Grauke, L. J. Hickories. Chapter 6. pp 117-166. In: Fulbright, Dennis (ed.) Nut Tree Culture in North America. Vol. 1. Northern Nut Growers Assoc., Inc. Pub. 2003.

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Hickories

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Introduction

The hickories are members of the walnut family, Juglandaceae. They constitute the genus *Carya*, which is a genus in the subtribe *Caryinae* of the tribe Juglandeae (Manos and Stone, 2001). Authorities disagree on the number of species recognized within the genus, with much of the disagreement centering on inherent ambiguities in the concept of "species". The taxa presented here fulfill the following criteria of species status; 1) they are morphologically distinct (although at times only obscurely); 2) they each have ecological adaptations which reduce competition with related, neighboring species; and 3) they have some level of reproductive isolation which limits gene exchange with other species (see Grant 1957). Grant (1980) has suggested that the ultimate criterion of species status is reproductive isolation. The genus *Carya* is characterized by numerous interspecific hybrids, some of which (e.g. *C. X lecontei* Little) are commonly encountered when the two parent populations overlap. Detailed evaluation of the level of reproductive isolation has not been conducted. After more critical evaluation, some of these taxa may be placed at other taxonomic levels.

Evolutionary History

The evolutionary history of the Juglandaceae has been well reviewed by Manchester (1987). The family is first distinguishable in the fossil record as distinctive pollen grains which occur from the late Cretaceous, about 135 million years ago (Frederiksen and Christopher, 1978). The subtribe *Carinae* (referred to by Manchester as the tribe *Hicoreae*) is believed to have evolved from these primitive ancestors about 70 million years ago, via intermediate species which can be found from the late Cretaceous to the late Paleocene (Nichols and Ott 1978). Primitive members of the *Carinae* were well distributed across North America and Eurasia during the Eocene, which began about 50 million years ago. The first recognizable *Carya* fruits occur in strata of the lower Oligocene, about 34 million years old, found in Colorado (MacGinitie 1953) and in Germany (Gregor 1978). *Carya* fruits are found in China in Miocene strata, about 20 million years old (Hu & Chaney 1940). The genus became extinct in Europe in the Pleistocene about 2 million years ago, possibly as a result of glaciation. In the same time period, the range of the genus in North America was greatly reduced and species in western North America became extinct. Fossils believed to represent living species are found in North America from the Pleistocene (Lamotte 1952).

Manchester (1987) noted that during the Paleocene and Eocene, the greatest number of genera of Juglandaceae occur in North America, indicating that this area is the likely place of origin for the family. Migration occurred across Beringia, as indicated by the presence of fossil *Carya* in Siberia. This explanation is consistent with the timing of the occurrence of *Carya* in Asia.

The earliest fossil fruits of *Carya*, found in Oligocene strata in North America and Europe and in Miocene strata in China, lack secondary septa in the walls of nuts (Manchester 1987). Manchester (1987) suggested that the development of secondary septa and increased shell thickness were evolutionary responses to predation by rodents, and offered as evidence the synchronous evolution of squirrels and complex seed-packaging modifications in hickories (both occurring after the Oligocene). An exception to that trend of evolutionary development is pecan, which lacks secondary septa and has a thin shell, possibly due to selection by man.

The other observable trend in the evolutionary history of the genus is toward increasing pollen size (Manchester 1987), a feature which has been reported among extant species to be correlated with polyploidy (Stone 1963, Whitehead 1963). It is possible that the extant "diploids" (n=16) in the genus are the result of increased ploidal level from ancestors having only 8 chromosomes. Increased ploidal level could account for the reported increased pollen grain size which occurred at the boundary between Wilcox and Claiborne (early Eocene) formations in the Mississippi Embayment (Tschudy 1973) and between Sabinian (late Paleocene) and Jacksonian (late Eocene) formations in South Carolina (Frederiksen and Christopher 1978).

Manchester (1987) noted that the Juglandaceae underwent a phase of rapid evolution during the Paleocene, establishing most morphological patterns which characterize modern tribes and genera within about 10 million years. Evolutionary rate slowed from the middle Eocene onward, with one example of post-Eocene evolution being the development of the secondary septum and internal locule ridges in *Carya*.

Information on the ancient distribution of plant populations is often based on studies of pollen recovered from strata that increase in age with increasing depth. Hickory pollen can be distinguished from that of other genera, being characteristically triporate, paraisopolar (the three pores are never exactly equatorial in position but are drawn toward the distal pole) and suboblate, with a textate surface (Whitehead 1965). Pollen diameter averages 46 um and ranges in diameter from 38 to 55 um in different species, with diploid species having the smallest pollen grains (Stone 1963). Despite that pattern of difference, species of *Carya* can not be reliably separated from each other on the basis of pollen characteristics. The distribution of hickory in North America during the past 20,000 years has been mapped based on pollen records (Delcourt and Delcourt, 1987). Those records allow generalizations concerning the movements of populations into geographic regions, as well as demographic changes in dominance structure of the entire forest population. Hickory advanced rapidly northward from a limit of 34^{o} N, beginning about 16,000 yr Before Present (BP). It reached its current northern limit of 45 ^{o} N by 8000 yr BP, with rates of advance as high as 354 m/yr. The period of fastest northward advance for *Carya* was between 14,000 and 12,000 yr BP. Hickory populations decreased from a mean of 9% dominance in the full-glacial interval (20,000 to 16,500 yr BP) to 7% for the late-glacial (16,500 to 12,500 yr BP) and early Holocene (12,500 to 9,000 yr BP) intervals, then remained between 5% and 6% for the mid- to late Holocene (from 9,000 to 6,000, and 6,000 to 500 yr BP, repectively). As hickory population mean dominance values declined over that period, it's area and maximum dominance values increased in a pattern that indicates a "K-migration" strategy. Such plants are typically long-lived, late-successional taxa that tend to colonize and then successfully maintain populations in nutrient-rich soils. K-strategists tend to be shade-tolerant, and invest more energy establishing biomass than in producing seed. Propagules are fewer but larger, remain viable longer in the soil, and are dispersed by gravity and animal vectors (Delcourt and Delcourt, 1987).

History

Bonnichsen et al. (1987) suggested a linkage between the climatic changes associated with the retreat of the Laurentide ice sheet, changes in vegetation patterns indicated by pollen studies, and changes in adaptive strategies of early human populations that reached a critical threshold between 11,200 and 10,800 yr BP. The changes in human adaptive strategies were indicated by correlated archaeological records that included artifacts in the Dalton complex. Bettis et al.

(1990) noted the conjunction in timing of the increased abundance of a bottomland *Carya* pollen (probably pecan) in the Upper Mississippi Valley with the influx of people associated with the Dalton culture and suggested that humans may have been an important vector in the northward spread of pecan.

The earliest record of man's use of *Carya* species comes from archeological excavations near both the northern and western edges of *Carya* distribution: hickory and pecan were recovered in strata dated from the Early Archaic (8900-8700 yr BP) at Modoc Rock Shelter, Illinois (Styles et al., 1983); pecan leaves and seed were recovered in association with human artifacts from strata dated from about 8000 BP at Baker's cave, Val Verde Co., Texas (Dering 1977, Hester 1981).

The record of Indian usage of *Carya* species made by the first European explorers is extensive. Strachey (1612) reported a native American myth of the afterlife which involved hickory; hominy corn and "pokahichary" (a drink which the Powhatan Indians of Virginia made by pounding hickory nuts with water) was served by a goddess to spirits travelling after death to the rising sun. The story implies an ancient and revered place for the nuts in Powhatan tradition. Our word "hickory" is derived from the word "pokahichary" (see Trumbull 1872).

Hernando de Soto (in True, 1919) explored the southeastern area of the United States during the period between 1539 and 1542 and reported finding large stores of nut oil. Ash (1682) reported that nut oil from both walnut and hickory trees was used for cooking and medicinally;

> "Its commended for a good Remedy in Dolors, and Gripes of the Belly; whilst new it has a pleasant Taste; but after six Months, it decays and grows acid" (p. 7).

The use of hickory nut oil is mentioned by Bossu (1771, p. 348), who also observed that the Indians baked pancakes in nut oil (p. 230). William Bartram (1792) reported "ancient cultivated fields" of hickory west of Augusta, Georgia;

> "Though these are natives of the forest, yet they thrive better, and are more fruitful, in cultivated plantations, and the fruit is in great estimation with the present generation of Indians, particularly juglans exaltata, commonly called shell-barked hiccory. The Creeks store up the last in their towns. I have seen above an hundred bushels of these nuts belonging to one family. They pound them to pieces, and then cast them into boiling water, which, after passing through fine strainers, preserves the most oily part of the liquid; this they call by a name which signifies hiccory milk; it is as sweet and rich as fresh cream, and is an ingredient in most of their cookery, especially homony and corn cakes" (p. 38).

Sargent (1884) suggested that the "Juglans exaltata" referred to by Bartram (1792) is a synonym of *C. ovata*.

Other early reports also document the Indian custom of crushing nuts in the shell in water to make a drink (Lawson 1714, p. 100; Romans 1775, p. 68;). The extraction of nut oil from native *Carya* species using similar techniques is also practiced in Asia (Louis 1921). Archeological studies have suggested that patterns of species utilization may be linked to the development of the nut crushing technology (Styles et al., 1983). In the earliest (oldest) strata (8900-8700 BP) in several Illinois excavations, pecan is recovered in high percentages relative to other hickories. Around 7600 BP, thick-shelled hickory becomes the dominant nut recovered. The change can not be attributed to changes in species availability, and has been speculated to be due to the improvement in processing techniques, such as crushing and boiling, that permitted easier recovery from thick-shelled nuts (Bettis, 1990; Styles et al., 1983).

In addition to use as a food, several tribes of native Americans found many other uses for hickory: the Ojibwa used wood of *C. ovata* to make bows, selecting pieces having heartwood to the front of the bow and sapwood nearest the user; the Cherokee used the inner bark of *C. tomentosa* and *C. laciniosa* to finish baskets; the Omaha used wood of *C. tomentosa* and *C. laciniosa* to make snowshoe rims, lacing them with rawhide (Moerman 1998). Native American tribes also used various hickories medicinally as abortifacients, analgesics, anthelmintics, antirheumatics, cold remedies, dermatological aids, diaphoretics, diuretics emetics, gast-intestinal aids, gynecological aids, laxatives, liver aids, oral aids and orthopedic aids (Moerman 1986). In Vietnam, bark from trees of *Carya tonkinensis* was used to make a tea that was given to women after childbirth to reduce bleeding (Grauke et al., 1991).

The area from which Indian usage of hickory is reported exceeds the area of species distribution. Gilmore (1919) reported that the Dakota tribe of North and South Dakota has words for hickory trees and nuts and use both, despite the fact that no *Carya* species is reported to be native to that area. Bernard (1980) noted that the distribution of shagbark hickory in Quebec, Canada, was "exactly the same as the Iriquois territorial supremacy at the time of the first settlement". Hall (1995) has suggested that the abundance of native pecans in the Gulf Coastal Plain of Texas provided a stable, abundant and nutritious food supply that drew prehistoric people into the region. These valuable nut-bearing trees may also have been involved in territorial claims by individual family bands, as indicated by the distribution of prehistoric cemeteries in Texas in relation to native pecan distribution.

The value of hickory as a multi-use plant was quickly recognized by European settlers in North America. Michaux (cited in Porcher, 1863) reported that hickory was preferred in making hoops for casks and boxes. In 1808, young seedlings six to twelve feet tall were cut and sold in bundles of one hundred for three dollars for use in hoop making. The author noted that because of this practice, "young trees

proper for this object have become scarce in all parts of the country which have been long settled. The evil is greater, as they do not sprout a second time from the same root, and as their growth is slow." During the Civil War, hickory bark was used in making yellow, olive, and green dyes, while ashes created from burning hickory produced fine quality lye used for making soap. (Porcher, 1863).

Taxonomy and Nomenclature

The history of the recognition of this group of plants is written in the names applied to them by various authors over time. The hickories have a relatively tortured nomenclatural history that was well reveiwed by Little (1943). The name "Carya" (from the Greek "karya" which means "nut tree") was given by Thomas Nuttall in 1818 to separate the hickories from the sister genus *Juglans*, the walnuts. In order to recognize a given species which has been called different names by different authors, synonymies are maintained. Table 2 is an index to the synonymy of the genus *Carya*.

The present taxonomic organization of the genus is presented in Table 1. Recognition of species follows Manning (1978).

Identification

Genus

The hickories are large, deciduous trees which tend to form upright, cylindrical crowns when grown in the open. All species have pronounced taproots which securely anchor the trees, if soil conditions allow deep root development.

Heimsch and Wetmore (1939) studied wood anatomy in the Juglandaceae and found the species in *Carya* to be characterized by extreme ring porosity, thick-walled rounded vessels with porous perforations, and shortened vessel length as compared to other genera. They concluded that *Carya* has attained a level of structural organization not found in the other genera of the Juglandaceae. Kribs (1927) noted that the woods of species in section Apocarya have thinner-walled vessels and fibers and are of lower density and strength that those of section Carya, an observation consistent with the reputations of the two sections in commerce. Taras and Kukachka (1970) noted that members of section Apocarya exhibit apotracheal banded parenchyma in the early wood zones while members of section Carya do not. Those authors also note that species in section Apocarya shows a gradation in size of pores from early to late wood (semi ring-porous), while species in section Carya are more distinctly ring-porous. To the extent that such structural differences influence the ease of water movement in the tree or reflect differences in duration of growth between sections, they may be involved in observed differences in graft compatibility between the sections.

Hickories have alternate, exstipulate, odd pinnately compound leaves which are aromatic when crushed. Leaflets are lanceolate to obovate with serrate edges.

Flowering of *Carya* species is complex and has been studied in detail by Manning (1938, 1940, 1948a) and has been recently reviewed for pecan (Grauke

and Thompson, 1996, Wetzstein and Sparks, 1986). Trees bear male and female flowers at different locations on the same tree; male flowers are produced on slender, drooping catkins which arise from one or two pair of opposite lateral buds encased, with the shoot bud, in outer scales (although occasionally from the leaf axils in some species). Each of the lateral staminate buds will produce three catkins on a single stalk. Female flowers are borne in a spike at the end of the current season's shoot. The period of maturation for male and female flowers differs on the same tree (dichogamy); some trees shed pollen before pistillate flowers mature (protandry) while others mature pistillate flowers prior to pollen shed (protogyny). Pollen is disseminated by the wind. This type of flowering encourages genetic heterozygosity within a species (Thompson & Romberg 1985). Trees of the upland hickory species tend to commence growth in the spring and to flower prior to bottomland species, but considerable overlap in pollen shed and pistillate receptivity occurs between species (Grauke et al., 1987). This allows for the large number of recognized interspecific hybrids in the genus (Table 1).

Fruits mature and fall in the autumn. The outer husk dehisces along sutures (more or less, depending on species and genotype) and either releases the hard-shelled nut or falls still encasing the nut. Fruit production tends to be cyclic, with an interval of 3-4 years in Texas native pecans (Chung et al., 1995).

To separate hickories (*Carya*) from walnuts (*Juglans*) in the field in any season, cut to the pith of previous season's shoots: hickories have a solid pith (Fig. 1, a); walnuts have a chambered pith (Fig. 1., b). If fruit is present, the genera can be separated on the basis of husk dehiscence: *Carya* spp. have husks which are dehiscent into valves (Fig. 1, c) while *Juglans* spp. have indehiscent or irregularly dehiscent (in *J. regia*) husks (Fig. 1, d). The genera can also be separated on the basis of the position of vascular bundles in the nut: in *Carya*, the funicular strands of the primary septum are widely separated, and nuts have a basal plexus (Fig. 1, e,f); in *Juglans*, the funicular strands in the primary septum are close together and nuts lack a basal plexus (Fig. 1, g,h) (see Leroy 1955, Manchester 1981). There is a practical horticultural need to separate the two genera in the field: grafts of pecan and other hickory cultivars might succeed on seedling rootstocks of any *Carya* species, but will definitely fail on seedlings of *Juglans*.

Sections

The genus *Carya* is divided into three sections: Sinocarya, Apocarya and Carya. Sinocarya (Cheng and R. H. Chang in Chang & Lu,1979) is characterized by species that lack terminal bud scales and includes only Asian species not presented here.

Section Apocarya contains the "pecan hickories", while section Carya contains the "true hickories". The best method for distinguishing between the two sections is by comparing internal nut structure: species in section Apocarya have relatively thin shells that have prominent cavities in the shell wall and middle septum, while species in section Carya have thick, woody shells that lack such cavities. The sections are also distinguished by the bud scales of terminal buds; pecan hickories

have 4-6 valvate bud scales that touch at the edges, but do not overlap (Fig. 2); true hickories have 6-12 overlapping or imbricate terminal bud scales (Fig. 2). The increasing development of bud scales is an adaptation to cold climates.

Other features, such as the number of leaflets per leaf and the presence of wings on the sutures of the husks, are helpful, but not as reliable. Pecan hickories tend to have greater numbers of leaflets than true hickories (7-13 in section Apocarya vs 5-9 in section Carya). Pecan hickories tend to have more pronounced wings on the sutures of the husk than do true hickories (Fig 3). All species in section Apocarya are diploids (n=16) while section Carya includes both diploids and tetraploids (n=32).

Species

Most species of hickory can be easily determined in the field using a combination of key characteristics. Detailed botanical descriptions of species are beyond the scope of this text but are provided by Sargent (1922) and Stone (1997). Following is an abbreviated dichotomous key based on the field characteristics deemed most reliable. More information concerning distinctions between similar species will be provided in subsequent text.

Field Key to the species of *Carya* in North America

1a. Nuts cut in cross section have prominent cavities in the shell walls and middle septum (lacunae) often filled with powdery, rust-colored, very bitter material (Section Apocarya)..... 2

1b. Nuts cut in cross section have woody shells without prominent cavities in the shell wall and middle septum
(Section Carya)..... 5

Section Apocarya

2a. Buds tan to black, outer bud scales not leaf-like. Commonly 11 (may be more) leaflets per compound leaf. Leaflets assymetrical (falcate)..... 3

2b. Buds bright yellow or yellow-orange, outer bud scales leaf-like. Commonly 9 (or fewer) leaflets per compound leaf (rarely 11). Leaflets symmetrical (rarely falcate) .....4.

3a. Nuts more or less circular in cross-section. Shell usually tan with dark stripes at apex, speckles at base, smooth or slightly ribbed, winter buds tan to brown, plump.....*Carya illinoinensis*.

3b. Nuts compressed. Shell dark, prominently ribbed and very rough. Kernel convoluted, very bitter. Winter buds very dark black, acute.....*Carya aquatica*.

4a. Wings on husk sutures from middle to apex. Nut a slightly compressed sphere with a prominently pointed tip.....*Carya cordiformis*

4b. Wings on husk sutures from apex to base of nut. Nuts round, lacking prominent tip at apex.....*Carya palmeri*.

Section Carya
5a. Dense tufts of hairs near the tips of the serrations on the leaf edge.
.....*Carya ovata*.

5b. Lacking dense tufts of hairs at the tips of the leaf serrations.....6

6a. Lower leaf surfaces velvety with dense pubescence. Twigs stout. Terminal buds very large (1-2 cm in length).....7

6b. Lower leaf surfaces not velvety with dense pubescence. Twigs slender. Terminal bud usually less than 1 cm in length.....8

7a. Outer terminal bud scales persistent. Current season's shoots hair-less, orange or tan in color, often with rachises persistent after leaflets drop. Bark of mature trees shedding in plates..... *Carya laciniosa*.

7b. Outer terminal bud scales shed in autumn. Current season's shoots pubescent. Bark of mature trees furrowed or ridged, tight.....*Carya tomentosa*.

8a. Leaf rachis and midrib covered with curly fascicles of hairs.....*Carya pallida*.

8b. Leaf rachis and midrib either hairless or pubescent with single hairs.....9

9a. Terminal bud and lower leaf surfaces densely covered with scales.....10

9b. terminal buds and lower leaf surfaces hairless or variously pubescent, but without abundant scales.....12

10a. Bark of mature trees shedding in plates. Lower leaf surfaces shiny, silver in spring to bronze in autumn, covered with dense peltate scales.
.....*Carya myristiciformis*.

10b. Bark of mature trees tight, smooth to furrowed but not shedding in plates. Lower leaf surfaces densly covered with rust colored wavy-margined peltate scales.....11

11a. Trees found west of the Mississippi River.....*Carya texana*.

11b. Trees of the Florida sand scrub, often small, multi-trunked.
.....*Carya floridana*.

12a. Shuck smooth, splitting to middle of nut only or to base along one suture. Bark of mature trees tight, not shedding in long thin plates.....*Carya glabra*.

12b. Shuck warty, splitting to base along 3-4 sutures. Bark of mature trees often "scaly", shedding in long thin plates.....*Carya ovalis*.

Section Apocarya

Species in Section Apocarya typically have 9-17 serrate, leaflets, 4-6valvate terminal bud scales that do not swell greatly in the spring and husks that often have prominent wings on the sutures. All species in this group are diploids (2n=32). There are 4 species; 3 in the United States, and 1 found only in Mexico.

C. illinoinensis (Wangenh.) K. Koch. Pecan

A chapter of this book is devoted to pecan and its culture. The species is briefly considered here in the context of its position within the hickory genus, with emphasis on species recognition and native distribution (Fig 4).

The pecan is a riverine species distributed along the Mississippi River and its tributaries from northern Illinois and southeastern Iowa to the Gulf Coast. In the east, isolated native populations are found in southwestern Ohio, northern Kentucky and central Alabama. Pecan is abundant on rivers and streams of central and eastern Oklahoma and in Texas west to the Edwards Plateau (Fig 4). The species occurs in regenerating stands as far south as Zaachila, Oaxaca, Mexico.

Although more pecans are harvested in Georgia than from any other state, pecan is not native to that state but was relatively recently introduced. Man has been responsible for increasing the distribution of this valuable species for thousands of years, making the distinction between "native" and "introduced" populations somewhat challenging and possibly artificial. On the western edge of its range, pecan can be linked with man as early as 8000 BP based on excavations at Bakers Cave in Val Verde County, Texas (Dering, 1977; Hester, 1981). In the north, pecan is found in Early Archaic (8900-8700 yr BP) strata. The pecan populations at the extreme southern extent of the range in Zaachila, Mexico may be associated with the use of that site as an ancient ceremonial and administrative center of the Olmecs. Other species in *Carya* as well as other genera share pecan's distribution pattern of disjunct populations stretching between the southeastern U.S.A. and Mexico. Some of those species [eg. nutmeg hickory (*Carya myristiciformis*) and Durand oak (*Quercus durandii*)] are unlikely to have been planted by man, giving credence to the possibility that associated pecan

populations might also be native, and are possibly remnants of refuge populations driven south during the last glaciation.

The name "pecan" comes from Native American languages, according to Trumbull (1872);

> "The common hickory-nut was called pacan, a general name for all hard-shell nuts, meaning 'that which is cracked with an instrument'- by a stone or hammer. Strachey's Virginian vocabulary has "paukauns" for "walnuts". Baraga, for the Chippeway, "pagan, pl. paganag, nuts, walnuts, hazelnuts". At the west and south, this name, as pacanes and modern "pekan" and "pekan nut", has been appropriated to a single species, the fruit of the Carya olivaeformis" (p. 25).

Two Native American tribal groups used pecan medicinally: the Comanche rubbed pulverized leaves on the affected part as a cure for ringworm, and the Kiowa took a decoction of bark as a remedy for tuberculosis (Moerman, 1998).

The history of the discovery and use of pecan by early explorers of America, up to Abner Landrum's first propagation of improved cultivars in 1822, has been extensively reviewed by True (1919). The development of the pecan industry through stages of native management, seedling orchard establishment, propagation of improved cultivars, and the formation of national and state pecan grower organizations can be traced in reports by Heiges (1896) and McHatton (1957).

Pecan is unusual in the genus for the combination of a thin shell and sweet kernel, factors that have contributed to its increased utilization by man. Pecan can be distinguished from all other *Carya* species by its nuts, which are more or less round in cross section and have tan shells marked with black stripes at the apex (Fig 4).

C. aquatica (F. Michx.) Nutt. Water hickory.

Water hickory is found in low, wet woods from Texas east to Florida and north to southern Illinois and Virginia (Fig. 5). Individuals of this species can tolerate both a wetter site and a wider range of soil moisture levels than any other hickory, surviving on poorly drained, tight textured soils that are flooded in winter and parched in summer. It is a major component of two forest cover types: Sugarberry-American Elm-Green Ash and Overcup Oak-Water Hickory (Fowells, 1965). In north Louisiana, water hickory is found in association with *C. ovata* and *C. cordiformis* on Guyton soils. The position of the species is distinct, however, with water hickory occupying the lowest, wettest sites (Grauke et al., 1987).

C. aquatica is most easily identified by its nuts, which are very flattened, strongly 4 angled, and rough. Nuts are usually dark brown and thin-shelled, with very prominent lacunae. Husks are thin (<2 mm) and have prominent wings on the sutures. Kernels are crinkled, reddish-brown, and very astringent.

Distinguishing *C. aquatica* from pecan without fruit can be a challenge. Water hickory leaflets are usually more narrow and have smoother margins than pecan leaflets. Terminal buds become very dark brown or black with maturity and lateral buds often appear "greasy". Early spring growth is characterized by purplish shoots and rachises and by heavy pubescence, as in juvenile pecan shoots.

Bark of trees varies from tight to shaggy. Sargent (1918) observed that the bark of trees growing in dry areas tended to be tighter than when trees grew in swamps.

Wood of water hickory is considered inferior to that of other species of hickory, having a tendency to be "shaky" upon drying (Boisen & Newlin 1910). The bitter fruit makes the water hickory less desirable to wildlife than most other hickories, although nuts have reportedly been found in the stomachs of mallard and wood ducks.

C. aquatica readily hybridizes with pecan where the two species occur on the same site, despite some phenological separation; water hickory is later to flush growth in spring and to bloom (Grauke et al. 1987). The morphological characteristics of the hybrid *C. X lecontei* are intermediate between the two parent species; flattened, rough and medium brown nuts are the most distinguishing characteristic of the hybrid (Stauder 1980). Although both water hickory and the hybrid are used as rootstocks for pecan, there is some indication that Fe uptake may be impaired by the former on pecan sites (Grauke and O'Barr, 1996).

A disputed hybrid, *C. X ludoviciana* (*C. aquatica* X *C. texana*) was reported by Ashe (1927), based on material collected by Caroline Dorman near Chestnut, in Natchitoches Parish, Louisiana. The influence of the water hickory was suspected, due to the flattening of the nut. Since *C. texana* nuts can be somewhat flattened, it is possible that the specimen is a variant of that species, rather than a hybrid.

Significant research in relation to water hickory and its hybrid with pecan has been conducted at Louisiana State University, under the direction of Dr. John Toliver. Research included the reliability of morphological characteristics in the distinction between different levels of hybrid (Rousseau 1976, Stauder 1980) as well as characterization of the growth of hybrid trees as compared to parent species (Toliver 1983). A planting of hybrids and parent species, some of which are the result of controlled crosses, was established at the LSU Idlewild Experiment Station.

C. cordiformis (Wangenh.) K. Koch. Bitternut Hickory

Bitternut hickory is possibly the most widely and uniformly distributed hickory, being found as far north as southern Quebec, Canada and as far south as the Gulf Coast of Louisiana. It is found throughout the Eastern United States from New Hampshire south to Florida and west to Minnesota and eastern Texas (Fig. 6). The species occurs on a wide range of sites, from dry upland sites in the

southwestern part of its range to low wet woods in Louisiana (Fowells 1965, Grauke et al 1987). Bitternut is a major component of the White Oak-Red Oak-Hickory forest in the northern U.S. and of the Swamp Chestnut Oak-Cherrybark Oak forest in the south (Fowells 1965).

C. cordiformis is easily recognized by its distinctive buds, leaves, nuts and bark. Terminal buds have sulphur yellow, leaf-like bud scales. Leaves are distinctive by the combination of their general symmetry and the presence of large, clear, plate-like scales on the lower leaflet surface, near the basal margin of the leaflet. The fruit is a slightly flattened sphere with a prominent point at the apex, making the nut almost heart-shaped. The name "cordiformis" means "heart-shaped". Husks are thin and have prominent wings on the sutures from the apex to the middle of the nut. Husks dehisce to the middle, but the nut often drops in the husk. Nuts have very thin shells marked by shallow grooves. Cross sections of the nuts reveal prominent lacunae and a well developed secondary septum which extends to the middle of the nut. Kernels are convoluted and bitter.

The bark of mature trees is tight, smooth and very light gray, a feature shared by the Mexican endemic *C. palmeri*.

The wood of *C. cordiformis* is inferior to that of the true hickories, leading Boisen and Newlin (1910) to recommend that it not only should not be planted, but should be removed from existing stands in favor of shagbark, shellbark, pignut and mockernut.

Bitternut was used medicinally by the Meskwaki tribe who drank an infusion of bark for different purposes: as a diuretic, laxative, or panacea (Moerman, 1998). The Iroquois used nutmeat oil, either alone or mixed with bear grease, for the hair (Moerman, 1998).

C. cordiformis has received little horticultural attention, due to its bitter kernel. There are however, two named cultivars of bitternut, 'Halesite' and 'Hatch'. Willard Bixby entered the nuts of 'Halesite' in the Northern Nut Grower's 1918 nut contest and won the title of "thinnest shelled hickory". When shell thickness was compared on 10 nuts from each of 5 trees from each of the 13 U.S. hickories, the thinnest shells were found on *C. aquatica*, while bitternut and pecan could not be distinguished (Ring, unpublished data).

Interspecific hybrids have been reported between *C. cordiformis* and pecan (*C. X brownii*). McDaniel (1968) speculated that interspecific hybridization between pecan and bitternut might have extended the northern range of pecan by contributing genes for early ripening of nuts. Named cultivars of that cross include 'Galloway', 'Mall', 'Nelson', 'Pleas', 'Pooshee', and 'Westbrook'. Hybrids typically have nuts which are somewhat flattened, have prominent apices, and are four-celled at the base due to the presence of a secondary septum as in *C. cordiformis*. Nuts may be astringent, as in 'Pleas', or "sweet-fruited" as in 'Galloway' (see Trelease 1896).

Interspecific hybrids have also been reported between *C. cordiformis* and *C. ovata* (*C. X laneyi*). Detailed description of this family of crosses is offered by

Manning (1948). The following cultivars have been named; 'Beaver', 'Creager', 'De Acer', 'Fairbanks', 'Laney' (type tree), 'Peck', 'Roof', 'Stocking', 'Stratford', 'Terpenny', and 'Weschcke'.

C. X demareei is supposedly a hybrid between *C. cordiformis* and *C. ovalis* (see Palmer 1937). This hybrid is reported from the area near Crowley's Ridge in northeastern Arkansas.

C. palmeri Manning. Mexican Hickory

Carya palmeri is endemic to Mexico and is found in the mountains of Nuevo Leon, Tamaulipas and Vera Cruz (Manning, 1962; Narave-Flores, 1983). It also occurs in San Luis Potosi ("ca. 2 mi. west of Xilitla", Stone 1133, 2 June 1962, Univ. of Texas herbarium)(Fig. 7). The tree grows on steep slopes, often in association with *C. myristiciformis*.

Mexican hickory is superficially similar to *C. cordiformis*, having bright yellow buds, smooth, tight, whitish bark on mature trees, and thin shelled (1mm) nuts with bitter, convoluted kernels. It differs from bitternut by having wings on the sutures to the base of the nut (as in *C. myristiciformis*), and lacks the prominent apex on the nut. Mexican hickory also resembles *C. myristiciformis*, due to its scale-covered leaves and fruit husks. It is distinguished by those features mentioned above which are similar to bitternut. No cultivars or hybrids of this species have been reported.

Section Carya

Section Carya is composed of species which typically have 3-9 serrate, oblong lanceolate leaflets on each of the alternate, odd pinnately compound leaves, 6-12 overlapping (imbricate) terminal bud scales which swell greatly in the spring (accressent), and 4-valved husks without prominent wings at the sutures. The section includes both diploid (2n = 32) and tetraploid (2n = 64) species. There are 9 species, all of which are present in the United States.

C. myristiciformis (F. Michx.) Nutt. Nutmeg Hickory

Nutmeg hickory occurs in scattered populations from the mountains near Monterrey, Mexico, north to central Arkansas and east to the coast of South Carolina (Fig. 8). It is found on moist, rich soils, typically as a minor associate in the Swamp Chestnut Oak-Cherrybark Oak Forest Type. In this forest type, nutmeg hickory is associated with shagbark, shellbark, mockernut and bitternut hickories, white ash, Shumard oak, and black tupelo. Fowells (1965) noted that the distribution of nutmeg hickory is almost identical to that of Durand oak, *Quercus durandii* var. *durandii*, and suggested that the species may represent a relic flora. Nutmeg hickory trees are said by Sargent (1918) to be "nowhere abundant", while Fowells (1965) described the species as abundant only near Selma, Alabama. The very restricted distribution of the species should alert us of the need to recognize and conserve this handsome tree.

Nutmeg hickory is one of the most easily recognized *Carya* species, having characteristics of buds, leaves, fruit and bark which are distinctive. Shoots of the current season are silver in early spring and retain a metallic shine throughout the season, due to the presence of peltate scales. Terminal buds are about 5 mm long, plump, and are often golden in color, sprinkled with silvery peltate scales. Scales also cover the lower leaf surface, giving it a silver sheen in early spring which often changes to bronze or gold as the season progresses. Upper leaf surfaces are green, with scattered silver scales. The shiny silver of the lower leaf surface flashes against the darker green of the upper leaf surfaces when the canopies are rustled by winds, making the tree the most attractive hickory. Leaflet number is highly variable, ranging from 5 to 11.

The fruit is nearly spherical, and is conspicuous by its coloration; nuts are reddish brown covered with silver stripes and resemble the spice seed nutmeg, *Myristica fragrans*, from which the tree gets both its scientific and common names. Husks are thin (2 mm), golden with scales, and have pronounced sutures from the tip to the base. Nuts have very thick shells and sweet kernels.

The bark of the tree is brownish gray and exfoliates in ~~the~~ plates. Trees are typically medium sized (< 2 ft dia.) and single trunked with strong limb structure. The reduced growth rate of nutmeg hickory compared to pecan is evidenced by comparison of the growth rate in cm/yr of 50 sections from each species (10 sections per tree from 5 trees per species); average growth for pecan was 1.17 cm/yr, while that for nutmeg hickory was only 0.85 cm/yr, or about 73% the rate for pecan (Grauke & Boudreaux, unpublished). Despite the slower growth of stocks, pecan scions grafted on hickory had greater survival (64% on nutmeg vs 20% on pecan) and made faster growth (5.27 cm dia/scion in hickory vs 2.82 cm dia/scion in pecan) than pecan on pecan stocks.

Sargent (1918) considered the nutmeg hickory to have characteristics which united Sections Apocarya and Carya, which could otherwise be considered distinct genera. The valvate bud scales and thin husk with prominent wings are typical of Section Apocarya (where Sargent classified it), while the small number of leaflets and thick shell of the nut, lacking lacunae, are typical of Section Carya. As evidence to the intermediate position of this taxon, Britton (1889) considered it a representative of Section Euhicoria (= Carya). Stone (1997) placed the species in Section Carya.

Wood of *C. myristiciformis* is considered comparable to that of *C. aquatica* and inferior to other hickories (Boisen and Newlin 1910). The small nuts have such thick shells that, despite the sweet kernel, most nuts lie where they fall under the tree, being of little use to wildlife.

Little research has been conducted on nutmeg hickory. Dr. Clinton Graves at Mississippi State University has included this hickory in attempts at interspecific hybridization with pecan (Windham et al., 1981). Some interest was focused on the species as a possible dwarfing rootstock for pecan by Guidry's Nursery in St. Martinsville, Louisiana in the 1970's. Several trees of the species were planted by

Dr. William Young as border trees in the Ben Hur orchard, Baton Rouge Louisiana.

C. ovata (Mill.) K. Koch. Shagbark hickory

Shagbark hickory is found from Maine west to southeastern Minnesota, with the northern-most extensions of the range being into Quebec, Canada along the St Lawrence River. Shagbark hickory is found in all of the southeastern United States except Florida, extending into the eastern portions of Texas, Oklahoma, Kansas and Nebraska. The species has a disjunct distribution, with isolated populations of variety *mexicana* occurring in the mountains of Mexico as far south as Puebla (Fig. 9). In the North, shagbark hickory is found on sloping upland sites with elevations to 610 m., while in the south it generally occurs on moist soils of alluvial origin. In a study of stand regeneration in a second-growth oak-hickory forest in Ohio, McCarthy and Wistendahl (1989) found *C. ovata* to be most abundant on upper elevations of north facing slopes, while *C. glabra* and *C. tomentosa* were most abundant on upper elevations of south facing slopes. *C. ovata* is a minor component of the White Oak-Red Oak-Hickory forest, the White Oak forest, and the Swamp Chestnut Oak-Cherrybark Oak forest (Fowells, 1965).

C. ovata is distinguished from all species by the presence of dense tufts of hairs at the tips of the serrations of leaves. Winter buds of *C. ovata* have conspicuous and persistent dark outer bud scales over the tan, tear-drop shaped bud. Shoots are typically stout with prominent lenticels and are bulged at the bud scar marking the current season's growth.

The fruit of *C. ovata* is prominently 4-angled, with the sutures of the husk occurring at the corners of the angles. Shucks are smooth, thick (to 5 mm) and turn rich brown before dehiscing. Nuts are 4-angled, cream colored, thick shelled and have sweet kernels.

The bark of young trees is light gray and smooth, but exfoliates in long loose plates on mature trees. The wood of shagbark hickory is among the best in the genus.

In his summary of Native American uses of plants, Moerman (1998) listed more tribes and uses for *C. ovata* than any other species, with specific uses attributed to the Chippewa, Delaware, Iroquois, Dakota, Lakota, Meskwaki, Ojibwa, Omaha, Pawnee, Ponca, Potawatoni, and Winnebago tribes. Nuts were eaten plain or with honey; nuts were crushed, boiled and the oil was used as a baby food, as a drink, or mixed with bread; sap was used as sweetener; chips of wood were boiled to make sugar; wood was used to make snowshoes, bows and arrows and the inner bark was used to make baskets. The plant was used medicinally by several tribes, including the Chippewa who steamed small shoots as inhalant for headache; the Delaware, who used a compound infusion of the bark as gynecological aid or tonic; and the Iroquois, who made a compound decoction with white from inside bark as anthelmintic (taken by adults for worms), used a decoction of bark taken internally as a treatment for arthritis or

externally as a poultice for that condition, and used nut oil as a dermatological aid (Moerman, 1998).

There are over 130 named cultivars of *C. ovata*, more than for any other hickory except pecan. Most of the shagbark "cultivars" have not been propagated and may not be worthy of propagation. Morris (1924) made the following observation concerning the entries of various samples in nut contests:

> "Many of the specimens were sent in with letters expressing an affectionate regard for particular trees, indicating very clearly that the shagbark hickory belonged very close to home feeling. Inferior specimens were sent for prize competition by children with painstaking letters and each one of the children should at least have had a kiss. There were specimens neatly done up in little cloth bags with careful needlework and the accompanying letters expressed hopes that the prizes would be judiciously awarded. There were boastful letters about walnuts and defiant letters relating to pecans but the shagbark hickory was the only one which brought forth expressions of tenderness in feeling" (p. 161).

Several shagbark hickory cultivars are listed in Table 3, along with information concerning origin and references on evaluation. Most of the named cultivars have originated in Iowa, New York, or Ohio, although 22 states and Canada are represented.

There are several recognized varieties of *C. ovata*. *C. ovata* var *australis* (considered by some to be the separate species *Carya carolinae-septentrionalis*) has more slender shoots, darker outer bud scales, and generally occurs on sites having a more shallow surface soil and higher pH than does var *ovata* (Gibbon, 1972). Hardin and Stone (1984) observed small round scales in var. *ovata* that were absent from var. *australis* and considered that the best leaf characteristic for differentiating these two varieties. *C. ovata* var. *pubescens* is characterized by extremely dense pubescence on lower leaf surface and twigs, giving the tree the appearance of *C. tomentosa*. Close observation of the tips of the serrations will reveal tufts of hairs characteristic of *C. ovata*. There has been one named cultivar of this variety; 'Kentucky'. It is possible that 'Barnes' is also from this group.

Interspecific hybrids between *C. ovata* and pecan include 'Burton', 'Henke', 'Pixley', and 'Wapello'. Leaves of 'Burton' have tufts of hairs at the tips of the serrations of the leaves, as do other unnamed specimens of this cross seen by the author. Manning (1962) reported tufts of hairs on the tips of the serrations of leaflets of the hybrid between pecan and *C. ovata* var. *mexicana* found in San Luis Potosi, Mexico. Other features of the hybrid include; 7-9, rarely 11 sessile, rarely falcate leaflets, outer bud scales broad, rusty brown, and overlapping. Fruit is intermediate in characteristics between the two parent species, often with a reddish tinge.

The diploid shagbark hickory hybridizes with the diploid shellbark hickory to produce *C. X dunbarii* Sarg. Several cultivars of this hybrid have been named, including 'Abundance' and 'Weiker' (Grauke, 1988).

As mentioned above, shagbark will also cross with the diploid bitternut to produce *C. X laneyi* Sarg.

C. laciniosa (F. Michx.) Loudon. Shellbark Hickory

Shellbark hickory is found from western New York west to southeastern Iowa. It ranges south to northeastern Oklahoma and over to Tennessee, with isolated populations in southern Arkansas, Mississippi and Alabama and in northern Georgia (Fig. 10). Shellbark is usually found on deep, fertile, moist, bottom-land soils, but in the northern part of its range can occur on dry, sandy soils. Shellbark hickory is a minor component of the Bur Oak forest and, especially in the south, of the Swamp Chestnut Oak-Cherrybark Oak forest (Fowells, 1965).

The species is distinguished by its very large buds, stout twigs which are buff to orange, lenticellate and glabrous, and by the very thick (around 1 cm) husks. Nuts are large, flattened, four-angled, cream colored, and thick shelled (4 mm), with sweet kernels. The flavor of the kernels is considered by many to be inferior to shagbark hickory.

The bark of the tree exfoliates in plates, as in shagbark hickory. Trees tend to be shorter and with heavier branches than shagbark. Often, rachises of the previous year remain attached to the previous seasons twigs.

Carya laciniosa was used extensively by the Cherokee, according to Moerman (1998) who reported a broad range of uses, including abortifacient, analgesic, cold remedy, dermatological aid (the astringent and detergent inner bark was used as dressing for cuts), diaphoretic, emetic, gastrointestinal aid, liver aid, oral aid (bark was chewed for sore mouth), and orthopedic aid (an infusion of bark was taken by ballplayers to make limbs supple). In addition to eating the nuts, the inner bark was used to finish baskets and make chair bottoms, while wood was used to arrow shafts and blowgun darts, and to make corn beaters, tool handles, and barrel hoops.

Over forty cultivars of shellbark hickory have been named, with most originating in Iowa or Pennsylvannia (Grauke, 1988). Table 4 gives information on several promising cultivars of shellbark hickory.

Shellbark hybridizes with pecan to form *C. X nussbaumeri* Sarg. This group of hybrids has attracted attention for their large nut size. Noteworthy cultivars include 'McAllister', which is widespread, but a poor nut producer, and 'Gerardi', which is recommended as a rootstock for pecan in Tennessee (Thompson, 1984).

As mentioned above, shellbark hybridizes with shagbark to produce *C. X dunbarii.*

C. tomentosa (Poir.) Nutt. Mockernut Hickory

Mockernut hickory is widely distributed from "eastern Massachusetts to Florida west across eastern and central New York and northern Ohio to southeastern Iowa, Missouri, southeastern Kansas, eastern Oklahoma, and eastern Texas" (Manning 1973)(Fig. 11). The species occupies upland sites on ridges and hillsides. It is a major component of one forest cover type: Northern Red Oak-Mockernut Hickory-Sweetgum. It is a minor component of 4 other forest types: Post Oak-Black Oak; White Oak-Red Oak-Hickory; Beech-Sugar Maple ; and Swamp Chestnut Oak-Cherrybark Oak (Fowells 1965).

Mockernut is easily distinguished by its tomentose rachises, lower leaf surfaces and twigs, which give the tree its scientific name. Terminal buds are large (> 1 cm) and drop their outer bud scales in the autumn to reveal the buff colored, silky pubescent inner bud scales. Twigs are stout and pubescent. Nuts are usually light brown in color and are thick shelled with sweet kernels. Husks are usually approximately 5 mm in thickness. Bark of trees is tight and furrowed, and light grey to grey.

Densmore (1927) reported the use of *Hicoria alba* (L.) Britt. (=*C. tomentosa*) as a medicinal plant by the Chippewa Indians. Small shoots were supposedly used as a treatment for convulsions. The Cherokee used mockernut hickory interchangeably with *Carya laciniosa*, according to Moerman (1998). Uses included abortifacient, analgesic, cold remedy, dermatological aid (the astringent and detergent inner bark was used as dressing for cuts), diaphoretic, emetic, gastrointestinal aid, liver aid, oral aid (bark was chewed for sore mouth), and orthopedic aid (an infusion of bark was taken by ballplayers to make limbs supple). In addition to eating the nuts, the inner bark was used to finish baskets and make chair bottoms, while wood was used to arrow shafts and blowgun darts, and to make corn beaters, tool handles, and barrel hoops.

The thick shell of the nuts accounts for the lack of horticultural attention which this species has received. One cultivar has been named; 'Droska', a 1929 selection from Pierce City, Missouri.

The tree is a stately landscape specimen when well spaced on good sites and is especially beautiful when it attains its bright yellow to golden fall color.

The tetraploid mockernut is reported to cross with the tetraploid black hickory to form C. X collina Laughlin.

Putative hybrids between mockernut and diploid species include *C. X schneckii* Sarg. (mockernut X pecan) and the cultivar 'Siers', described by Reed (1944) as a hybrid between bitternut and mockernut.

C. texana Buckley. Black Hickory

Black hickory is found west of the Mississippi River from Missouri south to central Texas. Isolated populations occur in Illinois and southern Indiana (Fig. 12). The tree is found on dry, shallow, upland sites in Texas, Arkansas and Louisians, in association with Post Oak, Black-jack Oak and other Quercus sp.

C. texana is identified by the rust colored scales which cover the buds, husks, and lower leaf surfaces. Nuts are usually globose, brown, and thick shelled. Husks are thinner than in *C. tomentosa*, usually being less than 5 mm.

Black hickory has tight, diamond checkered bark which is usually dark grey to black, giving the tree its common name. Branches are often short and twisted, descending in the lower canopy but ascending in the upper canopy.

One cultivar of *C. texana* has been named: 'Aber', originating in Cherokee Co., Texas. The cultivar was originally named as *C. ovalis*, but the pictures of the nut and twigs (Reed 1946), coupled with known distributions of the two taxa, leave little doubt as to the identity of the cultivar.

The tetraploid black hickory has been reported to hybridize with the tetraploid mockernut to form *C. X collina* Laughlin and with the diploid water hickory to form *C. X ludoviciana* (Ashe) Little.

C. glabra (Mill.) Sweet. Pignut Hickory

Pignut hickory is widely distributed, ranging from southwestern New Hampshire west to eastern Illinois, south to Louisiana and from there, east to central Florida. Distribution maps of *C. glabra* have included the distribution of *C. ovalis*, especially in maps prepared by Little (1971) since the reduction of *C. ovalis* to synonomy with *C. glabra* (Little 1969). Distribution reported here (Fig. 13) is based on maps prepared prior to that reduction (Little 1949), as well as subsequent reports which continue to distinguish the two taxa. Proponents of recognizing both species associate *C. glabra* with sites in valleys, along streams or less exposed hillsides, while *C. ovalis* is more common on dry exposed upland hillsides (Manning 1950). *C. glabra* is a minor component of two forest types: Post Oak-Black Oak; and White Oak-Red Oak-Hickory (Fowells, 1965).

C. glabra is distinguished by its glabrous leaves, usually with 5 leaflets, its pyriform fruit with smooth husks which are only partially dehiscent, and by the tight bark of mature trees. *C. ovalis* shares the feature of glabrous leaves, but usually has 7 leaflets. It has warty husks which dehisce to the base along sutures which are often somewhat winged. The bark of mature trees sheds in long thin strips. It is interesting that the only named cultivar of *C. glabra* is evidently wrongly attributed to that species. 'Brackett' was named in 1896, from a specimen received from G. B. Brackett, Denmark, Iowa (Heiges 1896). The figure of the fruit (Heiges 1896, Pl. 12, fig. 4, 4a, 4b.) is clearly not *C. glabra*, but is evidently *C. X laneyi*, the hybrid between *C. ovata* and *C. cordiformis*. This determination is based on the presence of prominent lacunae, which are lacking in both *C. glabra* and *C. ovata*, but are present in *C. cordiformis* and its hybrids; by the general appearance of the nut, with the prominent apex characteristic of *C. cordiformis* and its hybrids but atypical of *C. glabra*; by the dehiscent husks, apparently partially winged as in *C. cordiformis*, but atypical of *C. glabra*; and by the kernel which lacks the convolutions of *C. cordiformis* but is consistent with kernels of *C. X laneyi*. Heiges (1896) noted that "the kernel is large and full, and

in flavor resembles closely *H. ovata*, but in color of surface is more like the bitternut, *H. minima*" (p 69).

Manning (1950) noted that *C. glabra* readily hybridized with *C. ovalis* when the two occurred together, with hybrids confusing the distinctions between the species.

C. ovalis (Wangenh.) Sarg. Red Hickory

Red Hickory ranges farther west than pignut hickory, being found across southern Missouri into northeastern Oklahoma and across northern Arkansas (Fig. 14). Distinctions between red hickory and pignut in site and identification are given above.

Two cultivars have been named of *C. ovalis*, 'Green' and 'Huff', both of southern Michigan and both named in 1929 (Grauke, 1988).

C. X demareei Palmer was described as a cross between red hickory and bitternut.

C. pallida (Ashe) Engl. & Graebn. Sand hickory.

Sand hickory is distributed from Virginia west to Tennessee, south into Louisiana where it is limited to 3 parishes and east into northwestern Florida. Isolated populations occur as far north as Delaware and New Jersey and west into southern Indiana and Illinois (Fig. 15). The species is found on dry, upland sandy sites, often with pine.

Sand hickory is easily identified by the dense tufts of hairs on the rachises and midribs and silvery scales on the lower leaf surfaces. Twigs are slender, rather than stout as in *C. tomentosa*, and terminal buds are much smaller, with persistent reddish brown bud scales.

C. floridana Sarg. Scrub Hickory

Scrub hickory has the most restricted distribution of any Carya species in the United States, being confined to about 20 counties in central Florida centered around Osceola County (Little, 1977)(Fig. 16).

C. floridana is identified by the abundant, rust-colored scales on the buds and lower leaf surfaces which separate the species from all others except *C. texana*. Herbarium specimens of scrub hickory can be separated from those of black hickory only by information on the origin of the samples, the two species being entirely allopatric. It is interesting that these two species show close similarity grouping based on data from chromatographic analysis of nut oils (Stone et al., 1969).

Scrub hickory varies in habit from a multi-trunked shrub, bearing fruit on stems 3 to 4 feet in height, to a single trunked tree of 50 to 70 feet in height (Sargent 1922). Its nuts were found by Abrahamson and Abrahamson (1989) to be the most energy and nutritionally rich of the nine animal dispersed fruits of the Florida sandridge habitat which those authors examined. However, use by

wildlife is limited to rodents, black bear, foxes, raccoons, and specialist insect seed predators which can cut the thick, hard shells.

Economic Botany

In addition to being grown for their nutritious and delicious nuts, hickories are also valued for the utility and beauty of their wood, for their ornamental value in the landscape, and for their quality as a fuel wood.

The wood of hickories is known for strength and shock resistance, making it excellent for tool handles. It is also used extensively for sports equipment such as golf clubs, baseball bats, the backs of longbows, and laminae in tennis racquets and skis (Makepeace and Walker, 1989). High quality hickory is used as a flooring material for gymnasiums, roller skate rinks, and ballrooms. Some wood is used in making furniture, in piano construction, for butcher's blocks, for wall paneling, and interior trim. Hickory wood is also used for dowels, ladder rungs, and pallets (Harrar, 1958). Harrar (1958) reported that quality hickory lumber is in short supply, with much of the standing timber being so defective that harvest was not economical.

Hickory is considered to be an excellent fuel wood because of its density. One pound of any hardwood species yields about the same amount of heat as a pound of any other species of hardwood (8,580 to 8,920 BTUs per pound). However, wood is sold by the cord, which is a volume measure. Hickory wood is very dense, weighing about 4600 lbs. per cord and producing about 25 million BTUs per cord when burned. Lighter wood such as elm may weigh only 3200 lbs. per cord and produce 18 million BTUs when burned (Michaelson, 1978). Hickory wood is consumed in the smoking of meats and cheeses, where it imparts a distinctive flavor.

Of the 13 species described above, only pecan, shagbark and shellbark, have received much horticultural attention. In addition to their intrinsic ecological value, the remaining species are potentially useful for wood production or as specimen plants in the landscape. As more information is gained concerning mechanisms of disease and insect resistance or other genetic adaptations, these species could contribute to the development of the closely related pecan.

Bringhurst (1983) outlined 4 steps usually followed in the development of improved fruit crops from wild species: 1) identification of superior phenotypes in natural populations; 2) propagation of the best selections in an agricultural setting; 3) development of cultural practices that enhance performance of selected cultivars; and 4) hybridization among the best selections followed by selection of superior offspring (which are used as parents for further crosses). Despite their long history of utilization, the hickories are still at an early stage of crop development. Many "superior phenotypes" have been found in native populations, with nut characteristics being the primary basis of evaluation. The characteristics and performance of these "cultivars" following asexual propagation has been the focus of much of the literature related to hickory management.

Unfortunately, observations are often based on one stion of a cultivar, often with a rootstock of another species and growing on mediocre sites.

A significant stage in the horticultural development of pecan occurred when orchards were planted using selected seed. Seedlings were evaluated for horticultural traits, with cultivars such as 'Stuart', 'Schley', 'Success', 'Delmas', 'Alley', and 'Pabst' arising from "select seed orchards" in Jackson Co., Mississippi. 'Western', 'San Saba Improved', 'Sovereign' ('Texas Prolific'), 'Onliwon', and 'Squirrels Delight' originated from an orchard of 1000 trees grown from seed of the 'San Saba', a native selection made by E. E. Risien of San Saba Co., Texas. The James orchard at Mound, Louisiana, was planted from selected seed and produced 'Carman', 'James', and 'Moneymaker' while in Florida, 'Curtis', 'Hume', 'Kennedy', and 'Randall' arose from the seedling orchard of J. B. Curtis (Crane et al., 1937).

Pecan cultivars have traditionally been selected primarily on the basis of nut characteristics, with selections being asexually propagated on seedling rootstocks in orchard configurations where intensive management can be economically justified. The limitations to economically feasible orchard establishment in the hickories are the extremely long period of juvenility (> 10 years), low yields (22 to 45 kg/tree, once in 3 yr), and large tree size. These native trees are plagued by many co-evolved disease and insect pests (Harris et al., 1986), especially when grown in a "monoculture" having large numbers of a limited number of cultivars. Conventional systems of orchard production have emphasized chemical control of pests, which is both economically and environmentally expensive. As a result, the culture of hickories tends to be "unconventional", with most practitioners being motivated more by aesthetics than economics.

The value of hickory wood creates an economic incentive to harvest this slowly renewable forest resource. Wise management should integrate the needs of forestry with a long range program of selection for the improvement of the stand. The systematic maintenance, management, and development of this valuable natural resource deserves thoughtful attention.

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2a-d *C. tomentosa*
3a-d *C. texana*
4a-d *C. ovata*
5a-d *C. glabra*
6a-d *C. ovalis*
7a-d *C. pallida*
8a-d *C. floridana*
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Table 1. Taxa recognized as species by the NCGR-*Carya*, listed alphabetically within section.

Sect. Sinocarya

1. *C. cathayensis* Sarg. Chinese hickory * (probably includes *C. dabieshanensis*)
2. *C. hunanensis* Cheng & R. H. Chang. Hunan hickory *
3. *C. kweichowensis* Kuang & Lu. Guizhou hickory *
4. *C. tonkinensis* Lecomte. Viet Nam hickory *
5. *C. poilanei* (A. Chev.) J. Leroy. Poilane's hickory *

Sect. Apocarya

6. *C. aquatica* (F. Michx.) Nutt. Water hickory
7. *C. cordiformis* (Wangenh.) K. Koch. Bitternut hickory
8. *C. illinoinensis* (Wangenh.) K. Koch. Pecan
9. *C. palmeri* Manning. Mexican hickory

Sect. Carya

10. *C. floridana* Sarg. Scrub hickory
11. *C. glabra* (Mill.) Sweet. Pignut hickory
12. *C. laciniosa* (F. Michx.) Loudon. Shellbark hickory
13. *C. myristiciformis* (F. Michx.) Nutt. Nutmeg hickory
14. *C. ovalis* (Wangenh.) Sarg. Red hickory
15. *C. ovata* (Mill.) K. Koch.Shagbark hickory (includes *Carya carolinae-septentrionalis* (Ashe) Engl. & Graebn. Southern shagbark hickory
16. *C. pallida* (Ashe) Engl. & Graebn. Sand hickory
17. *C. texana* Buckley. Black hickory
18. *C. tomentosa* (Poir.) Nutt. Mockernut hickory

Interspecific Hybrids

1. *C. X brownii* (*C. cordiformis X C. illinoinensis*) Sarg.
2. *C. X collina (C. texana X C. tomentosa)* Laughlin
3. *C. X demareei (C. cordiformis X C. ovalis)* Palmer
4. *C. X dunbarii (C. laciniosa X C. ovata*) Sarg.
5. *C. X laneyi (C. cordiformis X C. ovata)* Sarg.
6. *C. X lecontei (C. aquatica X C. illinoinensis)* Little
7. *C. X ludoviciana (C. aquatica X C. texana)* (Ashe) Little **
8. *C. X nussbaumeri (C. illinoinensis X C. laciniosa)* Sarg.
9. *C. X schneckii (C. illinoinensis X C. tomentosa)* Sarg. **
10. *C. illinoinensis X C. ovata* (see Manning 1962)
11. *C. cordiformis X C. tomentosa* (see Reed 1944) **
12. *C. illinoinensis X C. myristiciformis* (see Windham 1981).

* = Asian species. ** parentage disputed

Table 2. Alphabetical index to the synonymy of the genus *Carya*.

Synonym	=	Accepted name
C. alba Nutt.	=	C. ovata (Mill.) K. Koch
C. alba (Mill.) K. Koch	=	C. tomentosa (Poir.) Nutt.
C. alba var. ovalis (Wangenh.) K. Koch	=	C. ovalis (Wangenh.) Sarg.
C. amara (F. Michx.) Nutt.	=	C. cordiformis (Wangenh.) K. Koch
C. amara var. porcina Darby	=	C. glabra (Mill.) Sweet
C. angustifolia Sweet	=	C. illinoinensis (Wangenh.) K. Koch
C. arkansana Sarg.	=	C. texana var. arkansana (Sarg.) Little
C. borealis (Ashe) Schneider	=	C. ovalis (Wangenh.) K. Koch
C. Buckleyi Durand	=	C. texana Buckley
C. carolinae-septentrionalis (Ashe) Engl. & Graebn.	=	C. ovata var. australis (Ashe) Little
C. diguetii Dode	=	C. illinoinensis (Wangenh.) K. Koch
C. Fernowiana Sudworth	=	C. myristiciformis (F. Michx.) Nutt.
C. glabra var.odorata(Marsh.) Little	=	C. ovalis(Wangenh.) Sarg.
C. glabra var. villosa Robinson	=	C. texana var. villosa (Sarg.) Little
C. illinoensis (Wangenh.) K. Koch	=	C. illinoinensis (Wangenh.) K. Koch
C. integrifolia (Raf.) Sprengel	=	C. aquatica (F. Michx.) Nutt.
C. integrifoliolata (Kuang) Hjelmqvist	=	Annamocarya sinensis Dode
C. leiodermis Sarg.	=	C. glabra var. megacarpa (Sarg.) Sarg.
C. magnifloridana Murrill	=	C. glabra var.megacarpa(Sarg.) Sarg.
C. megacarpa Sarg.	=	C. glabra var. megacarpa (Sarg.) Sarg.
C. mexicana Engelmann ex Hemsley	=	C. ovata var. mexicana (Engelm.) Manning
C. microcarpa Darlington	=	C. ovalis (Wangenh.) Sarg.
C. microcarpa Nutt. (1841)	=	C. ovata var. Nuttallii Sarg.
C. microcarpa Nutt. (1818)	=	C. ovalis (Wangenh.) Sarg.
C. olivaeformis Nutt.	=	C. illinoinensis (Wangenh.) K. Koch
C. ovalis var. hirsuta (Ashe) Sarg.	=	C. glabra var. hirsuta (Ashe) Ashe
C. ovata var. carolinae-septentrionalis (Ashe) Reveal	=	C. ovata var. australis (Ashe) Little
C. pecan Engl. & Graebn.	=	C. illinoinensis (Wangenh.) K. Koch
C. pecan (Walt.) Nutt.	=	C. glabra var. megacarpa (Sarg.) Sarg.
C. porcina Nutt.	=	C. glabra (Mill.) Sweet
C. sulcata Nutt.	=	C. laciniosa (F. Michx.) Loudon
C. tetraptera Liebmann	=	C. illinoinensis (Wangenh.) K. Koch
C. texana C. DC	=	C. X LeContei Little
C. villosa Schneider	=	C. texana var. villosa (Sarg.) Little

(Table 2, cont.) Alphabetical index to the synonymy of the genus *Carya*.

Synonym	=	Accepted name
Hicoria acuminata Dippel	=	C. laciniosa (F. Michx.) Loudon
H. alba (L.) Britton	=	C. tomentosa (Poir.) Nutt.
H. Ashei Sudworth	=	C. glabra var. megacarpa (Sarg.) Sarg.
H. austrina Small	=	C. glabra var. megacarpa (Sarg.) Sarg.
H. maxima (Nutt.) Raf.	=	C. tomentosa (Poir.) Nutt.
H. minima Britton	=	C. cordiformis (Wangenh.) K. Koch
H. sulcata Britton	=	C. laciniosa (F. Michx.) Loudon
H. texana LeConte	=	C. X LeContei Little
Juglans alba L.	=	C. ovata (Mill.) K. Koch or C. tomentosa (Poir.) Nutt.
J. alba acuminata Marsh.	=	C. glabra (Mill.) Sweet
J. alba minima Marsh.	=	C. cordiformis (Wangenh.) K. Koch
J. alba ovata Marsh.	=	C. ovata (Mill.) K. Koch
J. alba ovata Robin	=	C. cordiformis (Wangenh.) K. Koch
J. alba pacana Castiglioni	=	C. illinoinensis (Wangenh.) K. Koch
J. compressa Gaertner	=	C. ovata (Mill.) K. Koch
J. cylindrica Lamarck	=	C. illinoinensis (Wangenh.) K. Koch
J. illinea Weston	=	C. illinoinensis (Wangenh.) K. Koch
J. latifolia Poir.	=	C. ovata (Mill.) K. Koch
J. minima Borkhausen	=	C. cordiformis (Wangenh.) K. Koch
J. obcordata Poir.	=	C. ovata (Mill.) K. Koch
J. squamosa F. Michx.	=	C. ovata (Mill.) K. Koch
J. sulcata Willdenow	=	C. cordiformis (Wangenh.) K. Koch

Table 3. Cultivars of C. ovata (Shagbark hickory), a partial list.

Name	Origin	Comment
Anthony	Illinois	Recommended in IL
CES 26	Ontario	Recommended for North (Campbell, 1987)
Davis	New York	Promising (MacDaniels, 1979)
Fox	New York	Promising (MacDaniels, 1979) Recommendedfor North (Campbell, 1980, 1987)
Glover	Connecticut	Promising (MacDaniels, 1979) Qualified recommendation (Campbell, 1980, 1987)
Grainger	Tennessee	Promising (MacDaniels, 1979) Qualified recommendation (Campbell, 1980, 1987)
Harold	Wisconsin	Promising (MacDaniels, 1979)
Holden	Ohio	Ornamental, spruce-like form
Neilson	Ontario	Recommended for North (Campbell, 1980, 1987)
Porter	Pennsylvania	Promising (MacDaniels, 1979) Qualified recommendation (Campbell, 1980, 1987)
Retzer	Illinois	Recommended in IL
Weschcke	Iowa	May be C. X laneyi Qualified recommendation (Campbell, 1980) Recommended for North (Campbell, 1987)
Wilcox	Ohio	Promising (MacDaniels, 1979) Qualified recommendation (Campbell, 1980) Recommended for North (Campbell, 1987)
Yoder #1	Ohio	Recommended (Thatcher, 1985) Recommended for North (Campbell, 1987)

Table 4. Cultivars of C. laciniosa (Shellbark hickory), a partial list.

Cultivar	Origin	Comment
Bradley	Pennsylvania	Recommended for North (Campbell, 1980) Qualified recommendation (Campbell, 1987)
CES 24	Ontario	Recommended for North (Campbell, 1987)
Eureka	Iowa	Ornamental, red color at leaf burst Not recommended for production (Campbell, 1980)
Fayette	Pennsylvania	Recommended for North (Campbell, 1980, 1987)
Henry	Pennsylvania	Recommended for North (Campbell, 1980, 1987)
Keystone	Pennsylvania	Promising (MacDaniels, 1979) Qualified recommendation (Campbell, 1980, 1987)
Nieman	Illinois	Promising (MacDaniels, 1979) Not recommended (Campbell, 1980)
Scholl	Ohio	Not recommended (Campbell, 1980) Qualified recommendation (Campbell, 1987)
Stanley		Qualified recommendation (Campbell, 1987)
Stephens	Kansas	Promising (MacDaniels, 1979) Qualified recommendation (Campbell, 1980, 1987)

Figure 1 Diagnostic features of the genus *Carya*

a Solid pith of *Carya*

b Chambered pith of Juglans

c Dehiscent husk of *Carya*

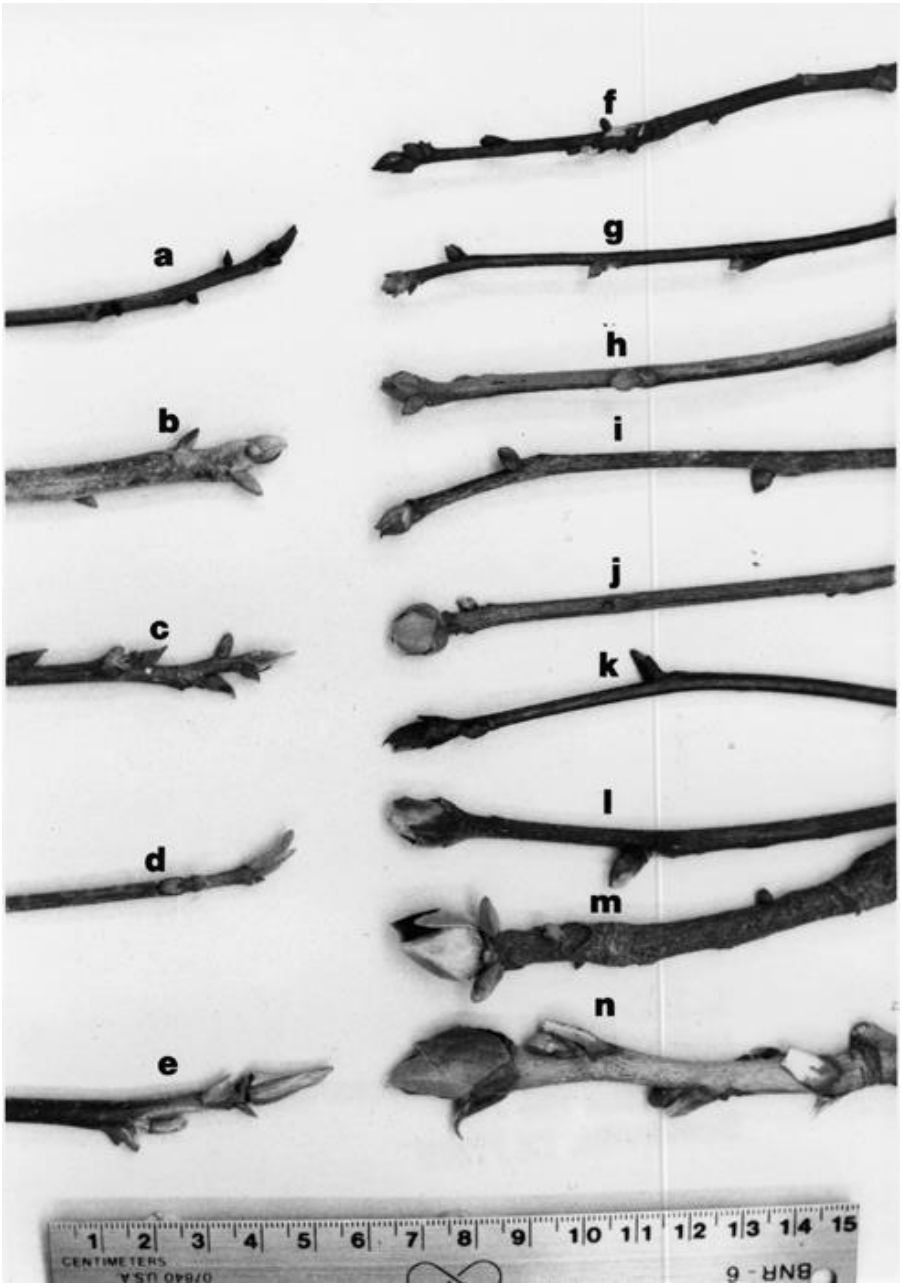
d Indehiscent husk of Juglans

e *Carya* tomentosa nut (cross section), with widely separated funicular strands in primary septum (arrow).

f *Carya* tomentosa nut (longitudinal section), with widely separated funicular strands in primary septum (arrow) and basal plexus (P).

g Juglans regia nut (cross section), with close spaced funicular strands in primary septum (arrow).

h Juglans regia nut (longitudinal section), with close spaced funicular strands in primary septum (arrow), and lacking a basal plexus.



Figture 2 Terminal buds of North American *Carya* species.
a *C. aquatica* b *C. myristiciformis* c *C. illinoinensis* d *C. cordiformis*
e *C. palmeri* f *C. pallida* g *C. floridana* h *C. texana* i *C. ovalis*
j *C. glabra* k *C. ovata var. australis* l *C. ovata* m *C. tomentosa*
n *C. laciniosa*

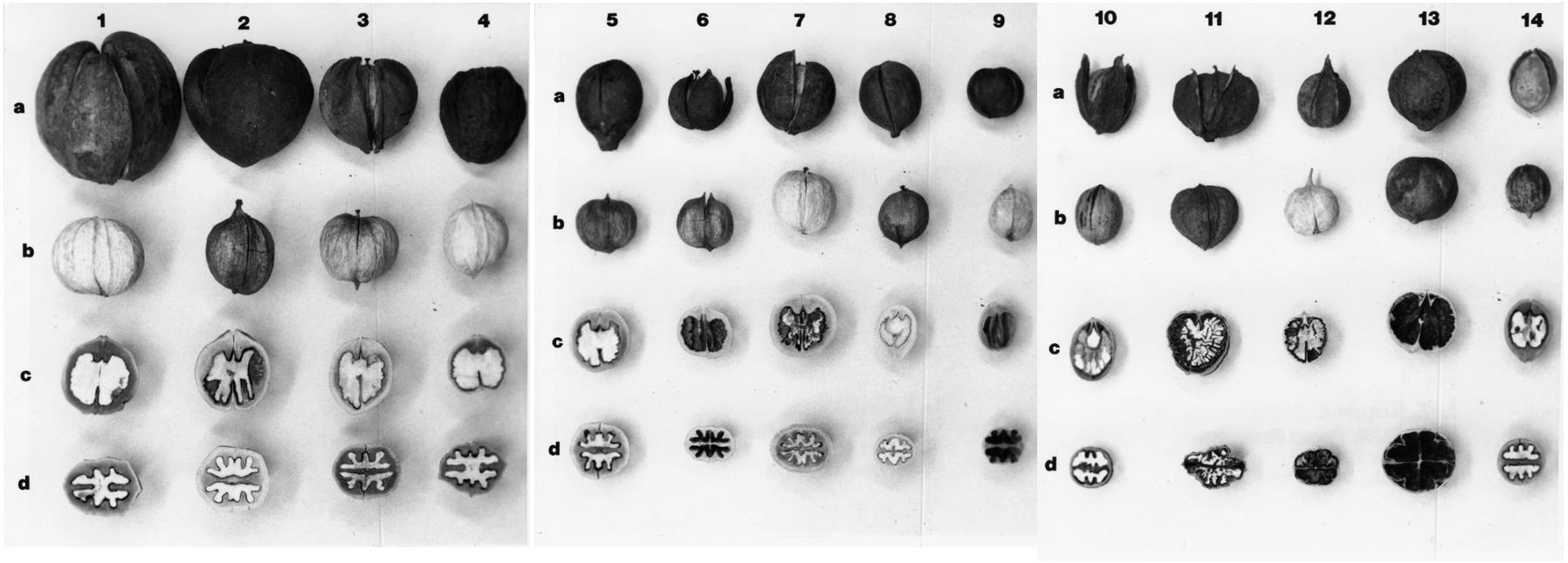


Figure 3 Fruits of North American *Carya* species.

a (all species) Nut in husk, apex up.

b (all species) Nut out of husk, apex up, suture visible.

c (all species) Nut sectioned in the plane of the primary septum, perpendicular to plane of suture.

d (all species) Nut cross section, plane of suture vertical, plane of primary septum horizontal.

1a-d *C. laciniosa* 2a-d *C. tomentosa* 3a-d *C. texana* 4a-d *C. ovata* 5a-d *C. glabra* 6a-d *C. ovalis* 7a-d *C. pallida* 8a-d *C. floridana* 9a-d *C. ovata var. australis* 10a-d *C. illinoinensis* 11a-d *C. aquatica* 12a-d *C. cordiformis* 13a-d *C. palmeri* 14a-d *C. myristiciformis*

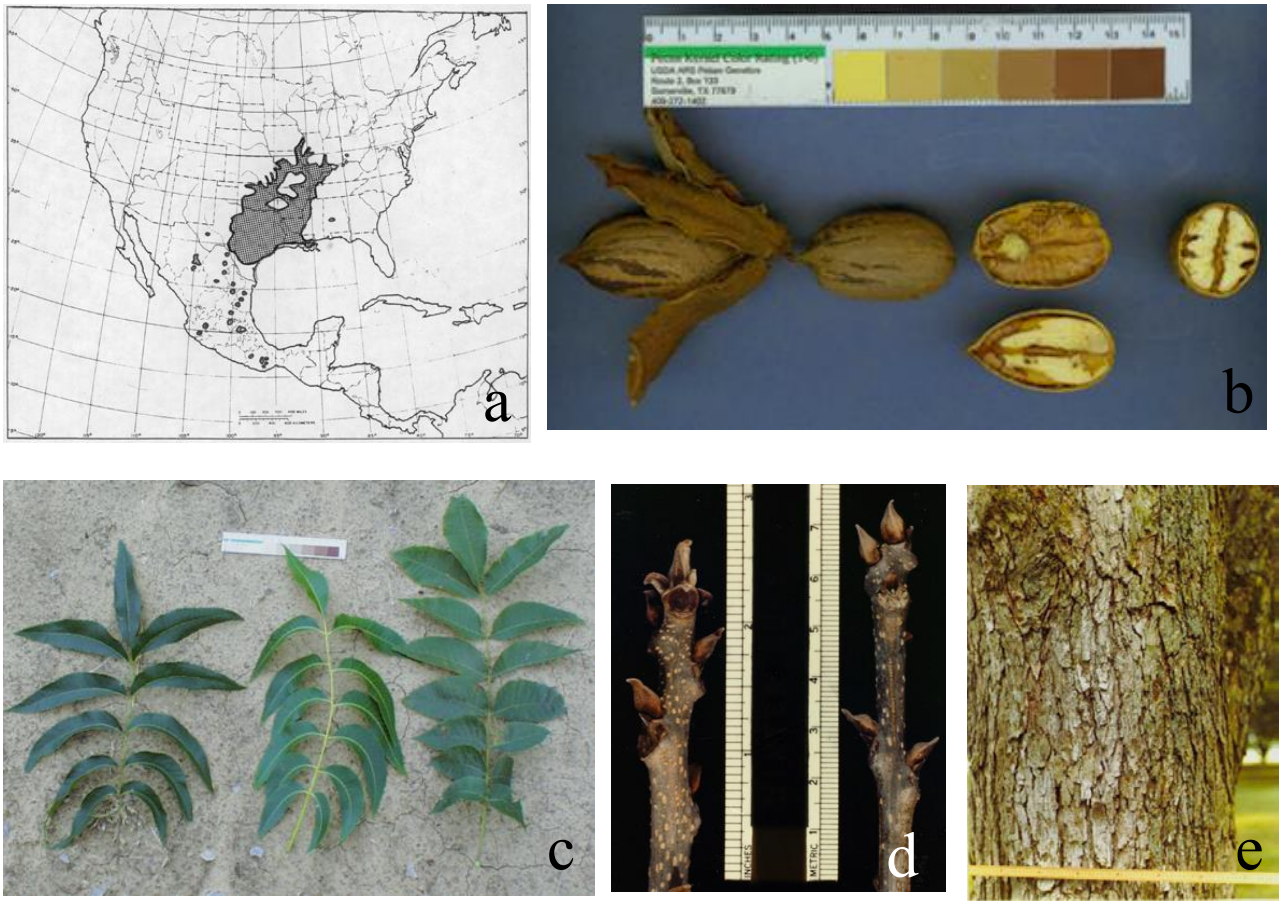


Figure 4. ***Carya illinoinensis*** (Wangenh.) K. Koch. Pecan
a. Native distribution of *C. illinoinensis*. b. Nuts of pecan, in the husk, in shell, longitudinal and cross sections. c. Leaves. d. Buds. e. Bark.

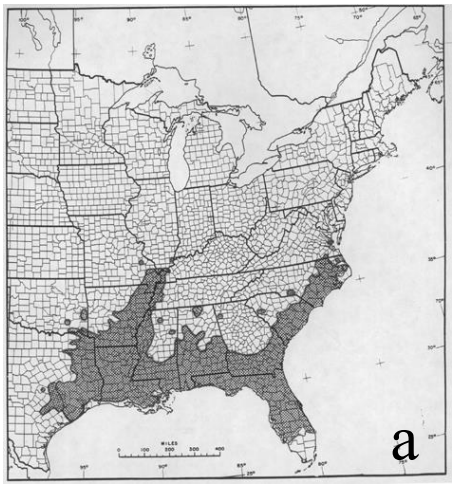


Figure 5. *Carya aquatica* (F. Michx.) Nutt. Water hickory**.**

a. Native distribution of *C. aquatica*. b. Nuts. c. Leaves with cluster of nuts.

b. d. Terminal bud of water hickory. e. Bark

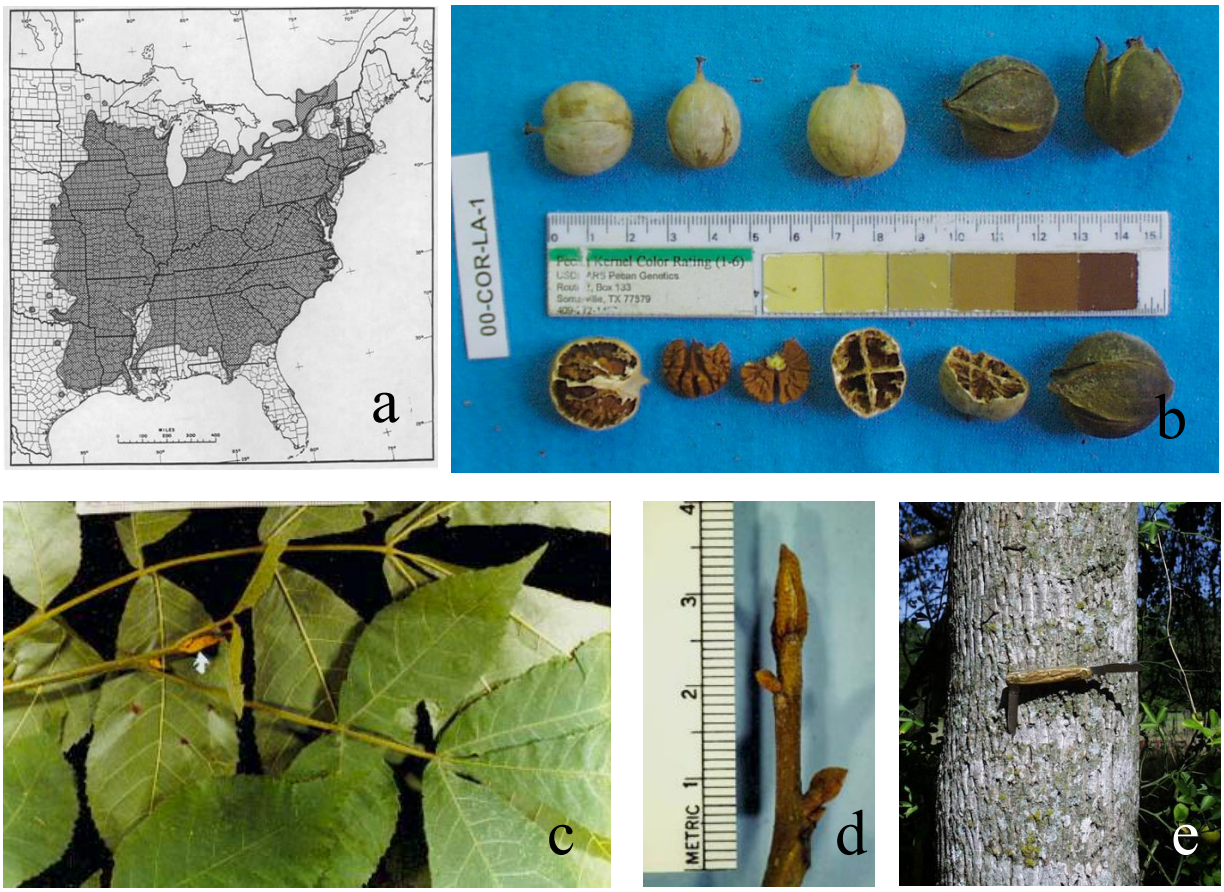


Figure 6 *Carya cordiformis* (Wangenh.) K. Koch. Bitternut Hickory
a. Native distribution of *C. cordiformis*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark.

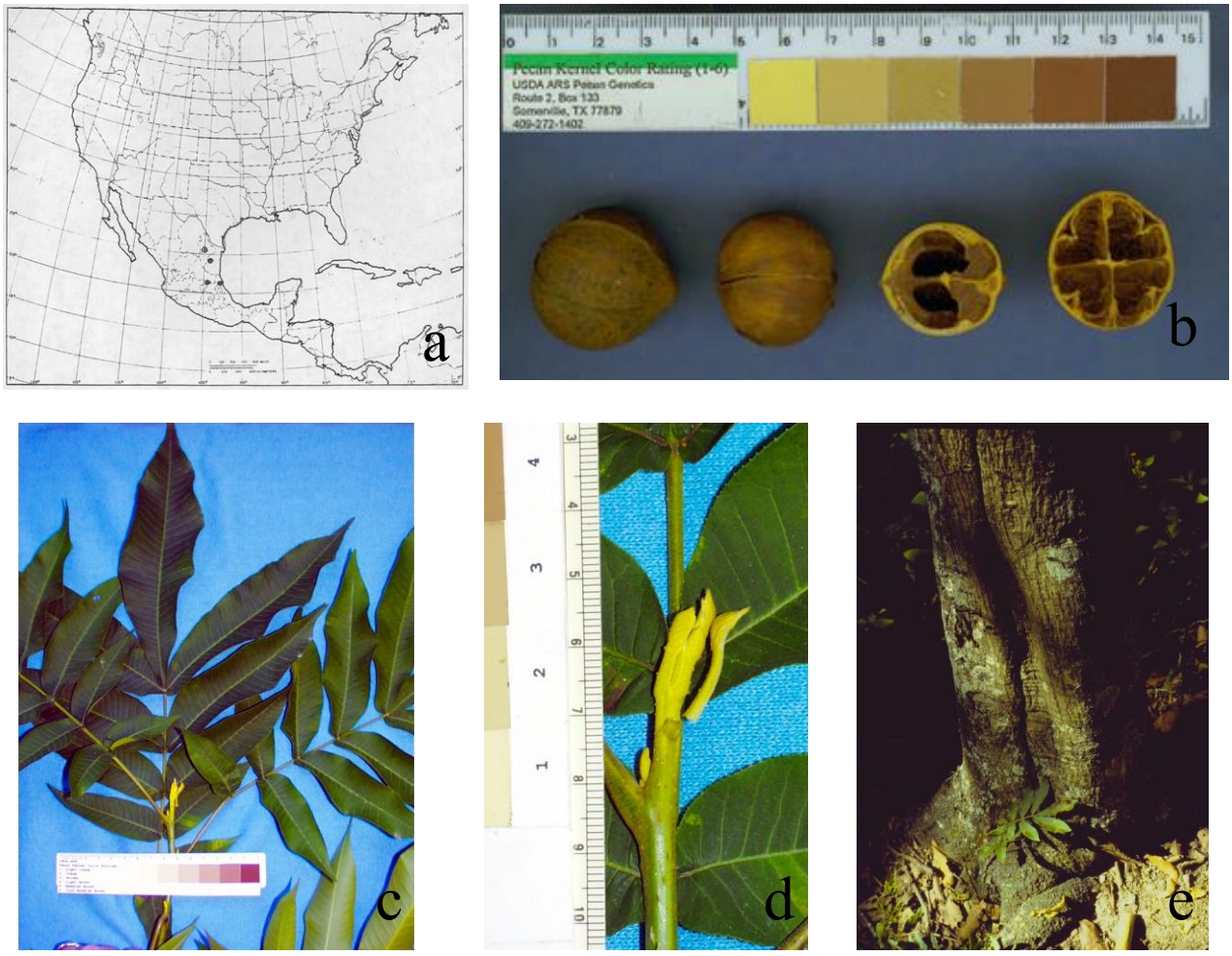


Figure 7. *Carya palmeri* Manning. Mexican Hickory
a. Native distribution of *C. palmeri*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark

Figure 8. *Carya myristiciformis* (F. Michx.) Nutt. Nutmeg Hickory
a. Native distribution of *C. myristiciformis*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark.

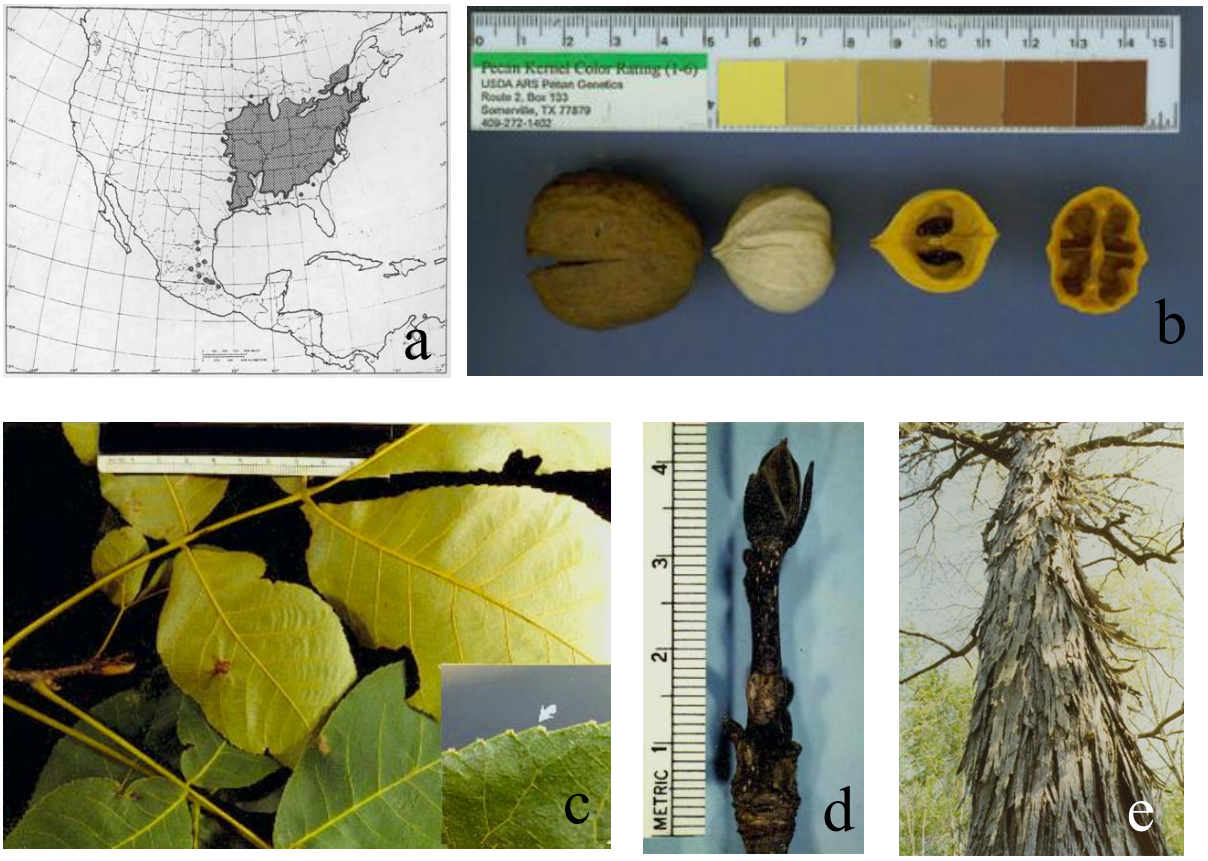


Figure 9. *Carya ovata* (Mill.) K. Koch. Shagbark hickory
a. Native distribution of *C. ovata*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark.

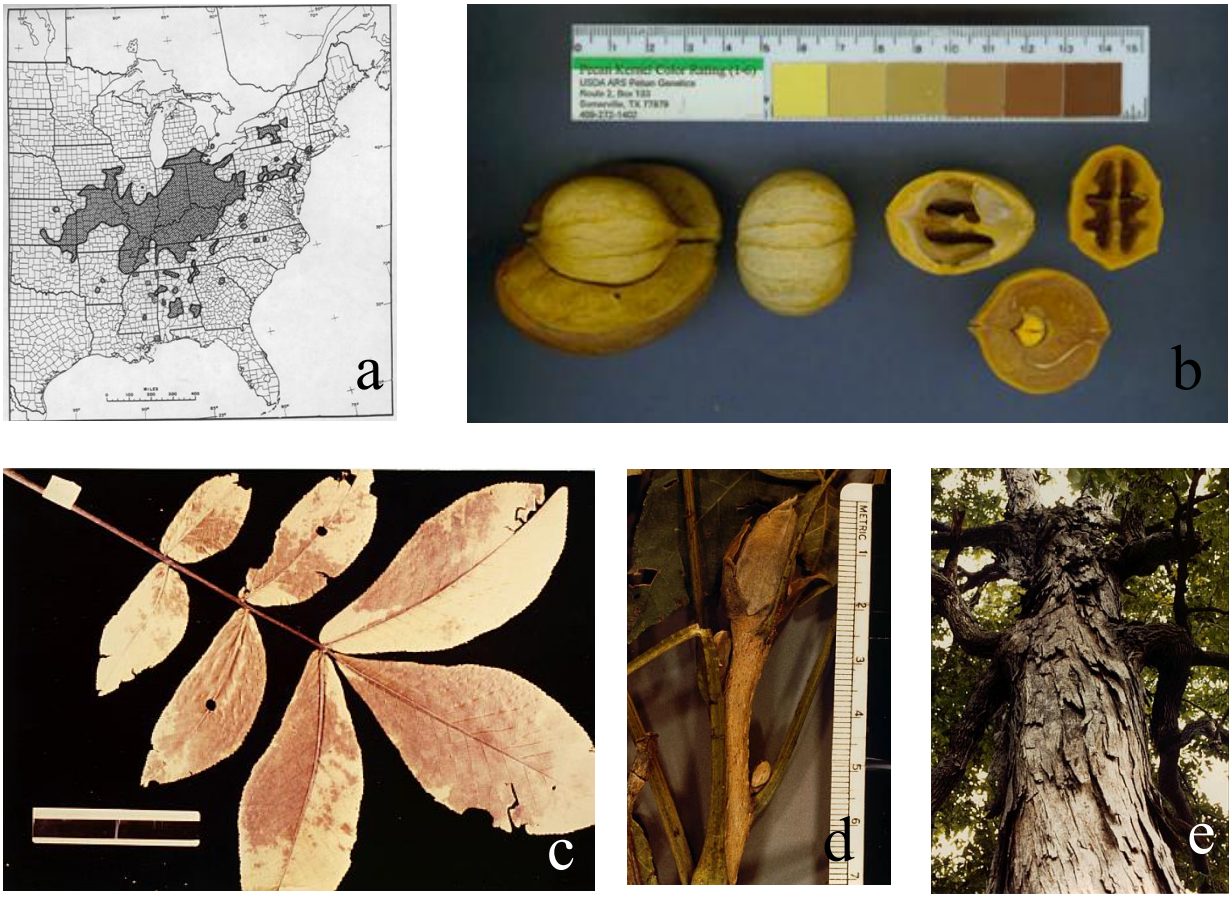


Figure 10. *Carya laciniosa* (F. Michx.) Loudon. Shellbark Hickory
a. Native distribution of *C. laciniosa*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark

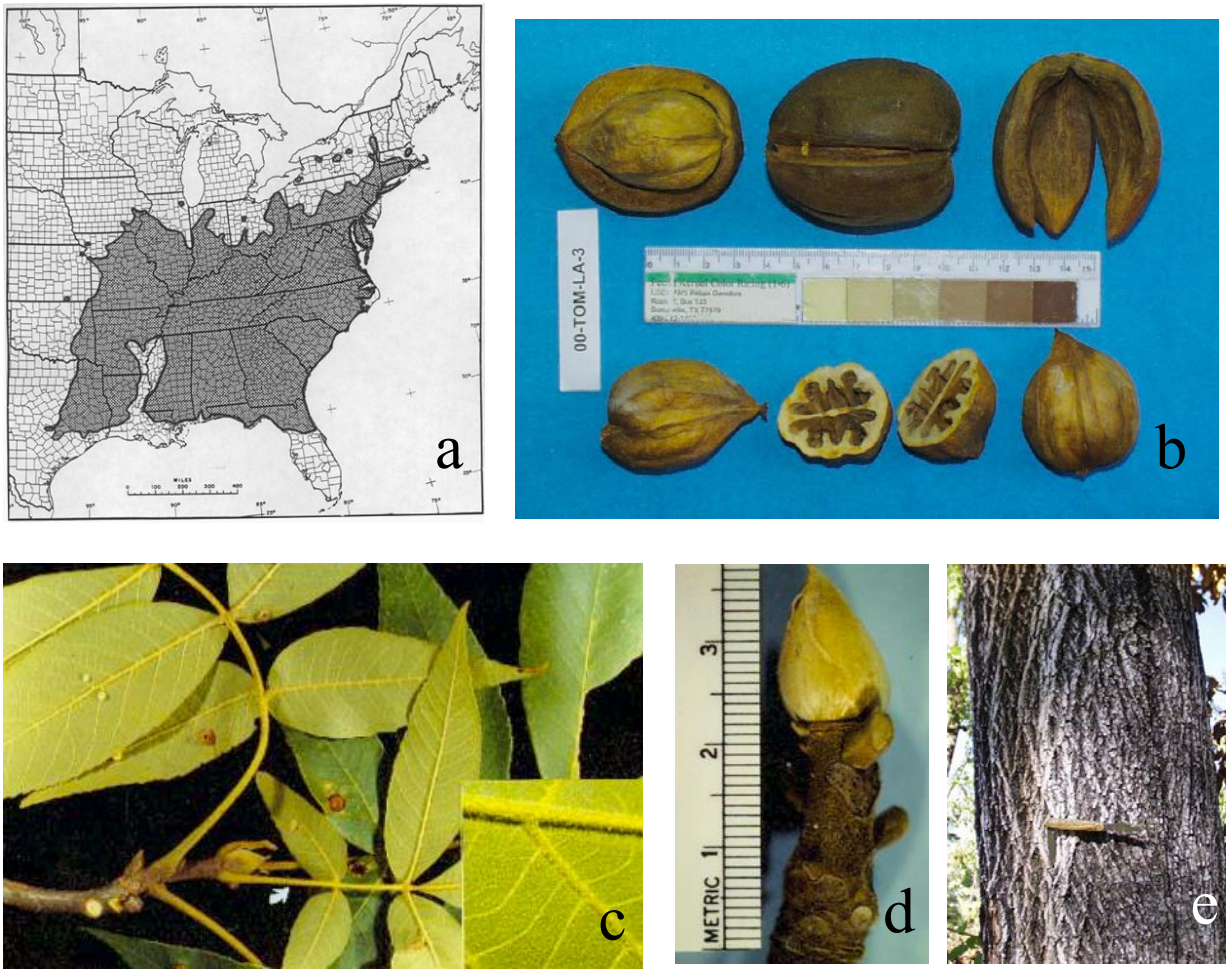


Figure 11. *Carya tomentosa* (Poir.) Nutt. Mockernut Hickory
a. Native distribution of *C. tomentosa*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark.

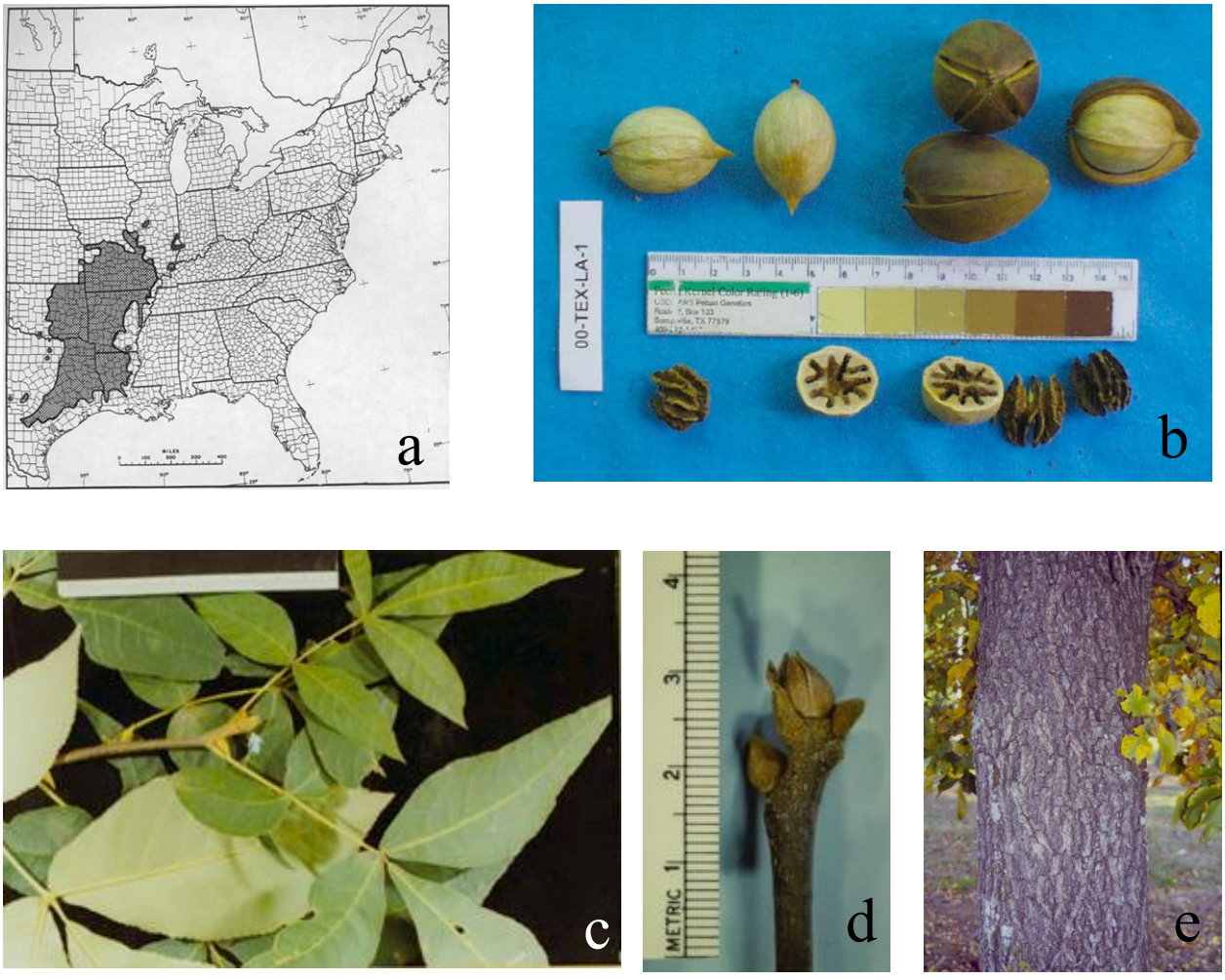
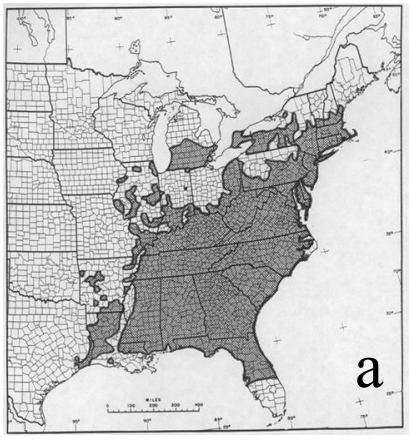


Figure 12. *Carya texana* Buckley. Black Hickory
a. Native distribution of *C. texana*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark



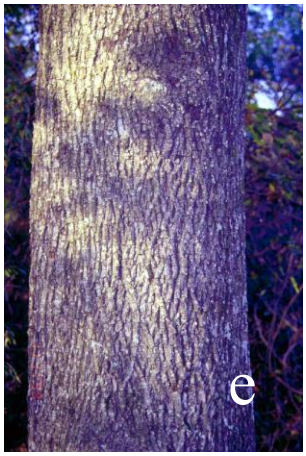


Figure 13. *Carya glabra* (Mill.) Sweet. Pignut Hickory
a. Native distribution of *C. glabra*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark.

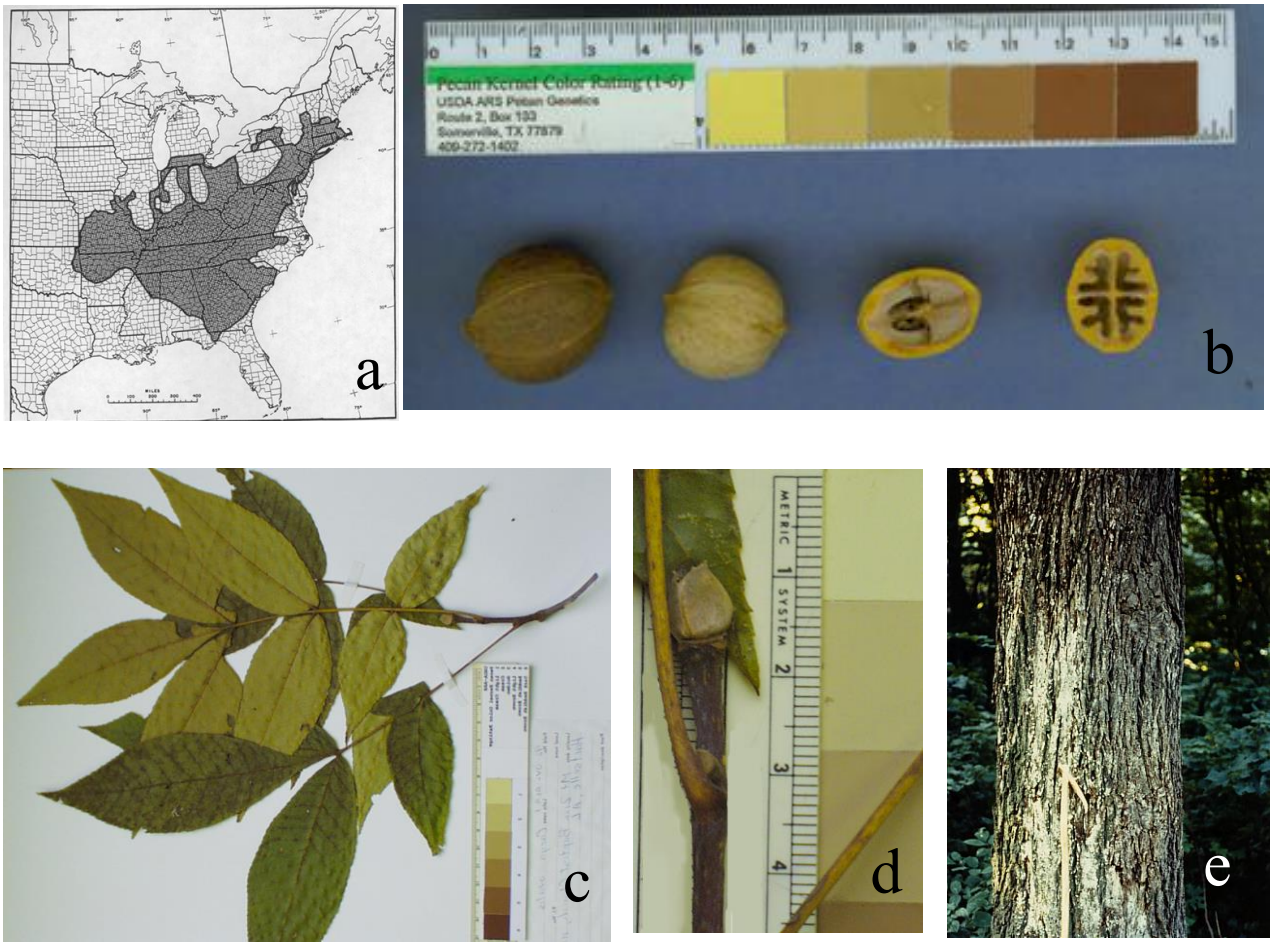


Figure 14. *Carya ovalis* (Wangenh.) Sarg. Red Hickory
a. Native distribution of *C. ovalis*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark

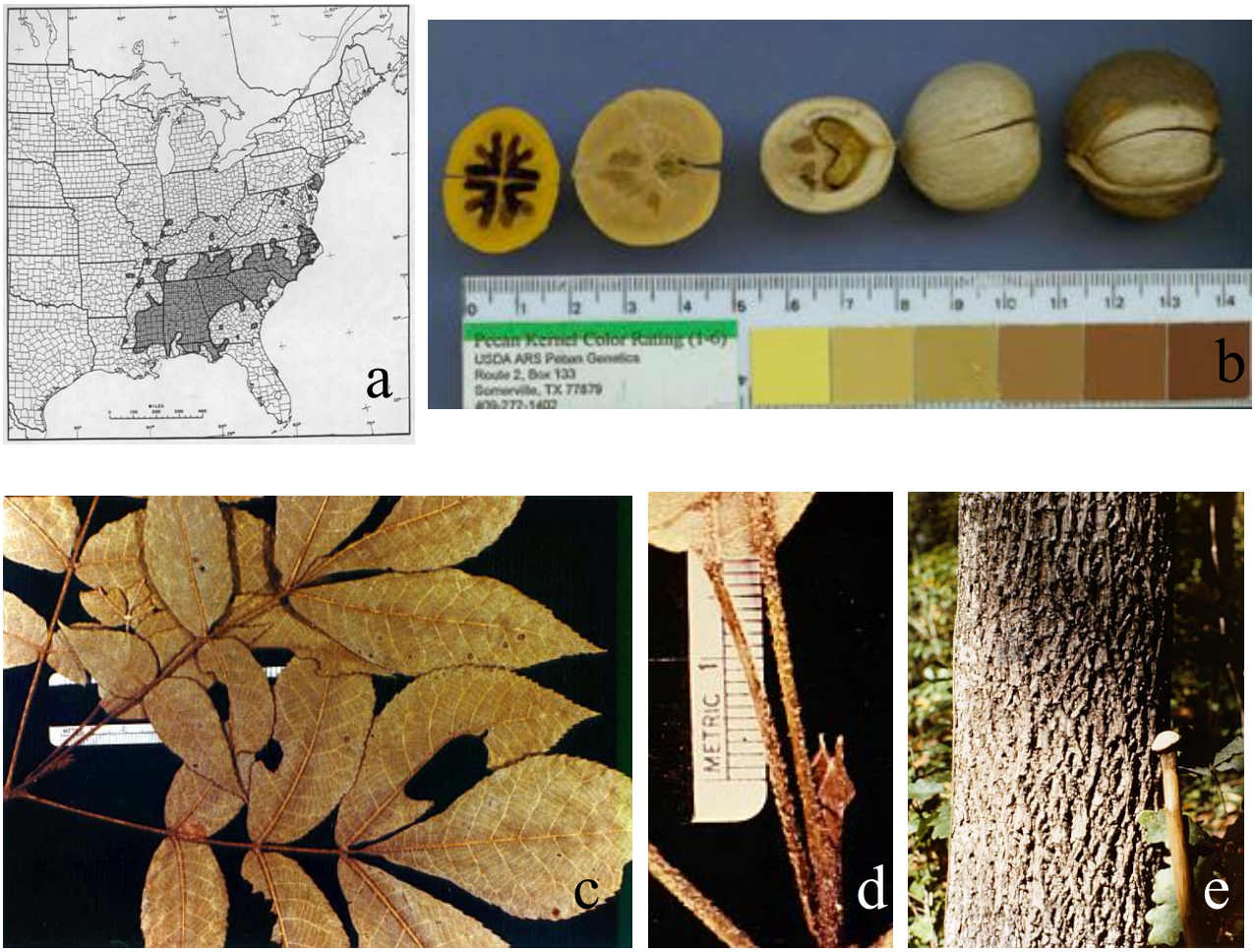


Figure 15. *Carya pallida* (Ashe) Engl. & Graebn. Sand hickory
a. Native distribution of *C. pallida*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark.

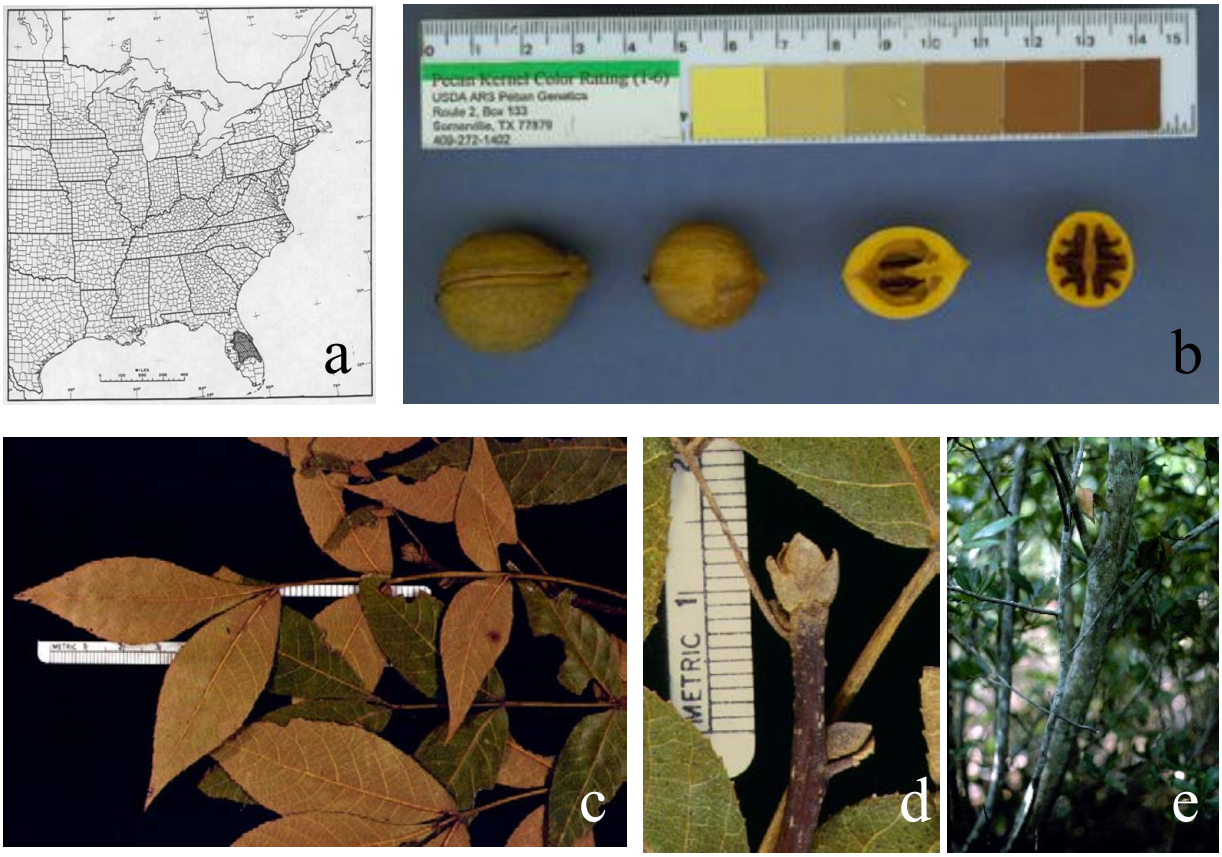


Figure 16. *Carya floridana* Sarg. Scrub Hickory
a. Native distribution of *C. floridana*. b. Nuts. c. Leaves. d. Terminal bud. e. Bark.