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Characteristic of species *Morus alba* L. and *Morus nigra* L. by some basic vegetative traits

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Abstract. *Establishing the leaf productivity of the species Morus alba L. and Morus nigra L. and the influence of the mulberry species on some basic vegetative traits was the aim of this paper. The study was conducted during 2018-2020 at the Training Experimental Station of the Sericulture section of the Faculty of Agriculture at Trakia University – Stara Zagora. Object of the study were representatives of the genus Morus – M. alba L. (variety "Vratsa 1") and M. nigra L. The studied mulberry trees were from a low-stemmed plantation of an intensive type. The analysis of variances shows that the type of mulberry has a highly significant influence (p>0.001) in all analyzed cases characterizing leaf productivity. The established differences between the species in terms of the studied vegetative traits are in favor of M. alba. However, for M. nigra the average values of some morphological indicators are within the limits of those generally established in practice. This gives reason to consider that the data obtained in the present study are a useful addition to the general characterization of the species and are relevant for the purposes of selection and production of mulberry cultivars and hybrids.*

Keywords: *Morus alba* L., *Morus nigra* L., vegetative traits, mulberry leaf productivity

Introduction

Mulberry is one of the earliest cultivated tree species, and most classifications according to its place in the systematics of plants are built almost entirely on the characteristic of morphological traits. Taxonomically, mulberry belongs to the genus Morus L. and has more than 68 species (Datta, 2000; Vijayan, 2010), of which *M. alba, M. indica, M. nigra, M. latifolia* and *M. multiculis* are cultivated for silkworm breeding, *M. rubra* – for fruit (Yaltirik, 1982) and *M. laevigata* and *M. serrata* – for wood (Tikader and Vijayan, 2010).

Mulberry plantations are a source of valuable raw materials with enormous potential and economic value in a wide range of directions. Besides being the only food for the mulberry silkworm (*Bombyx mori* L.), mulberry products can also be used as a source of fiber, human food, fodder and fuel. It has gained the status of a "super food" in European countries, thanks to the presence of bioactive compounds in the fruit (Krishna et al., 2020).

In a report by Kirechev and Nikolov (2017), mulberry is listed as one of the tree crops with a short rotation cycle eligible as Ecologically Targeted Areas – agricultural territory for the benefit of the climate and the environment. According to Lee (1981), Morus species show great potential for

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ethanol production and conversion of mulberry tree biomass into fuel is economically feasible. Walia (2013) determined a better suitability of *Morus nigra* L. wood for the production of pulp and paper compared to some conifers, as the yield and quality of the pulp depends mainly on the morphological properties and anatomical structure of the raw material (Mittal et al., 1978).

The use of medicinal plants for pharmacological purposes is a common practice worldwide. Almost all parts of the tree of the species *Morus nigra* L. (family Moraceae), known as black mulberry, can be used in medicine and pharmacy (Singab et al., 2005; Pawlowska et al., 2008; Volpato et al., 2011). According to Naderi et al. (2004), the fruits have an antiseptic and hemostatic effect, an extract of the bark helps with toothache, and the leaves act as an antidote for poisoning. Cui et al. (2019) claimed that consumption of mulberry tea has increased due to its hypoglycemic, antidepressant, antioxidant, and hepatoprotective effects.

Ursell (2000) and González et al. (2010) attributed the medicinal properties of black mulberry to the presence of bioflavonoids with powerful antioxidant, anti-HIV, hypotensive and cytotoxic effects (Eruygur and Dural, 2019). Studies by Polumackanycz et al. (2021) show that white and black mulberry leaves are a valuable source of phenolic compounds with bioactive potential. In many studies (Shukla et al., 2014; Akhlaq et al., 2016; Sánchez-Salcedo et al., 2017; Zhang et al., 2018) *M. nigra* was indicated as the species with higher bioactivity and inhibition potential of radicals in comparison with many other fruits and vegetables (Wang and Jiao, 2000). According to Seufi et al. (2019), further research on *M. nigra* will reveal many other bioactive substances with therapeutic, pharmacological and nutritional values.

Mulberry genetic resources are an important prerequisite for the development of mulberry farming; therefore, it is necessary to know the assessment of the genetic potential of mulberry species and varieties (Tikader and Dandin, 2008). According to Chanotra et al. (2019), high morphological and genetic diversity is observed among the different species of the genus Morus. Breeders often use the various morpho-anatomical characteristics for differentiation and evaluation of genotypes (Rahman and Islam, 2020). Varietal identification by phenotypic characteristics is an effective means of preliminary assessment of genetic diversity, since phenological and morphological indicators of leaves and fruits support a quick and easy assessment of variability (Colic et al., 2012), and in mulberry the main object of study is the mulberry leaf, as it is the most important organ from an economic point of view (Satoh, 1977; Wang, 1988; Sharieva, 1989; Gowda, 1990; Chanotra et al., 2023).

Morus alba L. and *Morus nigra* L. are widely cultivated in many countries due to their nutritional, economic and medicinal value (Erarslan et al., 2021). In general, representatives of the genus Morus are a source of valuable raw materials for mankind, according to Lu et al. (2009) and have a wide-spectrum beneficial effect on the climate and the environment, and according to Can et al. (2021), the bioactive compound-rich local cultivars *M. alba* and *M. nigra* are valuable material for breeding purposes. The selection of suitable genotypes from the gene pool requires in-depth knowledge of morphological characteristics of the different genotypes (Yilmaz et al., 2012).

Establishing the leaf productivity of the species, object of the present study, and the influence of the mulberry species on some basic vegetative traits is a contribution towards enriching the information about the mulberry genetic resources in the generally available scientific literature, which is an important prerequisite for expanding the options for selection and development in mulberry farming.

Material and methods

The research was conducted in 2018-2020 at the Educational and Experimental Station at the Department of Animal Husbandry of the Faculty of Agriculture at Trakia University. The subjects of the study were the representatives of the genus Morus – *M. alba* L. (variety „Vratsa 1“) and *M. nigra* L. The studied mulberry trees were from a low-stemmed plantation of an intensive type. Currently, there are almost no such type of plantations. This gives the study the necessary relevance.

To establish the leaf productivity of the analyzed mulberry trees of the considered species, basic quantitative vegetative traits characterizing leaf yield were determined.

- Lamina leaf length and width (mm).
- Petiole length and thickness (mm).
- Index, which is an indicator of the leaf shape, determined by the formula:

I = Ll / Lw, where Ll is Lamina length, Lw – Lamina width.

- Average area of one mulberry leaf (cm^2), determined by the formula:

La = (5 x Lm) / Pm,

where 5 is area of each cut piece (cm^2), Pm – mass of the piece (g), Lm – mass of the leaf (g).

From each leaf, 5 cut pieces were weighed for *M. alba* and 4 for *M. nigra* with an area of each piece of 5cm² (Figure 1).

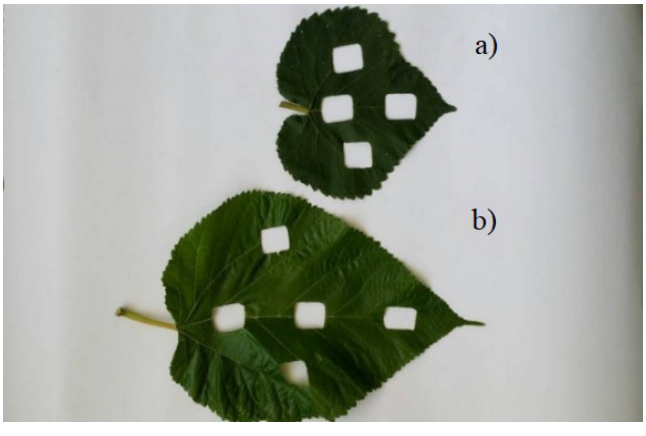

Figure 1. Determination of leaf area in: a) *M. Nigra* and b) *M. alba*

- Length (cm) and thickness (mm) of the branch.
- Number of branches per one tree.
- Number of leaves and weight of leaves per one branch.
- Number of buds per one branch and internodal distance (cm).
- Average weight of one leaf (g)

For the purposes of the study, 5 trees of *M. alba* and 4 of *M. nigra* were used, and for the determination of the above-mentioned traits, average samples of 12 leaves from 5 *M. alba* branches and 8 *M. nigra* branches were formed and analyzed.

- Leaf yield from one tree (kg), and for its determination, 3 trees of each species were pruned and the obtained leaf mass was weighed on an electronic scale.
- Leaf yield from one acre (kg), calculated on the basis of the yield of leaf mass from one tree and the number of trees in one acre (200 pcs.).

The obtained data were systematized and processed with the program STATISTICA of StatSoft. Statistical parameters were calculated, characterizing the variation in the values of the traits during the study period, and the influence of the mulberry species on the main quantitative and morphological traits were established. One-factor analysis of variance was used for this purpose.

Results and discussion

Concerning the morphological indicators characterizing the leaves (Table 1), higher average values were found for *M. alba* (with 74.58, 30.32, 18.57, 0.71, 0.34 mm and 78.16 mm^2 on average, respectively, for length and width of leaf petiole, length and thickness of leaf petiole, index and average area of one leaf) compared to those of *M. nigra*. This explains the wider application in practice of varieties belonging to *M. alba* (Penkov, 1966).

The morphological characteristics of the leaves of *M. nigra* (Table 1) show that the data for the average length (102.86 mm) and width (94 mm) of the mulberry leaf lamina, length (21.16 mm) and thickness (2 mm) of the petiole, as well as Index (1.09 mm) are within the limits of the generally established values in the literature. Hosseini et al. (2018) indicated ranges from 96.62 to 186.13 mm and from 75.14 to 147.66 mm, respectively, for the length and width of the lamina, from 19.12 to 38.68 mm for the length and from 1 .90 to 3.88 mm in diameter for the thickness of the leaf petiole. From the average values for Index, presented in Table 1, it can be seen that the leaf laminas of *M. alba* (1.43) are characterized by a more elongated shape, and of *M. nigra* (1.09) with a more oval shape, which is also in confirmation of what was found by Hosseini et al. (2018).

The average area of a mulberry leaf is an important feature, as it is related to the average weight of the leaves and, accordingly, the productivity of the trees. Based on the measurements made in the present study, it was found that the average leaf area of *M. alba* was 78.16 mm^2 greater than that of *M. nigra* leaves (Table 1).

Table 1. Morphological characteristics of the mulberry leaf (mm)

Trait	*M. alba*		*M. nigra*	
	$\bar{x}$±SE	min-max	$\bar{x}$±SE	min-max
Lamina length	177.44±15.58	102.74 – 256.62	102.86±6.15	56.46–136.22
Lamina width	124.33±10.37	77.30 – 180.5	94.01±4.65	56.36–120.38
Petiole length	39.73±2.02	28.84 – 50.39	21.16±1.55	12.59–37.03
Petiole thickness	2.71±0.23	1.55 – 4.21	2.00±0.10	1.2–2.71
Index	1.43±0.06	0.90 – 1.61	1.09±0.00	1.03–1.13
Average area of one leaf (cm^2)	142.47±52.86	73.8 – 246.43	64.31±5.68	55.87–75.12

Table 2. Analysis of variance of effect of a mulberry species on the leaf morphology

Sources of variation	df	F	P
Lamina length	1	106.732	* *
Lamina width	1	43.016	* * *
Petiole length	1	228.456	* *
Petiole thickness	1	91.148	* * *
Index	1	96.782	* *
Average area of one leaf	1	2.161	-

*** p>0.001
**p>0.01

The analysis of variance shows that the mulberry species has a significant influence (p>0.01) on the traits Lamina length and Petiole length and a highly significant influence (p>0.001) on the traits Lamina width and Petiole thickness (Table 2).

Table 3. Morphological characteristics of the branch

Trait	*M. alba*		*M. nigra*	
	$\bar{x}$±SE	min-max	$\bar{x}$±SE	min-max
Branch length (cm)	144.80±11.06	110.00 – 177.00	50.62±7.69	19.5 – 76
Branch thickness (mm)	10.99± 0.86	3.19 – 22.44	6.98±0.37	3.34 – 13.59
Number of buds	33±2.77	2.77 – 43.00	17.00 1.50	9.00 – 21.00
Internodes distance (cm)	4.79±0.30	3.88 – 7.29	3.24±0.20	2.16 – 4.50

In a comparative characterization of the average data presented in Table 3, it was found that the branches of *M. alba* were longer (by 94.18 cm) and thicker (by 4.01 mm) than those of *M. nigra*, as well as have 16 pcs. more buds per branch on average and 1.55 cm greater internodal distance (Table 3). Data on the traits Branch length (144.80 cm), Branch thickness (10.99 mm) and Internodes distance (4.79 cm) differ from the average values obtained by Petkov (2017) for *M. alba* (Branch length – 178.05 cm, Branch thickness – 11.74 mm, Internodes distance – 5.59 cm). The differences can be explained by the influence of growing conditions – climate, pruning and exploitation during the current and previous agricultural years (Petkov, 2017), as well as by the age of the mulberry, the type of soil and the state of soil nutrients (Lu et al., 2009).

Table 4. Analysis of variance of effect of a mulberry species on the branch morphology

Sources of variation	df	F	P
Branch length	1	78.344	* * *
Branch thickness	1	23.511	* * *
Number of buds	1	42.533	* * *
Internodes distance	1	19.560	* * *

*** p>0.001

The data presented in Table 4 show that the species exerts a highly significant influence (p>0.001) on all the analyzed traits characterizing the branch morphology.

Table 5 presents data on the characteristics determining the yield of a mulberry leaf. Productivity, expressed with the trait Leaf yield per branch, is a generalizing economic trait for integrating and combining other quantitative traits forming their essence (Petkov et al., 2016).

Table 5. Characteristics of leaf yield

Trait	*M. alba*		*M. nigra*	
	$\bar{x}$±SE	min-max	$\bar{x}$±SE	min-max
Number of leaves per one branch	62.0±8.22	41.00 – 85.00	16.87±5.56	8.00 – 27.00
Weight of leaves per one branch (gr)	221.11±35.35	150.00 – 320.00	27.37±4.34	9.00 – 45.00
Average weight of one leaf (gr)	5.69±0.48	4.70 – 7.14	1.55±0.13	0.91 – 1.94
Number of branches per one tree	38.20±2.08	32.00 – 43.00	51.00±0.00	51.00 – 51.00
Leaf yield per one tree (kg)	8.47±1.537	5.85 – 13.76	1.40±0.22	0.46 – 2.30
Leaf yield per one acre (kg)	1 406.35±255.17	971.10 – 2284.16	231.76±36.80	76.19 – 380.97

The analysis of the data (Table 5) shows that for *M. nigra* the trait Weight of leaves per one branch is an average of 193.74 gr less than that of *M. alba*, which can be explained by the smaller Number of leaves per one branch (45.13 pcs. on average) and the less average weight of one leaf (by 4.14 gr). As a result, smaller mulberry leaf yields were reported for *M. nigra* compared to *M. alba* – by 7.07 kg per one tree and 1,174.59 kg per one acre on average, respectively. In *M. nigra* a higher average value of the trait Number of branch per one tree is observed with 12.8 pcs.

The type of mulberry has a highly significant influence (p>0.001) in all analyzed traits determining leaf yield (Table 6).

Table 6. Analysis of variance of effect of a mulberry species on the leaf yield

Sources of variation	df	F	P
Number of leaves per one branch	1	38.876	* * *
Weight of leaves per one branch	1	48.777	* * *
Average weight of one leaf (gr)	1	97.056	* * *
Number of branches per one tree	1	63.887	* * *
Leaf yield per one tree (kg)	1	33.886	* * *
Leaf yield per one acre (kg)	1	33.886	* * *

*** p>0.001

Conclusion

The analysis of variances shows that the species of mulberry has a highly significant influence (p>0.001) in all analyzed cases characterizing leaf productivity. The differences found in the morphological characteristics of *M. alba* and *M. nigra* leaves are in sync with the significant morphological and anatomical differences between the studied species obtained by Erarslan et al. (2021), as the indicated results are a useful addition in differentiating the species affiliation and contribute to the taxonomy of the genus Morus. In general, the average values of the morphological traits of *M. nigra* are lower than those of *M. alba*, but they are within the limits of those generally established in practice. The high potential of the *M. nigra* species, reflected in the literature, is indicative of its importance in the breeding and improvement work in the selection and production of mulberry varieties and hybrids. This explains the great interest of scientists in researching the full capacity of the species, subject of the present study. In this sense, the obtained data enrich the scientific information, especially regarding the species *M. nigra*, and create a prerequisite for its further study and application possibilities.

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