



Imperiled Native Ash (*Fraxinus* spp.) Species of Georgia

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Native ash trees can be found in every county in Georgia. For a tree species, they are evolutionarily young compared to other forest tree species. Ash trees are part of the deep forest and the deep swamp – upland ridges and mountain slopes. They also have been planted, cultivated and conserved in communities and tree farms. Ash species have great ecological and commercial values. Unfortunately, ash species also have a major exotic pest (emerald ash borer -- EAB) stalking them, which leaves few survivors. Here let’s examine our native ash species of Georgia, and discuss their history, biology, identification, and potential demise (primarily from the emerald ash borer -- EAB). This publication is designed for tree and forest professionals, and is not suitable for homeowners / tree owners.

INTRODUCTION

Ash species of North America are wide-spread and varied, growing in many forest types and ecosystems as well as a significant component of urban and community forests. White, green, black, blue, pumpkin, and Oregon ash are considered commercially important for wood products in the United States. Ash is known for its resilient and hard wood, its strong growth with many values generated for communities and parks, and its ecosystem services in many forest types and habitats. (MacFarlane & Meyer 2005) Culturally, the ancient ash cults of Europe, human origin stories from ash, ash nymphs of mythology called meliae, and the Norse mythological evergreen ash tree holding Earth and Heaven called “Yggdrasil” all suggest a social and psychological importance of ash trees to humans.

OLIVE FAMILY

Ash, the *Fraxinus* genus, is in the olive family (*Oleaceae* – 1813). The *Oleaceae* (olive) family has 24-28 genera and 400-900 species (depending upon the author) found across the globe in both temperate and tropical environments. (Call & Dilcher 1992; Dupin et.al. 2020; Liu 2017; Wallander 2008; Wallander & Albert 2000). Olive family members are primarily trees, shrubs, or woody vines with opposite leaves, and simple or compound leaves without stipules. (Wallander & Albert 2000)

Oleaceae is divided into five divisions or tribes: *Myxopyreae* - night-flower, *Jasmineae* - jasmine, *Forsythieae* - forsythia, *Fontanesieae* - fontanesia, & *Oleeae* - olive. Tribe *Oleeae* is further subdivided

into four sub-tribes = *Oleinae* - olive, *Fraxininae* - ash, *Ligustrinae* - ligustrum, & *Schreberinae*. (Dupin et.al. 2020) Common genera in the olive family with tree forms include lilac (*Syringa*), olive (*Olea*), privet (*Ligustrum*), jasmine (*Jasminum*), forsythia (*Forsythia*), fringetree (*Chionanthus*), devilwood (*Osmanthus*), swamp-privet (*Forestiera*), and ash (*Fraxinus*). The last four genera have one or more species native to Georgia. (Sargent 1965; Sargent 1904)

GENUS *FRAXINUS*

Trees of the *Fraxinus* (ash) genus were introduced to European gardens in 1737 from North America. The *Fraxinus* (ash) genus was officially named in 1753. The genus name has varied over time and authors, and have included *Apilia*, *Aplilia* 1836, *Calycomelia*, *Fraxinoides*, *Leptalix* 1836, *Mannaphorus* 1818, *Meliopsis*, *Ornanthes* 1836, *Ornus* 1790, *Petlomeia*, and *Samarpsea* 1836. *Fraxinus* is the current, correct and accepted name of the ash genus. The meaning of the name is “spear tree” or “shaft tree.” (Sargent 1965; Sargent 1904)

Fraxinus is common and widespread in North America, Europe, and Asia (almost exclusively in the Northern Hemisphere). Common names for ash include esche, frene or fresno. (Call & Dilcher 1992) *Fraxinus* has 45-70 species distributed in a circumpolar pattern across the Northern Hemisphere and aligned in six distinct lineages. (Arca et.al. 2012; Hinsinger et.al. 2013; Jeandroz et.al. 1997; Liu 2017; Qazi et.al. 2018; Taylor 1945; Wallander 2008; Wallander & Albert 2000). Only one species (*Fraxinus griffithii*) has a range which extends into the Southern Hemisphere (i.e. in Java). (Call & Dilcher 1992) Worldwide ash species distribution are 39% in the United States, 9% in Mexico and Central America, 45% in east Asia, and 7% in Europe and western Asia. (Liu 2017; MacFarlane & Meyer 2005; Qazi et.al. 2018; Wallander 2008).

Ash are usually medium to large deciduous trees in temperate zones & evergreen in sub-tropical zones. There are a few species which are evergreen and adapted to more arid environments. One of the evergreen ashes is *Fraxinus uhdei* from Central America. There are many ash cultivars used in community settings. (Call & Dilcher 1992; Liu 2017). About one-third of ashes are insect pollinated and two-third are wind pollinated. The wind pollinated species tend to be dioecious. (Liu 2017) *Fraxinus* has the most unique fruit in the olive family. The fruit has four ovules, but normally develops into a one-seeded samara – a nutlet with a broad, long wing. (Taylor 1945; Wallander 2008) The fruit is key because *Fraxinus* species are difficult to identify without flowers and fruit. (Taylor 1945)

The *Fraxinus* genus has six evolutionary lineages or sections with three in North America and three in Eurasia. Sections *Dipetalae*, *Melioides*, and *Pauciflorae* are in North America and Sections *Fraxinus*, *Ornus*, and *Sciadhanthus* are in Eurasia. Figure 1. (Arca et.al. 2012; Hinsinger et.al. 2013; Wallander 2008)

ASH ORIGINS

Fraxinus originated in North America near the Arctic circle during a warm period of Earth in north central to north western Canada. Ash gradually moved southward and dispersed across North America. (Sargent 1965; Sargent 1904) *Fraxinus* had diverged from among the *Oleaceae* (olive) family members

by the early Eocene (55mya -- millions of years ago) in North America. Figure 2. (Call & Dilcher 1992) The first half of the Eocene (55-45mya) was some of the warmest tree growth periods ever, with CO₂ at twice today's level. By the middle Eocene (45mya), *Fraxinus* had diversified into a variety of habitats and ecosystems of North America. (Call & Dilcher 1992; Hinsinger et.al. 2013; Jeandroz et.al. 1997; Wallander 2008) *Fraxinus* Section *Dipetalae* was first to split-off around 45mya. (Hinsinger et.al. 2013) There are fossil records of ash species from the middle Eocene (45mya) in the southeast. (Jeandroz et.al. 1997) By the middle Eocene (44mya), *Fraxinus* fruit were essentially modern in appearance. (Call & Dilcher 1992) Figure 3.

Divergence of other taxonomic sections of *Fraxinus* occurred during the middle and late Eocene (44-35mya) and Oligocene periods (34-25mya). For example, the important southeastern ash Section *Melioides* diverged around the late Eocene (30mya). The split between North American and Asian species occurred in the Oligocene (29mya). (Hinsinger et.al. 2013) *Fraxinus* dispersed widely during the Oligocene (23-34mya) as global and continental temperatures fell roughly -8°F. The cooling climate initiated a major extinction period for both angiosperm and gymnosperm trees. Ash species migrated across the Beringia land bridge to Asia leading to the development of many ash species in Asia and a few in Europe. (Hinsinger et.al. 2013; Jeandroz et.al. 1997; Liu 2017) Fossil records do not contain ash species in Asia or Europe until the Oligocene or later (28mya). (Jeandroz et.al. 1997) Two major ash dispersals between continents used the land bridge into Eurasia. (Jeandroz et.al. 1997) The Beringia (Bering Sea) land bridge to Asia occurred around 28mya. (Call & Dilcher 1992; Hinsinger et.al. 2013; Jeandroz et.al. 1997; Liu 2017; Wallander 2008)

Diversification of species within *Fraxinus* Sections occurred through the late Oligocene (25mya) and Miocene (24-14mya) as climates began to warm again. (Hinsinger et.al. 2013) *Fraxinus* genus diversification remained constant over time until it slowed around 20mya and slowed even further around 5mya. (Hinsinger et.al. 2013) The North Atlantic land bridges to Northern Europe occurred later in the Miocene around 15mya and 5.3mya. A third ash dispersal event from Eurasia back to North America occurred in the middle Miocene generating one Eastern North American species (black ash - *Fraxinus nigra*). (Call & Dilcher 1992; Hinsinger et.al. 2013; Jeandroz et.al. 1997; Liu 2017; Wallander 2008)

The most recent movement of ash species occurred after the last ice age ~12,000 – 18,000 years ago. During glaciation, some species were climatically pushed into the sea and extinction. The ice age refuge for ash species of Eastern North America during maximum glacial coverage was located in the Mississippi and Alabama coastal plains, and the lower Mississippi river valley areas. As glaciers began to melt and retreat northward, ash species effectively began moving back north at about 800 feet per year (i.e. 1 mile north every six (6) years on average). This suggests ash species could have regained current range distributions after about 10,000 years.

ASH SPECIES COMPLEXES OF THE SOUTHEAST

The four ash groups of southeastern North America are blue ash - *Fraxinus quadrangulata*, the green ash - *Fraxinus pennsylvanica* complex of species, the white ash - *Fraxinus americana* complex of species, and the water ash complex of species. Blue ash - *Fraxinus quadrangulata* remains relatively uniform while variants of the white, green, and water ash groups have been repeatably split, lumped, accepted and rejected. (Campbell 2017; Hardin & Beckmann 1982; Jeandroz et.al. 1997) Both the white ash - *Fraxinus americana* and green ash - *Fraxinus pennsylvanica* complex of species seem to have multiple species groups imbedded within them, possibly from hybridization, and not completely defined or recognized. (Wallander 2008) *Fraxinus* genus subsection *Melioides* includes Georgia native species in the white, green and water ash groups, and genus subsection *Dipetalae* includes blue ash. (Hardin & Beckmann 1982)

There has been other divisions and grouping of ash species in the southeastern United States. One study using genetic markers delineated the species groups as: white ash - *Fraxinus americana* / green ash - *Fraxinus pennsylvanica* group; Biltmore ash - *Fraxinus biltmoreana* group; Carolina ash - *Fraxinus caroliniana* group; and, blue ash - *Fraxinus quadrangulata*. (Hinsinger et.al. 2013) Another author defined the primary ash species of the southeast as: blue ash - *Fraxinus quadrangulata* (*Dipetalae* section), white ash - *Fraxinus americana* (*Melioides* section), Carolina ash - *Fraxinus caroliniana* (*Melioides* section), green ash - *Fraxinus pennsylvanica* (*Melioides* section), and pumpkin ash - *Fraxinus profunda* (*Melioides* section), but added there are a number of secondary variants of these ash species which carry variety or species designations. (Liu 2017) Another species relationship “tree” is shown in Figure 4. Nesom (2014) defined three ash groups with a total of eight (8) species in the southeastern United States: blue ash - *Fraxinus quadrangulata*; the *Pennsylvanica* group (green, Carolina, & pumpkin ash); and the *Americana* group (white, Biltmore, swamp white, & Small’s ash). Figure 5.

The best summary of ash species, which will be used in this publication, are the nine (9) recognized species and varieties in the southeastern United States listed with common name, scientific name and chromosome number shown in Figure 6. (Nesom 2014; Wallander 2008; Whittemore et.al. 2018)

Blue ash - *Fraxinus quadrangulata* represents the oldest lineage of the ashes, having split off the main core of ash species lines the earliest. (Jeandroz et.al. 1997) Blue ash - *Fraxinus quadrangulata* is a more northern species which is found in small remnant forest locations along its southern range. In its main distribution range, blue ash is found on dry limestone uplands along Ohio and Upper Mississippi valleys and is tolerant of drought. (MacFarlane & Meyer 2005)

WHITE ASH COMPLEX

The white ash group can be considered as a continuum from white ash - *Fraxinus americana* (diploid $2n = 46$), Small’s ash - *Fraxinus smallii* (tetraploid $2n = 92$ and hexaploid $2n = 138$), and Biltmore ash - *Fraxinus biltmoreana* (tetraploid $2n = 92$ and hexaploid $2n = 138$). Biltmore ash appears to have several

varieties which have not been explored. All three species can be found growing in the same area. (Campbell 2017; Nesom 2010a; Nesom 2014; Santamour 1962) Small's ash - *Fraxinus smallii* can also be called by the common names of Small's white ash and Sullivan's ash. Triploid ($2n = 69$) and pentaploid ($2n = 115$) hybrids within the white ash complex do rarely occur but are sterile. (Nesom 2010a)

Biltmore ash - *Fraxinus biltmoreana* and Small's ash - *Fraxinus smallii* are considered distinct species of ash separate from *Fraxinus americana* in the uplands of the eastern United States, differing from each other in fruit, leaf, twig, and petiole. (Nesom 2010a; Santamour 1962) Because of minute differences primarily based upon pubescence among Biltmore ash - *Fraxinus biltmoreana* and Small's ash - *Fraxinus smallii*, it is suggested referring to Small's ash - *Fraxinus smallii* as a variety *Fraxinus biltmoreana* var. *subcoriacea*. (Campbell 2017) The separation of glabrous from pubescent trees was found to be neither accurate nor precise. For example Biltmore ash - *Fraxinus biltmoreana* is a generally more glabrous species where the very similar, usually pubescent Small's ash - *Fraxinus smallii* can also contain glabrous individuals. (Whittemore et.al. 2018)

In the white ash complex of species, white ash - *Fraxinus americana* tends to be distributed more north and west of the polyploid species. Biltmore ash - *Fraxinus biltmoreana* range is in the southeast of the United States. (Nesom 2010a; Santamour 1962) Biltmore ash - *Fraxinus biltmoreana* has been suggested as a hybrid between white ash - *Fraxinus americana* and green ash - *Fraxinus pennsylvanica*. Biltmore ash seems to be a southern form of white ash and has leaves like white ash, and buds and twigs like green ash. (Black-Schaefer & Beckmann 1989; Nesom 2010a; Nesom 2014; Santamour 1962) Small's ash - *Fraxinus smallii* is found from east Texas to Florida and north to Missouri, Ohio and Pennsylvania. (Nesom 2010a; Santamour 1962) Small's ash - *Fraxinus smallii* was considered a hybrid by several authors. Other examinations showed the hybrid origins of Small's ash - *Fraxinus smallii* and Biltmore ash - *Fraxinus biltmoreana* were not supported. (Campbell 2017; Hardin & Beckmann 1982)

GREEN ASH COMPLEX

Green ash - *Fraxinus pennsylvanica* is separated into one group of more southern and eastern trees considered *Fraxinus pennsylvanica* var. *subintegerrima* and *Fraxinus pennsylvanica* var. *pennsylvanica* (more pubescent), and into a second group of more northern and western trees listed as *Fraxinus pennsylvanica* var. *campestris* and *Fraxinus pennsylvanica* var. *austini* (more pubescent). (Campbell 2017) The green ash group has been divided to include green ash - *Fraxinus pennsylvanica* (diploid $2n = 46$) & pumpkin ash - *Fraxinus profunda* (hexaploid $2n = 138$). (Campbell 2017) There is a tree growth and occurrence gradient along increasing site wetness going from green ash - *Fraxinus pennsylvanica* to pumpkin ash - *Fraxinus profunda* to Carolina ash - *Fraxinus carolinana*. (Campbell 2017) Pumpkin ash - *Fraxinus profunda* and Carolina ash - *Fraxinus carolinana* are usually grouped with the water ashes due to habitat similarity. (Nesom 2010c) Note that a common name for green ash in more northern parts of its range is red ash.

WATER ASH COMPLEX

Water ashes include at least two native wetland species of the southeastern United States – Carolina ash - *Fraxinus caroliniana* and swamp white ash - *Fraxinus pauciflora*. (Nesom 2010c) Carolina ash - *Fraxinus caroliniana* appears more closely related to green ash - *Fraxinus pennsylvanica* than to white ash - *Fraxinus americana*. (Nesom 2010a) There is a gradient along increasing site wetness going from green ash - *Fraxinus pennsylvanica* to pumpkin ash - *Fraxinus profunda* to Carolina ash - *Fraxinus caroliniana*. (Campbell 2017) As such, pumpkin ash - *Fraxinus profunda* is many times included within the water ash group.

Carolina ash - *Fraxinus caroliniana* is found on the Coastal Plain from northeast Virginia south to northern Florida and west to southeast Texas. Both diploid and tetraploid populations were found in Carolina ash - *Fraxinus caroliniana*, suggesting another taxonomic subdivision exists which may be swamp white ash - *Fraxinus pauciflora* (Whittemore et.al. 2018) Carolina ash - *Fraxinus caroliniana* is tolerant of wet sites and flooding. (MacFarlane & Meyer 2005)

Swamp white ash - *Fraxinus pauciflora* is found in northern FL to southern GA. It occurs in swampy and river bottom habitats which are usually flooded. (Nesom 2010a; Nesom 2010c) Swamp white ash - *Fraxinus pauciflora* is a native species associated more with the white ash group integrating with Carolina ash - *Fraxinus caroliniana*. (Campbell 2017; Nesom 2014) Swamp white ash - *Fraxinus pauciflora* is similar in leaflet underside to upland white, Biltmore, and Small's ash, and all seem related. Swamp white ash appears to be a hybrid between white ash - *Fraxinus americana* and green ash - *Fraxinus pennsylvanica*. (Nesom 2010a; Nesom 2010c) Swamp white ash - *Fraxinus pauciflora* is also called swamp ash and Florida ash as common names, and has been called *Fraxinus floridana* (1902). (Nesom 2010c)

The common name for pumpkin ash - *Fraxinus profunda* comes from its stem base being butt-swelled in its wetland habitat. (Nesom 2010b) Pumpkin ash - *Fraxinus profunda* grows along the Atlantic and Gulf coasts, and northward into the Mississippi and Ohio river valleys. Pumpkin ash (*Fraxinus profunda*) is found on the Coastal Plain from southern Maryland to northern Florida and west to Louisiana, then north to the southern tip of Illinois on wet sites. (MacFarlane & Meyer 2005; Nesom 2010b) The tree grows in river swamps, wetlands and floodplains which are seasonally flooded with fresh water along with baldcypress, cottonwood and water tupelo. One of pumpkin ash - *Fraxinus profunda* synonym is *Fraxinus michauxii*. (Nesom 2010b)

Pumpkin ash - *Fraxinus profunda* was thought to be a hexaploid ($6X$ or $2n = 138$), and probably a hybrid. (Nesom 2014; Nesom 2010b) Pumpkin ash - *Fraxinus profunda* was suggested as a hybrid between white ash - *Fraxinus americana* and green ash - *Fraxinus pennsylvanica*. (Black-Schaefer & Beckmann 1989; Nesom 2010a) Later work showed pumpkin ash - *Fraxinus profunda* is an octaploid ($8X$ or $2n = 184$), not hexaploid ($6X$) as previously cited. (Whittemore et.al. 2018) In addition, the hybrid origin of pumpkin ash - *Fraxinus profunda* is not supported. (Campbell 2017; Hardin & Beckmann 1982) Figure 7 is a summary of ash (*Fraxinus* spp.) complexes of the southeast and Georgia.

FIELD IDENTIFICATION ISSUES

Field identification of ash species is difficult and, depending upon the time of year, may not be possible except to the level of multi-species ash complexes. Below are descriptions from multiple authors and references detailing attributes of different native ash trees. Although a limited character key is not provided here, many individual characters should always be used to determine any one species. The first set of descriptions cover ash - *Fraxinus* in general to show what all the native species have in common.

There is significant overlap in fruit and leaflet characters among *Fraxinus* species rendering field and herbarium identification difficult. (Call & Dilcher 1992) *Fraxinus* species identifications are error-prone when based solely on morphological characters. (Jeandroz et.al. 1997) Identification of ash species is hampered by the trees not reaching sexual maturity until 15-20 years of age. (Black & Beckmann 1983) It is critical to use mature leaves for identification, not immature or juvenile leaves. (Hardin & Beckmann 1982)

Many people use tree size, leaf size, number of leaflets and their size, and samara length as important features of ash identification. These large, visible features do not differentiate effectively among native ash species. Using identification keys and species descriptions, tree height (Figure 8), leaf length (Figure 9), number of leaflets (Figure 10), leaflet length (Figure 11), and samara length (Figure 12) all show both the average value and range of values for each species. The overlapping averages and range of values for these major tree components show why ash identification is so difficult and error-prone.

Key characters cited for helping define and differentiate species are: leaf size, samara size, leaf serrations, leaf width, samara characters, pubescence, notched petioles, and waxy papillose lower leaf surface. (Campbell 2017) One field character used for identification is how inserted the lateral bud is into the petiole leaf scar, with diploid buds at least 40% inserted within the petiole scar and tetraploids buds roughly only 12% inserted. (Santamour 1962) Leaf color and texture of lower leaflet surfaces, decurrence of samara wings below seed cavity summit, and elongated shape of seed cavity in the samara has been cited as the best way to differentiate species groups, but not species. (Campbell 2017)

Identification of species in the *Melioides* section has proven difficult and traditionally been based upon the undersurface of leaflets differentiating between white and green ash groups. But, hybridization and polyploidy has complicated this section. (Wallander 2008) Polyploidy has been important in generation of species in ash, so ploidy level determinations should be used to help establish species boundaries. (Whittemore et.al. 2018) Figure 13 shows how many species of ash have mixed levels of chromosome counts which have not been defined and focused into species or variety levels. (Islam-Faridi et.al. 2020) New chromosome number based taxonomy splits among existing species will eventually be made and rearrange species groups.

SPECIES DESCRIPTIONS

References for Field Identification of Ash (*Fraxinus* spp.): Burns & Honkala 1990; Duncan & Duncan 1988; Harrar & Harrar 1962; Kirkman et.al. 2007; Lance 2004; Little 1979; Miller & Jaques

1972; Nelson et.al. 2014; NWF 2008; Petrides 1986; Preston 1976; Radford et.al. 1968; Sargent 1965; Sargent 1904; Swanson 1994; and, Taylor 1945.

GENERAL ASH SPECIES ATTRIBUTES **(*Fraxinus* spp.)**

Fraxinus is a genus containing ash tree species. The *Fraxinus* genus was officially named in 1753. A number of newly discovered species from North America had been introduced into European gardens 20 years earlier. Worldwide, there is debate about how many species are in the *Fraxinus* genus, ranging from 45-70. Every decade brings new changes to the organizational structure of the genus as new species concepts are developed.

Working with ash species for identification in the field requires careful observation skills because of similarities of the species and the variability of each individual. There are a number of field attributes shared by all species of ash, and are given below.

SITE / HABITAT:

Ash - *Fraxinus* spp. are relatively fast growing trees which are moderately intolerant to intolerant of interference and shade. Ash reproduces well naturally in forest settings and can be planted with good success in urban and community settings. Once established ash successfully colonizes and controls site resources along water (wet to dry) and heat (hot to cool) gradients. The white ash complex tends to be found more associated with upland sites, and the green ash complex tends to found more associated with bottomland or wet sites. (Islam-Faridi et.al. 2020) Figure 14 provides general habitat descriptions for the ash species complexes.

LEAVES:

Ash - *Fraxinus* spp. are almost all deciduous, with several species leaves persisting into the following spring. Leaves of ash are held opposite each other on twigs and are odd-pinnately compound. Figure 15. One western species has a single simple leaf and is not compound. Ash compound leaves carry from 3-15 leaflets, most with 7-9 leaflets. The leaflet margins can be smooth and entire, to variously toothed (serrated). Figure 16 shows leaflet cuticle appearance for select southeastern ash species. Figure 17 provides both trichome coverage and cuticle descriptions for upper and lower sides of leaflets.

FLOWER / FRUIT:

Ash - *Fraxinus* spp. flowers are small (<1/4" wide), usually without petals, and inconspicuous. A majority of ash are dioecious, with separate male and female trees. All but one tree in southeast United States are dioecious. Ash flowers are usually wind pollinated, although two western species have showy flowers and are insect pollinated. It should be remembered ash gender observations depend upon site, tree age, and the environment over time. A female ash will have a few male flowers and a male tree will have female flowers, with flower gender proportions changing over the life of a tree.

Ash seeds are contained in a single terminally winged samara with two (rarely 3) edges. Figure 18. If a samara wing has a vane down its middle, it is considered “3-veined” or 3-edged fruit. Samaras grow in loose drooping clusters or panicles developed in the axil of leaves. Each fruit has potential to hold several seeds, but only one usually develops. Flowering is in spring, fruit matures through summer, and drops in early to late fall. Trees without fruit, like male trees in dioecious species, can be difficult to identify.

TWIGS / TWIG SCARS:

Ash - *Fraxinus* spp. twigs have a terminal bud present and show no stipule scars. Visible buds usually have 2-3 pairs of bud scales. The pith is round and solid. Leaf scars are large with numerous bundle scars within. Leaf scars are in a U or V shape with lateral buds growing from the top to well inside the leaf scar. Figure 19.

PERIDERM (bark):

Many people visualize and recognize ash - *Fraxinus* spp. periderm as an interlaced pattern of fissures and ridges generating a diamond shaped bark surface pattern.

WOOD:

Ash - *Fraxinus* spp. wood is ring-porous, tough, and straight grained. It usually is not considered structural timber except in agriculture and maintenance structures. There have been many historic and a few current specialty wood uses for ash. Ash is thought of as tough, hard, and strong, but different ash species vary in these characters with some being more brittle and less dense than others.

FIELD IDENTIFICATION:

Ash - *Fraxinus* spp. are notorious for being difficult to identify at the species level, and even more difficult in identifying to variety level. In the past, two concepts were used to try and determine species: pubescence or its lack; and, hybrid integration. Both features are prone to significant mistakes based upon the discipline and experience of the observer. It has been shown the presence of, or lack of, pubescence coverage on leaflets, rachis, and twigs are not dependable identification characters. In the past, differentiating ash species in keys used pubescence as a decision point. Trichome presence or absence does not lead to accurate and precise species determination in the field. In addition, many ash species interpretations have been developed over whether some species are integrations between other ash species – a hybrid. Although proposed and tested many times, hybrid origins and associated intermediate field characters, have not been substantiated.

Below are listed the features of native ash species of Georgia. These native species have many valuable and interesting characters.

BLUE ASH

Fraxinus quadrangulata

Blue ash was discovered in 1795 by a botanist in Allegheny mountains. Blue ash has been given a number of species names over the last few centuries as its taxonomy was evaluated. Blue ash - *Fraxinus quadrangulata* has been named: *Fraxinus quadrangulata* 1803; *Fraxinus tetragona* 1811; *Fraxinus quadrangulata* var. *nervosa* 1838; *Fraxinus americana* var. *quadrangulata* 1846; and, *Fraxinus quadrangulata* var. *subpubesoens* 1892.

SITE / HABITAT:

Blue ash inhabits dry uplands and ridge tops, limestone areas and outcrops, and rich but dry bottomlands. Blue ash is found nowhere in large populations or in concentrated numbers. It is intolerant of interference and shade, and is fire damage prone. Blue ash is a medium sized, slender branched, branchy, short trunked tree with a narrow to rounded open crown. It has an average height of 64' tall (range = 40-80' tall), and 2' diameter (range 1-3' diameter). Maximum size is about 120' tall and 4' diameter. Blue ash range in Georgia is given in Figure 20, and encompasses only a few northwest Georgia counties.

LEAVES:

Blue ash leaves are an average of 10" long (range = 5-15" long) with an average of 7 leaflets (range = 5-11). Leaflets average 3.7" long (range = 2-5.5" long) and average of 1.5" wide (range = 1-2" wide). Leaflets are yellow green to green and smooth above with no trichomes, and slightly paler beneath with tufts of trichomes along the midvein and primary leaflet veins. Leaflets are thick and short stalked with coarsely toothed margins and a sharply pointed tip. The leaf rachis is slender, smooth or minutely pubescent.

FLOWER / FRUIT:

Blue ash flowers in April before leaves emerge. The flowers are cosexual (not dioecious) and inconspicuous. Blue ash fruit are slightly twisted, one-wing samaras with a broad rounded or square wing tip, sometimes with a small notch in the end. The samara wing runs the length of the seed cavity beyond more than half-way to its base. The seed cavity is notably flattened. Samaras are held in loose panicles. Samara are an average of 1.5" long (range = 1-2' long), and 0.3" wide (range = 0.12 - 0.4" wide).

TWIGS / TWIG SCARS:

Blue ash twigs are distinctly 4-sided and usually with 4 narrow, thin corky wings between the nodes. The twigs have no trichomes, and are stout with orange brown to slight reddish coloration when young, turning more brownish or greyish brown with age. The twigs have scattered lenticels and a solid round pith.

Twig surfaces show lines or striations coming from leaf scars. Leaf scars are U-shaped with a crescent shaped row of bundle scars. The upper edge of the leaf scar has a shallow notch where the lateral bud emerges. The twig terminal bud is pointed with three pairs of reddish brown scales. Crushed twigs

placed in water will generate a blue colored liquid upon exposure which gave rise to the common name of the species, as well as generating a water-based blue dye for textiles.

PERIDERM:

Blue ash periderm is thin ($\frac{1}{2}$ " thick), whitish to light grey in color – sometimes with a reddish grey coloration, and furrowed into flat scaly plates. It can be slightly shaggy looking (similar to older pecan hickory periderm). The secondary cortex / inner bark turns blue with oxidation.

WOOD:

Blue ash wood has been used for a variety of things where a harder, tougher wood is needed. Some of the cited uses of blue ash include: tool handles, lumber, sporting goods, veneer, flooring, interior wood work, carriage wood, and a blue dye.

OTHER:

Blue ash has been a common planted tree of communities, parks and cemeteries. It is most common in its native range along the Ohio and upper Mississippi river valleys.

WHITE ASH

Fraxinus americana

White ash - *Fraxinus americana* is a quintessential tree of Eastern North America. It was first described and grown in European gardens in 1739. White ash has had a number of species names over the last few centuries including: *Fraxinus americana* 1753; *Fraxinus nova* 1768; *Fraxinus alba* 1785; *Fraxinus acuminata* 1786; *Fraxinus juglandifolia* 1786; *Fraxinus caroliniensis* 1787; *Fraxinus canadensis* 1788; *Fraxinus epiptera* 1803; *Fraxinus americana* var. *latifolia* 1838; *Fraxinus americana* var. *normale* 1892; *Fraxinus americana* var. *acuminata* 1892; *Fraxinus americana* var. *eipiptera* 1892; *Fraxinus biltmoreana* 1898; and, *Fraxinus americana* var. *biltmoreana* 1947. Examination of white ash taxonomy has generated a number of unique off-shoots of the species definition. Common names have included white ash, American ash, Biltmore ash, and Biltmore white ash.

SITE / HABITAT:

White ash is a large tree averaging 75' tall (range = 50-100' tall), and 2.5' diameter (range = 2-3' diameter). Maximum size approaches 130' tall and 7' diameter. White ash grows in rich moist upland woods, moist fertile uplands, well-drained sites, low slopes and terraces but not flooded. It is not flood tolerant and does not grow in or near swamps and wetlands. White ash is intermediate tolerant to interference and shade, and is fire damage prone. White ash has a long straight trunk, round open symmetrical crown, and fast growth. In woodlands it tends to be a good self-pruner showing a clear trunk and high narrow crown. In community plantings, the tree tends to have a round crown with lower branches retained which require arboricultural management. White ash range in Georgia is shown in Figure 21.

LEAVES:

White ash leaves average 7 leaflets (range = 5-9) with an average length of 10" (range = 6-13" long). The leaflets are greyish white, pale and silvery beneath, and glossy dark green to pale green above. White ash leaflets average 5.75" long (range = 2.3 - 7" long), and 2" wide (range = 0.75 - 3" wide). The leaflet margins are smooth and entire, occasionally with a few faint teeth near the tip. Leaflets are pointed and long stalked. The underside of white ash leaflets is notable. The leaflet undersides can be either smooth and trichome free, or slightly pubescent. The leaflet underside has many minute, densely packed, rounded projections (i.e. glaucous) which makes the underside of the leaflet appear pale or whitish-grey. White ash leaflets are held on short unwinged stalks which average 0.4" long (range = 0.1-0.75" long). The leaflet stalks can occasionally be winged. The petiole is trichome free and the rachis is stout and grooved in cross-section.

FLOWER / FRUIT:

White ash flowers are small inconspicuous, emerging before the leaves in spring. The flowers are wind pollinated and dioecious, with male and female flowers on separate trees. The fruit is a plump, round cross-section samara averaging 1.5" long (range = 0.6 - 2.6" long), and with a 0.25" wide wing (range = 0.1-0.5" wide). The fruit are held in loose panicles. The samara wing is predominantly terminal or at most surrounding the top 1/4 of the seed cavity. The wing is blunt at the tip, smooth and light brown. The tip can be occasionally minutely notched.

TWIGS / TWIG SCARS:

White ash has stout, round, glabrous, lustrous dark green, grey green, or grey brown twigs, which are flattened at the nodes. The twigs have no trichomes but do have pale large lenticels. The pith is large, white, and solid. The leaf scars are U-shaped with a deep notch surrounding the lateral bud, and have numerous but indistinct bundle scars. The lateral buds are set deep into the leaf scar. Lateral buds commonly have superposed buds around their nodal location. The first pair of lateral buds are at the base of the terminal bud. The terminal bud has a rounded tip, 4-8 scales, and is dark brown.

PERIDERM:

White ash periderm is thick, rough, and dark brown tinged with red to grey brown in color. The periderm has narrow fissures separating into broad interlaced ridges which interweave into a diamond pattern. The secondary cortex is a dark tan or “cork” color.

WOOD:

White ash is a commercially important timber species. It has hard, heavy, straight-grained wood which is known for its toughness and strength. White ash has been used for: furniture, veneer, sporting goods, paneling, containers, oars, tennis rackets, musical instruments, skis, implements, tool handles, ice boxes, baseball bats, railroad ties, and fuelwood.

OTHER:

White ash is the most common of the native ash species in North America. It has been widely planted in community parks, cemeteries, greenways, and along streets. Many cultivars have been developed primarily showcasing fall color and lack of fruit.

BILTMORE ASH

Fraxinus biltmoreana

Biltmore ash - *Fraxinus biltmoreana* was first described from examinations of white ash - *Fraxinus americana* across its range in the 1890's. It is close to white ash in appearance and their ranges overlap, but there are significant genetic differences, some visible and some not. Biltmore ash's range is smaller than white ash. Biltmore ash has carried the species names of *Fraxinus biltmoreana* (1898), and *Fraxinus americana* var. *biltmoreana* (1947). Common names include Biltmore white ash and Biltmore ash.

SITE / HABITAT:

Biltmore ash is not a wetland species. It grows in drier upland woodlands and in more rich mesic forests. Biltmore has some flood tolerance for short shallow inundations. Biltmore ash is an infrequent occurring, open crown form, small to medium sized tree averaging 45' tall (range = 40-50' tall), and 14" diameter. It is localized to the southern-eastern Appalachians, Piedmont, more east of the fall line, and in more eastern states than southern. It shares a number characteristics with both white ash - *Fraxinus americana* and green ash - *Fraxinus pennsylvanica*. It is usually mistaken for white ash - *Fraxinus americana* because they grow on similar sites. It range overlaps with white ash - *Fraxinus americana* and is found from NJ west along the Ohio River valley to IL and MO, south to LA and TX, and east to Ga and FL, and north to VA. Biltmore ash range in Georgia is given in Figure 22.

LEAVES:

Biltmore ash leaves are 10-12" long with a stout petiole and 7-9 leaflets. The leaflet margins are entire and smooth with infrequent teeth. The leaflets are smooth, trichome free or glabrous above, and pubescent below along the mid-vein with long white trichomes. Biltmore leaflets are 3-6" long and 1.25-2" wide, and tapering and relatively narrow. Leaflets are thick, leathery, and glossy dark green on top, and pale whitish (glaucous) on the underside with a yellow mid-vein. Young leaves are smooth and trichome free for the first 5 years on seedlings and saplings, then become progressively more pubescent. The leaflet undersides, petioles, and rachis can be densely covered in trichomes. The petiole has fine short pubescence. The rachis can be sparingly to densely pubescent. Biltmore ash leaflets are held on a short pubescent stalk 0.25-0.5" long, with the terminal leaflet on a very long stalk up to 2" in length. Older leaflet undersides appear whitish and velvety.

FLOWER / FRUIT:

Biltmore ash flowers are small and inconspicuous, flowering in April and fruit ripening in September. It has only one gender on each tree (dioecious). Biltmore ash is wind pollinated. The fruit is a single winged, stout, blunt samara less than 2" long, usually between 1.5" and 1.75" long and 0.25" wide. The samara wing is primarily terminally connected to the seed cavity end and is roughly 2.5-3 times the length of the seed cavity, and extends about 1/3 the way down the seed cavity. The tip of the wing can be notched. The seed cavity is plump and rounded in cross-section.

TWIGS / TWIG SCARS:

Biltmore ash has stout, light to dark grey to grey brown twigs. The twigs are softly and usually quite densely pubescent with fine short trichomes. The leaf scar on the twigs are rough with a U-shape and deeply notched, almost surrounding the lateral bud. The terminal bud is fat and squat, with bright brown scales which have the outer scales keeled.

PERIDERM:

Biltmore ash has dark grey, rough, and slightly furrowed periderm. The secondary cortex and inner periderm are not reddish.

WOOD:

The wood can not be effectively differentiated from white ash - *Fraxinus americana*. It has specifically been used for wagon parts, tool handles, local hobby wood, and fuelwood.

OTHER:

Biltmore ash is very difficult to differentiate from white ash. Some consider Biltmore ash as a downy form of white ash - *Fraxinus americana*, but each have a different chromosome count. Biltmore ash has been suggested as a hybrid between white ash - *Fraxinus americana* and green ash - *Fraxinus pennsylvanica*, but other studies do not support the hybrid concept.

SMALL'S ASH
***Fraxinus smallii* or**
Fraxinus americana* var. *coriacea
Fraxinus biltmoreana* var. *subcoriacea

Small's ash - *Fraxinus smallii* was just defined as a species in 2010, although there has been observations of genetic variance in both Biltmore ash - *Fraxinus biltmoreana* and white ash - *Fraxinus americana* populations, suggesting a more comprehensive examination was needed. For many observers, the white ash variety name (*Fraxinus americana* var. *coriacea*) is sufficient.

SITE / HABITAT:

Small's ash - *Fraxinus smallii* is a small to medium sized tree growing in bottomland forests, on floodplains, river bluffs, slopes and ridges in from southeast Georgia and north Florida westward to Louisiana and north along the Mississippi and Ohio river valleys. Small's ash is 23-65' tall. It is easily confused with green ash - *Fraxinus pennsylvanica* foliage and white ash - *Fraxinus americana* fruit. Small's ash range in Georgia is given in Figure 23. The range is difficult to reliably determine. Small's ash is growing in the states of AL, AR, FL, GA, IL, IN, and KY.

LEAVES:

Small's ash has leaves which are 8-14" long with 7-9 leaflets. Leaflets are pointed with a round base, and 2.75-4.75" long and 1-2.75" wide. Underside of leaflets are whitish to pale green. Leaflet margins range from smooth and entire, to having shallow short teeth. Leaflet stalks are 0.1-0.75" long, and not winged. The rachis is not winged. Leaf petiole, leaflet stalks, and rachis are without trichomes.

FLOWER / FRUIT:

Small's ash has small inconspicuous flowers which emerge with the leaves. The tree is dioecious and wind pollinated. The fruit is a samara which is round and plump, and 1.3-1.75" long and 0.2-0.3" wide. The wing is more terminal on the end of the seed cavity and may grow down 1/4 of the way on the seed cavity sides. Small's ash samara tend to be slightly wider and longer than white ash - *Fraxinus americana*. Small's ash has been found to be at least a tetraploid ($2n = 92$) in chromosome number.

TWIGS / TWIG SCARS:

Small's ash twigs are round, smooth, and with no trichomes. The leaf scars are U-shaped with a shallow to medium depth notch where the lateral buds are enclosed. Winter buds are brown.

PERIDERM:

Periderm in Small's ash is light to dark grey with evenly spaced furrows and smooth ridges.

WOOD:

The wood of Small's ash is not commercially viable, although any larger trees harvested would be identified as white ash - *Fraxinus americana*, and used for similar items.

CAROLINA ASH

Fraxinus caroliniana

Carolina ash is a highly variable species in appearance which confounds clear species identification specifically with other water ash species, as well as other ashes in general.

Carolina ash was first described in 1731 as an addition from North America to European gardens. Carolina ash has been given a number of species names over the last few centuries as its taxonomy was evaluated. Carolina ash - *Fraxinus caroliniana* has been named: *Fraxinus caroliniana* 1768; *Fraxinus americana* 1785; *Fraxinus juglandifolia* 1786; *Fraxinus excelsior* 1788; *Fraxinus platycarpa* 1803; *Fraxinus pallida* 1808; *Fraxinus pubescens* 1808; *Fraxinus triptera* 1818; *Fraxinus curvidens* 1824; *Fraxinus pauciflora* 1849; *Fraxinus americana* var. *caroliniana* 1846; *Fraxinus american* var. *triptera* 1846; *Fraxinus nuttallii* 1860; *Fraxinus nigresoens* 1862; *Fraxinus cubensis* 1866; *Fraxinus platycarpa* var. *floridana* 1883; *Fraxinus nigra* sbsp. *caroliniana* 1892; *Fraxinus caroliniana* var. *cubensis* 1907; *Fraxinus rehderiana*; and, *Fraxinus caroliniana* var. *oblanceolata*. Its common names across its native range is Carolina ash, water ash, Florida ash, pop ash, poppy ash, and swamp ash.

SITE / HABITAT:

Carolina ash is a small, crooked, usually multi-trunked ash with a round to more narrow crown with many small branches. The base of the trunk is many time swollen or buttressed when growing in water or flooded conditions. Carolina ash averages 40' tall (range = 30-50' tall), and 10" diameter (range = 7-12" diameter). This ash is found in Coastal Plain swamps and along river backwaters, flatwood ponds and wet depressions in the landscape. Carolina ash is moderately intolerant to intolerant of interference and shade, and tolerant of excessive soil moisture, flooding, and permanently wet sites. Carolina ash is found skirting the Atlantic and Gulf coasts from the DelMar peninsula to halfway down the Florida peninsula, and west across to east Texas – always close to the coast and in wetlands. Carolina ash range in Georgia is given in Figure 24.

LEAVES:

Carolina ash leaves average 10" long (range = 5-15" long), with usually 7 leaflets (range = 3-9 leaflets). Leaves are dark green above and paler yellow green below, but not whitish in color. Leaves are considered mostly smooth and trichome free. Leaflets are thin, long slender stalked, with a wedge-shaped leaflet base. Leaflet margins are smooth and entire with occasional coarse, shallow, irregular teeth. Both leaflets and rachis can be trichome covered, or smooth and glabrous. Leaflet undersides can range from smooth and trichome-free, to velvety, and anywhere in-between. Leaflet undersides have no minute whitish rounded projections like in white ash.

Lateral leaflets are on slender long stalks 0.1-0.5" long, with the basal leaflet stalks not winged. The terminal leaflet is almost round in shape. Carolina ash leaflets average 4" long (range 1-6" long), and 2" wide (range = 0.75 - 3" wide). The rachis is stout and round in cross-section. An identification concept when examining Carolina ash is it has twigs like green ash and leaves like white ash, except for white ash's whitish projections on leaflet undersides.

FLOWER / FRUIT:

Carolina ash is a dioecious tree, with functional male and female flowers on different trees. Carolina ash flowers are small and inconspicuous, generated before the leaves expand. The fruit is an diamond shaped or rhomboid shaped samara widest in the middle and sometimes 3-winged (i.e having a 3rd wing vane or edge). The samara is large, broad, and flattened on a long stalk growing in loose panicles. The samara has a flattened seed cavity which takes up almost ½ of the total length of the samara. The wing surrounds the seed cavity and extends all the way to the base of the seed cavity. The wing is pointed or notched at the tip. Carolina ash samaras average 2" long (range = 1-3" long) and 2/3" wide (range = 0.4 - 0.9" wide).

TWIGS / TWIG SCARS:

Carolina ash has slender rounded, light greenish brown, slightly pubescent twigs, becoming grey-brown with no trichomes with age. Twigs are slightly flattened at the nodes and have scattered lenticels. The pith is round and solid. The leaf scars are U-shaped, with a line of U-shaped bundle scars, and are not deeply notched. The lateral buds sit at or above the leaf scar top. The terminal bud is 1/8" long and chestnut brown in color.

PERIDERM:

Carolina ash has tight, somewhat irregularly scaly grey bark with thin shallow fissures and long narrow scaly ridges.

WOOD:

Carolina ash is a small, poor-form tree of little commercial importance. Carolina ash has lighter and softer wood than other ashes, and generates a poor quality wood. It has been used for white-wood pulp and local fuelwood.

OTHER:

Carolina ash has been confused with, and named as a synonym with, swamp white ash - *Fraxinus pauciflora* growing in the same areas. Carolina ash can be found from Washington, DC. to middle Florida, and along the Atlantic and Gulf coasts as far west as Texas. The Cuban ash - *Fraxinus cubensis* can be considered a separate species in the southern half of Florida and into Cuba. Carolina ash can also be easily confused with both green ash - *Fraxinus pennsylvanica* and pumpkin ash - *Fraxinus profunda* on wet sites, especially when the tree is either male, or female without fruit.

SWAMP WHITE ASH

Fraxinus pauciflora

Swamp white ash - *Fraxinus pauciflora* was only split from Carolina ash - *Fraxinus caroliniana* in 2010. It has been named by several scientific names over the last two centuries. It was first identified and named in 1849. Swamp white ash has been named: *Fraxinus pauciflora* 1849; *Fraxinus cubensis* 1866; *Fraxinus platycarpa* var. *floridana* 1883; and, *Fraxinus caroliniana* var. *cubensis* 1907. Swamp white ash - *Fraxinus pauciflora* is sometimes considered a synonym with *Fraxinus floridana*, *Fraxinus hybrida*, and *Fraxinus profunda* var. *ashei*. Common names for the species include swamp white ash, pop white ash, water white ash, and Florida ash.

SITE / HABITAT:

Swamp white ash is an uncommon small tree of swamps, sloughs, low pastures, riparian woodlands, and standing water areas. Swamp white ash is similar to Carolina ash - *Fraxinus caroliniana* except for the underside of leaflets. It ranges from 14-35' tall and 12" diameter. Swamp white ash is usually grows in a single stem, straight, erect form. It is one of the water ashes. Swamp white ash is found on the southern Coastal Plain and lower Piedmont of east North Carolina, south to south Georgia and north Florida. Swamp white ash range in Georgia is given in Figure 25.

LEAVES:

Swamp white ash has small leaves roughly 4-9" long with 5 (3-7) leaflets. The lower surface of the leaves have minute projections in shallow depressions giving a pale to whitish appearance. Leaflets are thick, dark green on top and tend to have a rolled (revolute) margin with fine to course teeth. Leaflets are 3.5" long and 1.125" wide. There is light pubescence on the upper surface and heavy pubescence on the underside. The leaflet stalks are 0.25 to 0.5" long and the petioles are round and stout.

FLOWER / FRUIT:

Swamp white ash flowers are small and inconspicuous, flowering in March with fruit ripe in fall. Tree is dioecious and wind pollinated. Fruit is a single winged samara with a broad rounded (sometimes notched) wing which surrounds seed cavity to its base. Seed cavity is flattened and short stalked. Swamp white ash requires warm temperatures for seed germination which occurs in early summer.

TWIGS / TWIG SCARS:

Swamp white ash twigs are light orange brown in color with large pale lenticels visible in the first growing season. The terminal bud is pointed and 0.25" long.

PERIDERM:

Swamp white ash has tight, thin, light grey periderm with small scales.

WOOD:

Swamp white ash wood is of no commercial value and has been used for local hobby wood and tool handles. It is easily confused with white ash - *Fraxinus americana* wood.

OTHER:

Swamp white ash because of where it grows in swamps and wetlands, could be confused with Carolina ash - *Fraxinus caroliniana*. Swamp white ash having smaller leaves and shorter samara stalks than Carolina ash.

PUMPKIN ASH

Fraxinus profunda

Pumpkin ash - *Fraxinus profunda* has been considered a synonym with *Fraxinus tomentosa*, *Fraxinus michauxii*, *Fraxinus pennsylvanica* var. *profunda*, and *Fraxinus pennsylvanica* ssp. *profunda*. Pumpkin ash has been scientifically named *Fraxinus tomentosa* 1813; *Fraxinus americana* var. *profunda* 1894; and, *Fraxinus profunda* 1897. Its most common names are either pumpkin ash or ash. The scientific species name means deep swamps, and its common name of pumpkin ash denotes its swollen and buttressed trunk base when growing in water.

SITE / HABITAT:

Pumpkin ash can be found over a large range, most commonly observed in flooded bottomlands, coastal swamps, flooded areas, wetlands, river swamps, and flatwoods. Pumpkin ash has a slender tall trunk, many times with a swollen or buttressed trunk base when growing in flooded areas. It has a narrow upright crown, and is fast growing, short lived, and intolerant to moderately intolerant of interference and shade. Pumpkin ash is fire prone when fire comes into the wetlands during severe dry periods. Pumpkin ash is a medium to large tree averaging 85' tall (range = 80-100' tall), and 3' diameter (range = 2 - 5.5' diameter). Maximum size approaches 125' tall and 5.5' diameter. It appears similar to green ash - *Fraxinus pennsylvanica*. Pumpkin ash range in Georgia is given in Figure 26.

LEAVES:

Pumpkin ash leaves average 12" long (range 4-20" long). Leaves have 7 leaflets (range = 5-9). The leaves tend to droop. Leaf petioles and rachis are covered with trichomes. The leaflets are large, lustrous, long pointed, round based, and leathery. Leaflet margins can be entire, and rarely sparingly toothed, or wavy edged. The underside of leaflets are covered with dense velvety trichomes, especially along the midvein and in vein intersections. Leaflets are dark yellow green and lustrous above, and red brown pubescent below. There are no whitish or pale small rounded projections on the underside of leaflets. Pumpkin ash leaflets are held on trichome covered stalks averaging ½" long (range = 0.2 - 1" long). The basal leaflet stalks are wingless.

FLOWER / FRUIT:

Pumpkin ash is dioecious with inconspicuous flowers on both male and female trees. The fruit is a single winged samara which averages 2.3" long (range = 1.5 - 3" long), and 0.4" wide (range = 0.24 - 0.5" wide). The wing is attached down below halfway on the plump rounded seed cavity, sometimes completely surrounding the seed cavity to the base. The wing tip is squared at the tip. Pumpkin ash samaras sometimes have a third vane along the wing length giving a 3 wing appearance.

TWIGS / TWIG SCARS:

Pumpkin ash young twigs are densely pubescent. Twigs are velvety round, stout, and light grey to grey brown. Leaf scars on twigs are deeply concave with a U or V shape, and deeply notched surrounding a lateral bud. The terminal bud is rounded with 3 pairs of reddish brown scales, and the lateral buds are rusty brown to dark brown.

PERIDERM:

Pumpkin ash periderm is tight, thin, light grey, deep narrow ridged, somewhat scaly, with shallow furrows. The interlacing ridges and furrows form a diamond shaped pattern like in white ash.

WOOD:

Pumpkin ash wood is of little economic value. It has been locally used for boxes, veneer, and furniture.

OTHER:

Because of great variability among most ash species and the amount of trichomes on leaves and twigs, trichomes should not be used as an singular feature of identification. A non-pubescent form of pumpkin ash exists and has been called *Fraxinus profunda* var. *ashei*. Some consider pumpkin ash a hybrid between white ash and green ash in northern Georgia.

GREEN ASH

Fraxinus pennsylvanica

Green ash - *Fraxinus pennsylvanica* is an ash species with highly variable characteristic and can be confused with several other ash species. It was first recorded as being introduced to English gardens in 1783. Green ash has been given a number of scientific names over the last few centuries: *Fraxinus pennsylvanica* 1785; *Fraxinus pubescens* 1786-1789; *Fraxinus lanceolata* 1800; *Fraxinus juglandifolia* var. *subintegerrima* 1804; *Fraxinus pubescens* var. *longifolia* 1804; *Fraxinus pubescens* var. *latifolia* 1804; *Fraxinus pubescens* var. *subpubescens* 1804; *Fraxinus longifolia* 1808; *Fraxinus subvillosa* 1808; *Fraxinus tomentosa* 1813; *Fraxinus viridis* 1813; *Fraxinus discolor* 1817; *Fraxinus americana* var. *pubescens* 1846; *Fraxinus oblongocarpa* 1862; *Fraxinus viridis* var. *pubescens* 1891; *Fraxinus pennsylvanica* var. *lanceolata* 1894; *Fraxinus darlingtonii* 1901; *Fraxinus campestris* 1908; *Fraxinus smallii* 1908; *Fraxinus pennsylvanica* var. *austini* 1938; and, *Fraxinus pennsylvanica* var. *subintegerrima* 1947. Common names include: green ash, red ash, Darlington ash, white ash, swamp ash, and water ash.

There are currently at least 4 varieties of green ash named – two are more north and west within the green ash range, and two are more south and east in the green ash range. The latter two will be covered here as they grow in Georgia and the southeast. These varieties of green ash are: typic green ash - *Fraxinus pennsylvanica* var. *pennsylvanica*, and narrow-leaf green ash - *Fraxinus pennsylvanica* var. *subintegerrima*.

SITE / HABITAT:

Green ash is a medium sized tree averaging 50' tall (range = 30-100'), and 21" diameter (range = 12-36" diameter). Maximum size can approach 130' tall and 4.5' diameter. Green ash is smaller proportioned than white ash, with a compact and irregular crown. The species is intermediate tolerant to intolerant of interference and shade, and although considered a moist site tree, is not flood or swamp adapted. It grows fast on moist uplands, wet (not flooding) bottomlands, stream edges, and near wet depressions. It tends to be more of a Piedmont site tree, rather than a mountain tree species. The two varieties of green ash ranges for Georgia are given in Figure 27 and Figure 28.

LEAVES:

Green ash leaves average 10" long (range = 6-16" long). Each leaf averages 7 leaflets (range 5-11), with 5 leaflets and 11 leaflets being quite rare. Green ash leaflets average 4.4" long (range = 2.8-6" long), and 1.3" wide (range = 0.9-1.8" wide). In one citation, leaflets were listed as always <4.3" long. The leaflets are glossy yellow green to green above without trichomes, and green to light green without trichomes or with fine pale rusty pubescent below. Green ash leaflet undersides can be light green (not pale), with no rounded whitish projections (i.e. not glaucous) below, and with any pubescence concentrated on the midvein. Leaflet margins can be entire and smooth, or more rarely fine blunt toothed especially near the pointed tip. Leaflet bases are wedge shaped. Green ash leaflets are short stalked with stalks averaging 0.25" long (range = 0.125 - 0.5" long). The basal leaflet stalks on each leaf usually are flattened or winged. Petioles and rachis are trichome covered. The rachis is stout and sometimes winged.

FLOWER / FRUIT:

Green ash flowers are small and inconspicuous, generated as the leaves are expanding. The species is wind pollinated and dioecious. The fruit is a single wing samara averaging 1.75" long (range = 1-2.5" long) with a wing 0.25" wide (range 0.2 - 0.3" wide). The light brown samaras grow in a wooly panicle. Green ash samara's seed cavity are plump and round in cross-section. The wing arises from near the seed cavity tip, growing about half-way down the seed cavity. Green ash samara wings range from pointed to notched at the tip.

TWIGS / TWIG SCARS:

Green ash has round, stout, red-grey, green-grey, and grey-brown twigs, with older branchlets shiny, without trichomes, and smooth. Young twigs up to 2 years old are usually pubescent to velvety, with trichomes being a reddish brown color. Green ash twigs are flattened at the nodes, with a round solid pith. Green ash has visible leaf scars which are U-shaped, half round, and usually straight across the top but can have a slight notch. Green ash leaf scars partially encircle roughly ½ the lateral bud, or the lateral bud sits above the top of the leaf scar. The terminal bud can be pointed or rounded, and roughly 0.175" long with 6 velvety rusty-red scales.

PERIDERM:

Green ash periderm is smooth, tight, thin, brown tinged with red, grey brown, green brown or brown in color. The periderm is a close fitting network of narrow fissures separated by interlacing ridges forming a diamond shape pattern. The secondary cortex is a light red color.

WOOD:

Green ash wood is usually grouped with white ash, but green ash wood is more brittle and considered inferior to white ash. Green ash wood has been used for sporting goods, handles, veneer, and boxes.

OTHER:

Green ash is a highly variable species usually divided into a number of varieties, none of which reach sub-species or species level of definition. Green ash is known as a great shelterbelt and windbreak tree, and is widely planted in communities. It is both the most widely and most northerly distributed of the ashes in North America. Many cultivars have been developed primarily showcasing fall color and lack of fruit.

There is a great problem with green ash identification, especially differentiating among the water ashes. Green ash can be either glabrous without trichomes, or covered extensively with heavy trichomes, and everything in between. A number of authors and keys over the last century have partially used presence or absence of trichomes as a guide for identification. It is clear green ash can not (should not) be differentiated by trichome presence or absence alone. There are many intragradations of green ash.

As mentioned earlier, in the southeast and in Georgia, two varieties of green ash are identified. The varieties of green ash are: typic green ash - *Fraxinus pennsylvanica* var. *pennsylvanica* (trichome dominate form), and narrow-leaf green ash - *Fraxinus pennsylvanica* var. *subintegerrima* (no trichome or glabrous form). The narrow-leaf green ash - *Fraxinus pennsylvanica* var. *subintegerrima* (12, 13) has been considered a synonym of all the green ash varieties and to the species.

Narrow-leaf green ash - *Fraxinus pennsylvanica* var. *subintegerrima* grows on moist sites along river valleys, but can be found planted in more western shelterbelts & windbreaks, within communities, and doing well under more harsh conditions, once established. Narrow leaf green ash tends to be more western among the whole range of green ash, with a great overlap with typic green ash is southwest & west central Georgia. Narrow leaf green ash has a rounded crown with many slender sprawling branches, seldom exceeding 65' tall and 2' diameter. Narrow-leaf green ash leaflets are lustrous green above and below, with sharply toothed margins. The leaflets tend to be more narrow than typic green ash (*Fraxinus pennsylvanica* var. *pennsylvanica*), with trichomes sometimes along the mid-vein, but usually trichome free. The twigs are smooth, round, ashy grey with pale lenticels and no trichomes. Bud scales are covered with dark rusty pubescence.

The Threat of Emerald Ash Borer (EAB)

Emerald Ash Borer (EAB) is an exotic, invasive insect *Agrilus planipennis* (Coleoptera: Buprestidae) first found in North America in the early 2000s in Michigan. (Islam-Faridi et.al. 2020; Qazi et.al. 2018) EAB is a phloem and wood boring beetle native to northeast Asia. EAB was likely introduced to the United States in the 1990's from solid wood packing materials from Asia. (Liu 2017) It was first noticed in 2001 in the Great Lakes area. It quickly spread and decimated ash trees. EAB was identified in Georgia in 2013. (Islam-Faridi et.al. 2020; Liu 2017)

Native ash of North America have not co-evolved with this pest from Asia, and although native ash resistance varies, all North American ash species are highly vulnerable. (Tanis & McCullough 2012) In its native range in Asia, EAB is a secondary pest attacking stressed and dying trees. In North America it attacks healthy trees as well, with all native ashes vulnerable and showing little resistance. (Liu 2017; Tanis & McCullough 2012) EAB has killed tens of millions of ash trees in the United States and threatens to kill eight billion ash trees across North America. (Islam-Faridi et.al. 2020; Qazi et.al. 2018)

Ash was once a dominant forest and urban tree in Eastern North America, but now the species in North America is endangered by the rapid spread of EAB. (Whittemore et.al. 2018) Forested tract ash mortality can exceed 99% in a few years after heavy infestations. (Liu 2017; Tanis & McCullough 2012) In one case, EAB caused mortality among ash species in forest and urban settings was 95-98% over a 2-3 year period. (Whittemore et.al. 2018)

High risk of EAB attack and mortality include urban sites with a large number of ash trees which might be stressed from climate and site issues. In addition, much of the urban ash present are of limited genetic diversity (low number of individual cultivars or limited geographic origin of gene sets), and species (concentrated single species) diversity. (MacFarlane & Meyer 2005) EAB prefers trees which have been nitrogen enriched or fertilized. (MacFarlane & Meyer 2005) Ash is usually killed within six years of detection of infestation. (Qazi et.al. 2018)

Ash trees are injured by EAB larvae feeding on phloem and cambium area of tree excavating serpentine galleries. (Tanis & McCullough 2012) EAB symptoms do not become noticeable until they are quite severe, usually seen as crown dieback. (Islam-Faridi et.al. 2020) Signs and symptoms of EAB infestation include crown dieback, crown thinning, epicormic shoots, woodpecker feeding damage, periderm splits, serpentine larval galleries, notched leaflets from adult feeding, D-shaped exit holes, and tree mortality. Tree mortality usually occurs within 2-4 years after canopy decline and dieback. (Liu 2017; Tanis & McCullough 2012) An ash dieback pathogen (*Hymenoscyphus fraxineus* – *Chalara fraxinea*) from Eastern Asia is sometimes associated with EAB and is spreading across Europe and may soon be present in North America. (Islam-Faridi et.al. 2020)

Most North American ashes are susceptible to EAB. (Islam-Faridi et.al. 2020; Whittemore et.al. 2018) There are some small differences and resistance in ash responses to EAB. Southeastern *Fraxinus* species resistance to EAB based upon measured host defense response are listed from most resistant to

least: blue ash - *Fraxinus quadrangulata*; pumpkin ash - *Fraxinus profunda*; green ash - *Fraxinus pennsylvanica*; Biltmore ash - *Fraxinus biltmoreana*; and, white ash - *Fraxinus americana*. (Kelly et.al. 2020; Tanis & McCullough 2012) Pumpkin ash - *Fraxinus profunda* has seldom been attacked by EAB, and blue ash - *Fraxinus quadrangulata* appears somewhat resistant to attack. (Qazi et.al. 2018)

Blue ash - *Fraxinus quadrangulata*, of all the North America species, shows some small degree of resistance to EAB due to the presence of unique defensive compounds which are also found in northeast Asian ash species. (Liu 2017; Islam-Faridi et.al. 2020; Qazi et.al. 2018; Whittemore et.al. 2018) Blue ash may be slightly less preferred or less suitable for EAB than other native ashes, and has shown more resistance with longer survival rates, but can still show severe symptoms. (Tanis & McCullough 2012)

CONCLUSIONS

Ash represents an unique and problematic set of species in Georgia. The old identification rules involving trichomes, leaves, habitats, and twigs have proven to not be accurate at the species level. Identifications to species-group level are easier, but not without significant errors. Until more genetic work is completed and better species definitions crafted, ash identification will remain hit-or-miss. Figure 29 provides a simple summary matrix of field identification attributes for native ash complexes of Georgia, but does not represent a taxonomic key.

Ash susceptibility to EAB in Georgia may be catastrophic for the species. Breeding programs for tree resistance derived from surviving trees, exotic resistant trees, or from changing periderm chemical constituents are all potentially valuable in combating EAB and still keeping ash trees as part of the landscape. Unfortunately, if people can not tell one ash species from another, or appreciate the diversity of different ash species in Georgia, identifying and quantifying resistance will be difficult.

Monitoring and quick control of EAB outbreaks are critical to ash defense. From a community tree management standpoint, new ash species plantings should be avoided at the current time and into the near future. Tree health care (PHC) monitoring cycles should be accelerated for mature ash stands and landscape plantings. Rapid appropriate response is key to continuing to have sustainable ash.

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NORTH AMERICAN ASH SECTIONS

Dipetalae **

**North America, southwest / central /
eastern United States, central Canada.**

Melioides **

**North America, United States, Hawaii,
eastern Canada, Mexico, central America.**

Pauciflorae

**southwest United States, Mexico,
central America.**

EURASIAN ASH SECTIONS

Fraxinus

**Europe, north Africa, southwest Asia,
northeast Asia, China.**

Ornus

China, Asia, Japan, southern Europe.

Sciadanthus

northwest Africa, Afghanistan, China.

Figure 1: Lineage divisions or sections in *Fraxinus* genus and their native range / location. ** = southeastern US species.

(Wallander 2008)

Cenophytic Age = Age of Flowering Plants Age of Angiosperms

name	starting time
Holocene	0.1 mya
Pleistocene	1.8 mya
Pliocene	5.4 mya
Miocene	24 mya
Oligocene	34 mya
Eocene	55 mya
Paleocene	65 mya

Figure 2: Geologic and evolutionary time divisions and their starting times in millions of years before present (mya).

NUMBER OF ASH SPECIES

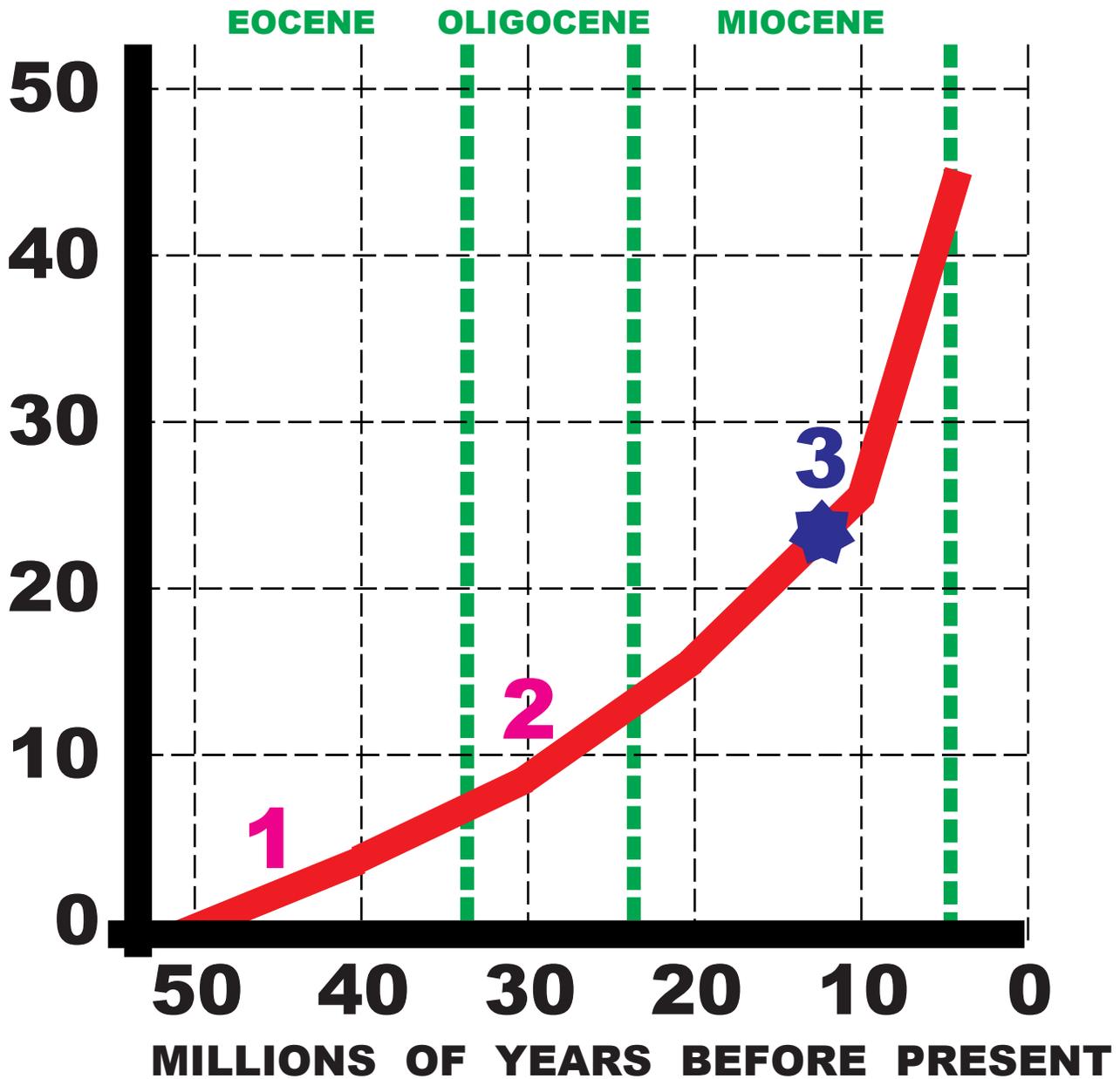


Figure 3: Divergence and diversification of ash species (*Fraxinus* spp.) over time. Number **1** was divergence of *Dipetalea* (blue ash), number **2** was divergence of North American *Melioides*, and number **3** was rapid diversification of North American *Melioides*. (after Hinsinger et.al. 2013)

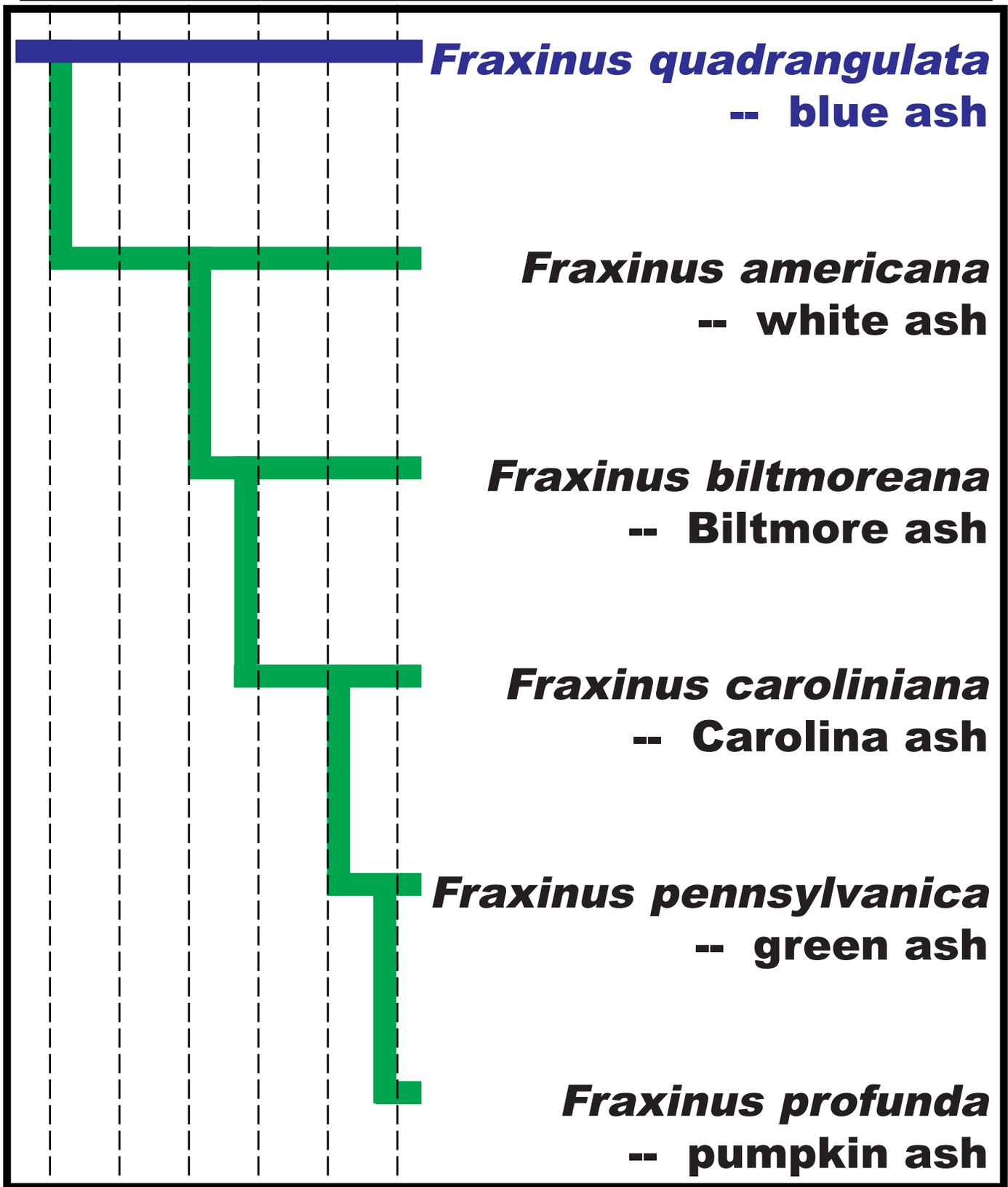


Figure 4: Genetic relationships between select native ash species of the southeast. (after Wallander 2008)

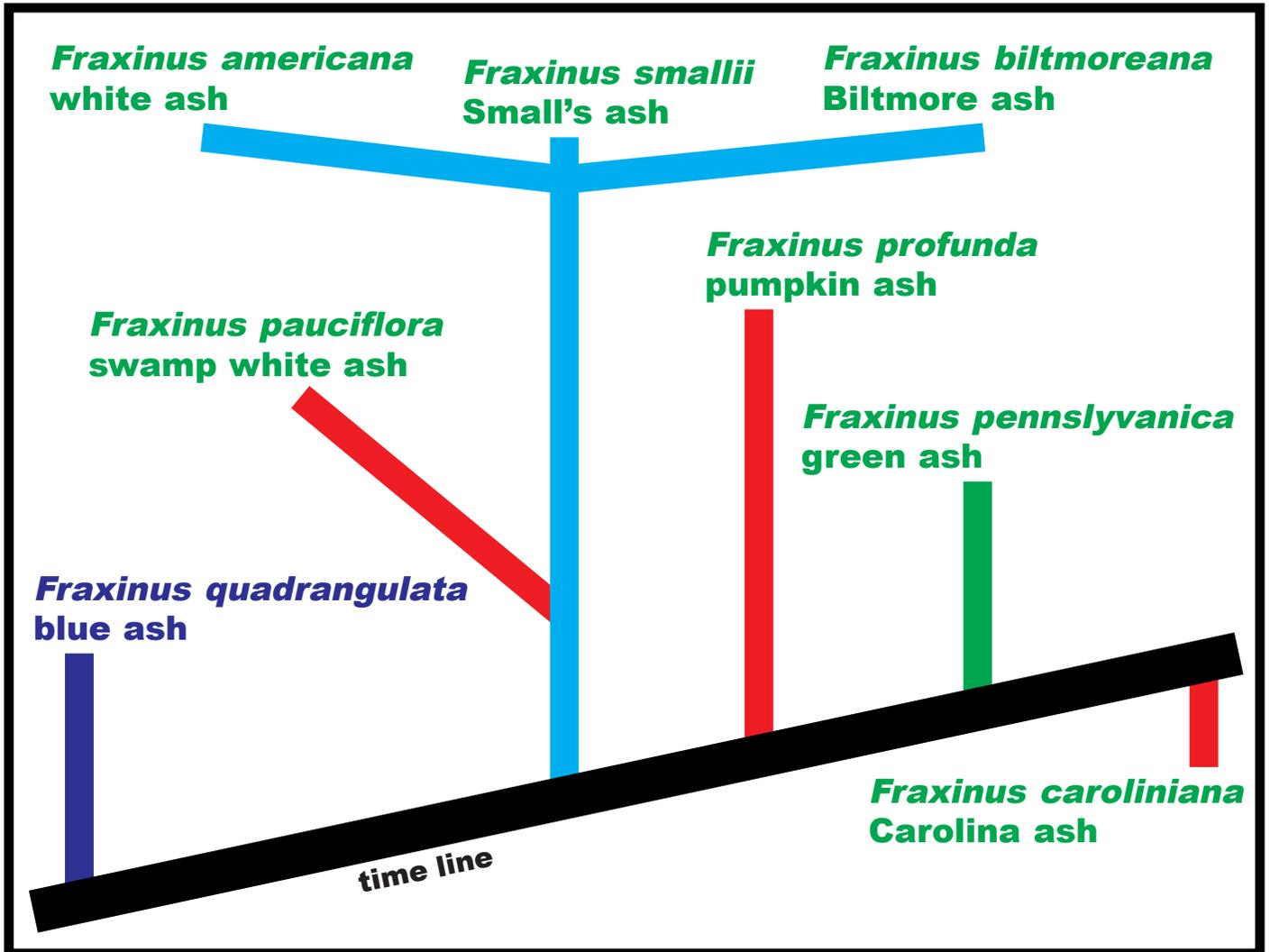


Figure 5: Relationships between southeastern ash species (*Fraxinus* spp.) and their development over time. (Nesom 2014).

- 1. blue ash - *Fraxinus quadrangulata***
(diploid $2n = 46$)
- 2. WHITE ASH COMPLEX:**
 - white ash - *Fraxinus americana***
(diploid $2n = 46$)
 - Biltmore ash - *Fraxinus biltmoreana***
(hexaploid $2n = 138$) *
 - Small's ash - *Fraxinus biltmoreana* var. *subcoriacea* or *Fraxinus smallii***
(hexaploid $2n = 138$) *
- 3. GREEN ASH COMPLEX:**
 - green ash - *Fraxinus pennsylvanica* var. *pennsylvanica*** (diploid $2n = 46$)
 - narrow-leaf green ash - *Fraxinus pennsylvanica* var. *subintegerrima***
(diploid $2n = 46$)
- 4. WATER ASH COMPLEX:**
 - Carolina ash - *Fraxinus caroliniana***
(diploid $2n = 46$) *
 - swamp white ash - *Fraxinus pauciflora***
(tetraploid $2n = 92$)
 - pumpkin ash - *Fraxinus profunda***
(octaploid $2n = 184$)

* = tetraploid levels found in minority (<20%) of samples

Figure 6: List of nine (9) ash species recognized in the southeastern United States -- listed with common name, scientific name and chromosome number.

(Nesom 2014; Wallander 2008; Whittemore et.al. 2018)

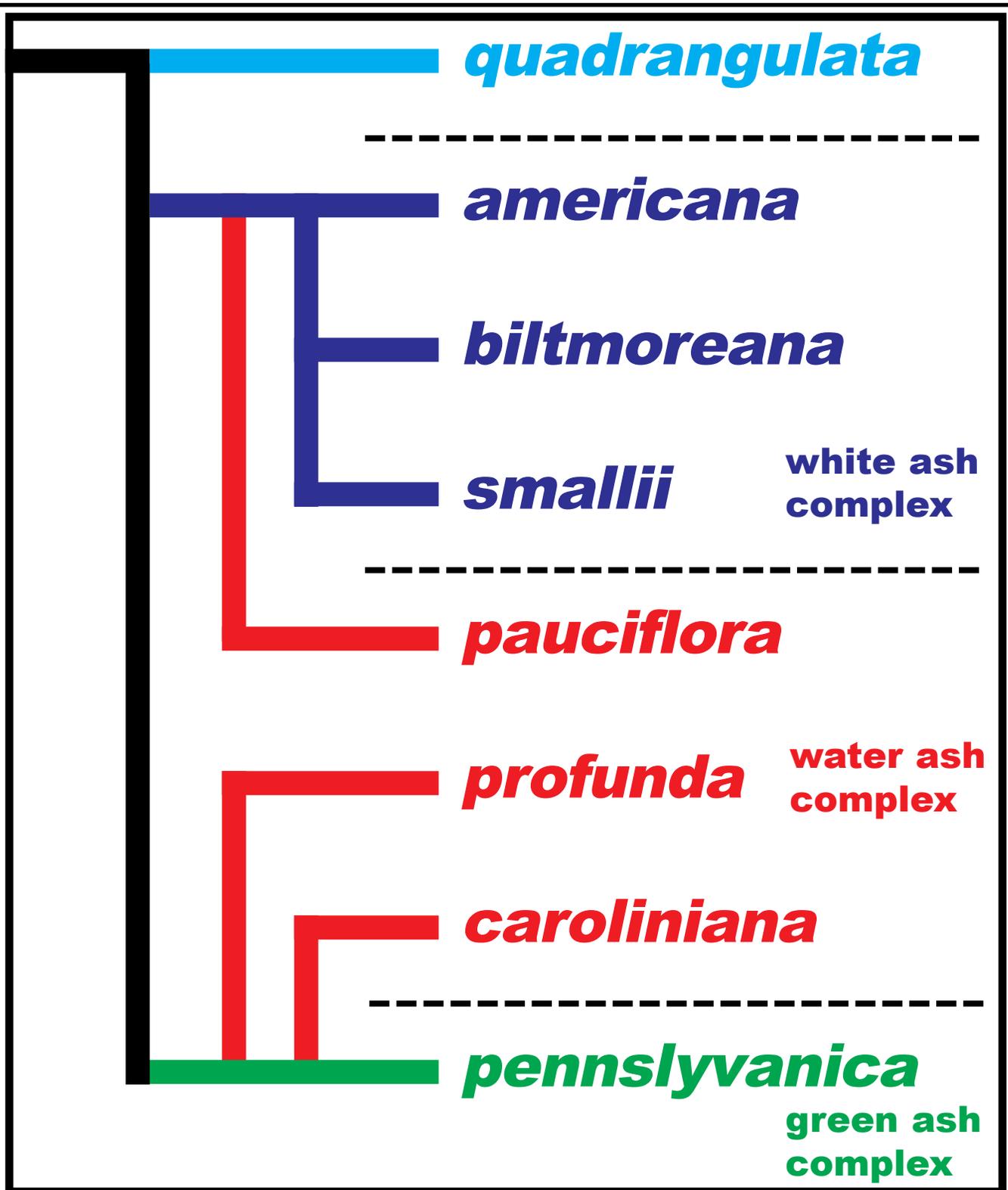


Figure 7: The ash - *Fraxinus* species and complexes of the southeast and Georgia.

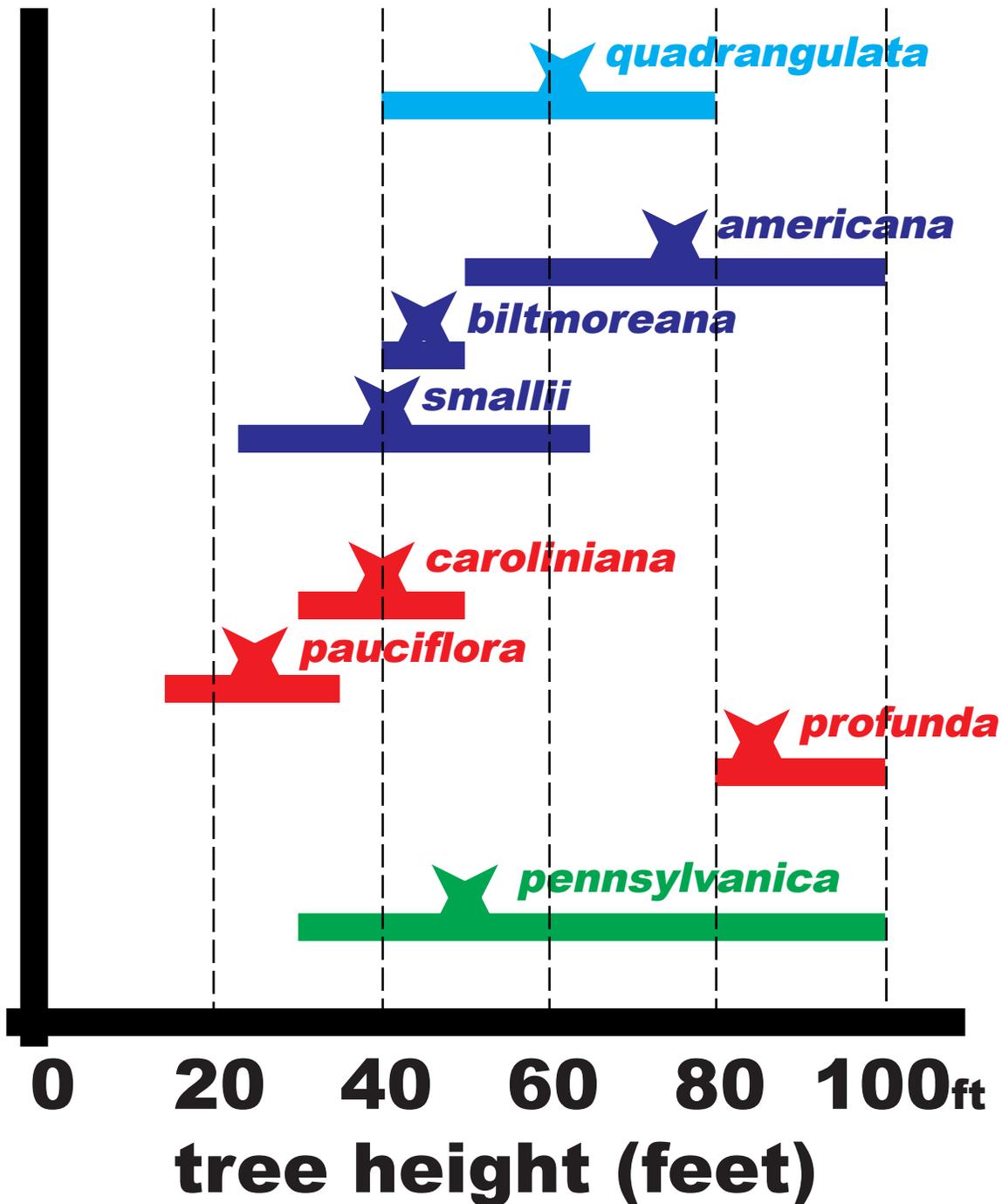


Figure 8: Survey of average tree heights (star) and ranges (bar) cited in tree identification references.

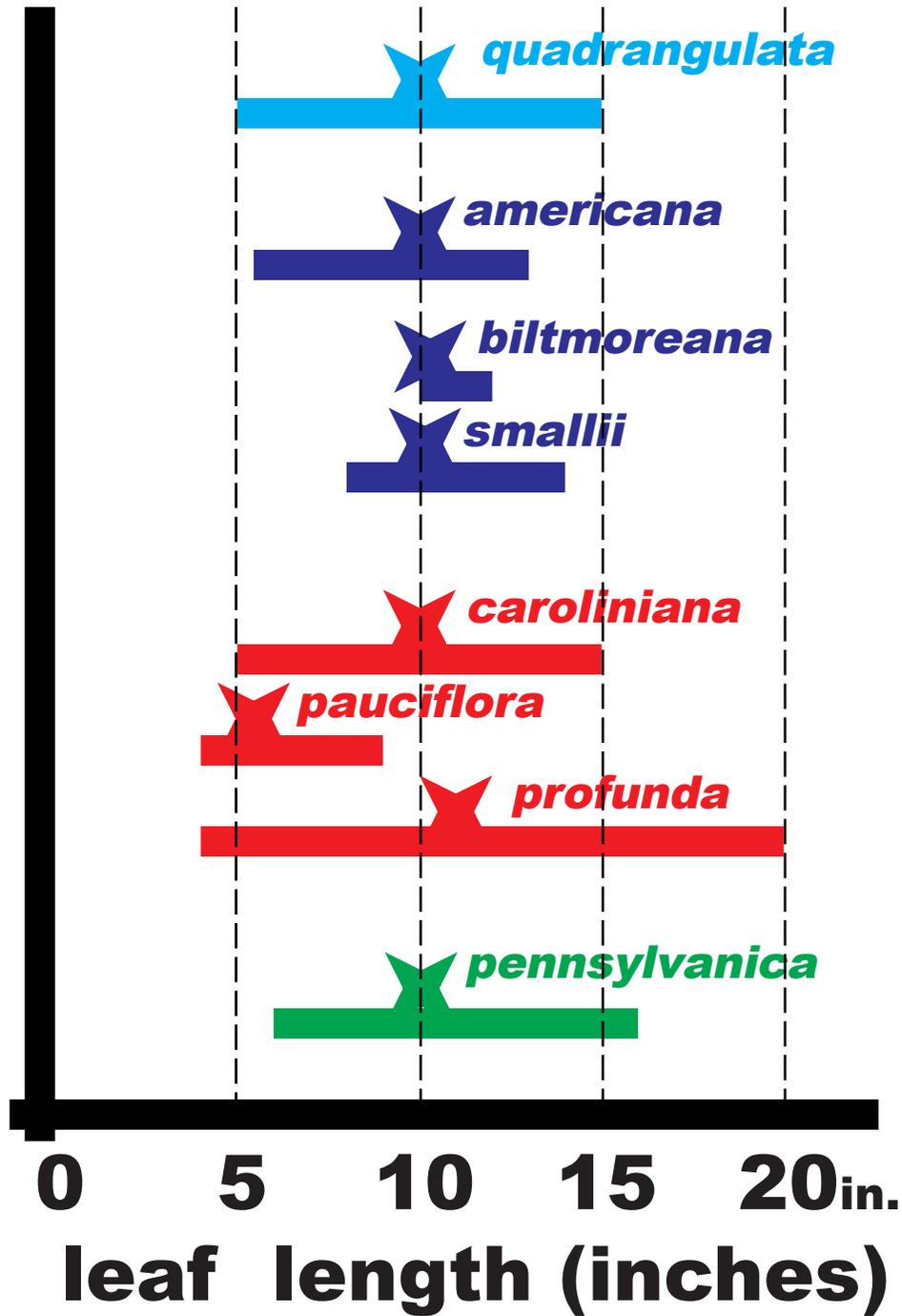


Figure 9: Survey of average leaf length (star) and ranges (bar) cited in tree identification references.

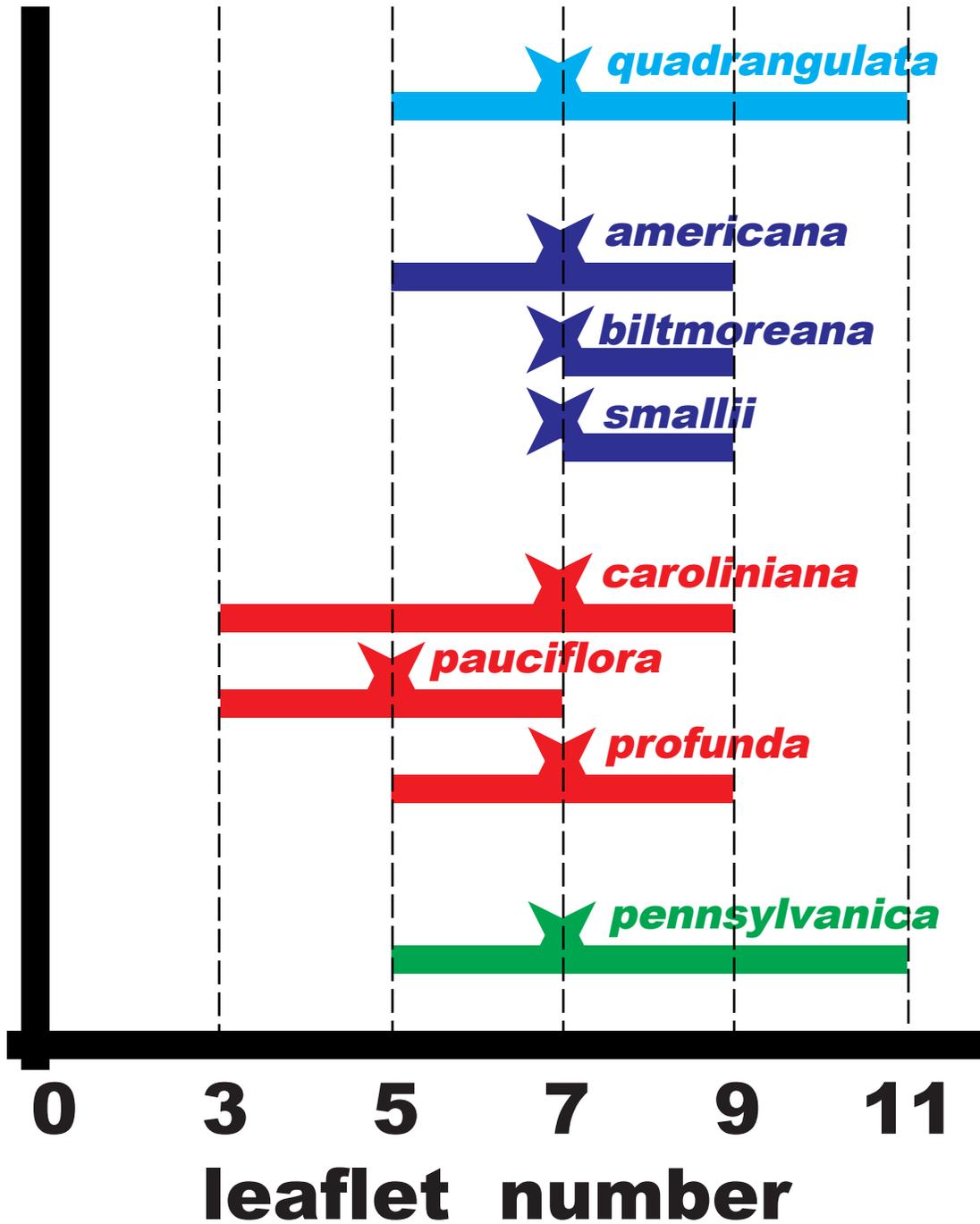


Figure 10: Survey of average number of leaflets per leaf (star) and range (bar) of values cited in tree identification references.

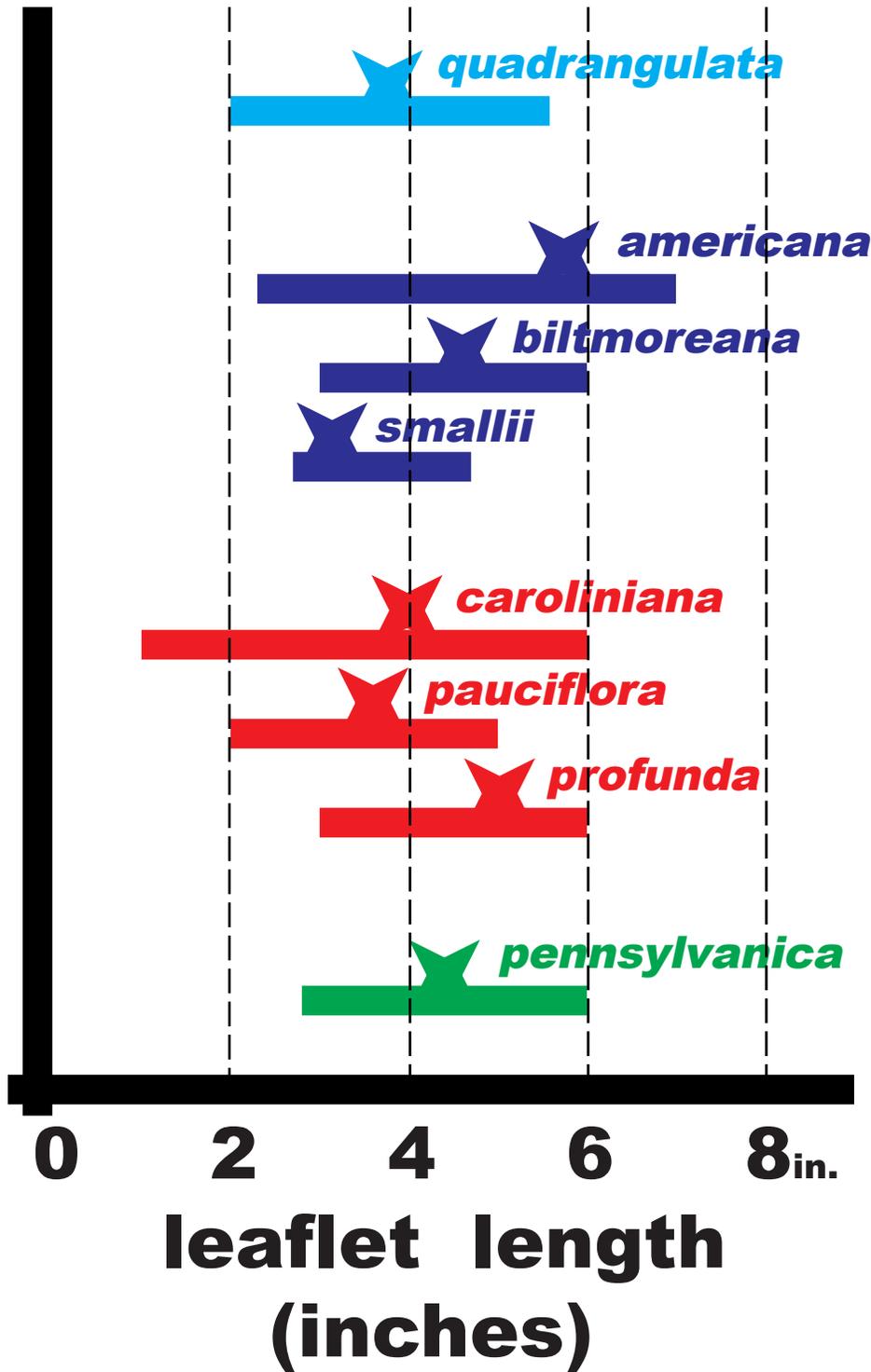


Figure 11: Survey of average leaflet length (star) and range of values (bar) cited in tree identification references.

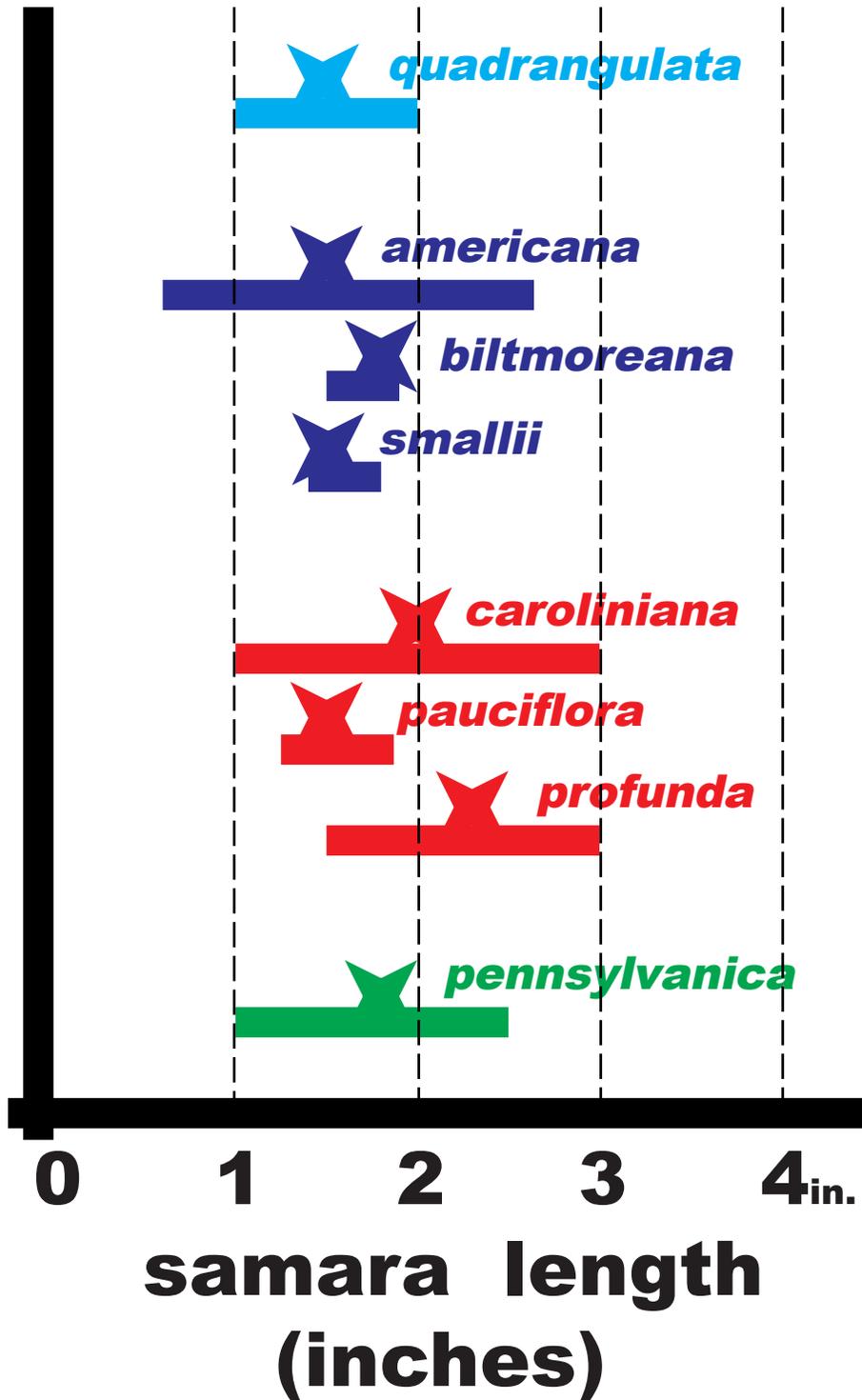
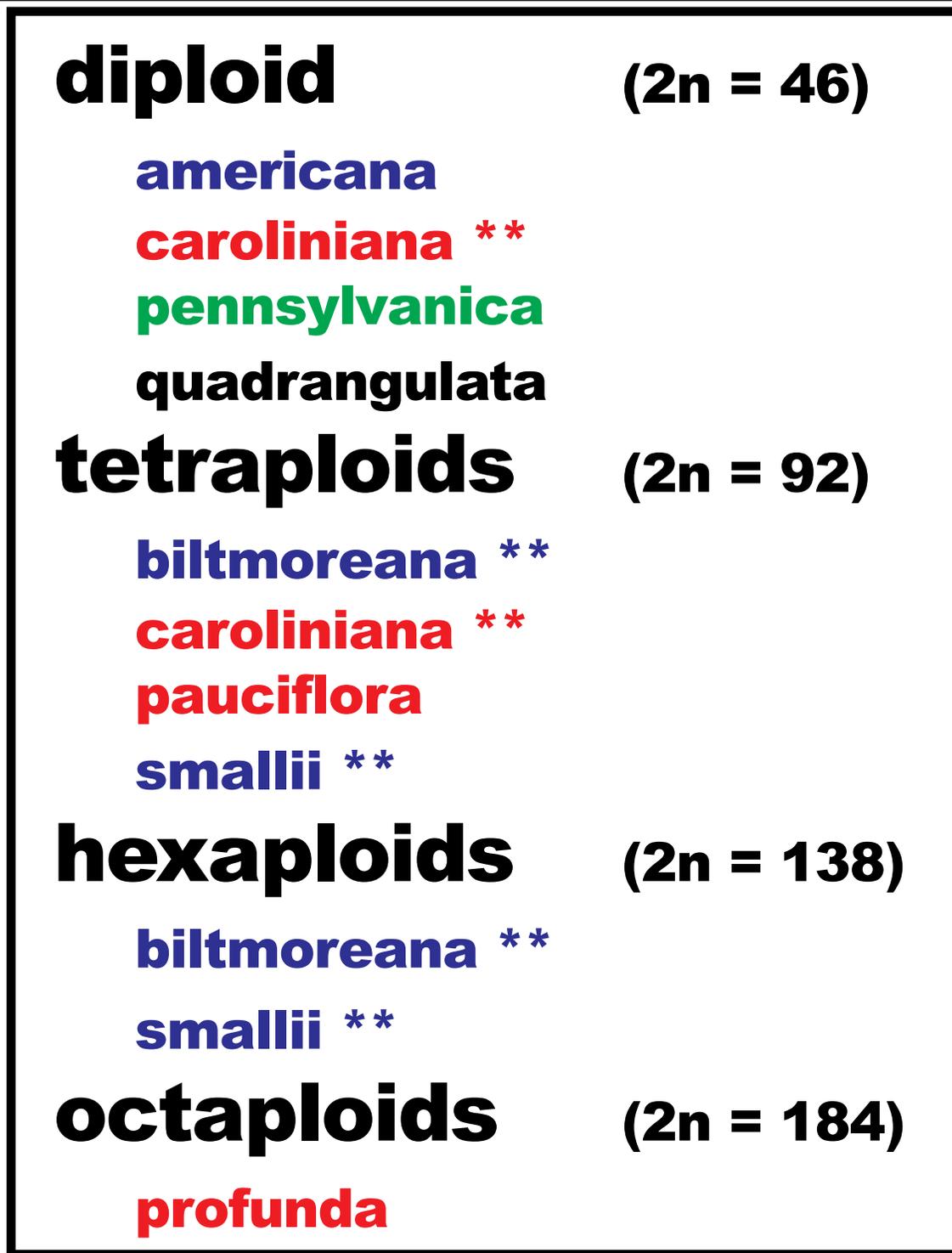


Figure 12: Survey of average samara length (star) and range of values (bar) cited in tree identification references.



(** = polyploidy not worked out)

Figure 13: Chromosome number descriptions for selected ash - *Fraxinus* species with base number 23 (n = 23)
(derived from Islam-Faridi et.al. 2020)

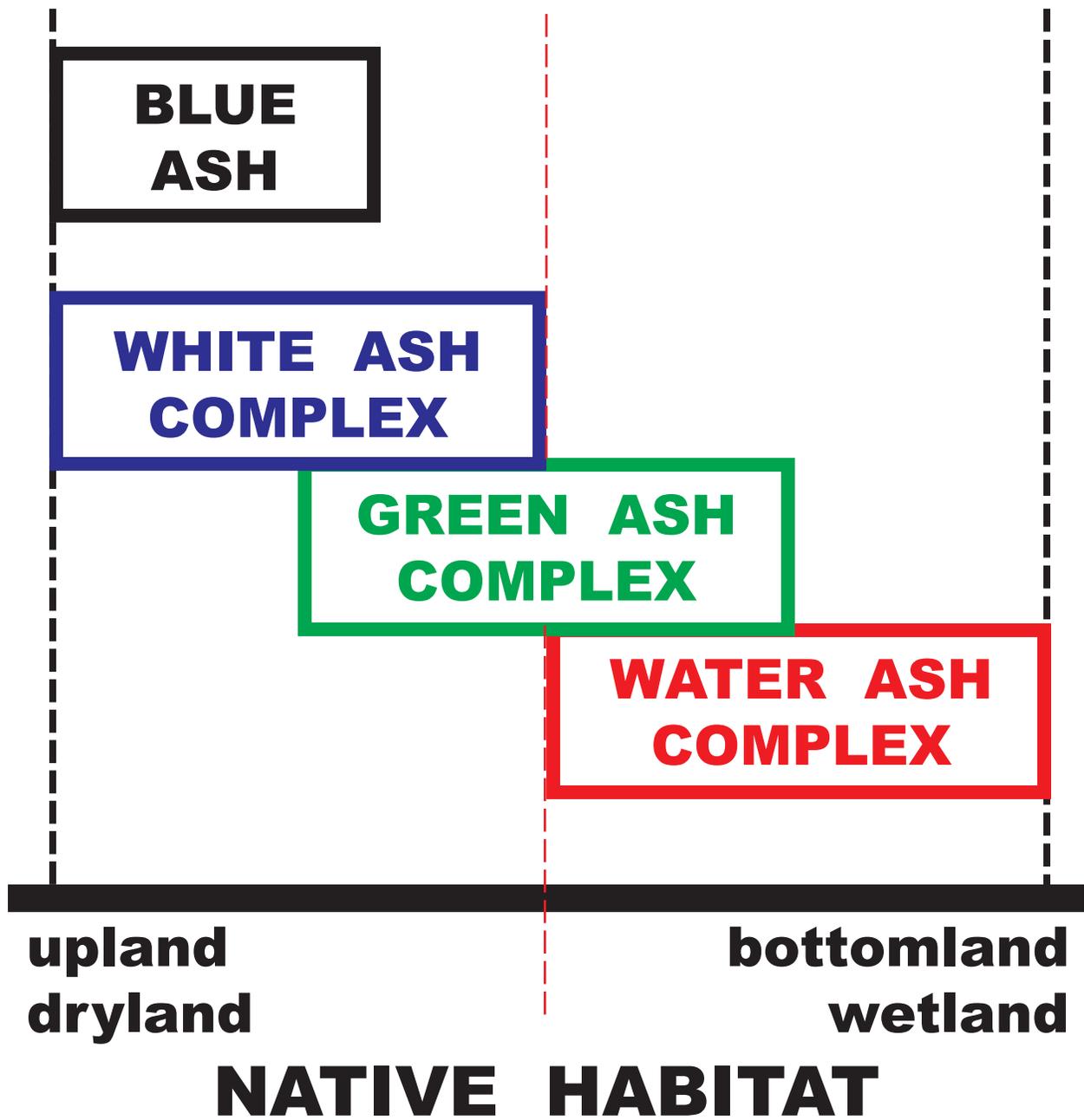


Figure 14: Ash species (*Fraxinus* spp.) groups found across native habitat gradients. Note significant habitat overlap among species groups.

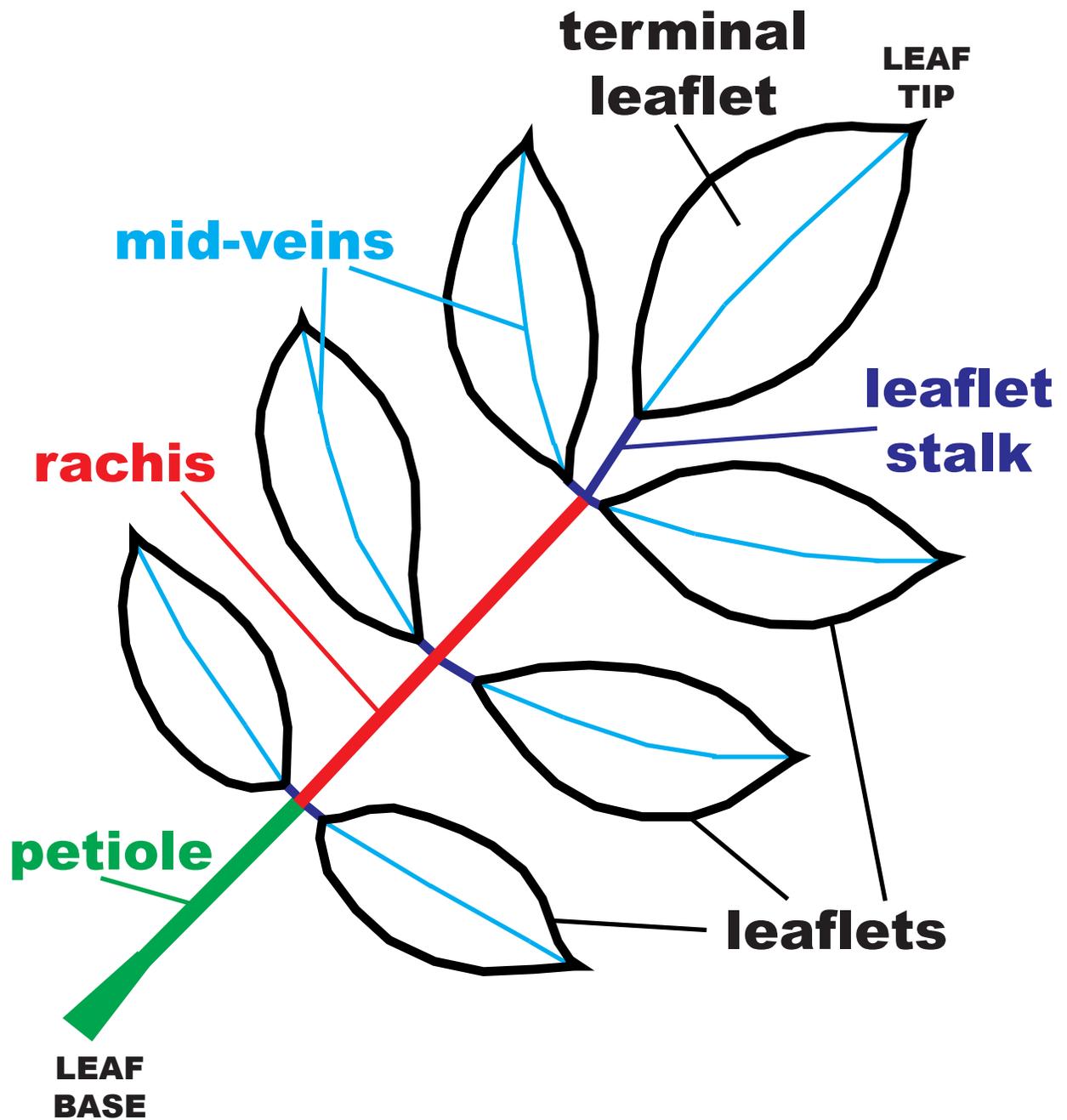


Figure 15: Generalized odd-pinnate compound ash (*Fraxinus* spp.) leaf with 7 leaflets, where each leaflet could have smooth and entire, serrated, or a mix of margins.

ash species	leaflet cuticle appearance
Subsection <i>Meliodes</i>	
<i>Fraxinus americana</i>	<p>top = smooth, striae bottom = papillae, coronulae</p>
<i>Fraxinus pennsylvanica</i>	<p>top = smooth bottom = smooth</p>
<i>Fraxinus caroliniana</i>	<p>top = smooth bottom = striae</p>
<i>Fraxinus profunda</i>	<p>top = smooth bottom = striae</p>
Subsection <i>Fraxiunus</i>	
<i>Fraxinus quadrangulata</i>	<p>top = smooth bottom = smooth</p>

Figure 16: General description of leaflet cuticle (top / bottom of leaflet) for select ash species. (from Call & Dilcher 1992)

LEAFLET SURFACES

species

leaflet trichome type (top / bottom) leaflet cuticle type (top / bottom)

Fraxinus americana

acicular, peltate gland, scale / smooth / striate-papilose, coronulate
acicular, peltate gland, scale

Fraxinus caroliniana

acicular, peltate gland, scale / smooth / striated
acicular, peltate gland, scale

Fraxinus pennsylvanica

acicular, peltate gland / smooth / smooth, striated
acicular, peltate gland, scale

Fraxinus profunda

acicular, peltate gland, scale / smooth / striated
acicular, peltate gland, scale

Fraxinus quadrangulata

acicular, peltate gland / smooth / smooth
acicular, peltate gland

Figure 17: Select ash species leaflet surface descriptions (both upper and lower surfaces) for trichomes and cuticles.

(Hardin & Beckmann 1982)

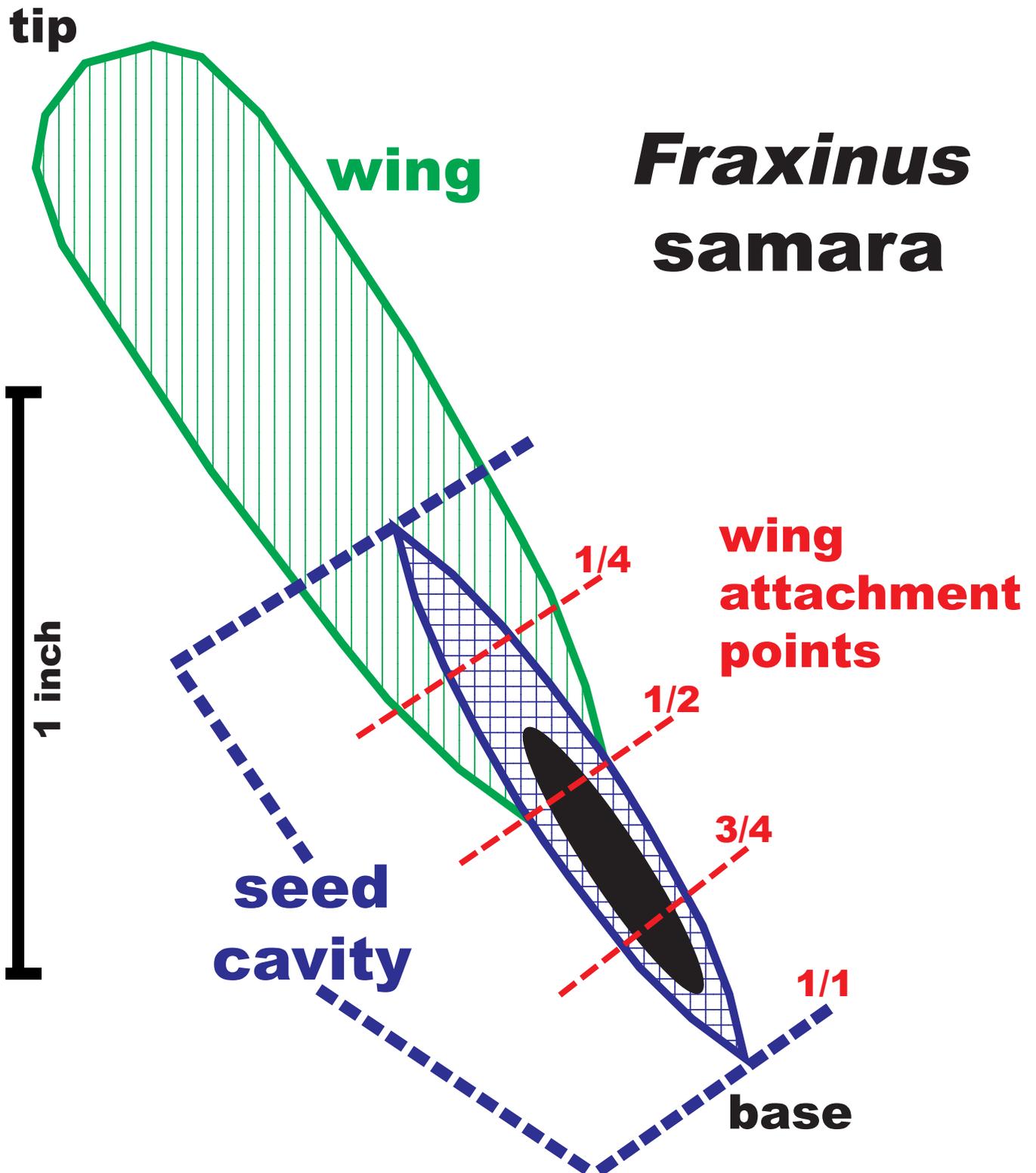


Figure 18: Idealized ash - *Fraxinus samara*, in this case with wing attached at $1/2$ seed cavity length.

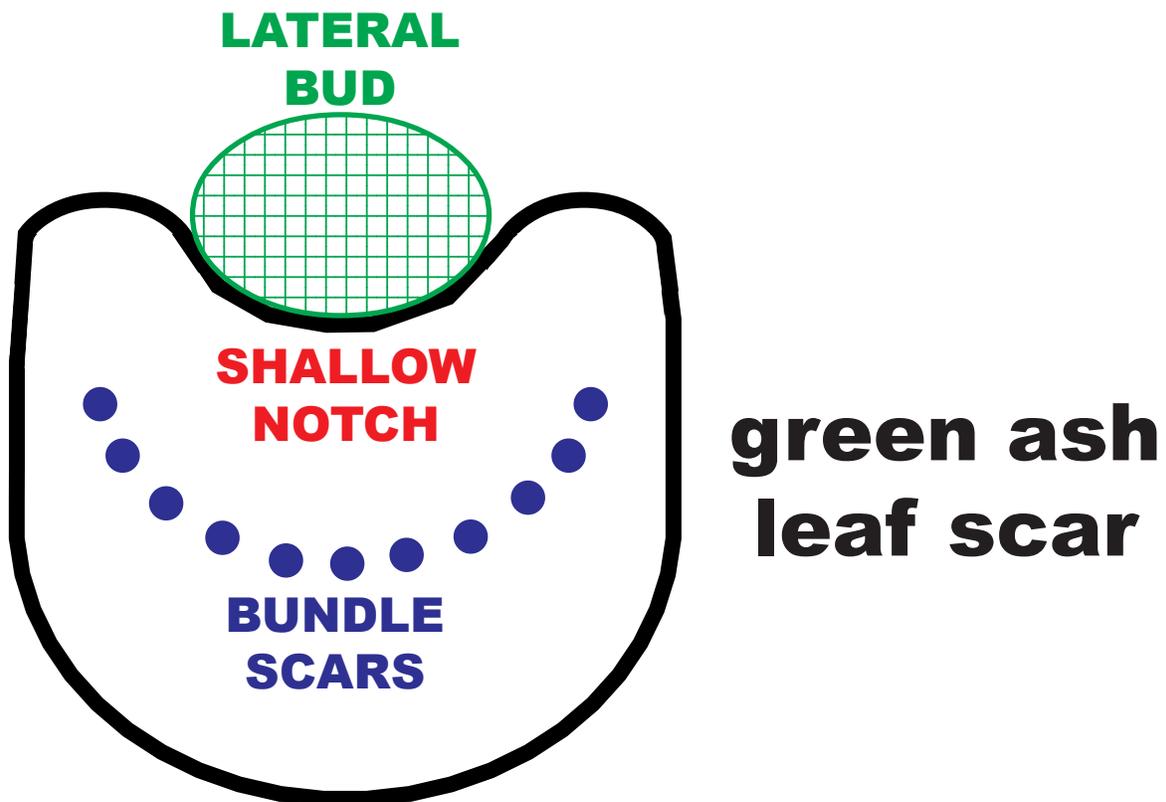
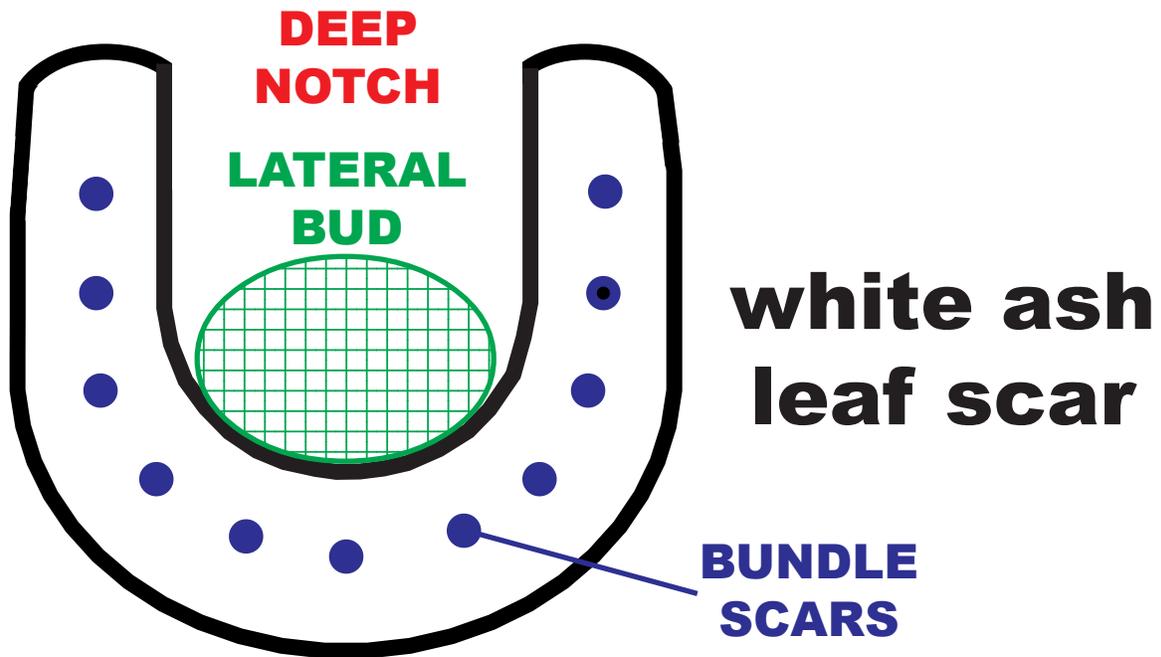


Figure 19: Two examples of leaf scars in ash (*Fraxinus*) showing lateral bud position and indistinct bundle scar locations.



Figure 20: General range map of Georgia native ash species *Fraxinus quadrangulata* (blue ash).

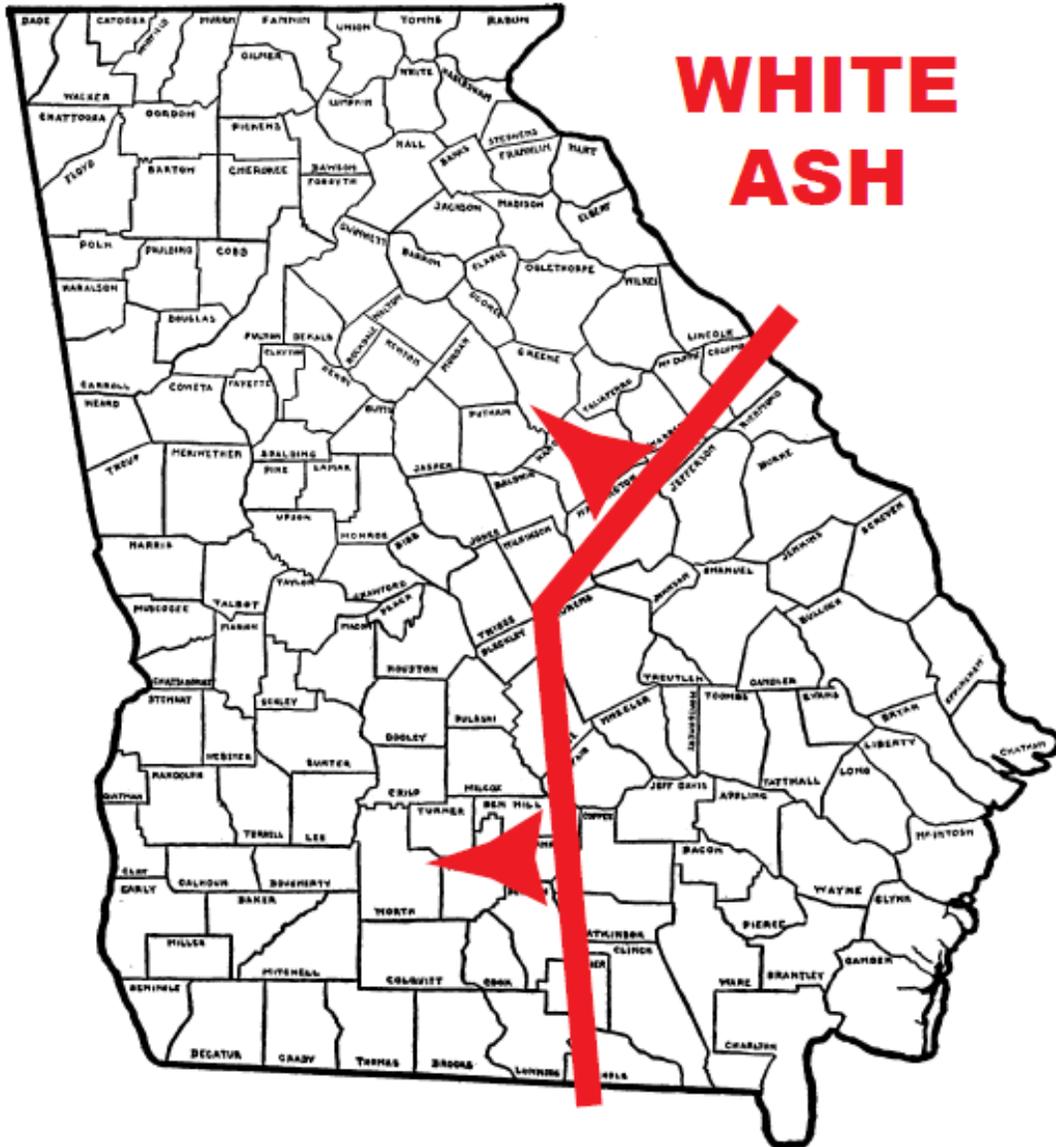


Figure 21: General range map of Georgia native ash species *Fraxinus americana* (white ash).

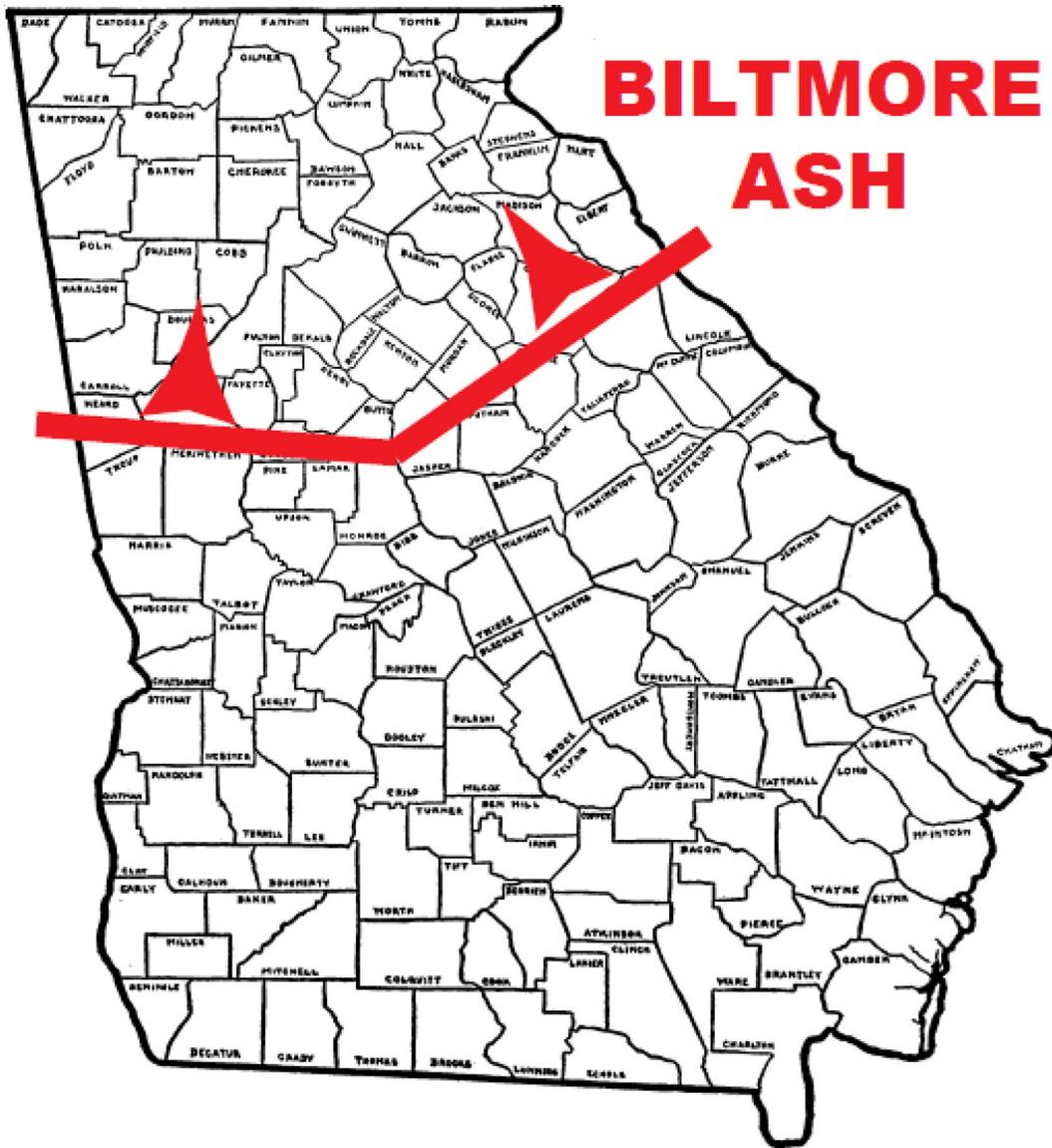


Figure 22: General range map of Georgia native ash species *Fraxinus biltmoreana* (Biltmore ash).



Figure 23: General range map of Georgia native ash species *Fraxinus biltmoreana* var. *subcoriacea* / *Fraxinus smallii* (Small's ash).



Figure 24: General range map of Georgia native ash species *Fraxinus caroliniana* (Carolina ash).

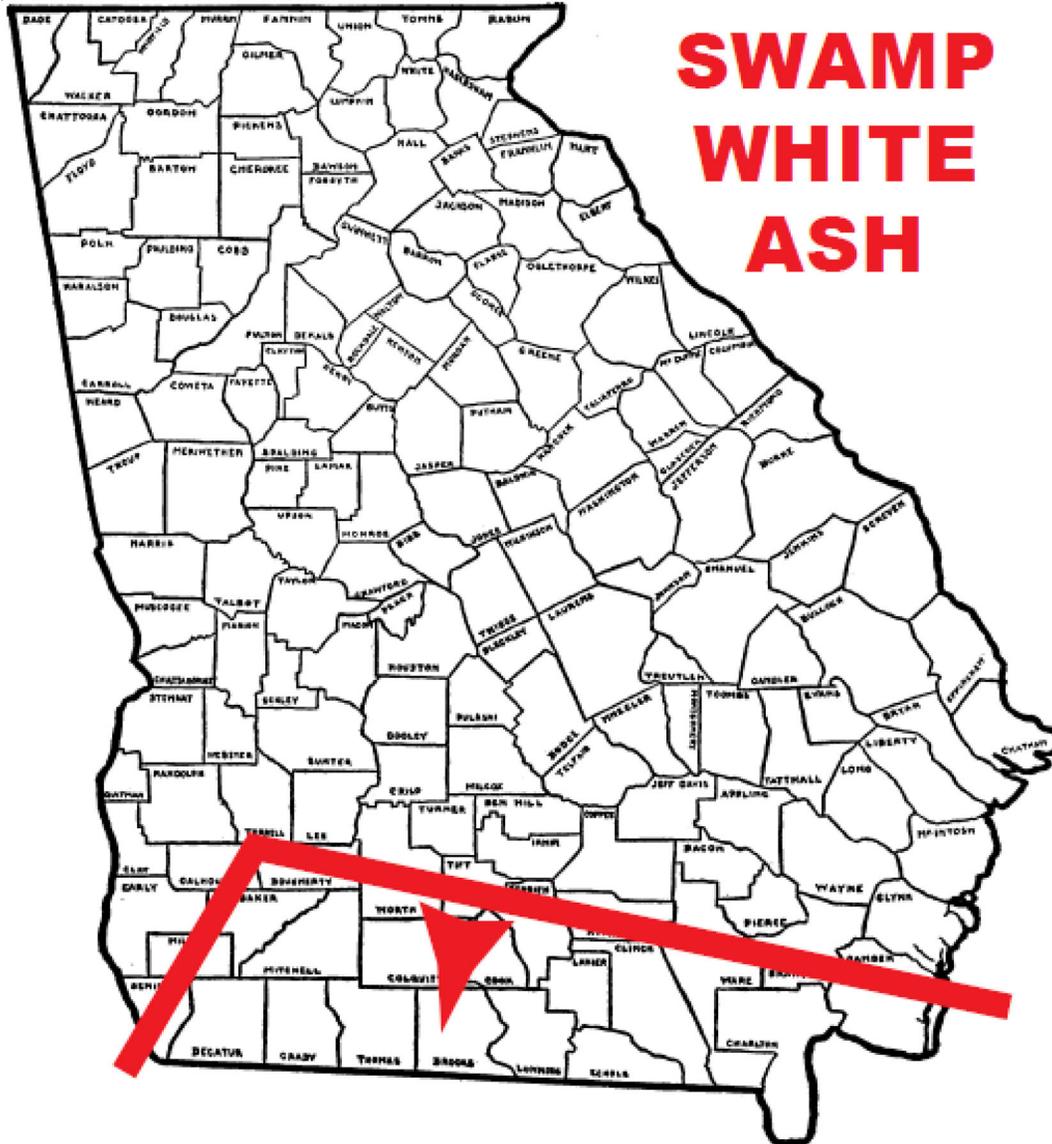


Figure 25: General range map of Georgia native ash species *Fraxinus pauciflora* (swamp white ash).



Figure 26: General range map of Georgia native ash species *Fraxinus profunda* (pumpkin ash).



Figure 27: General range map of Georgia native ash species *Fraxinus pennsylvanica* var. *pennsylvanica* (green ash).



Figure 28: General range map of Georgia native ash species *Fraxinus pennsylvanica* var. *subintegerrima* (narrow leaf green ash).

attribute / character	blue ash	white ash complex	green ash complex	water ash complex
sexual system **	co	di	di	di
samara wing width	thin	thin	thin	wide
samara wing attachment length along seed cavity	>1/2	<1/4	<1/4	>3/4
samara seed cavity cross-section shape	flat	round	round	flat
twig internode cross-section shape	square	round	round	round
leaf scars axillary bud notch	shallow	deep	very shallow	shallow*
terminal bud tip	point	round	point or round	point or round
lateral leaflet average stock length (in.)	0.15"	0.4"	0.3"	0.5"
general habitat	upland dry	upland mesic	mixed sites	bottoms wetland

** = sexual system -- cosexual (co); dioecious (di).

* = pumpkin ash with deeper notch than other complex members.

Figure 29: Matrix of field identification attributes for differentiating native ash species (*Fraxinus* spp.) groups. Do not use trichome presence or density on leaves / twigs for identification.