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IDENTIFICATION OF EASTERN NORTH AMERICAN *MORUS* (MORACEAE): TAXONOMIC STATUS OF *M. MURRAYANA*

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ABSTRACT

Recent recognition of a new species of *Morus* (*Morus murrayana* D.E. Saar & S.J. Galla) from eastern North America highlights a general misapplication of the characters that discriminate the native *M. rubra* and the morphologically and ecologically variable introduced species *M. alba*. Morphological and molecular data presented here show that *M. murrayana* is best treated as a synonym of *M. rubra*, well within its range of morphology and sexual expression. Salient features of *M. alba* and *M. rubra* are presented in order to clarify the distinctions among these species.
KEY WORDS: Moraceae, *Morus alba*, *Morus murrayana*, *Morus rubra*

Two species of *Morus* L. (mulberry) occur in eastern North America (Wunderlin 1997). The native *M. rubra* L. ranges throughout much of the eastern United States — from the Edwards Plateau of Texas and north in the eastern Great Plains, to southern New England and the southern extreme of Ontario, Canada (Parks Canada Agency 2011), and south to northern Florida (Wunderlin 1982). It occurs in rich, circumneutral soils in native forested land and is now considered rare and threatened in many areas, particularly in the northeastern United States and southeastern Canada (United States — see USDA, NRCS 2012; Canada — Ambrose & Kirk 2004, Penskar 2009, Parks Canada Agency 2011). The introduced *M. alba* L., native to China, was established in North America during colonial times and is now naturalized and often invasive throughout most of the range of *M. rubra* (Wunderlin 1997). It has broad ecological amplitude, occurring in forests and open areas alike (and it continues to be commonly cultivated). The two species are known to hybridize where they co-occur (Burgess et al. 2005; Burgess & Husband 2006; see also Salah, 2006; Nepal 2008), with *M. alba* posing a potential threat to conservation of the native species. These species are generally easily distinguished in the field, but the recent description of *M. murrayana* highlights confusion often encountered when discriminating among them.

Students of dendrology commonly encounter the "weedy" *Morus alba* but ironically may be less familiar with the native *M. rubra*. Because *M. alba* thrives in a variety of habitats and exhibits much morphological variation, workers may — and commonly do — mistakenly identify variants within *M. alba* as the native *M. rubra*. Herein, we analyze the evidence used to support recognition of a new species of *Morus* — the recently described *M. murrayana* (Galla et al. 2009). We purport that *M. murrayana* and *M. rubra* are taxonomic synonyms and that recognition of the new species

resulted from the authors' failure to understand the identity of the type of *M. rubra.* Their misconception further led to misinterpretation of their molecular data (discussed below). Our taxonomic position with respect to *M. murrayana* is also supported by the available taxonomic information on these species (including the Flora of North America North of Mexico [FNANM] treatment by Wunderlin [1997], with which we concur). We think this clarification is critical and urgent because *M. rubra* is a species of conservation concern (see Parks Canada Agency 2011) and because of the potential for further propagation of a broad, multifaceted misunderstanding of its taxonomy. The present contribution is intended to serve primarily as an aid to proper identification of eastern North American *Morus* and to promote further study of these species.

Morus murrayana* is fairly typical *M. rubra

Identification of *Morus alba* and *M. rubra* is complicated by intraspecific variation in these species, coupled with contemporary abundance of the introduced species. For example, leaf size, lobing, and vestiture are highly variable within both species and must be properly contextualized when used as criteria for taxonomic recognition (see Britton & Brown 1913; Radford et al. 1968; Gleason & Cronquist 1991; Mohlenbrock 2002). Fruit color (a character highlighted by common names and sometimes employed by the layperson) is highly variable within *M. alba* and non-diagnostic. In fact, in wild populations, fruits of *M. alba* are usually red to black rather than white. Breeding system variation has also caused confusion. In describing *M. murrayana*, Galla et al. (2009) state that "*Trees produce either predominately staminate or carpellate inflorescences, but the presence of some staminate inflorescences on carpellate trees and vice-versa is common. … Both staminate and carpellate inflorescences may occur on the same large branch, usually separated on different twigs.*" They suggest, by contrast, that *M. rubra* is consistently monoecious. In fact, breeding system has generally not been carefully documented in North American *Morus* species and is intriguing. Despite wide reports of monoecy in *M. rubra*, our observations for this species in Kansas are corroborated by the *description* in Galla et al. (for *M. murrayana*, quoted above). We have found populations of both *M. alba* and *M. rubra* in the eastern Great Plains to be subdioecious, with the majority of individuals producing catkins of a single sex but with some (ca. 10%) being hermaphrodites (Nepal 2008 and unpubl.). The lectotype of *M. rubra* includes two separate branches, one with only staminate inflorescences and another with one twig bearing staminate inflorescences and another bearing carpellate inflorescences (Fig. 1).

The primary character emphasized by Galla et al. (2009) in support of their initial recognition of a new species (*Morus murrayana*) was large leaf size (>15cm). The authors further noted that Wunderlin's (1997) description of *M. rubra* in FNANM mostly encompasses the larger leaf size of *M. murrayana*. In addition, they state that "[*M. murrayana*] *... can be distinguished from M. rubra based on leaf vein pattern … leaves longer than 15 cm with caudate tips (vs. leaves <15 cm with cuspidate to broadly acute or acuminate tips), and fruits longer than 3 cm (vs. ≤3 cm).*" These features are congruent with the type of *M. rubra* (Fig. 1), and, in our experience, with the morphology of typical individuals of *M. rubra* from across the range. It is likely that larger leaves are under-represented in herbarium collections because leaves near flowering material are typically smaller and larger leaves may also be avoided by collectors. Overall, the details of the shape, vestiture, margins, and venation of leaves (rather than overall size) provide the most distinctive aspects of the leaves. The typical unlobed leaf of *M. rubra* is well represented by Figure 2C (*M. murrayana*) of Galla et al. (2009; p. 108). Most characteristic (*M. rubra*-like) are the drawn out "caudate" apices, closed venation, and smaller, more numerous, marginal teeth, features that are typically utilized in keys for *M. rubra* based on leaf morphology (e.g., Britton & Brown 1913; Gleason & Cronquist 1991; Wunderlin 1997). We have not been able to access type material of *M. murryana* (isotypes noted by Galla et al., 2009 have not been distributed). However, consideration of the description and illustration of *M. murrayana* (coupled with molecular data; see below) indicate that it is truly *M. rubra*.

Figure 1. *Morus rubra* lectotype (LINN 1112.6; Reveal 2007) image reproduced by the permission of the Linnaean Society of London. The upper branch and right side portion of the lower branch bear staminate inflorescences, while the left side portion of the lower branch bears carpellate inflorescences.

Galla et al. (2009) rightly highlight the value of field study (they studied plants directly in the field in Kentucky), but fieldwork cannot take the place of careful comparative study of herbarium

specimens collected over space and time. While species descriptions in floras accommodate typical variation, they are **mostly based upon herbarium specimens**. Galla et al. reported study of specimens at Missouri Botanical Garden (MO; which has holdings from throughout eastern North America) and considered some of the *M. rubra* specimens to be *M. murrayana* ("*There were no herbarium specimens at MO with similar morphological characteristics from any continent, except those identified as Morus rubra*" Galla et al. 2009, p. 111), but they did not annotate material (MHM, pers. obs. 2009). Most surprisingly, they did not indicate any study of the type specimens of *M. alba* and *M. rubra* (both of which are housed at the Linnaean Herbarium with images readily accessible online: *M. alba*, LINN 1112.1, <http://www.linnean-online.org/11602/>; *M. rubra*, LINN 1112.6, <http://www.linnean-online.org/11607/>; Fig. 1).

Molecular data confirm *M. murrayana* as a case of misidentification

Galla et al. (2009) applied molecular data to bolster their hypothesis of a new species, but an underlying assumption—proper identification of samples—was incorrect. The authors reported their sequence data for the internal transcribed spacer (ITS) region of the nuclear ribosomal DNA for accessions they identified as *M. murrayana* (three individuals) and *M. rubra* (two individuals), with comparison to some accessions from GenBank. They pointed out that sequences from what they described as *M. murrayana* were very different from their other sequences, which we contend represent *M. alba*. The latter set of sequences was in turn similar to GenBank accessions of Asian material. In a molecular phylogenetic study of the genus *Morus*, we have found *M. rubra* to form a well-supported clade with the native North American species *M. celtidifolia* Kunth and *M. microphylla* Buckley based on combined ITS and chloroplast data (Nepal & Ferguson, in press). Furthermore, alignment of our sequences of *M. alba* and *M. rubra* with sequences presented by Galla et al. (2009; as well as with additional sequences of these taxa now available on GenBank) confirms that their *M. murrayana* sequences match with *M. rubra*, while sequences of material they identified as *M. rubra* match with *M. alba* (Table 1).

Voucher information	**18S ITS1 ITS2** 11223445555666 26677777777778898801701166922 3 76901234567890187898903503578 6
FJ605515^, *M. murrayana* (= ***M. rubra***), KY	GCCGTGCGCAATGCGCTTTGTTTTATACGT
HM747165*, ***M. rubra***, KS	GCCGTGCGCAATGCGCTTTGTTTTATACGT
HQ144176, ***M. rubra***, MO	GCCGTGCGCAATGCGCTTTGTTTTATACGT
FJ605516^, *M. rubra* (= ***M. alba***), KY	AT----------TCCCACCACGCGTTC
HM747164*, ***M. alba***, KS	AT----------TCCCACCACGCGTTC
AM041998, ***M. alba***, India	AT----------TCCCACCACGCGTTC
AY345145, ***M. alba***, China	AT----------TCCCACCACGCGTTC

Table 1. ITS sequence differences between *Morus murrayana* of Galla et al. (2009) and other accessions of *M. rubra* and *M. alba*. Each row lists the GenBank accession number for the sequence, taxon as listed by submission authors and identification if interpreted differently here (in parentheses; inferred identification for each accession shown in bold face font), general locality, and base pair positions in the aligned ITS sequence matrix for which there are differences among these accessions. ^ indicates a sequence of Galla et al. (2009). * indicates new data reported herein (see also Nepal & Ferguson, in press).

Salient features for correct identification of *M. alba* and *M. rubra*

Morus rubra can be easily distinguished from *M. alba* using morphological characters of the leaf, bud, branch, bark and infructescence. Leaf characters present a challenge because of the tendency for leaves of juvenile shoots to converge in morphology among these species. Nearly all of the unique characteristics of *M. rubra* fail in juvenile leaves. Leaves of *M. rubra* (5–40 x 3–28 cm) are larger overall than those of *M. alba* (2–20 x 1.5–18 cm). In *M. rubra* leaves, the adaxial (upper) surface is rough and dull green (vs. smooth and lustrous) and the abaxial (lower) surface is usually densely hairy with erect trichomes evenly distributed (soft to the touch); the base is often cordate (heart-shaped); the apex is acute, acuminate to subcaudate; marginal teeth are often pointed; and the color of the main veins is more or less like the color of the lamina on the underside. Leaves of *Morus alba* are usually deep green and lustrous adaxially and have few hairs concentrated along the main veins on the abaxial surface; the base is rounded (vs. cordate); the apex is obtuse; the marginal teeth are fewer, relatively larger, and rounded; and the primary veins (underside) contrast more with the leaf surface than in *M. rubra*. The winter buds of *M. rubra* have bud scale margins with a darker (almost black) apical band, while in *M. alba*, the bud scale margins are uniformly brown. *Morus rubra* has grayish bark with flattened, thin plates that peel outwards in age. *Morus alba* bark has thick and solid ridges that are more of a reddish tan coloration. The orientation of branches in a mature *M. rubra* is somewhat planar (flat) and spreading like an umbrella. In *M. alba* the orientation of branches is more erect or spreading, and the plants appear more rounded or bushy as a result. The fruit of *M. rubra* is longer and narrowly cylindric, while in *M. alba* it is typically ovoid or ellipsoid.

Opportunities for future study

There is no question that *Morus* exhibits intriguing morphological variation in eastern North America, and further study is warranted. Patterns of intraspecific variation as well as effects of interspecific hybridization between *M. alba* and *M. rubra* warrant additional morphological and ecological scrutiny. We are encouraged to know that colleagues are exploring these issues (D. Saar, pers. comm.; Salah 2006; A. Whittemore, pers. comm.). We hope the present contribution clarifies the identities of the species *M. alba* and *M. rubra* in North America and spurs additional work on these taxa.

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