Fraxinus pennsylvanica Marsh . Green Ash

Oleaceae Olive family

Harvey E. Kennedy, Jr.

Green ash ***(Fraxinus pennsylvanica),*** also called red ash, swamp ash, and water ash, is the most widely distributed of all the American ashes. Naturally a moist bottom land or stream bank tree, it is hardy to climatic extremes and has been widely planted in the Plains States and Canada. The commercial supply is mostly in the South. Green ash is similar in property to white ash and they are marketed together as white ash. The large seed crops provide food to many kinds of wildlife. Due to its good form and resistance to insects and disease, it is a very popular ornamental tree.

Habitat

Native Range

Green ash (fig. 1) extends from Cape Breton Island and Nova Scotia west to southeastern Alberta; south through central Montana, northeastern Wyoming, to southeastern Texas; and east to northwestern Florida and Georgia.

Climate

The climate within the range of green ash is subhumid to humid, with the following ranges: Annual precipitation from 380 to 1520 mm (15 to 60 in), warm season precipitation from 250 to 890 mm (10 to 35 in); average January temperature of -18" to 13" C (0° to 55" F); average July temperature of 18" to 27" C (65" to 80" F); snowfall from 0 to 254 cm (0 to 100 in); average length of frost-free season 120 to 280 days.

Soils and Topography

Like most trees, green ash grows best on fertile, moist, well-drained soils. It is probably the most adaptable of all the ashes, growing naturally on a range of sites from clay soils subject to frequent flooding and overflow to sandy or silty soils where the amount of available moisture may be limited (24). Natural stands of green ash are almost completely confined to bottom lands, but the species grows well when planted on moist upland soils. It thrives when planted on medium- to coarse-textured upland sands and loams from North Dakota to Texas where soils had good moisture and neutral to alkaline reactions. Green ash most commonly is found on alluvial soils along rivers and streams and less frequently in swamps *(25)*. It lines the watercourses in the western parts of its range where rainfall is insufficient to support upland growth. It is common on land subject to flooding and can remain healthy when flooded for as long as 40 percent of the time during a growing season. Green ash grows on soils most common to the orders Inceptisols and Entisols.

In fertilizer experiments, green ash was tolerant of soil alkalinity but showed severe chlorosis when grown on a soil with a pH of 8.1 *(25)*. Culture-species tests on a riverfront site in Mississippi have shown that ash grew well on a silt-loam soil with a pH ranging between 7.5 and 8.0.

Other studies have shown the importance of soil characteristics to tree growth. Growth was much better on soils that had not been cultivated than on ones that had been in cultivation *(7)*. The longer an area had been in cultivation or the more severely eroded the A horizon, the poorer the growth of green ash. Forest sites support better growth than old field sites, probably because of suitable mycorrhizae and organic matter in the forest soils.

Green ash has been planted on spoil banks resulting from strip-mining (25). These soils usually are highly acidic. Survival generally has been high, but annual growth rates of only about 0.3 m (1 ft) have been reported. Studies in Arkansas on sandy loam soils with pH ranging from 5.0 to 5.4 have shown excellent survival and growth rates of 1.5 to 1.8 m (5 to 6 ft) per year.

Associated Forest Cover

Green ash is an integral part of the forest cover type Sugarberry-American Elm-Green Ash (Society of American Foresters Type 93) and is an associated species in the following types (22):

16 Aspen
26 Sugar Maple-Basswood
42 Bur Oak
52 White Oak-Black Oak-Northern Red Oak
62 Silver Map&American Elm
63 Cottonwood
65 Pin Oak–Sweetgum
87 Sweetgum-Yellow-Poplar
88 Willow Oak-Water Oak-Diamondleaf (Laurel) Oak

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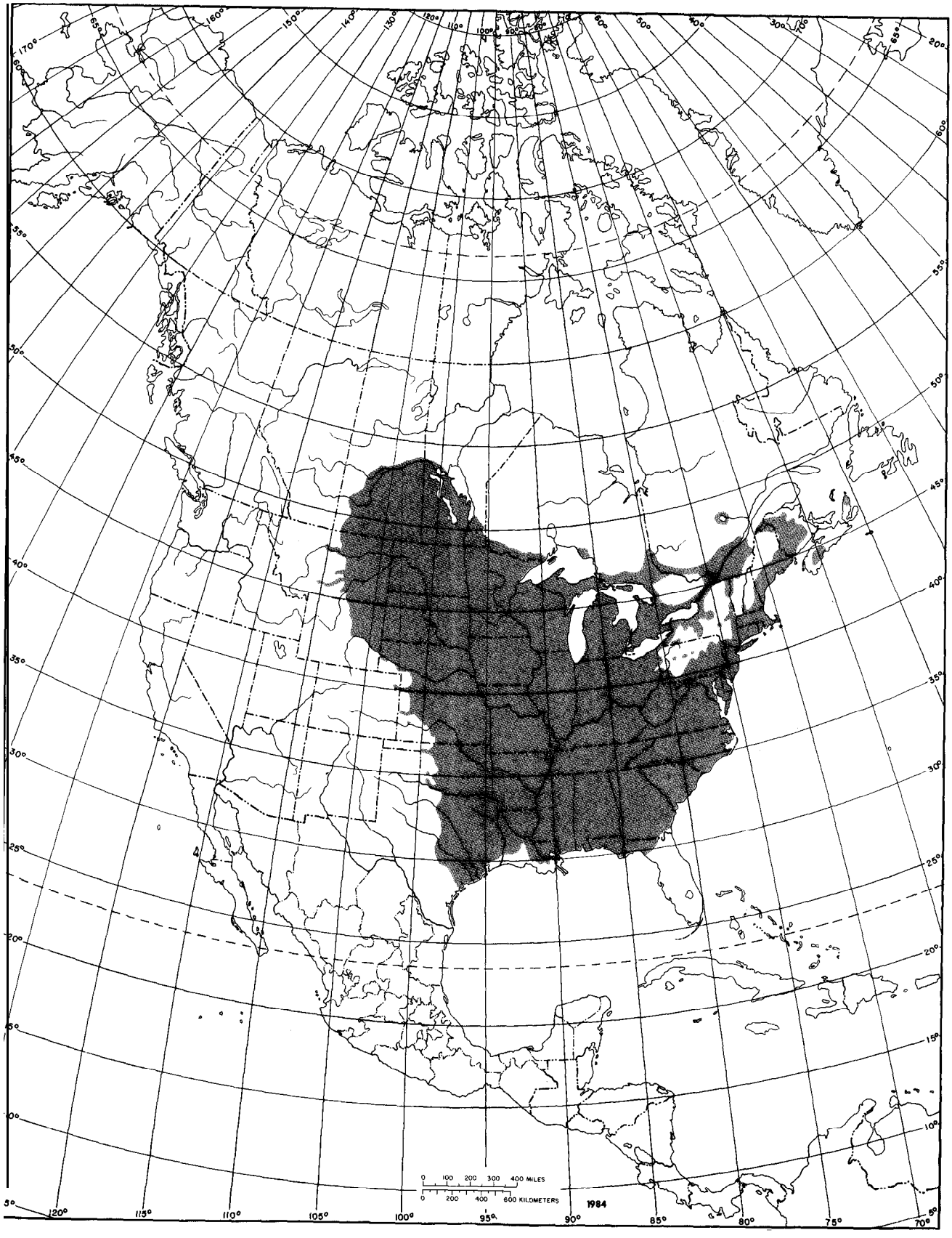

Figure *1-The native range of green ash.*

89 Live Oak
91 Swamp Chestnut Oak-Cherrybark Oak
92 Sweetgum-Willow Oak
94 Sycamore-Sweetgum-American Elm
95 Black Willow
96 Overcup Oak-Water Hickory
101 Baldcypress
102 Baldcypress-Tupelo
103 Water Tupelo–Swamp Tupelo

Species most commonly associated with green ash are boxelder *(Acer negundo),* red maple *(A. rubrum),* pecan *(Carya illinoensis),* sugarberry *(Celtis laevigata),* sweetgum *(Liquidambar styraciflua),* American sycamore *(Platanus occidentalis),* eastern cottonwood *(Populus deltoides),* quaking aspen *(P. tremuloides),* black willow *(Salix nigra),* willow oak *(Quercus phellos),* and American elm *(Ulmus americana).*

Life History

Reproduction and Early Growth

Flowering and Fruiting-Green ash is dioecious. The small, usually inconspicuous flowers appear in the spring, with or just before the leaves, in terminal or axillary clusters (4). Flowers are generally borne over the entire outer part of the live crown. Usually, flowering starts when trees are 8 to 10 cm (3 to 4 in) d.b.h. and 6 to 8 m (20 to 25 ft) tall. A high percentage of the male and female trees bear flowers annually, and many female trees bear fruit each year.

Flowers may appear as early as March or April in Florida and from late April to early May in the northern part of its range (25). Male flowers require 1 to 2 weeks to pass from the enlarged winter condition to completion of pollen shedding. Individual trees shed pollen over an interval of 3 to 4 days. Within a stand, range among individual trees in onset of pollen shedding is only 2 to 3 days. The pollen is disseminated by wind and is dispersed relatively short distances, most of it falling within 61 to 91 m (200 to 300 ft) of the source.

Flower bud enlargement starts a few days later on female trees than on male (25). The stigmas of the female flowers are receptive as soon as they emerge from the bud and remain receptive for about a week. Receptivity appears to end just before the stigmas start to wither. The female flowers and young fruit are very sensitive to late spring frosts.

Within a month after pollination, the samaras developing from fertilized flowers reach mature size. Ash fruits are elongated, winged, single-seeded samaras borne in clusters. Unpollinated flowers or flowers pollinated by an incompatible ash species drop off within the first month. Growth and ripening of embryos lag behind growth of samaras and are not completed until late September or early October.

Physiological maturity of green ash seeds can be related to a fully elongated embryo that fills the entire embryonic cavity. When ripe, the embryo should be about 10 mm (0.4 in) long and slightly less than 1 mm (0.04 in) in diameter. Mature embryos have firm, white tissues that break crisply. Physical characteristics indicating seed maturity can be utilized by workers in the field during seed collections *(3).* Color change in the samaras, from green to yellow or brown, is not complete until after the embryo is fully grown. Samples picked in mid-October in central Mississippi gave excellent germination though samaras were still slightly green. While samaras are still green, they may contain as much as 50-percent moisture, and care must be taken to prevent seed lots from overheating. A little heat damage at this stage may significantly reduce seed quality, especially if long-term storage is contemplated. In seed collections, especially bulk collections, complete change of samaras to a brown color probably is a safer index to maturity than size of the embryo.

Seed Production and Dissemination-Green ash seeds start to fall as soon as they ripen and continue to fall into the winter (25). Most seeds are dispersed by wind within short distances of the parent tree. Some dispersal by water also may occur, but the importance of water as a long-distance dispersal agent is unknown.

Seed clusters can be collected from trees by hand or with pruners and seed hooks. Fully dried samaras also may be shaken or whipped from limbs of standing trees onto plastic sheets spread under the trees. Fruit should be spread in shallow layers for complete drying, especially when collected early. Dried clusters may be broken apart by hand, by flailing in sacks, or by processing through a macerator. Seeds should be dried to 7- to lo-percent moisture content for storage. No loss in viability for 7 years was found when green ash seeds were stored in sealed containers at 5° C (41" F) with a seed moisture content of 7 to 10 percent.

The epigeal germination may occur in the spring following seedfall, or seeds may lie dormant in the litter for several years before germinating. Dormancy is apparently due to both internal factors and to seedcoat effects *(3,4).* For the nursery, dormancy may be overcome by cold, moist stratification in a suitable medium, or simply storing in containers of water. Both methods should be used at temperatures of 2"

to 4" C (35" to 40" F) for 90 to 120 days. Seeds may be sown in fall and allowed to stratify in the nursery bed.

Seeds should be sown in nursery beds at approximately 80 to 100/m (25 to 30/ft) of row with rows 15 to 30 cm (6 to 12 in) apart (25) and covered with burlap or greenhouse shade cloth until germination starts. Seedbed densities of 110 to 130/m^2 (10 to 12/ft^2) are recommended for green ash to produce high-quality seedlings.

Seedling Development-Under good nursery conditions in the northern part of its range, seedlings grow about 30 cm (12 in) in height the first year and another 46 cm (18 in) the second year. In the southern part of the green ash range, nurseries can produce seedlings 0.8 to 0.9 m (2.5 to 3.0 ft) tall the first growing season.

Uninjured nursery seedlings usually develop no side branches during the first year. On vigorous seedlings, the uppermost one or two pairs of lateral buds develop into branches during the second year.

Apical dominance usually is strong enough in vigorous, uninjured open-grown trees so that they often have a single, straight stem until they are 5 m (15 ft) or more tall. If this dominance is lost by the removal of a terminal bud, the uppermost lateral branch quickly takes over and reasserts dominance over the lower branches (25). In slow-growing shaded specimens, the tendency for quick assertion of apical dominance following deer nipping or other damage to a terminal bud is much less pronounced. As a consequence, understory seedlings frequently have poor form.

Vegetative Reproduction-Stumps of sapling- and pole-size green ash sprout readily. Studies in Mississippi have shown ash, as sprouts, to be one of the dominant species in bottom-land clearings *(11,13)*. Dominants among the ash sprouts were 3.8 cm (1.5 in) d.b.h. and 5 m (15 ft) tall after five growing seasons.

Cuttings made from 1-O seedlings or l-year-old sprouts root easily under greenhouse and field conditions (25). Cuttings may be planted horizontally under the soil or vertically with good results (fig. 2) *(14,15)*. However, no practical way to root cuttings from older trees has yet been found. Green ash can be successfully bench-grafted or field-grafted *(2,18)*. Understocks can be stored by severely root-pruning young seedlings and heeling them in by groups of 50 to 100. Most of the seedlings remain alive but grow so little that they supply an assortment of small understocks whenever needed.

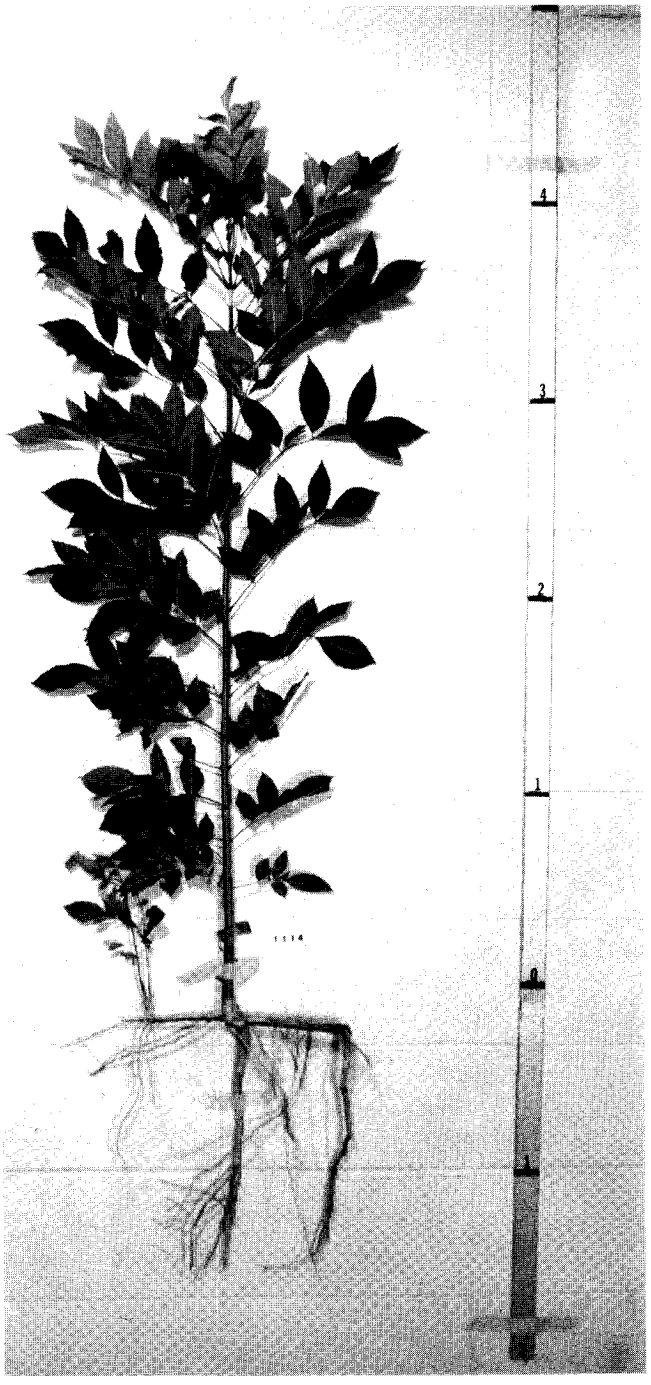

Figure 2—*Stem and root development of a horizontally planted green ash cutting* after *one growing season.*

Sapling and Pole Stages to Maturity

Growth and Yield-In shelterbelts in the Great Plains, green ash averaged 0.4 m (1.3 ft) per year height growth for the first 6.5 years (25). Open-grown trees planted on a fertile soil in Pennsylvania

grew 14 to 17 m (45 to 55 ft) tall and 20 to 30 cm (8 to 12 in) in d.b.h in 21 years.

In most areas in the northern part of its range, green ash reaches heights of 15 to 18 m (50 to 60 ft) and breast-high diameters of 46 to 61 cm (18 to 24 in). On good sites in the southern part of its range, trees attain a height up to 37 m (120 ft) and a d.b.h. of 61 to 76 cm (24 to 30 in) *(20)*. Diameter growth of dominant crop trees in well-stocked, managed stands is about 6 to 8 cm (2.5 to 3.0 in) in 10 years (5).

Little data exist on growth rates and volumes of trees grown under natural stand conditions. Probably the best information available is contained in results of research conducted in Georgia (6). Four sites included in the study ranged from well-drained sandy loams on levees or terraces to poorly drained, wet, silty flats. Green ash was the dominant species in these stands, comprising about 80 percent of the total stand basal area. Stand ages ranged from 27 to 65 years. Average stand heights for green ash sawtimber ranged from 24 m (78 ft) in the 27-year-old stand to 35 m (116 ft) in the 65-year-old stand.

Figure *3-A good natural stand of green ash on Falaya-Waverly soil.*

Volume growth ranged from 2.7 to 4.6 m^3/ha (39 to 65 ft^3/acre) per year. Growth was related to stand age with better growth rates occurring in the younger stands. Merchantable sawtimber volume ranged from 104.4 m^3/ha (1,491 ft^3/acre) in the 27-year-old stand to 175.8 m^3/ha (2,511 ft^3/acre) in the 65-year-old stand. In addition to sawtimber, pulpwood volumes from tops and small trees ranged from 144.8 m^3/ha (23 cords/acre) in the younger stand to 245.6 m^3/ha (39 cords/acre) in the older stand.

Green ash on most sites in the southern part of its range is characterized by a clear, straight bole for about half the total height (fig. 3) (6). Above this point the stem often forks or crooks and has large branches that degrade the lumber. Merchantable height for saw logs averages about two 5-m (16-R) logs. Merchantable height for pulpwood to a 10-cm (4-in) top may extend to 12 m (40 ft) in younger stands. Its pioneer nature and ability to grow rapidly in relatively pure, even-aged stands indicate green ash is well suited for plantation management. Studies in Mississippi and Arkansas have shown that green ash grows about 1.2 to 1.5 m (4 to 5 ft) in height and 13 mm (0.5 in) in d.b.h. the first 5 to 10 years under plantation management (fig. 4).

Natural stands appear to support sufficient volume to allow commercial thinnings at 25 to 30 years *(6)*. To ensure reasonable volume production and reduce epicormic branching in the residual stand, basal area should not be reduced below 23.0 to 27.6 m^2/ha (100 to 120 ft^2/acre). This should be represented by about 250 to 300 trees/ha (100 to 120 trees/acre).

Rooting Habit-Root systems were studied in North Dakota on a Fargo clay soil, with a 0.3-m (1-R) layer of black surface soil overlaying a light-colored, calcareous, clayey soil with no hardpan (25). The soil

Figure *4-Five-year-old plantation-grown green ash.*

was poorly drained and wet in the spring; later in the growing season the water table was at a depth of about 5 m (15 ft) or more. Roots had extended laterally for 15 m (48 ft) and 1.1 m (3.6 ft) downward; they were about equally distributed in the upper 0.9 m (3 ft) of soil. Excavations of other root systems have shown green ash roots to penetrate about 1 m (3.2 ft) deep in sandy and clay soils and 1.4 m (4.5 ft) deep along the edges of sloughs. In the southern part of its range, green ash has a root system that is typically saucer-shaped with no distinct taproot; roots penetrate to depths of 0.9 to 1.2 m (3 to 4 ft). The extensive root system of this species makes it relatively windfirm.

Green ash seedlings, and probably older trees, have certain rooting habits or adaptations that enable them to withstand flooding *(1,16,21)*. Young green ash *(8)* has been shown to have the ability under flooded conditions to regenerate new secondary roots from the primary root, develop adventitious water roots on the submerged stem, accelerate anaerobic respiration rate in the absence of oxygen, and oxidize its rhizospheres. These root adaptations enable it to withstand flooding regimes of several months during the dormant and early growing season that would kill other species *(9,10,25)*. Specific gravity has been shown to be related to flooding in some hardwoods *(19)*.

Reaction to Competition-Green ash varies from intolerant to moderately tolerant to shade in the northern part of its range. It comes in early in succession on alluvial soils, either as a pioneer species or following cottonwood, quaking aspen, or black willow (25). It is less able to maintain its position in the crown canopy than some of its more rapidly growing associates such as red maple and American elm.

In the southern part of its range, green ash would be considered tolerant when young and moderately tolerant as it grows older. Studies have shown that advanced reproduction of green ash can be maintained in the understory for more than 15 years (12). Green ash may not grow more than 15 cm (6 in) in height yearly, with 12- to 15-year-old trees being 4 to 5 m (12 to 15 ft) tall and 2.5 cm (1 in) in diameter. However, these trees respond well to release and outgrow many of their competitors *(13)*. Other studies of green ash in plantations, where various levels of cultural treatments were applied, showed that green ash could tolerate competition from weeds and vines better than any of the 6 to 10 other species tested *(17)*. Overall, green ash may most accurately be classed as tolerant of shade.

Damaging Agents-Many insects feed at least occasionally on green ash. One of the most serious is the oystershell scale *(Lepidosaphes ulmi)*, which is distributed throughout the Northeast and can cause serious damage among seedlings and small trees. The carpenterworm *(Prionoxystus robiniae)* bores into the heartwood of large branches and trunks, permitting the entrance of fungi. The brownheaded ash sawfly *(Tomostethus multicinctus)* and the black-headed ash sawfly *(Tethida barda)* occasionally cause serious damage to shade trees. The ash borer *(Podosesia syringae)* damages the stems of trees of all sizes, causing lumber degrade in timber-sized trees and contributing to decline and mortality in shelterbelt plantings (23,251.

Several diseases are of general importance. The fungus *Mycosphaerella fraxinicola* creates a leaf spot which may cause premature defoliation of young trees. Anthracnose *(Gloeosporium aridum)* also causes premature defoliation. A rust caused by *Puccinia peridermiopora* results in distortion of petioles and small twigs. Several rots cause minor damage in green ash. In Texas and Oklahoma, green ash has shown intermediate susceptibility to a root rot caused by *Phymatotrichum omnivorum (25).*

Young trees are subject to damage from deer browsing, and rabbits may sever the stems.

Special Uses

Green ash wood, because of its strength, hardness, high shock resistance, and excellent bending qualities, is used in specialty items such as tool handles and baseball bats but is not as desirable as white ash. It is also being widely used in revegetation of spoil banks created from strip mining (25). Green ash is very popular as a shade tree in residential areas because of its good form, adaptability to a wide range of sites, and relative freedom from insects and diseases. Seeds are used for food by a number of game and nongame animals and birds.

Genetics

Population Differences

Green ash is composed of three or more geographic ecotypes. The trees belonging to these ecotypes are easily distinguishable when growing under uniform conditions in a nursery but not when growing naturally. For that reason, they have not been given Latin varietal or subspecific names.

Three different ecotypes were evident in the Great Plains (25). The population from the arid, northwestern part of the green ash range was more drought resistant than that from the more moist central Great Plains. As compared with the Coastal Plain ecotype, the Northern States ecotype grew more

slowly, had greener petioles, was more winter hardy, and was less subject to leaf damage by fall frosts. These ecotypes may or may not be identical with those from the Eastern United States.

Hybrids

Attempts have been made to artificially cross green ash with other ash species. Only the cross of green ash with velvet ash *(Fraxinus velutina)* was consistently successful, yielded viable seed, and produced identifiable hybrids that grew as fast as the eastern parent. The other crosses yielded no identifiable hybrids.

The pumpkin ash *(Fraxinus profunda)* is a rare hexaploid (2n = 138 chromosomes) species of the Coastal Plain and Mississippi Valley (25). Its leaves, twigs, flowers, and fruit are larger than those of green ash or white ash but qualitatively similar to one or the other of these two species. The patterns of morphological variation and geographic distribution taken together are strong evidence for the view that pumpkin ash is a true-breeding polyploid derivative of a cross between a diploid green ash and tetraploid white ash.

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