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THE VARIABILITY OF *MORUS ALBA* L. (MORACEAE) LEAVES IN THE GREEN AREAS OF POZNAŃ

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Abstract. The paper presents the results of a biometrical study on the leaves of vegetative and generative shoots of *Morus alba*. Mature leaves were collected from the green areas of Poznań (Poland) city. Leaves from vegetative shoots were collected from 34 sites. Leaves from generative shoots were collected from specimens with blackish purple or purple fruit (13 trees) and with pale yellow to creamy fruit (21 trees). Eleven morphological traits were analysed in the leaves from vegetative and generative shoots, including the petiole and blade. The seven examined features were characterised by low or moderate variability and four features were characterised by high or very high variability. The research revealed slight differences between trees with blackish purple or pale yellow fruit and significant morphological differences between the leaves of vegetative and generative shoots. The article includes descriptions of quantitative features have not been published in Poland. White mulberry leaves (*Morus alba*) with white and dark fruit did not make clearly separated groups. Therefore, they should be treated as morphotype of cultivars rather than a distinct taxonomic rank.

Key words: white mulberry, morphology, petiole, blade, fruit, taxonomic, Poland

INTRODUCTION

The mulberry family comprises about 50 genera of trees, shrubs, climbers and herbaceous plants, often with milky sap. 12–16 species were distinguished within the *Morus* genus (Bugała 2000, Zhekun & Gilbert 2003) which can be found both in the tropical and temperate zone. Mulberries naturally grow in forests in the mountains of Japan, China and India (Bugała 2000, Zhekun & Gilbert 2003, Seneta & Dolatowski 2011).

Identification of the *Morus* genus is based on the morphological traits of leaves and fruit. The leaves are usually single, undivided or palmate lobed, margin toothed; primary veins 3–5 from base, secondary veins pinnate. Fruit with enlarged, succulent calyx usually aggregated into juicy syncarp. The leaves are used as food for silkworms and the fruit for human consumption (Zhekun & Gilbert 2003). The high diversity of leaves of cultivated and naturally growing *Morus* sp. depends on the cultivation, use, the age of a tree and the environmental conditions (Golański 1957, Peris et al. 2014). Tokarska-Guzik et al. (2012) consider white mulberry to be a domesticated species in Poland. It is often used in urban and rural green spaces because it can be grown easily. It is dispersed in western and central Poland. Some white mulberry trees are older than 100 years, which shows that the species has adapted to the existing conditions (Pokorný 1992). *Morus alba* with some other species, like *Pyrus communis* L., *Sophora japonica* L., *Quercus petrea* L., *Q. robur* L., *Eleagnus angustifolia* L. belong to the group of plants most resistant to unfavourable conditions (Łukasiewicz 2011). Biometrical data referring to *M. alba* variability are usually limited to the extreme lamina length and width and less frequently to the petiole length (Kremer 1995, Zhekun & Gilbert 2003, Peris et al. 2014). So far there has been no research on the morphological variability of *M. alba* leaves in Poland. The study by Klimko (2016) concerned the micromorphology and anatomy of leaves.

The main goal of this study was to determine the morphological variability of *M. alba* leaves from specimens cultivated as ornamental plants in temperate

regions. The differentiation of leaves was described in reference to its placement on shoots (leaves collected from fertile short shoots and sterile long shoots) as well as in reference to fruits' color variability (trees with white and dark fruits).

MATERIAL AND METHODS

Fully developed *M. alba* leaves were collected from unpruned trees aged 35 to 40 years growing in the green areas of Poznań (Poland) (Table 1). Material was collected at 34 sites of street, residential areas and parks. Leaves were collected from trees with different colours of fruit: dark purple or purple fruit (13 trees; hereinafter referred to as dark fruit) and light yellow or creamy fruit (21 trees; hereinafter referred to as white fruit). Five vegetative and five generative shoots were randomly collected from each tree in the middle part of the crown and 10 leaves were measured from each shoot. The studied characteristics and methods of measuring are shown in Table 2 and Figure 1. These measurements have been adopted from Staszkiewicz (1997), Adolkar et al. (2007) and Food and Agriculture Organization (FAO/IAEA 2007). The range (minimum-maximum), arithmetic mean (X) and coefficient of variation (CV) were calculated for each of the studied trait (Tables 3, 4). Student's t-test for dependent samples was used to test the significance of differences between the traits in leaves collected from vegetative and generative shoots. The blade length/width correlation and the blade length/petiole length correlation were calculated separately for the leaves from vegetative and generative shoots. The following classes of the correlation strength were identified: $0.0 \leq r \leq 0.2$ – no correlation; $0.2 < r \leq 0.4$ – weak correlation; $0.4 < r \leq 0.7$ – moderate correlation; $0.7 < r \leq 0.9$ – strong correlation; $0.9 < r \leq 1.0$ – very strong correlation. The chi-square test was used to compare the strength of correlations in the leaves from the two types of

Table 1. A list of tree locations

Locality	No. of tree	Date of collection	Fruit color
Lazurowa	1	27.07.2015	white
Dąbrowskiego	2–5	27.07.2015	dark
Szydłowska	6	27.07.2015	dark
Łęgi Dębińskie	7	20.07.2015	dark
Malta (Baraniaka)	8, 9	04.07.2015	white
Rubież	10	11.07.2015	dark
Dziadoszańska	11	08.07.2015	white
Park Tysiąclecia	12–14	20.07.2015	white
Warszawska	15	20.07.2015	white
Malta (Komandoria)	16	20.07.2015	dark
Szeląg owska	17, 18	12.07.2015	white
Czarnucha	19	12.07.2015	dark
Włodarska	20	12.07.2015	white
Pasterska/Żytnia	21	12.07.2015	white
Żytnia/Karbowska	22	12.07.2015	white
Osiedle Lecha	23, 25–29	14.07.2015	white
Osiedle Lecha	24	14.07.2015	dark
Park Cytadela	30, 31	30.08.2015	dark
Park Cytadela	32, 33	30.08.2015	white
Park Cytadela	34	18.07.2015	dark

Table 2. Quantitative characters studied in *Morus alba*

No.	Abbreviation	Character
1	PL	length of petiole (cm)
2	BL	length of the blade (cm)
3	BW	width of the blade (cm)
4	BL/BW	ratio between length and width of the blade
5	PWB	position of the widest part of a blade as percentage of its length
6	NVL	number of veins to the left of the midrib
7	NVR	number of veins to the right of the midrib
8	DLL	depth of incision in the lower lobe (cm)
9	DB	depth of incision in the blade (cm)
10	LL	length of lateral lobe (cm)
11	NL	number of lobes

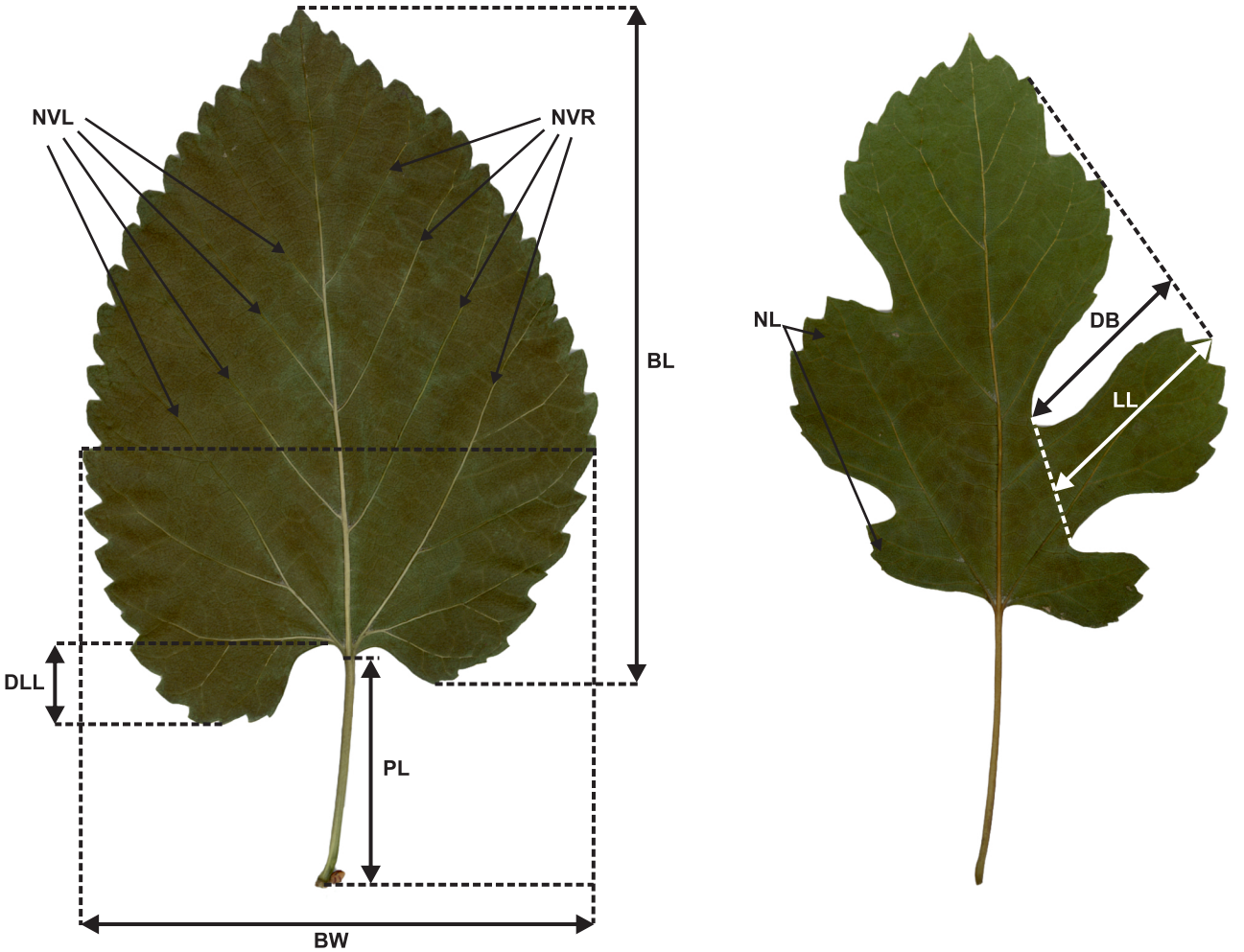

Fig. 1. *Morus alba* leaf measurement method (characters as in Table 2)

shoots. The differences among analysed individuals were verified by the cluster analysis using the nearest neighbour method and Euclidean distances (Watała 2002). The principal component analysis (PCA) and scatter diagram were made was performed to check the discontinuity between the leaves from trees of different colors of fruits (Sokal & Sneath 1973). The data were analysed statistically by Statistica 11 PL for Windows.

RESULTS

The ranges and variability of the examined features of leaves from generative and vegetative shoots are present in Figures 2 and 3. The mean petiole length (PL) varied from 1.65 to 6.96 cm, on vegetative shoots and from 1.44 to 4.02 cm on generative ones. The coefficients of variation on vegetative and generative shoots ranged from low to moderate (Tables 3, 4). The mean of blade length (BL) varied from 5.97 to 12.84 cm on vegetative shoots and from 3.78 to 10.76 cm on generative ones. The coefficients of variation on vegetative and generative shoots ranged from low to moderate. The mean blade width (BW) varied from 4.77 to 10.04 cm on vegetative shoots and from 3.09 to 7.32 cm on generative ones. The coefficients of variation on vegetative and generative shoots ranged from low to moderate. The mean blade length/width ratio (BL/BW) varied from 1.16 to 1.58 on vegetative shoots and from 1.19 to 1.63 on generative ones. The coefficients of variation on vegetative and generative shoots was low. The mean position of the widest part of the blade as percentage of its length (PWB) varied from 31.04 to 54.34 on vegetative shoots and from 33.04 to 54.34 on generative ones. The coefficients of variation of this trait for vegetative and generative shoots ranged from low to moderate. The mean number of veins to the left of the midrib (NVL) varied from 4.2 to 7.7 for leaves on vegetative shoots and from 4.0 to 6.0 for leaves on generative ones. The coefficients of variation on vegetative and generative shoots ranged from low to moderate. The mean number of veins to the right of the midrib (NVR) varied from 4.5 to 7.8 on vegetative shoots and from 4.0 to 5.8 on generative ones. The coefficients of variation on vegetative and generative shoots ranged from low to moderate. The mean

Table 3. The range (minimum–maximum), arithmetic mean (X), and coefficient of variation (CV) of leaves characteristics from *Morus alba* vegetative shoots

No. of tree	Characteristic														
	petiole length			blade length			blade width			blade length/blade width ratio			position of the widest part of leaf		
	min–max	X	CV	min–max	X	CV	min–max	X	CV	min–max	X	CV	min–max	X	CV
1	2.50–5.00	3.62	25.61	8.00–13.00	10.33	16.97	6.30–9.00	7.97	12.32	1.16–1.44	1.29	8.07	36.00–51.58	44.27	11.89
2	2.30–3.90	3.23	17.02	9.00–11.60	10.23	9.11	7.10–9.00	7.96	8.50	1.16–1.41	1.29	5.42	39.09–52.29	45.84	9.63
3	1.50–3.10	2.31	22.30	5.20–8.90	7.04	21.03	3.90–6.50	4.98	18.28	1.24–1.85	1.41	13.05	34.83–61.54	47.36	17.01
4	2.70–5.00	3.88	18.81	7.00–10.60	8.71	13.96	4.80–9.00	6.26	16.31	1.22–1.54	1.40	7.05	23.61–52.86	36.39	21.49
5	3.70–6.00	4.62	16.38	11.00–14.40	12.84	10.28	7.20–9.30	8.65	8.60	1.18–1.64	1.48	11.05	34.35–53.85	44.60	14.07
6	2.50–4.30	3.20	16.47	8.10–14.20	11.08	15.88	5.80–9.60	8.10	14.54	1.03–1.62	1.38	11.51	40.38–67.68	49.66	16.22
7	1.30–2.40	1.76	21.96	4.40–8.50	6.69	21.74	3.00–6.20	4.70	23.97	1.27–1.70	1.44	8.92	40.00–56.82	46.74	13.34
8	1.50–3.50	2.71	22.31	4.80–10.80	7.76	26.70	3.40–8.00	5.36	23.17	1.13–1.60	1.39	10.92	36.67–47.44	42.30	9.63
9	2.30–3.70	2.83	14.04	5.70–10.50	8.51	18.62	5.40–8.30	6.99	14.23	0.93–1.44	1.22	12.12	27.27–48.24	37.45	16.71
10	2.50–4.70	3.70	21.55	8.70–12.40	10.43	11.14	5.70–8.50	7.09	15.82	1.36–1.62	1.50	6.06	29.79–42.00	36.14	11.04
11	1.70–3.90	2.66	29.82	4.80–10.90	7.59	29.19	3.20–6.10	4.77	23.18	1.27–1.91	1.58	12.31	23.58–36.78	32.03	12.08
12	1.40–3.10	2.52	21.15	6.80–13.40	9.77	19.24	3.70–8.80	6.83	20.73	1.19–1.56	1.36	8.94	31.53–68.29	41.76	25.28
13	1.40–2.80	2.12	19.74	3.90–8.10	6.30	23.38	3.10–6.80	4.79	25.63	1.18–1.54	1.32	7.64	30.00–46.15	37.62	11.94
14	2.10–3.30	2.93	12.47	6.50–10.00	8.53	14.51	5.40–8.10	6.65	13.80	1.18–1.50	1.28	7.23	32.22–53.85	41.55	13.42
15	3.50–5.10	4.15	14.02	9.90–13.00	11.85	9.22	6.50–9.20	8.00	9.37	1.10–1.72	1.49	11.61	32.81–44.62	39.57	9.03
16	3.00–5.10	4.07	15.67	7.70–13.80	10.84	17.42	5.10–10.30	8.06	24.32	1.00–1.50	1.26	12.83	30.43–50.56	38.42	13.62
17	1.90–4.00	2.85	24.38	5.90–12.00	9.71	19.65	4.00–8.90	7.24	19.12	1.19–1.52	1.36	9.42	27.72–47.37	34.02	18.45
18	3.10–5.50	4.37	19.06	7.80–11.60	10.20	12.14	5.30–7.50	6.79	10.38	1.31–1.60	1.50	6.46	26.26–46.91	38.03	16.57
19	2.40–3.20	2.85	9.82	7.30–11.40	9.31	15.43	5.30–11.20	7.54	22.31	1.02–1.43	1.26	9.98	23.16–50.98	36.52	23.75
20	2.50–5.00	3.61	18.35	7.00–12.70	10.56	18.91	4.50–8.90	7.06	21.51	1.31–1.63	1.51	6.29	25.00–37.50	30.03	14.71
21	0.90–2.20	1.65	24.62	4.80–9.30	6.76	22.45	2.90–6.50	4.90	24.57	1.26–1.66	1.38	8.83	20.83–46.94	36.26	22.53
22	1.90–3.30	2.74	19.56	6.30–11.40	8.97	21.05	4.80–8.90	6.98	18.88	1.10–1.42	1.28	7.71	21.93–37.23	31.36	14.29
23	1.60–3.60	2.77	24.19	3.60–11.50	8.35	29.35	2.90–7.80	5.79	32.03	1.18–1.80	1.46	13.85	22.61–42.03	33.63	18.71
24	1.20–3.40	2.29	31.65	4.20–9.20	6.45	24.07	3.00–7.60	5.22	28.11	1.14–1.42	1.25	8.37	37.84–60.66	47.72	12.29
25	1.80–4.90	3.57	25.26	5.30–5.40	11.61	27.48	1.40–11.80	8.10	37.73	1.09–1.52	1.28	12.29	26.90–45.88	35.07	18.17
26	2.80–6.50	5.25	19.35	4.70–11.10	9.00	21.46	4.80–11.30	7.86	24.32	0.98–1.42	1.16	15.38	27.93–46.85	36.05	18.84
27	1.60–2.90	2.15	18.11	5.00–7.00	5.97	10.77	3.70–5.60	4.80	14.20	1.02–1.89	1.27	20.36	36.67–84.29	51.15	26.86
28	2.50–4.20	3.27	13.53	6.30–9.40	7.72	10.57	4.90–6.90	5.84	10.09	1.25–1.43	1.32	4.75	21.25–37.45	30.44	18.13
29	1.10–3.50	2.63	30.21	3.60–11.00	8.19	33.22	2.50–8.30	6.16	31.33	1.14–1.48	1.33	7.32	34.31–56.86	42.04	18.18
30	2.80–4.40	3.58	13.80	8.60–13.10	10.88	12.45	7.00–9.90	8.19	12.30	1.19–1.53	1.32	8.97	36.84–51.30	43.27	9.63
31	5.60–8.60	6.96	13.78	10.00–14.70	12.79	12.69	9.10–11.00	10.04	6.79	1.08–1.44	1.27	9.26	33.57–53.10	42.95	13.43
32	2.40–4.40	3.41	19.13	6.00–11.10	8.04	20.61	4.20–7.20	5.35	17.45	1.30–1.80	1.50	10.17	43.24–56.76	48.92	9.13
33	2.10–4.90	3.74	24.25	5.80–13.20	9.63	24.31	4.10–8.30	6.18	21.10	1.29–1.68	1.51	8.04	39.29–62.12	49.99	16.22
34	1.90–4.00	3.23	20.44	6.50–10.60	8.28	16.40	4.50–8.10	5.88	17.92	1.27–1.74	1.42	10.39	32.86–47.83	42.02	11.52

No. of tree	Characteristic																	
	number of veins of the left of midrib			number of veins of the right of midrib			depth of incision of the lower lobe			depth of incision in the blade			lobe length			number of lobes		
	min–max	X	CV	min–max	X	CV	min–max	X	CV	min–max	X	CV	min–max	X	CV	min–max	X	CV
1	5.00–8.00	6.60	16.29	4.00–8.00	6.80	18.08	0.20–0.80	0.48	37.78	0.50–2.30	1.59	41.28	1.90–4.10	2.69	26.38	1.00–5.00	3.30	47.49
2	5.00–8.00	6.40	13.18	5.00–7.00	6.00	11.11	0.10–1.00	0.44	53.78	0.40–2.10	1.19	48.55	2.20–5.20	2.99	36.56	1.00–6.00	3.71	57.56
3	4.00–7.00	5.60	17.25	4.00–7.00	5.40	15.62	0.00–0.50	0.17	100.17	0.50	0.50	–	2.70	2.70	–	2.00	2.00	–
4	4.00–8.00	5.40	23.42	4.00–8.00	5.80	21.19	0.00–0.30	0.06	179.16	0.30	0.30	–	1.10	1.10	–	1.00	1.00	–
5	4.00–9.00	7.10	19.30	5.00–8.00	6.60	14.64	0.20–0.70	0.38	42.61	0.40–1.20	0.73	41.96	1.20–7.00	3.47	62.13	1.00–6.00	3.33	70.14
6	6.00–9.00	6.80	15.19	5.00–7.00	6.40	10.93	0.20–1.50	0.93	43.03	0.90–1.80	1.36	23.94	1.80–5.50	3.04	37.49	1.00–5.00	2.44	54.55
7	3.00–6.00	4.20	24.59	4.00–5.00	4.50	11.71	0.00–0.50	0.27	55.35	–	–	–	–	–	–	–	–	–
8	5.00–9.00	6.40	18.34	5.00–8.00	5.90	16.85	0.00–0.30	0.16	73.36	0.40–1.30	0.87	52.03	1.75–4.20	3.35	41.39	1.00–2.00	1.33	43.30
9	3.00–8.00	5.40	31.72	4.00–8.00	5.70	24.88	0.30–0.80	0.55	30.00	0.75–0.90	0.85	10.19	2.00–2.55	2.34	12.78	2.00–5.00	3.00	57.74
10	6.00–9.00	7.60	12.71	6.00–8.00	7.30	11.28	0.40–0.90	0.62	27.20	1.30–2.00	1.67	13.55	1.90–4.80	3.23	28.04	2.00–5.00	3.60	35.14
11	3.00–6.00	4.60	25.52	3.00–7.00	4.90	24.43	0.00–0.30	0.12	109.71	–	–	–	–	–	–	–	–	–
12	5.00–8.00	5.80	15.84	4.00–8.00	6.00	17.57	0.00–0.90	0.43	61.09	0.90–1.90	1.46	24.80	2.20–5.40	3.29	35.54	1.00–5.00	2.78	50.20
13	4.00–7.00	5.80	19.57	4.00–9.00	6.40	22.34	0.20–0.50	0.31	28.25	0.80–2.60	1.40	41.03	1.30–4.30	2.18	44.15	2.00–5.00	4.22	25.88
14	5.00–7.00	5.50	12.86	5.00–8.00	5.80	17.81	0.20–0.80	0.47	47.10	0.40–1.90	1.37	31.89	2.00–6.10	3.46	46.37	1.00–5.00	3.33	45.00
15	5.00–8.00	6.30	13.07	4.00–7.00	6.10	18.04	0.10–0.70	0.31	61.68	0.40–1.20	0.68	53.24	1.50–4.90	2.78	55.47	1.00	1.00	0.00
16	6.00–11.00	7.70	17.37	6.00–11.00	7.80	20.76	0.60–1.30	0.93	23.26	1.10–2.20	1.68	18.57	1.70–3.30	2.47	22.26	6.00–10.00	8.30	15.08
17	5.00–9.00	7.20	17.07	5.00–8.00	6.80	15.19	0.20–0.40	0.30	31.43	0.40–2.20	1.21	58.12	1.10–4.80	2.53	57.93	1.00–7.00	3.14	69.78
18	4.00–8.00	5.50	24.62	4.00–7.00	5.40	19.91	0.30–1.00	0.60	35.14	0.60–1.60	1.09	26.16	1.70–5.60	2.86	40.20	1.00–5.00	3.22	55.47
19	5.00–8.00	7.00	16.50	5.00–8.00	6.90	14.41	0.30–1.20	0.71	37.82	1.20–2.80	1.90	33.29	4.00–6.70	5.33	19.61	3.00–4.00	3.14	12.03
20	4.00–8.00	5.60	25.53	5.00–9.00	6.50	24.33	0.00–0.40	0.17	78.68	–	–	–		–	–	–	–	–
21	4.00–8.00	6.00	22.22	4.00–7.00	5.80	19.57	0.10–0.50	0.33	40.53	0.40–1.70	1.09	40.21	0.70–2.80	1.74	37.66	1.00–6.00	4.50	40.91
22	5.00–9.00	6.50	24.33	5.00–9.00	6.70	27.30	0.10–0.70	0.44	48.15	0.20–0.40	0.30	47.14	4.50–6.20	5.35	22.47	1.00	1.00	0.00
23	4.00–9.00	5.80	26.71	3.00–8.00	5.40	27.88	0.00–0.30	0.19	52.34	–	–	–	–	–	–	–	–	–
24	4.00–6.00	5.00	16.33	4.00–6.00	4.80	13.18	0.40–1.00	0.69	29.35	0.80–2.80	1.48	39.71	1.40–3.90	2.27	35.36	3.00–6.00	4.22	28.46
25	4.00–10.00	6.50	30.98	3.00–9.00	6.30	29.98	0.30–1.20	0.80	32.27	0.90–1.80	1.24	28.63	1.90–5.90	3.06	43.88	1.00–3.00	1.63	45.79
26	3.00–7.00	5.30	29.57	5.00–6.00	5.30	9.11	0.00–0.60	0.34	50.37	0.60–0.90	0.77	19.92	1.80–6.80	4.00	63.84	1.00–2.00	1.33	43.30
27	4.00–8.00	5.70	23.46	3.00–7.00	4.90	24.43	0.10–0.60	0.43	39.60	0.60–1.20	0.90	26.19	1.30–3.10	1.84	26.77	1.00–5.00	3.70	40.39
28	4.00–6.00	4.90	15.06	3.00–6.00	4.50	18.89	0.00–0.60	0.24	71.36	0.201.00	0.60	66.67	1.80–4.30	3.23	39.89	1.00	1.00	0.00
29	4.00–8.00	5.80	24.11	5.00–8.00	6.10	18.04	0.40–1.10	0.72	32.61	0.80–2.70	1.83	36.32	1.40–3.80	2.76	32.26	3.00–5.00	4.50	20.57
30	4.00–8.00	6.10	19.63	5.00–9.00	6.80	18.08	0.30–1.30	0.71	46.69	0.60–1.50	1.07	32.83	1.40–4.60	2.68	50.96	1.00–4.00	2.33	51.90
31	4.00–7.00	5.50	21.43	3.00–7.00	5.80	21.19	0.20–1.20	0.64	49.52	0.50–0.80	0.63	24.12	1.60–3.10	2.53	32.15	1.00–2.00	1.67	34.64
32	4.00–7.00	5.40	21.74	4.00–6.00	5.30	15.53	0.00–0.00	0.00	–	1.60–1.60	1.60	–	2.60	2.60	–	2.00	2.00	–
33	4.00–10.00	6.10	34.08	5.00–9.00	6.30	19.87	0.20–0.60	0.30	44.44	0.40–0.40	0.40	–	5.40	5.40	–	1.00	1.00	–
34	4.00–7.00	5.80	19.57	5.00–8.00	6.10	16.30	0.00–0.40	0.18	86.07	0.90–1.70	1.23	20.87	2.10–4.00	3.01	27.05	3.00–6.00	4.14	29.33

Table 4. The range (minimum–maximum), arithmetic mean (X), and coefficient of variation (CV) of leaves characteristics from Morus alba generative shoots

No. of tree	Characteristic														
	petiole length			blade length			blade width			blade length/blade width ratio			position of the widest part of leaf		
	min–max	X	CV	min–max	X	CV	min–max	X	CV	min–max	X	CV	min–max	X	CV
1	1.90–4.20	2.50	28.16	4.40–9.70	6.51	22.02	3.50–7.50	5.07	23.47	1.09–1.38	1.29	6.65	37.04–62.90	50.68	14.21
2	1.60–3.50	2.70	21.17	3.50–9.00	6.73	26.00	2.70–6.90	4.81	26.81	1.23–1.72	1.41	10.43	29.11–67.16	44.84	24.67
3	1.50–2.90	2.18	22.14	3.20–7.40	5.13	30.46	3.10–5.40	4.10	17.36	0.97–1.68	1.23	18.50	31.91–62.50	46.70	25.28
4	1.80–3.30	2.49	19.53	4.30–7.40	5.07	18.27	3.40–5.20	3.99	14.44	1.05–1.65	1.28	14.18	34.09–75.00	46.49	24.80
5	3.20–5.10	4.02	15.90	7.50–13.50	10.76	17.78	5.00–9.20	7.32	18.47	1.18–1.69	1.48	11.56	33.06–56.12	44.11	14.63
6	1.50–3.50	2.50	21.75	4.30–10.30	6.87	26.17	3.30–6.50	4.83	19.69	1.19–1.63	1.41	10.67	41.86–65.33	53.67	13.91
7	1.00–2.30	1.44	24.76	4.20–8.20	5.72	23.74	3.00–5.60	4.23	21.38	1.16–1.78	1.36	12.60	34.38–52.08	43.41	14.49
8	1.30–2.10	1.62	18.59	3.90–7.60	5.64	20.15	2.90–5.10	4.13	16.66	1.21–1.69	1.36	10.07	32.89–53.13	44.67	14.93
9	1.50–2.70	1.94	19.16	4.00–8.10	6.04	23.59	3.50–6.80	4.67	22.00	1.14–1.57	1.29	9.42	28.75–44.44	38.47	11.39
10	2.00–5.30	3.76	28.10	5.20–11.00	8.51	20.63	3.50–6.50	5.20	15.57	1.48–1.85	1.63	9.31	32.69–51.72	41.48	13.53
11	2.20–3.00	2.62	12.70	5.70–10.90	8.64	16.45	4.90–7.00	6.27	10.58	1.15–1.63	1.38	12.67	29.46–49.12	36.39	15.48
12	1.40–3.30	2.15	27.84	4.00–9.00	5.92	26.48	3.20–6.20	4.53	20.89	1.22–1.45	1.30	6.84	33.33–43.64	40.03	7.29
13	1.20–2.20	1.79	15.46	2.60–5.00	3.78	18.06	1.80–4.00	3.09	19.08	1.06–1.61	1.24	13.42	37.78–59.38	46.72	16.19
14	1.30–3.50	2.61	27.42	3.00–10.70	7.09	29.93	2.30–7.30	5.31	28.81	1.23–1.48	1.34	6.73	37.08–50.00	42.66	12.03
15	1.70–3.90	2.72	30.31	3.50–8.10	5.87	24.86	3.00–6.30	4.70	21.01	1.10–1.45	1.24	9.37	35.71–53.23	45.59	13.86
16	1.50–4.70	2.58	35.61	1.20–10.10	6.37	40.24	2.50–9.10	5.34	35.81	1.11–1.62	1.39	9.29	30.51–43.56	36.04	11.83
17	2.50–3.70	2.94	12.95	5.10–7.70	6.49	12.31	3.90–5.50	4.74	9.91	1.19–1.54	1.37	9.43	27.59–50.65	36.52	22.25
18	1.50–3.30	2.51	27.95	3.20–6.80	5.20	23.90	2.30–5.10	3.88	23.99	1.18–1.53	1.35	7.84	19.70–44.12	31.04	24.34
19	1.60–2.50	2.13	15.66	4.50–7.40	6.11	15.11	3.90–5.70	4.65	15.84	1.15–1.48	1.32	8.34	27.27–44.26	31.96	16.87
20	2.20–4.80	3.07	30.56	4.10–9.60	6.61	28.79	3.50–7.80	5.51	29.42	1.11–1.44	1.27	7.27	26.67–45.83	36.11	16.47
21	1.30–3.30	2.26	29.95	3.50–6.70	5.36	20.02	2.90–5.60	4.40	20.10	1.14–1.33	1.22	5.01	42.31–51.72	47.03	7.68
22	1.40–3.30	2.48	21.74	3.60–9.20	6.66	24.29	3.00–6.50	4.92	22.26	1.20–1.48	1.35	7.70	24.59–41.67	31.50	14.69
23	0.90–2.10	1.46	29.45	2.30–7.20	4.70	35.81	2.00–5.40	3.90	33.12	1.00–1.44	1.21	12.23	26.76–52.38	41.20	17.96
24	1.80–3.20	2.71	18.36	5.80–10.20	8.25	17.60	4.40–7.40	6.12	16.89	1.22–1.57	1.35	8.76	34.12–45.05	39.79	9.76
25	1.70–3.50	2.58	22.88	5.90–11.30	8.65	20.45	4.90–8.30	6.78	16.35	1.11–1.46	1.27	9.46	27.66–44.00	36.64	16.06
26	1.30–3.90	3.10	24.04	4.30–10.10	7.67	22.08	3.10–6.50	5.45	19.05	1.24–1.58	1.40	7.76	32.39–46.25	38.69	12.47
27	1.30–2.50	1.82	19.17	2.90–6.10	4.61	20.82	3.00–4.70	3.88	13.52	0.91–1.56	1.19	15.60	31.48–47.54	39.76	12.45
28	0.80–3.70	2.34	38.60	3.40–8.90	6.64	26.49	2.80–6.00	5.20	20.37	1.04–1.51	1.27	11.68	29.41–52.94	38.34	22.84
29	2.00–3.30	2.66	15.67	4.60–11.10	7.48	29.17	4.20–7.80	5.79	21.39	1.10–1.52	1.28	9.88	38.31–50.77	44.56	10.56
30	1.90–3.50	2.61	21.25	3.90–9.40	5.94	28.44	2.50–4.70	3.91	17.86	1.26–2.00	1.50	14.09	39.36–58.93	49.88	13.00
31	2.10–4.60	3.07	23.74	5.10–10.30	7.42	23.76	3.60–7.80	5.45	26.11	1.27–1.51	1.38	5.73	35.29–69.64	54.34	20.36
32	1.70–3.70	2.55	23.69	4.20–8.00	6.08	21.86	3.50–5.40	4.30	14.83	1.05–1.82	1.41	14.61	44.87–61.90	51.49	10.98
33	2.00–4.20	3.03	24.25	4.30–10.50	7.28	26.53	3.00–7.50	5.34	25.95	1.15–1.75	1.37	11.55	40.38–62.07	51.65	16.10
34	1.50–3.20	2.26	29.51	4.40–7.60	5.69	19.87	2.70–5.70	4.01	23.44	1.33–1.89	1.51	12.22	37.04–52.94	44.36	10.57

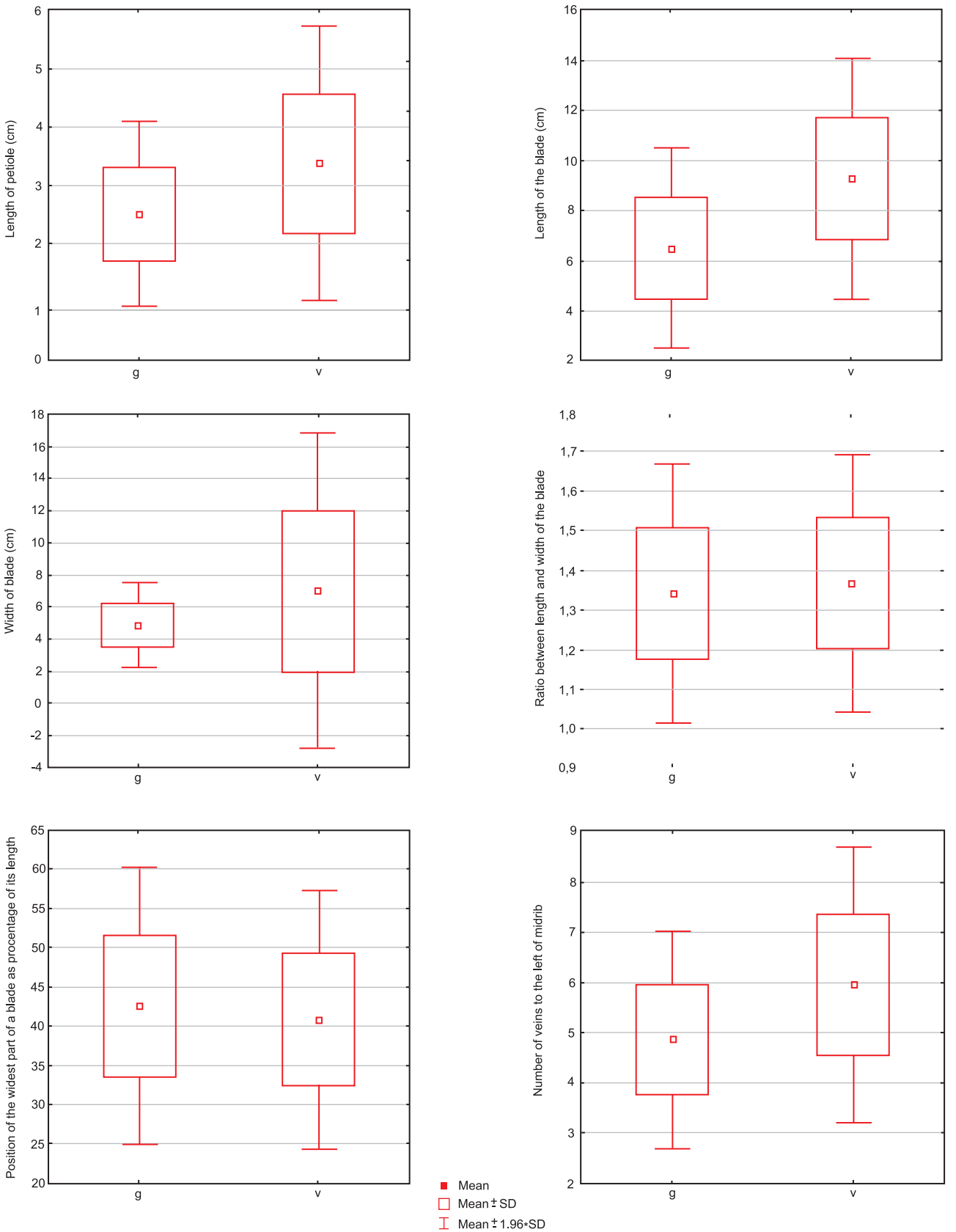

Fig. 2. Box-plot diagrams for the six characteristics of *Morus alba* leaves under study

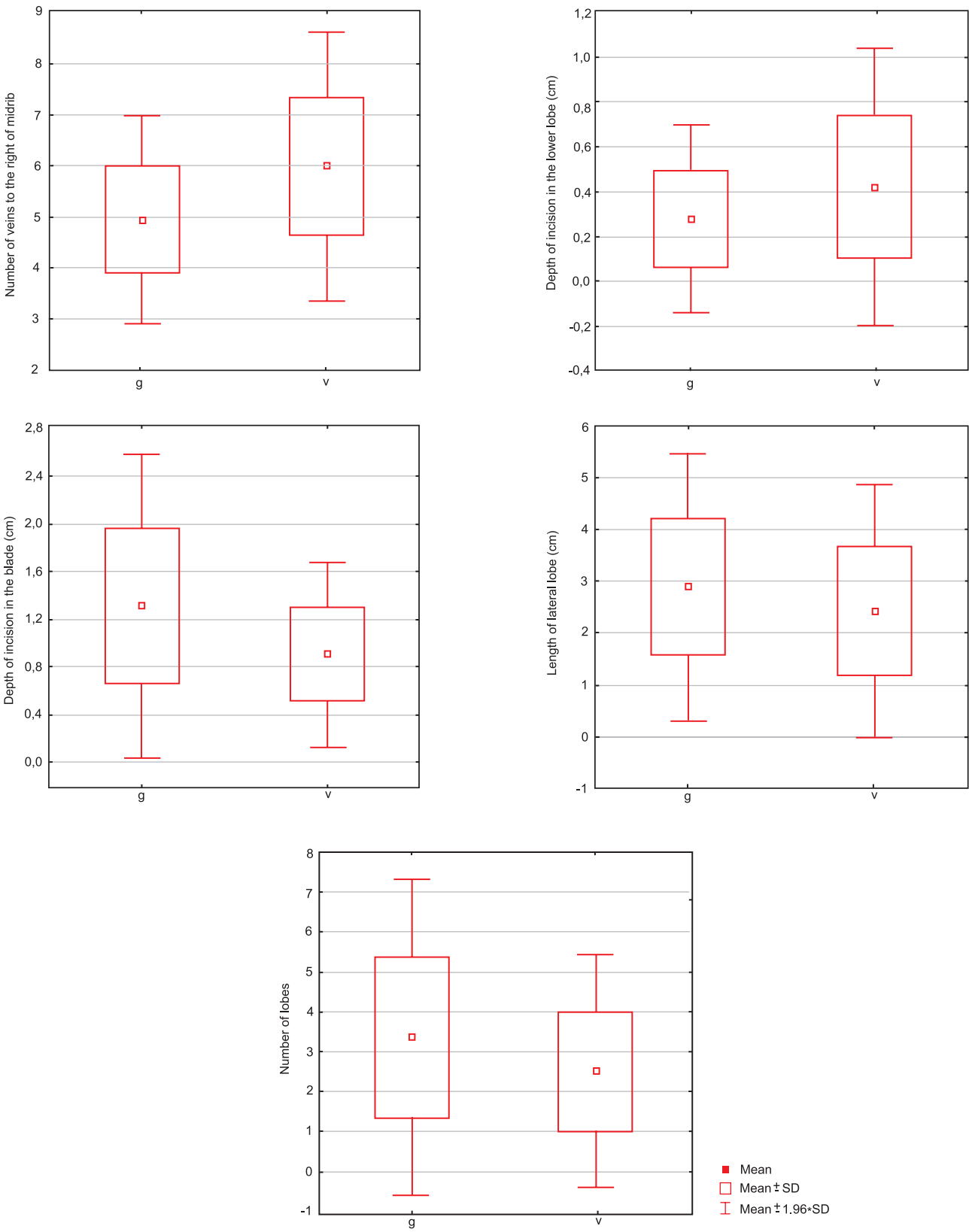

Fig. 3. Box-plot diagrams for the five characteristics of *Morus alba* leaves under study

Table 5. A comparison of leaves characteristics from vegetative and generative shoots (Student's t-test for dependent samples): G – generative shoots, SD – standard deviation, V – vegetative shoots

No.	Features	Mean					Student's t-test		
		V	G	SDV	SDG	no. of leaves	t	df	p
1	PL	3.27	2.51	1.20	0.81	1700	11.5187	339	0.000
2	BL	9.14	6.51	2.44	2.03	1700	17.2506	339	0.000
3	BW	6.96	4.88	5.43	1.34	1700	6.8976	339	0.000
4	BL/BW	1.37	1.34	0.17	0.17	1700	2.0297	339	0.043
5	PWB	40.33	42.55	8.59	8.99	1700	–3.8641	339	0.000
6	NVL	5.97	4.86	1.44	1.10	1700	11.7621	339	0.000
7	NVR	5.97	4.95	1.34	1.03	1700	12.0051	339	0.000
8	DLB	0.42	0.28	0.31	0.21	1700	8.1978	339	0.000
9	DL	1.34	0.88	0.50	0.37	120	4.9977	39	0.000
10	LL	2.97	2.46	1.49	1.22	120	2.0072	39	0.052
11	NL	3.60	2.58	1.98	1.50	120	2.5157	39	0.016

depth of incision in the lower lobe (DLL) varied from 0.06 to 0.93 on vegetative shoots and from 0.0 to 0.69 on generative ones. The coefficients of variation on vegetative shoots ranged from low to very high, whereas on generative shoots they ranged from moderate to very high.

Thirty-one trees had lobed leaf blades on vegetative shoots, and 15 trees had such type of leaves on the generative shoots. The depth of incisions in the blade (DB) varied from 0.0 to 1.9 cm on vegetative shoots and from 0.0 to 1.53 cm on generative shoots. The coefficients of variation on vegetative and generative shoots ranged from low to very high (Tables 3, 4). The lobe length (LL) varied from 0.0 to 5.4 cm on vegetative shoots and it ranged from 0.0 to 4.75 cm on generative shoots. The coefficients of variation on vegetative and generative shoots ranged from low to very high. The number of lobes on the leaves (NL) from vegetative shoots ranged from 0.0 to 8.3 whereas on generative shoots they ranged from 0.0 to 4.00. The coefficients of variation on vegetative and generative shoots ranged from low to very high.

Student's t-test for dependent samples proved significant differences between vegetative and generative shoots in ten out of eleven traits under study (Table 5). The lobe length was the only trait which did not exhibit significant differences between leaves from different shoots. In leaves from vegetative shoots the correlation between the blade length and width was very strong in 46% of cases, strong – in 32% of cases, moderate – in 12% and weak in 7%. There was no correlation in 3% of cases. The correlation between the blade length and petiole length was very strong in 17% of cases, strong – in 44% of cases, moderate – in 22% and weak in 12%. There was no correlation in 5% of cases. In leaves from generative shoots the correlation between the blade length and width was very strong in 47% of cases, strong – in 35% of cases, moderate – in 21%. There was no correlation in 6% of cases. The correlation between the blade length and petiole length was very strong in 38% of cases, strong – in 35% of cases, moderate – in 21%, whereas in 6% of cases there was no correlation.

The leaves from vegetative and generative shoots did not differ significantly in the correlation strength between the blade length and width ($\lambda^2 = 5.13$; df = 4; p = 0.27). The leaves differed in the correlation strength between the blade length and petiole length ($\lambda^2 = 21.16$; df = 4; p = 0.000). The correlation was stronger in leaves from generative shoots.

As can be seen in the hierarchical clustering dendrogram (Fig. 4) illustrating the diversification of leaves from vegetative shoots, the collected samples can be divided into two groups. The first group includes the leaves from trees: 4, 9–11, 13, 15–21, 22, 23, 25, 26, 28, the second group includes the trees 1–3, 5–8, 12, 14, 27, 29–34. Within the first group at the Euclidean distance ca. 6.5, the subgroup 1.1 (11, 20, 22, 23, 28) and the subgroup 1.2 (4, 9, 10, 13, 15–19, 21, 25, 26) can be distinguished. Similarly, within the second group, we can distinguish a subgroup 2.1 (3, 6, 7, 24, 27, 32, 33) and 2.2 (1, 2, 5, 8, 12, 14, 29–31, 34). The dendrogram based on the characteristics of leaves collected from generative shoots is shown in Figure 5. The samples were divided into two groups. The first group includes the leaves of trees: 9–12, 16–20, 22–28, whereas the second group consist of leaves from trees: 1–8, 14, 15, 21, 29-34. Within the first group, at a distance ca. 7.5, the subgroup 1.1 (18, 19, 22) and 1.2 (9–12, 16, 17, 20, 23–28) are separated. Within the second group the subgroup 2.1 (2–4, 7, 8, 13–15, 21, 29, 34) and the subgroup 2.2 (1, 6, 30–33) can be distinguished.

The principal component analysis revealed that specimens with white and dark fruit did not make clearly separated groups. However, they were slightly diversified in PC1, which explains 36% of the total variation (Fig. 6).

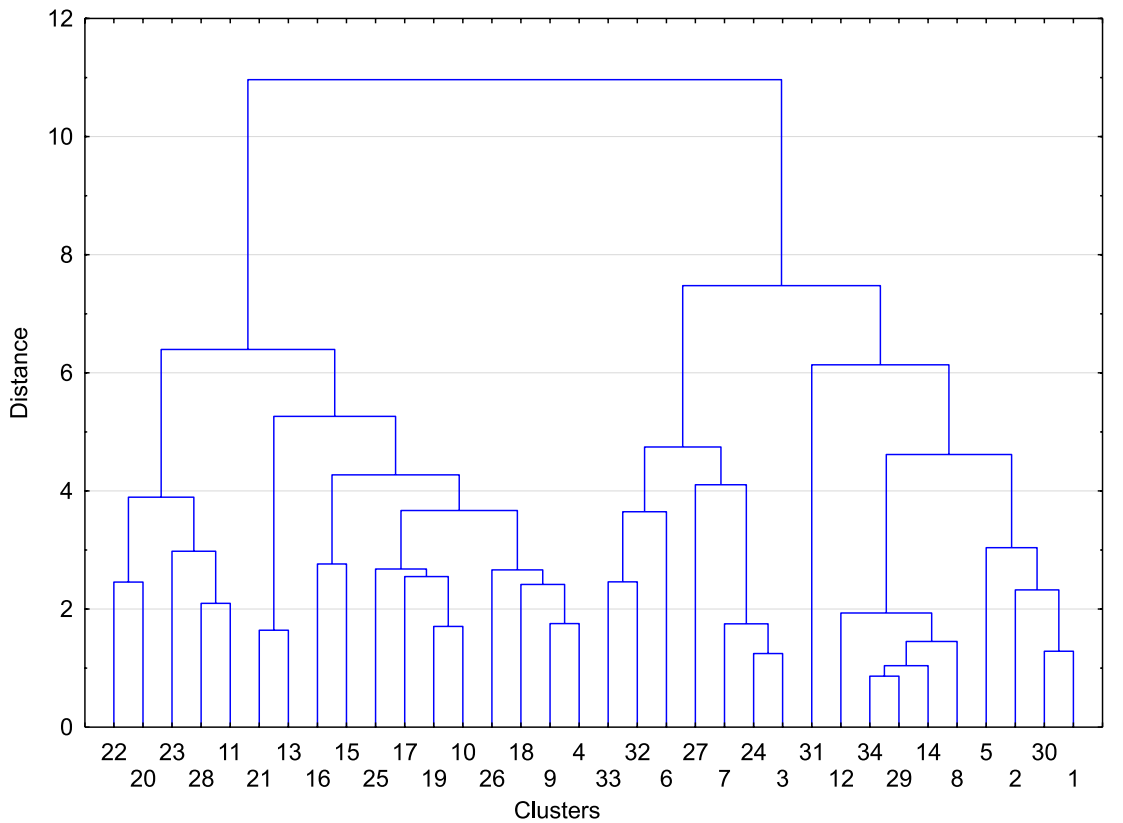

Fig. 4. Dendrogram constructed on the basis of the shortest Euclidean distances for characteristics of leaves from *Morus alba* vegetative shoots

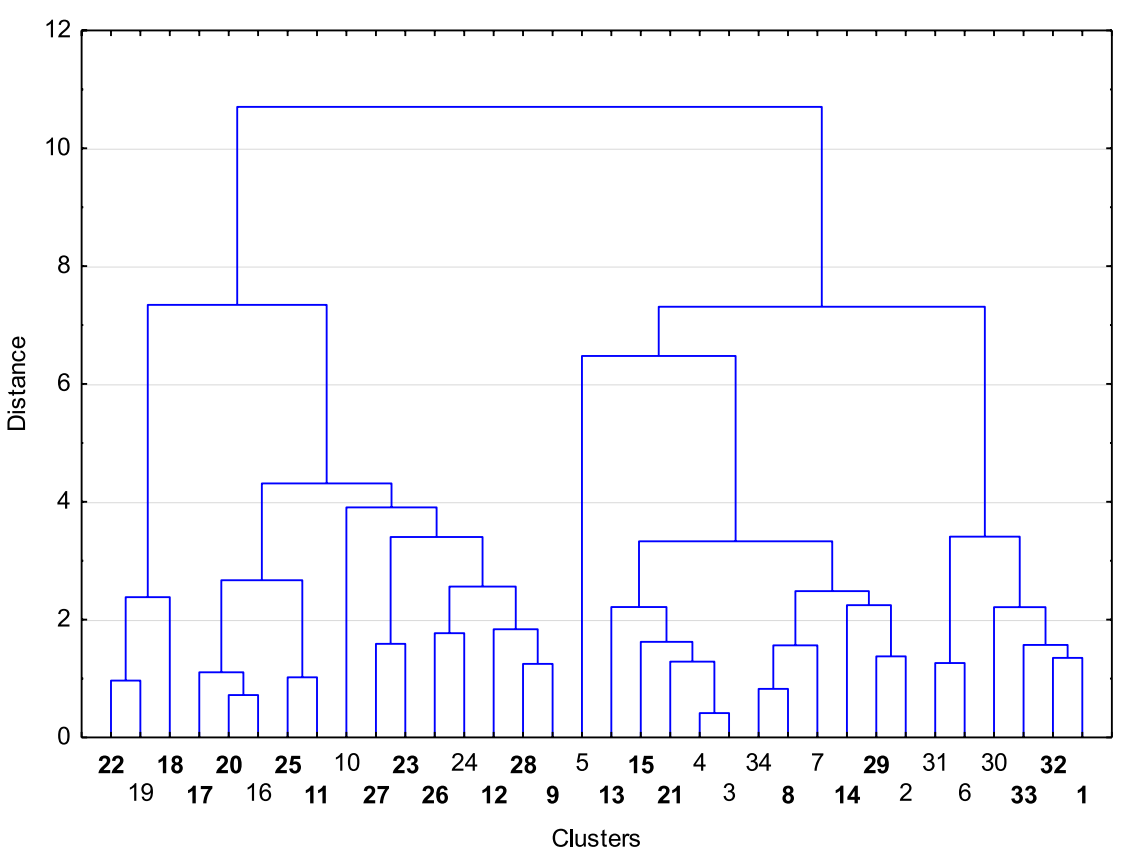

Fig. 5. Dendrogram constructed on the basis of the shortest Euclidean distances for characteristics of leaves from *Morus alba* generative shoots: bold – trees with white fruits

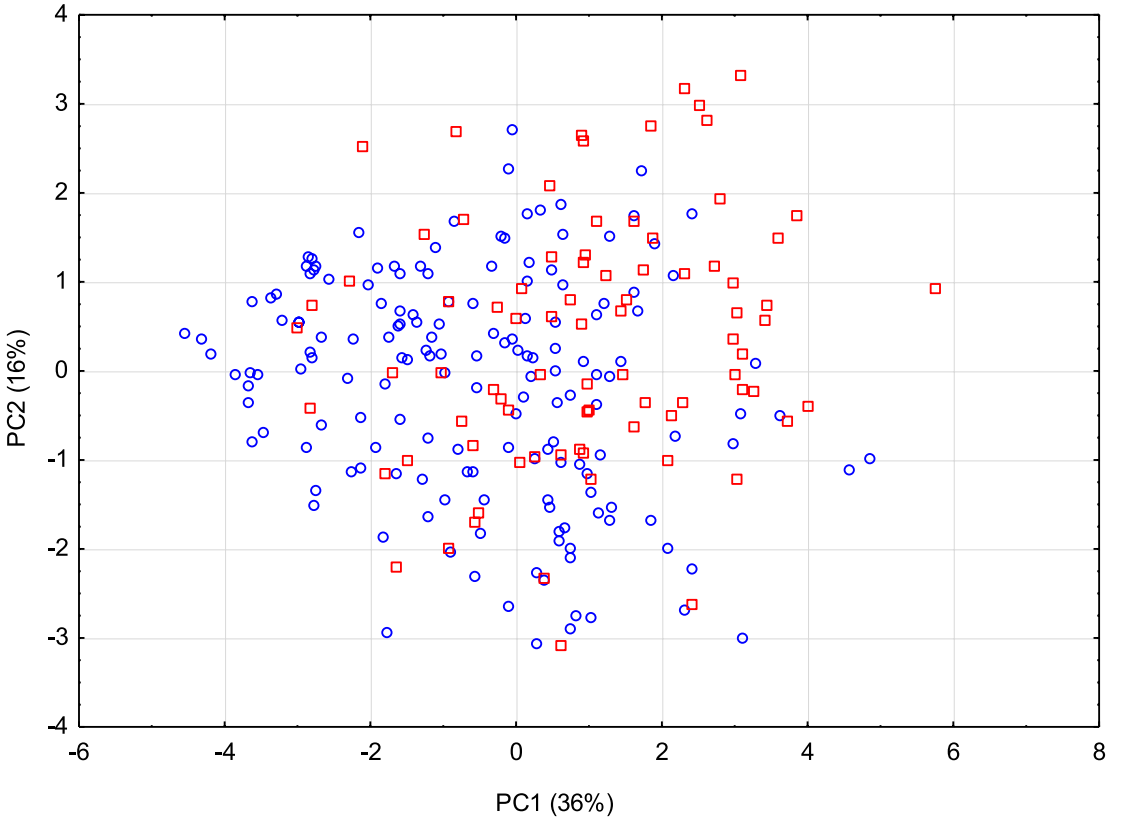

Fig. 6. The results of the principal component analysis (PCA) – scatter diagram: circle – trees with white fruit, square – trees with dark fruit

DISCUSSION

In Poland, only one species of mulberry, *Morus alba*, is widely cultivated. Seneta & Dolatowski (2011) inform that leaves of this species are ovate or roundish, 7–15 cm long, older trees have leaves slightly lobed or without indentations. According to Kremer (1995), the blade length varied from 7 to 18 cm. While those examined by us on the vegetative shoots were 5.97–12.84 × 4.7–10.04 cm and petiole length 1.65–6.96 cm and on generative shoots 3.78–10.76 × 3.09–7.32 cm and petiole length 1.44–4.02 cm. The seven examined features (1–7) were characterised by low or moderate variability and four features (8–11) were characterised by low or very high variability. Significant differences between vegetative and generative shoots in ten out of eleven traits was found. The lobe length was the only trait which did not exhibit significant differences between leaves from different shoots. Turskienė (2013) examined the leaves of *M. alba* trees, that have been introduced in Lithuania. They were from 6 and 10.5 cm long and from 5 to 8.5 cm wide. Petiole length ranged from 2.2 to 3.1 cm. Moreover, Turskienė (2013) stated that the number of veins on the right side of the blade is slightly higher than on the left side, and this observation was confirmed by our findings. Abbasi et al. (2014) collected wild plant from different areas of Lesser Himalays. The climate of this region ranges from tropical at the base of the mountans to permanent ice and snow at the highest elevation. Leaves were from 12 to 2.9 cm long and 12.5–1.6 cm wide. Peris et al. (2014) examined the leaves from long shoots grown in Kenya. The means of the different morphological features showed that the lamina length, lamina width and petiole length were significantly differ across the two enviroments: with Eldoret they had higher parameters than Nairobi. Lamina length was 11.9 cm and lamina width was 9.7 cm from Nairobi and 17.7 cm lamina length and 14 cm lamina width from Eldoret. The mean petiole length was 2.9 cm and 3.6 (respectively). Blade length was positively and significantly correlated to blade width and petiole length which was confirmed by our study. Significant positive correlation was also found between lamina length and petiole length growth height. Zhekun & Gilbert (2003) report, that in *M. alba* there are two varieties of this species: *alba* and *multicaulis*. *M. alba* var. *alba* L. is characterised by blackish purple or purple fruit and leaf blade 5–15 × 5–12 cm. *M. alba* var. *multicaulis* (Perrottet) Loudan has dark fruit and leaf blade ca. 30 cm and petiole length 1.5–5.5 cm. According to Katsumata (1971) and Kumar et al. (2012), *M. alba* L. and *M. multicaulis* Perrottet are

separate species. The length of petioles studied by Boubaya et al. (2009) in *M. alba* ranged from 1.93 to 6.56 cm. Bajpai et al. (2015) studied the phenotypical variability in natural white mulberry populations (*Morus alba*) at high altitudes (2815–3177 m AMSL) in Himalays. Coefficient of variation showed high phenotypic variability of length, width of leaves as well as petiole length. Each 100-metre increase in the altitude caused the leaf length, width and area to decrease by 1 cm, 0.8 cm and 16.6 cm^2, respectively. The incision in the blade is a key characteristic of *M. alba* leaves. At the base there is no incision in the leaf blade or it is much shallower than the petiole length (Szafer et al. 1969). Our study confirmed this observation – the average depth of the incision in the blade of vegetative shoots was 1.33 cm, whereas in generative shoots it was 0.87 cm. The average length of petioles amounted to 3.27 cm and 2.51 cm, respectively. To sum up the results of dendrograms we can say that the leaves from vegetative shoots were located in different subgroups even if they came from near sites and from generative shoots showed that the groups isolated due to their greatest similarity were not related to each other in terms of a specific colour. Comparisons of the biometrical data of morphological features of leaves with different localities showed that the ranges of trait variability overlap. The largest dimensions of mulberry leaves (11.32–21.43 × 7.61–15.63 cm) and greatest petiole length (2.06–4.36 cm) had the leaves from natural localities in India (Banerje et al. 2007).

CONCLUSIONS

The analysis of the material confirmed the relation between the size and shape of leaves and the type of shoots. There were significant differences between vegetative and generative shoots. The leaves from the trees with light yellow to creamy fruit and the from the trees with dark purple to purple fruit exhibited the smallest differences in the ratio between the blade length and width. White mulberry leaves (*Morus alba*) with white and coloured fruit did not make clearly independent groups. Therefore, they should be treated as morphotyp of cultivars rather than given a taxonomic distinction.

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