis* subsp. domestica × *Pyrus communis* subsp. *pyraster*) under the name *Pyrus* × *amphigenea* DOMIN. They were identified as wild growing plants without thorns, with widely ovate

leaves, pear-shaped fruits and short fruit petioles. Mature fruits are acerb and they are edible only after stagnation. Hybrid fruits have smaller dimensions than those of the cultivated pears. They have usually two shapes – whirl or ovate. They are considered to be intermediate between wild pear and cultivated pear sorts.

TERPÓ (1960) found several pears of hybrid origin in Hungary and he applied the name *Pyrus amphigenea* Dom. in a broader sense to all naturalised pears. He used the taxonomic category "status" for more distinctive hybrids and he classified them "domestica" according to characteristics on fruits or on leaves and twigs.

TERPÓ (1960) stated that the process of naturalisation and domestication would never stop. Many new forms and species originate and the description of a particular form is then impossible.

MATERIAL AND METHODS

Plants were evaluated according to the classification (PAGANOVÁ 1996) that involves morphological characteristics of trunk, crown, leaves and fruits. 1,149 pear individuals were evaluated in total. Great attention was paid to the evaluation of generative pear progenies only within this classification. In the period of material collection 37 trees were without fruits, therefore their taxonomic classification was done only according to their leaves.

Morphological characteristics of leaves and fruits were classified according to TERPÓ (1960) and on this basis plants were classified into some taxa.

These characteristics were evaluated and measured separately on a representative population of leaves and fruits from each individual. Basic statistical characteristics and extent of variability were calculated for each of the evaluated traits. Statistical significance of differences in the values of studied traits between the particular pear taxa was evaluated by one-way analysis of variance. Statistical significance of differences in the mean values of studied traits was tested by Tukey's test on 95% confidence level.

The obtained material allowed to find a range of values and to judge the suitability of particular morphological characteristics of leaves and fruits for the identification of the mentioned taxa.

RESULTS

Three taxa: *Pyrus pyraster* (L.) BURGSD., *Pyrus* × *amphigenea* DOMIN and *Pyrus nivalis* JACQ. occurred on 64 experimental plots where 1,149 pear individuals were evaluated. The study was focused on a comparison of differences in the frequency of qualitative traits and also in the values of quantitative characteristics of leaves and fruits of basic taxa.

The representation of the qualitative traits of leaves was evaluated from basic data (Table 1). Eight shapes of leaf blade occurred within *Pyrus pyraster*. Ovate shape was most frequent (33%), cordate shape had a lower representation (21%) as well as orbicular (20%) and elliptic (18%) shapes. The rhomboidal shape of leaf blade was quite scarce (3%), as well as lanceolate (2%), obovate (up to 2%) and compressed shape of leaf blade (over 1%).

Within *Pyrus amphigenea* there occurred 4 shapes of leaf blade: ovate (43%), elliptic (29%), lanceolate (19%) and orbicular (9%).

Within *Pyrus nivalis* only the lanceolate shape of leaf blade was observed.

The base of leaf blade was obtuse (61%), cordate (23%), truncate (11%) and attenuate (5%) within *Pyrus pyraster*. The individuals of *Pyrus amphigenea* also had a few types of leaf base, mostly they were obtuse (60%), frequently attenuate (21%) and cordate (17%). The truncate shape of leaf blade was very scarce (2%). *Pyrus nivalis* had only the attenuate base of leaf shape.

Within *Pyrus pyraster* the margin of leaf blade was mostly serrate to 1/2 of its perimeter (36%) or to 1/3 (29%). Serrate margin of leaf blade was found in 22%

Table 1. The percentage proportion of qualitative leaf characteristics within the evaluated pear taxa

Taxon	Shape of leaf blade (%)							
	cordate	ovate	orbicular	elliptic	obovate	lanceolate	compressed	rhomboid
Pyrus pyraster	20.8	32.8	19.7	18.2	1.9	2.0	1.5	3.0
Pyrus amphigenea	0.0	42.9	9.5	28.6	0.0	19.0	0.0	0.0
Pyrus nivalis	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Total	19.9	33.0	19.2	18.5	1.8	3.2	1.5	2.9

Taxon	Base of leaf blade (%)				Margin of leaf blade (%)			
	cordate	obtuse	cuneate	truncate	entire	serrate	serrate to 1/3	serrate to 1/2
Pyrus pyraster	22.8	61.0	5.3	10.9	13.0	22.3	28.5	36.2
Pyrus amphigenea	16.7	59.5	21.4	2.4	57.1	2.4	11.9	28.6
Pyrus nivalis	0.0	0.0	100.0	0.0	71.4	0.0	28.6	0.0
Total	22.5	60.6	6.4	10.5	15.0	21.4	27.9	35.7

Table 2. The basic statistical characteristics of quantitative traits of leaves for the evaluated pear taxa

Characteristic	Taxon	*N*	*X*	*Sx*	$Sx_{\%}$	Min	Max
Length of leaf blade (mm)	*Pyrus pyraster*	1,100	41.59	6.36	15.29	22	72
	Pyrus nivalis	7	78.14	8.32	40.64	60	85
	Pyrus amphigenea	42	54.81	9.06	16.52	41	78
Width of leaf blade (mm)	*Pyrus pyraster*	1,100	35.24	4.67	13.27	21	56
	Pyrus nivalis	7	38.43	3.21	8.35	33	43
	Pyrus amphigenea	42	37.88	4.89	12.90	27	49
Angle of leaf blade tip (º)	*Pyrus pyraster*	1,100	119.85	22.52	18.79	48	190
	Pyrus nivalis	7	81.14	6.31	7.78	73	90
	Pyrus amphigenea	42	102.88	27.43	26.67	51	146
Length of leaf petiole (mm)	*Pyrus pyraster*	1,100	34.12	9.23	27.05	9	68
	Pyrus nivalis	7	30.29	7.78	25.70	21	44
	Pyrus amphigenea	42	35.95	10.63	29.57	13	59
Leaf slenderness quotient	*Pyrus pyraster*	1,100	1.19	0.20	16.43	0.71	2.19
	Pyrus nivalis	7	2.04	0.19	9.31	1.81	2.31
	Pyrus amphigenea	42	1.48	0.35	23.70	0.98	2.70
Leaf shape quotient	*Pyrus pyraster*	1,100	0.44	0.05	12.36	0.29	0.74
	Pyrus nivalis	7	0.54	0.04	7.06	0.50	0.59
	Pyrus amphigenea	42	0.42	0.05	12.95	0.30	0.50

of plants and entire type was found in 13% of its individuals.

Within *Pyrus amphigenea* the margin of leaf blade was mostly entire (57%), a quite frequent type of leaf margin was serrate to 1/2 (29%) and to 1/3 (12%) of its perimeter. Serrate margin along the whole perimeter of leaf blade was very scarce (2%).

The most frequent type of leaf blade margin within *Pyrus nivalis* was entire (71%) and serrate to 1/3 (29%).

Apart from the evaluation of morphological characteristics of leaves and fruits we calculated basic statistical characteristics and range of values for the length and width of leaf blade, for the angle of leaf blade tip, length of leaf petiole, slenderness quotient and shape quotient of leaf blade for all mentioned taxa (Table 2).

Pyrus nivalis had the highest mean value of the length of leaf blade (78.14 mm). Plants of this taxon had longer leaves in comparison with *Pyrus pyraster* and *Pyrus amphigenea* – it is evident. High variability (40.64%) of this characteristic within *Pyrus nivalis* is probably caused by the small population of it plants.

Among the three evaluated taxa, the lowest mean value of leaf blade width (35.24 mm) was found in *Pyrus pyraster*. However, this specimen had the largest range of measured dimensions 21–56 mm. The highest mean value of the width of leaf blade (38.43 mm) was found in *Pyrus nivalis*.

The angle of leaf blade tip is a characteristic that describes the leaf shape in greater detail similarly like the width of leaf blade. The highest value of this character (120°) was found in *Pyrus pyraster*, which indicates the abundance of the cordate, ovate and orbicular shapes of leaf blade in this taxon. On the other hand, *Pyrus nivalis* had the lowest mean value of the angle of leaf blade tip (81º), which confirms the abundance of leaves with lanceolate (sharp pointed) shape. Medium value of this character (103º) was found in *Pyrus amphigenea*.

The differences in the mean values of leaf petiole length between the evaluated taxa were not distinctive. They were more evident only within particular species. The wide range of values was found especially in *Pyrus pyraster* and *Pyrus amphigenea*, which was confirmed by quite high variability ($S_{x\%}$ = 27.5% and 29.57%).

Slenderness quotient (ratio of the leaf blade length to its width) is a character that describes the shape of leaf blade in quantitative terms. *Pyrus nivalis* had the highest mean value of the slenderness quotient of leaf blade 2.04 with the range of values 1.81–2.31, which is related with its lanceolate shape of leaf blade. The mean value of slenderness quotient in *Pyrus amphigenea* was 1.48 with the range of values 0.98–2.70. It corresponds with the abundance of ovate and elliptic shapes of leaf blade in this species. Within *Pyrus pyraster* the mean value of the investigated characteristic was 1.19, with the range of values 0.71–2.19, which corresponds with the high variability of leaf blade shapes in the individuals classified in this taxon.

The shape quotient (ratio of the distance of the widest place of leaf blade from its base to the length of leaf blade) describes the localisation of the widest part of leaf blade in relation to its length. Within *Pyrus pyraster*, the mean value of the shape quotient of leaf blade was 0.44 with a wide range of extreme values 0.29–0.74 and coefficient of variance 12.36%. Such a wide range of values results from the high variabil-

Table 3. The results of one-way analysis of variance for morphological characteristics of leaves of the evaluated pear taxa

Characteristic	Source of variation	Sum of squares		Mean square	*F*-value	Significance α
		SS	DF	MS		
Length of leaf blade (mm)	between taxa	16,121.379	2	8,060.6896	191.644	0.0000
	residual	48,201.602	1,146	42.0607		
	total	64,322.982	1,148			
Width of leaf blade (mm)	between taxa	349.813	2	174.90660	8.000	0.0004
	residual	25,054.136	1,146	21.86225		
	total	25,403.950	1,148			
Angle of leaf blade tip (º)	between taxa	21,734.31	2	1,0867.155	21.167	0.0000
	residual	588,363.60	1,146	513.406		
	total	610,097.91	1,148			
Length of leaf petiole (mm)	between taxa	242.096	2	121.04779	1.406	0.2455 n. s.
	residual	98,660.439	1,146	86.09113		
	total	98,902.534	1,148			
Leaf slenderness quotient	between taxa	8.105988	2	4.0529942	97.914	0.0000
	residual	47.437023	1,146	0.0413936		
	total	55.543011	1,148			
Leaf shape quotient	between taxa	0.0855362	2	0.0427681	14.707	0.0000
	residual	3.3326415	1,146	0.0029081		
	total	3.4181777	1,148			

ity of leaf shapes within *Pyrus pyraster*. Similarly, the shape variability of leaves was also reflected in the values of the shape quotient of leaf blade within *Pyrus amphigenea*, where the mean value of shape quotient was 0.42 with the range of values 0.30–0.50. The individuals of *Pyrus nivalis* had only lanceolate leaves and their

Table 4. Tukey's test of statistical significance of differences in the mean values of the analysed leaf characteristics between the evaluated pear taxa

Characteristic	Source of variation	*N*	Mean value	95% confidence interval of the analysed characteristic	Homogeneous group
Length of leaf blade (mm)	*P. pyraster*	1,100	41.59	41.27–41.91	A
	P. amphigenea	42	78.14	74.08–82.21	B
	P. nivalis	7	54.81	53.15–56.47	C
	Total	1,149	42.30	41.98–42.61	
Width of leaf blade (mm)	*P. pyraster*	1,100	35.24	35.00–35.47	A
	P. amphigenea	42	37.88	35.50–41.36	B
	P. nivalis	7	38.43	36.68–39.08	A B
	Total	1,149	35.35	35.12–35.58	
Angle of leaf blade tip (º)	*P. pyraster*	1,100	120	97–109	C
	P. amphigenea	42	103	67–95	B
	P. nivalis	7	81	119–121	A
	Total	1,149	119	118–120	
Length of leaf petiole (mm)	*P. pyraster*	1,100	34.12	33.65–34.58	A
	P. amphigenea	42	35.95	33.58–38.33	A
	P. nivalis	7	30.29	24.47–36.10	A
	Total	1,149	34.16	33.71–34.61	
Leaf slenderness quotient	*P. pyraster*	1,100	1.19	1.18–1.20	A
	P. amphigenea	42	1.48	1.42–1.53	B
	P. nivalis	7	2.03	1.91–2.16	C
	Total	1,149	1.21	1.20–1.22	
Leaf shape quotient	*P. pyraster*	1,100	0.44	0.43–0.44	B
	P. amphigenea	42	0.42	0.40–0.43	A
	P. nivalis	7	0.54	0.50–0.57	C
	Total	1,149	0.44	0.43–0.44	

Table 5. The percentage proportion of qualitative characteristics of fruits within the evaluated pear taxa

Taxon	Shape of fruits				Base of fruits			Calyx	
	pear	apple	cherry	whirl	wedge	flat	concave	persistent	rudimentary
Pyrus pyraster	5.1	67.9	2.3	24.6	43.4	37.8	18.7	99.3	0.7
Pyrus amphigenea	77.5	15.0	0.0	7.5	77.5	12.5	10.0	97.5	2.5
Pyrus nivalis	0.0	100.0	0.0	0.0	40.0	60.0	0.0	100.0	0.0
Total	7.7	66.2	2.2	23.9	44.7	37.0	18.3	99.3	0.7

mean value of the shape quotient of leaf blade was 0.54 with the range of values 0.50–0.59.

All the mentioned leaf characteristics were evaluated by one-way analysis of variance (Table 3).

The results showed statistical significance of differences between the analysed taxa in the values of leaf blade length and width, angle of leaf blade tip, slenderness and shape quotients. Statistically significant differences were not confirmed only in the values of leaf petiole length. It is evident that this quantitative character of leaves is very variable although this is not related with taxonomic reference of the analysed plants. Tukey's test on 95% confidence level confirmed statistical significance of differences in the mean values of the investigated leaf characteristics of analysed pear taxa. The analysed taxa were arranged into homogeneous groups according to these results (Table 4).

The taxa were arranged into three different homogeneous groups according to statistical significance of differences between their mean values of leaf blade length, angle of leaf blade tip, slenderness and shape quotients. This fact confirms reliability of the classification of evaluated pear plants into different taxa.

According to the results of Tukey's test for the characteristic "width of leaf blade" *Pyrus pyraster* and *Pyrus amphigenea* were arranged into separate groups. *Pyrus nivalis* had the highest mean value of the width of leaf blade (38.43 mm) in comparison with the rest of the analysed taxa although it did not differ significantly from the other two taxa (probably because of its small population – 7 plants).

The representation of the qualitative characteristics of fruits was also evaluated from the obtained data (Table 5).

Four shapes of fruits were found within *Pyrus pyraster*. Apple-shape was most frequent (68%), whirl-shape was also quite frequent (25%) and pear-shape (5%) and cherry-shape were very scarce (2%). Three fruit shapes occurred within *Pyrus amphigenea*. Pear-shape of fruits was most frequent (77%). Apple-shape (15%) and whirl-shape were very scarce (8%). *Pyrus nivalis* had only the apple shape of fruits.

The fruit base was wedge-shaped (43%), flat (38%) and concave (19%) in *Pyrus pyraster*. Plants of *Pyrus amphigenea* mostly had the wedge-shaped fruit base (77%), scarcely they had flat (13%) or concave (10%) shapes. The fruit base within *Pyrus nivalis* was mostly flat (60%) or wedge-shaped (40%).

The calyx of *Pyrus pyraster* population was persistent (99%) and only exceptionally it was rudimentary (1%). The individuals of *Pyrus amphigenea* also had mostly persistent calyx (97%). The individuals of *Pyrus nivalis* had only persistent calyx.

Particular taxa differ from each other in the length of fruits as it results from the data given in Table 6.

Table 6. The basic statistical characteristics of fruits of the evaluated pear taxa

Characteristic	Taxon	N	X	S_x	$S_{x\%}$	Min	Max
Fruit length (mm)	*Pyrus pyraster*	1,068	24.33	5.24	21.54	11	49
	Pyrus nivalis	5	34.60	6.15	17.77	26	41
	Pyrus amphigenea	40	40.48	4.89	12.09	32	53
Fruit diameter (mm)	*Pyrus pyraster*	1,068	26.42	4.53	17.15	13	42
	Pyrus nivalis	5	42.20	6.94	16.45	34	52
	Pyrus amphigenea	40	37.25	5.84	15.69	29	54
Length of fruit petiole (mm)	*Pyrus pyraster*	1,068	24.09	8.18	33.95	2	53
	Pyrus nivalis	5	19.00	7.31	38.50	11	27
	Pyrus amphigenea	40	25.73	9.89	38.45	2	41
Fruit slenderness quotient	*Pyrus pyraster*	1,068	0.92	0.14	15.22	0.58	1.75
	Pyrus nivalis	5	1.11	0.05	4.50	0.76	0.87
	Pyrus amphigenea	40	0.82	0.17	20.7	0.71	1.47
Fruit shape quotient	*Pyrus pyraster*	1,068	0.55	0.08	15.11	0.29	1.27
	Pyrus nivalis	5	0.61	0.11	17.81	0.53	0.78
	Pyrus amphigenea	40	0.60	0.08	12.49	0.43	0.75

Table 7. The results of one-way analysis of variance for fruit characteristics of the evaluated pear taxa

Characteristic	Source of variation	Sum of squares		Mean square	*F*-value	Significance α
		SS	DF	MS		
Fruit length	between taxa	10,522.694	2	5,261.3472	192.312	0.0000
	residual	30,367.782	1,110	27.3584		
	total	408,990.476	1,112			
Fruit diameter	between taxa	5,698.732	2	2,849.3658	134.996	0.0000
	residual	23,428.850	1,110	21.1071		
	total	29,127.581	1,112			
Length of fruit petiole	between taxa	235.116	2	117.55799	1.731	0.1776 n.s.
	residual	75,378.525	1,110	67.90858		
	total	75,613.641	1,112			
Fruit slenderness quotient	between taxa	1.335620	2	0.6678100	34.696	0.0000
	residual	21.364660	1,110	0.0192474		
	total	22.700280	1,112			
Fruit shape quotient	between taxa	0.1075042	2	0.0537521	7.767	0.0004
	residual	7.6815218	1,110	0.0069203		
	total	7.7890261	1,112			

The highest mean value of fruit length 40.48 mm was found within *Pyrus amphigenea* with the range of values 32–53 mm. The lowest mean value of fruit length 24.33 mm was found within *Pyrus pyraster*, where the values ranged from 11 mm to 49 mm.

The analysed taxa were also different in basic statistical characteristics for fruit diameter. The lowest mean value of fruit diameter 26.42 mm was found within *Pyrus pyraster* with the range of values 13–42 mm. Plants of this specimen had on average the smallest fruits. The highest value of fruit diameter 42.20 mm was found within *Pyrus nivalis* with the range of values 34–52 mm.

Length of fruit petiole is a character with the highest variability within the whole studied population ($S_{x\%}$ = 33.95–38.50%). The lowest mean value of this character was found within *Pyrus nivalis* (19.00 mm) and the highest mean value was found within *Pyrus amphigenea* (25.73 mm). Mean value of the length of fruit petiole within *Pyrus pyraster* was 24.09 mm.

Table 8. The results of Tukey's test of the statistical significance of differences in the mean values of fruit characteristics between the mentioned pear taxa

Characteristic	Source of variation	*N*	Mean value	95% confidence interval for analysed characteristic	Homogeneous group
Fruit length (mm)	*P. pyraster*	1,068	24.33	24.06–24.59	A
	P. amphigenea	40	40.48	39.10–41.85	C
	P. nivalis	5	34.60	30.72–38.48	B
	Total	1,113	24.95	24.69–25.21	
Fruit diameter (mm)	*P. pyraster*	1,068	26.42	26.19–26.66	A
	P. amphigenea	40	37.25	36.04–38.46	B
	P. nivalis	5	42.20	38.79–45.61	B
	Total	1,113	26.88	26.65–27.11	
Length of fruit petiole (mm)	*P. pyraster*	1,068	24.09	23.67–24.51	A
	P. amphigenea	40	25.73	23.56–27.89	A
	P. nivalis	5	19.00	12.88–25.11	A
	Total	1,113	24.12	23.72–24.53	
Fruit slenderness quotient	*P. pyraster*	1,068	0.92	0.92–0.93	A
	P. amphigenea	40	1.11	1.07–1.14	B
	P. nivalis	5	0.82	0.72–0.92	AB
	Total	1,113	0.93	0.92–0.94	
Fruit shape quotient	*P. pyraster*	1,068	0.55	0.55–0.56	A
	P. amphigenea	40	0.60	0.58–0.62	B
	P. nivalis	5	0.61	0.55–0.67	AB
	Total	1,113	0.55	0.55–0.56	

Slenderness quotient of fruit (ratio of its length to its width) describes the fruit shape in greater detail. The highest mean value of fruit slenderness quotient (1.11) was found in *Pyrus nivalis*, whose fruits had only apple-shape. *Pyrus amphigenea* had the lowest mean value of fruit slenderness quotient (0.82), and its fruits have mostly pear-shape.

Shape quotient of fruits (ratio of the distance between the widest fruit dimension and its base to fruit length) describes the localisation of the widest fruit dimension in relation to its length. The lowest mean value of fruit shape quotient (0.55) was found in *Pyrus pyraster* with the values ranging from 0.29 to 1.27. The highest mean value of fruit shape quotient (0.61) was found in *Pyrus nivalis*.

Differences in the values of all analysed fruit characteristics of pears were evaluated by one-way analysis of variance (Table 8). The results showed statistically significant differences between the investigated taxa in values of fruit length and diameter as well as in values of slenderness and shape quotients. No significant differences between the analysed taxa were confirmed in the length of fruit petiole. This characteristic was very variable within all basic pear taxa, which is confirmed by high values of the coefficient of variance.

It is evident from the results of Tukey's test on 95% confidence level (Table 8) that all three taxa (*Pyrus pyraster*, *Pyrus nivalis*, *Pyrus amphigenea*) significantly differ from each other in the mean values of fruit length. With the mean value of fruit diameter (26.42 mm), *Pyrus pyraster* significantly differs from the other two taxa *Pyrus amphigenea* (37.25 mm) and *Pyrus nivalis* (42.20 mm). *Pyrus pyraster* and *Pyrus amphigenea* were included into different groups on the basis of statistically significant differences in the mean values of slenderness and shape quotient. This fact results from quantitative and shape differences of the fruits of these two taxa. *Pyrus pyraster* has apple-shape of fruits, on the other hand *Pyrus amphigenea* has mainly fruits with pear-shape. *Pyrus nivalis* has an interesting status – this specimen is not significantly different from the other two taxa although it had the highest mean value of fruit shape quotient (0.61), possibly because of the small size of analysed population (5 individuals).

DISCUSSION

Our data confirmed the information about shape variability of pear leaves as it was mentioned by TERPÓ (1960) and other authors (PENIAŠTEKOVÁ 1992; HOFMANN 1993; FEDOROV 1954; ROLOFF 1998; BOUČEK 1954; BORATYŇSKA 1990). Within *Pyrus pyraster* 8 various shapes of leaf blade were found: cordate, ovate, orbicular, elliptic, obovate, lanceolate, compressed and rhomboidal. The ovate shape of leaf blade was most frequent (33%) and the frequency of cordate (21%), orbicular (20%) and elliptic (18%) shapes was nearly identical. *Pyrus amphigenea* had the ovate leaf shape most frequently (43%), relatively frequent was also elliptic (29%) and lanceolate (19%) shape, the orbicular shape of leaf blade was scarce (9%). Cordate, obovate, compressed and rhomboidal shapes did not occur at all. Only the lanceolate shape of leaf blade was found in *Pyrus nivalis*.

FEDOROV (1954) described the base of leaf blade as obtuse only. TERPÓ (1960) as well as PENIAŠTEKOVÁ (1992) and BORATYŇSKA (1990) described the base of leaf blade as truncate, obtuse, cordate or cuneate, which also corresponds with our findings. Within the comparison of particular taxa, *Pyrus nivalis* always had only the cuneate base of leaf blade. However, such type of leaf base had the lowest frequency (5%) within *Pyrus pyraster*, but a relatively high frequency (21%) was found in *Pyrus amphigenea*. The ovate type of leaf blade base was most frequent within *Pyrus pyraster* (61%) as well as in *Pyrus amphigenea* (60%). The cordate base was most frequent (23%) in *Pyrus pyraster*, as well as the truncate base of leaf blade (11%).

The leaf tip can be acuminate, obtuse or flattened. Except these general descriptions the other authors have not presented any equivalent information that would give a more detailed characteristic of this trait. In our study "the angle of leaf blade tip" was measured. Its mean value was 119.85º with quite wide range of values 48–190°.

Leaf covering is also different; juvenile leaves can be glabrous, alternatively they are pubescent later becoming glabrous, sometimes their pubescence is persistent mainly on the bottom near venation and margin of leaf blade (BOUČEK 1954; FEDOROV 1954; TERPÓ 1960; BORATYŇSKA 1990; PENIAŠTEKOVÁ 1992; HOFMANN 1993). The above-mentioned characteristics of leaf covering were also found within our study with different frequency. All plants of *Pyrus nivalis* had tomentose leaves as it was reported by PENIAŠTEKOVÁ (1992) and TERPÓ (1960, 1985, 1992).

The information about the length of leaf blade of *Pyrus pyraster* is different according to particular authors. TERPÓ (1960) mentioned the length of leaf blade 30–60 (70) mm, PENIAŠTEKOVÁ (1992) 25–40 (70) mm, BORATYŇSKA (1990) 20–80 mm, FEDOROV (1954) 20–70 mm, BOUČEK (1954) 35–60 mm, ROLOFF (1998) and WAGNER (1995) give the maximum value of leaf blade length 50 mm, HOFMANN (1993) and MÜLLER and LITSCHAUER (1994) mentioned the leaf length below 60 mm. Within the analysed population of 1,100 individuals of *Pyrus pyraster* the mean value of leaf length was 41.59 mm and the values within this population ranged from 22 mm to 72 mm, which corresponds approximately with the values reported by other authors.

The values of leaf blade width are also mentioned in literature. FEDOROV (1954) gave the range of values 15–25 mm, TERPÓ (1960) 20–55 mm, BOUČEK (1954) 28–50 mm, BORATYŇSKA (1990) 30–50 mm, HOFMANN (1993), MÜLLER and LITSCHAUER (1994) and WAGNER (1995) reported the equal width of leaf blade or below 50 mm and PENIAŠTEKOVÁ (1992) only about

25 mm. Within the evaluation of our data, the mean value of leaf blade width was 35.24 mm with the range of values 21–56 mm, which corresponds with the information given by other authors.

The largest range of the values of leaf petiole length for *Pyrus pyraster* was reported by BORATYŇSKA (1990) 15–70 mm, TERPÓ (1960) and PENIAŠTEKOVÁ (1992) 20–70 (100) mm. According to BOUČEK (1954) it was 30–50 mm, ROLOFF (1998) mentioned 50 mm, HOFMANN (1993) and MÜLLER and LITSCHAUER (1994) gave the values up to 60 mm. Within our analysis the mean value for the leaf petiole length was 24.11 mm with the values ranging from 9 mm to 68 mm, while the found minimum (9 mm) is the lowest value in comparison with measures given by other authors.

WAGNER (1995) gave also relative characteristics – the ratio of leaf length to its width equal 1.00. Similarly RITTERSHOFFER (1998) specified the ratio of leaf length to leaf width 0.9–1.59. According to KÜHN (1998) this ratio was in the range of 0.9–1.5. Our results indicate a wider range of values for this character within *Pyrus pyraster* (0.71–2.19) in comparison with other authors.

Qualitative characteristics of pear fruits are also variable. Within *Pyrus pyraster* four types of fruit shape occurred: apple, whirl, pear and cherry.

These findings basically correspond with the information given by TERPÓ (1960), who described the fruit shape as spherical, compressed spherical, apple-shaped or whirl-shaped. Other authors presented a narrower scale of fruit shapes: e.g. spherical or pear-shaped (BORATYŇSKA 1990; BOUČEK 1954; HOFMANN 1993; WOLF 1981), spherical or compressed as they are described by FEDOROV (1954), spherical or whirl-shaped according to PENIAŠTEKOVÁ (1992), spherical or ovate according to ROLOFF (1998) and just spherical according to WAGNER (1995) and KÜHN (1998).

Calyx was mostly persistent, exceptionally it was rudimentary (1%) in *Pyrus pyraster*, it also corresponds with the findings of TERPÓ (1960) and PENIAŠTEKOVÁ (1992). In *Pyrus nivalis* calyx was always persistent, so it was reported by PENIAŠTEKOVÁ (1992).

Differences in qualitative characteristics of fruits were also found, especially in their length. The highest mean value of fruit length (40.48 mm) was found within *Pyrus amphigenea*. The population of *Pyrus nivalis* had the mean value of fruit length (34.6 mm). According to TERPÓ (1960) the length of fruits within this taxon is 25–35–50 mm in dependence on its variety and similarly according to PENIAŠTEKOVÁ (1992) the range of fruit length is 30–40 (–50) mm.

The lowest mean value of fruit length (24.33 mm) was found within *Pyrus pyraster*, but this population also had the highest value of the coefficient of variation ($S_{x\%}$ = 21.54%). In literature various values of fruit length are given for *Pyrus pyraster*. Fruits can be 10 to 30 mm long (TERPÓ 1960). According to PENIAŠTEKOVÁ (1992) and WOLF (1981) the fruit length ranges from 15 mm to 35 mm, according to FEDOROV (1954) and BORATYŇSKA (1990) this characteristic ranges from 20 mm to 40 mm and BOUČEK (1954) gives the range of 15–45 mm.

Differences were found also in the values of fruit width. *Pyrus nivalis* had the highest mean value (42.2 mm). TERPÓ (1960) gave the values of fruit width 25–40–50 mm for this taxon and PENIAŠTEKOVÁ (1992) 30–40–50 mm.

The lowest mean value of fruit width (26.42 mm) was found in the population of *Pyrus pyraster* with the range of values 13–42 mm. These data correspond approximately to data mentioned by other authors. According to TERPÓ (1960) it is 12–35 mm, PENIAŠTEKOVÁ (1992) gives the range of 18–35 mm, BOUČEK (1954) 17–40 mm, and BORATYŇSKA (1990) 15–20 mm.

The highest variability within the whole analysed pear population was found in the length of fruit petiole. It ranged from 2 mm to 53 mm. The lowest mean value of this characteristic (19 mm) was found in *Pyrus nivalis*, the highest mean value (25.73 mm) was found in *Pyrus amphigenea* and *Pyrus pyraster* took a medium position with its mean value (24.09 mm).

The variability of the length of fruit petiole was also mentioned in evaluations of other authors. For *Pyrus pyraster* FEDOROV (1954) specified that the fruit petiole is 2–3 times longer than the fruit. According to MÜLLER and LITSCHAUER (1994) it is much longer than fruits. TERPÓ (1960) gave an exact range of fruit petiole length (3) 5–65 mm, also KÜHN (1998) 6–16 mm, HOFMANN (1993) 10–35 mm, BOUČEK (1954) 20–40 mm and BORATYŇSKA (1990) 20–50 mm.

For *Pyrus nivalis* PENIAŠTEKOVÁ (1992) reported only the length of flower stalk 15–40 mm that exceeded the range of values (11–27 mm) for the length of fruit petiole found within this taxon in our analysis. However, such comparison is considered to be only informative. TERPÓ (1990) gave the length of fruit petiole for *Pyrus nivalis* var. *orientalis* 10–26 mm and for var. *slavonica* 36–40 mm. Our findings correspond with the range of the values for var. *orientalis*.

TERPÓ (1960) reported the range of values 21–50 mm for the length of fruit petiole in *Pyrus amphigenea*, specifically for its hybrid forms. The author used the taxonomic category "state" (st. *dominii, costata, attenuata, longipetiolata, compressa, heterocarpa, stenophylla* and var. *hemisphaerica*) in connection with these hybrids. They were also found in the territory of Slovakia. According to our analysis, the values of fruit petiole length in *Pyrus amphigenea* had a narrower range (2–41 mm) although a relatively small population of plants was evaluated (42 individuals).

The mean value of the fruit slenderness quotient in *Pyrus pyraster* was 0.92. WAGNER (1995) gives slenderness quotient 1.00.

CONCLUSION

It was found that qualitative leaf characteristics that are considered to be important for the identification of

pear taxa allowed the exact identification of a particular taxon only in some cases. For example: cordate, obovate, compressed and rhomboidal shapes of leaf blade occurred only within *Pyrus pyraster*. On the other hand, lanceolate (or elongately obovate) shapes, which are typical of *Pyrus nivalis*, were found also in the other two taxa (*Pyrus pyraster* and *Pyrus amphigenea*).

Quantitative characteristics of leaves proved to be more suitable for the identification of analysed taxa. Statistically significant differences were found between all the studied taxa in the values of nearly all quantitative characteristics of leaves. Exceptionally the length of leaf petiole had very variable values within all taxa and it was impossible to classify the species on the basis of this characteristic.

The evaluated qualitative characteristics of fruits can be used for the identification of some of these taxa according to the analysed material from Slovakia only exceptionally. For example, cherry shape of fruits occurred only within the population of *Pyrus pyraster*. Other fruit shapes occurred in two taxa at least and apple-shape was found in all the analysed taxa. *Pyrus nivalis* had only the apple-shape of fruits. Three types of fruit base were found within all analysed taxa, except the concave type of leaf base that was not found in the population of *Pyrus nivalis*.

Statistically highly significant differences between the analysed taxa were confirmed in quantitative characteristics of fruits (fruit length, fruit width, and relative characteristics – quotients). Exceptionally, the differences in the length of fruit petiole were not significant. This characteristic had very high intraspecific variability. One-way analysis of variance did not confirm any significant differences between the analysed taxa.

On the other hand, statistically highly significant differences were confirmed between these taxa in the values of fruit length.

Pyrus pyraster was classified into one group while *Pyrus amphigenea* and *Pyrus nivalis* were included into another group according to the values of fruit diameter. There were also found significant differences between *Pyrus pyraster* and *Pyrus amphigenea* in the values of relative fruit characteristics – slenderness and shape quotients. They were classified into different groups.

It is clear from the obtained results that correct classification of pear plants into one of the mentioned taxa needs consideration of a few morphological characteristics of leaves and fruits. Classification based just on one of these characteristics is not correct. Shape and length of leaf blade as well as its slenderness and shape quotients and also the shape and length of fruit can be considered as appropriate and significant taxonomic traits. The length of leaf and fruit petioles was the least significant characteristic. Its values were very variable within the particular taxa.

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Overenie preukaznosti morfologických znakov listov a plodov pri taxónoch rodu *Pyrus* na Slovensku

ABSTRAKT: Na základe morfologických znakov listov a plodov sa analyzoval súbor 1 149 hrušiek zo Slovenska. Identifikovali sa tri základné taxóny – *Pyrus pyraster, Pyrus amphigenea* a *Pyrus nivalis*. Kvalitatívne znaky (tvar listovej čepele, tvar plodov, typ bázy listu alebo plodu atď.) umožnili len v niektorých prípadoch presnú identifikáciu taxónu. Pre identifikáciu hodnotených taxónov sa ukázali byť vhodnejšie kvantitatívne znaky. Medzi skúmanými taxónmi sa zistili štatisticky významné rozdiely v hodnotách dĺžky a šírky listovej čepele a tiež v hodnotách pomerných znakov, ktoré charakterizujú tvar listov. Výnimku predstavoval znak dĺžka listovej stopky, ktorý mal veľmi premenlivé hodnoty ($S_{x\%}$ = 25,70–29,75 %); preto nebolo možné urobiť klasifikáciu na základe tohto znaku. Vo všeobecnosti môžeme konštatovať, že tvar plodov a ich rozmery sú menej preukazné pre taxonomické účely, aj keď štatisticky významné rozdiely boli zaznamenané medzi všetkými skúmanými taxónmi v hodnotách dĺžky plodov. Správne taxonomické zaradenie hrušiek sa nedá urobiť len na základe jedného znaku. Pre správne klasifikovanie hrušiek je dôležité vziať do úvahy niekoľko znakov (tvar a dĺžku listovej čepele alebo štíhlostný a tvarový kvocient listov a tiež tvar a dĺžku plodov).

Kľúčové slová: *Pyrus* L.; taxóny klasifikácie; listy; plody; morfologické znaky

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