Populus deltoides Bartr. ex Marsh.

Eastern Cottonwood

Salicaceae -- Willow family

P. deltoides Bartr. ex Marsh. var. deltoides

Eastern Cottonwood (typical)

D. T Cooper

P. deltoides var. occidentalis Rydb.

Plains Cottonwood

David F. Van Haverbeke

Eastern cottonwood *(Populus deltoides),* one of the largest eastern hardwoods, is short-lived but the fastest-growing commercial forest species in North America. It grows best on moist well-drained sands or silts near streams, often in pure stands. The lightweight, rather soft wood is used primarily for core stock in manufacturing furniture and for pulpwood. Eastern cottonwood is one of the few hardwood species that is planted and grown specifically for these purposes.

Besides the typical eastern variety (var. *deltoides),* there is a western variety, plains cottonwood (var. *occidentalis).* Its leaves, more broad than long, are slightly smaller and more coarsely toothed than the typical variety.

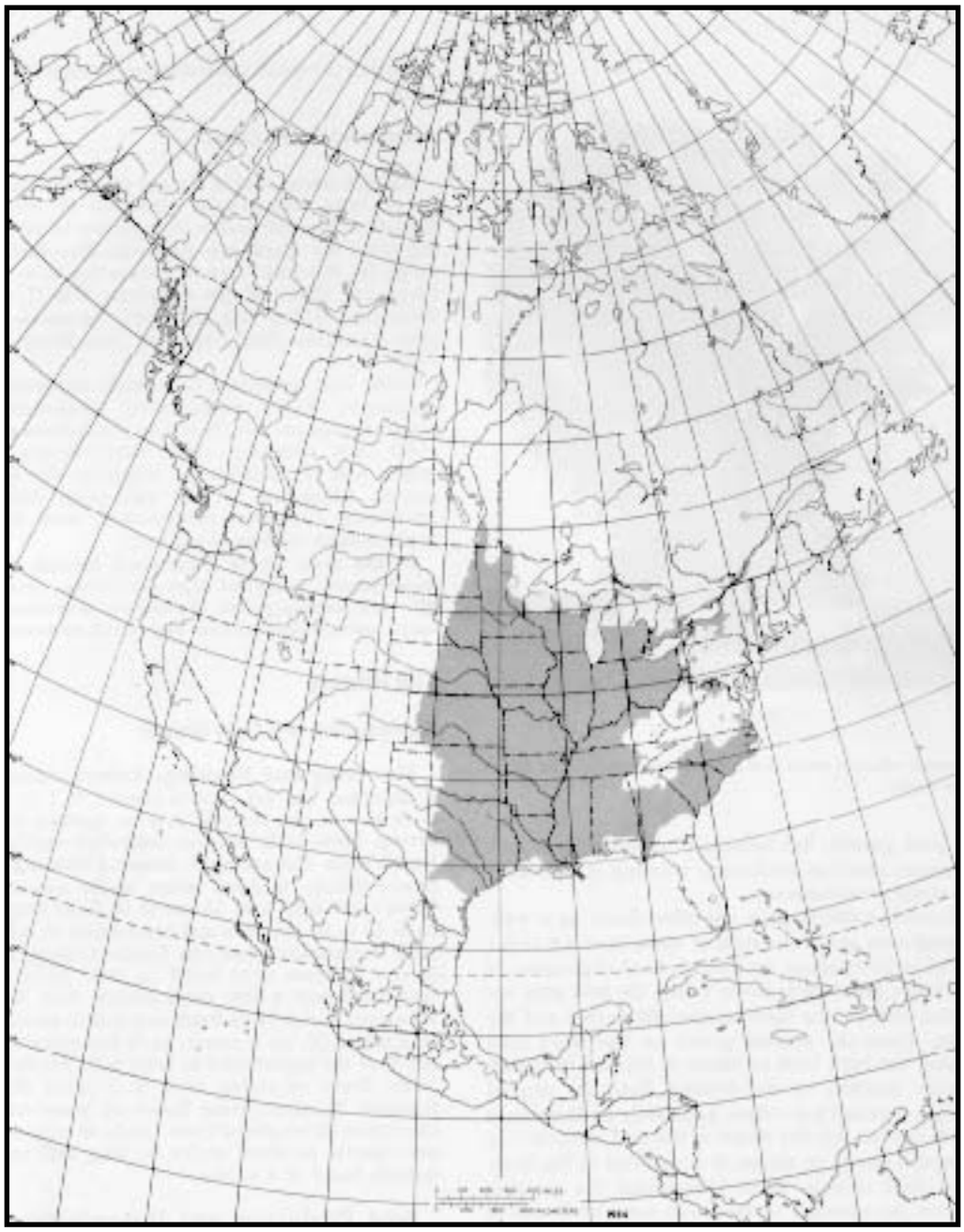
EASTERN COTTONWOOD

Eastern cottonwood (typical) *(Populus deltoides* var. *deltoides)* is also called southern cottonwood, Carolina poplar, eastern poplar, necklace poplar, and álamo.

Habitat

Native Range

Eastern cottonwood grows along streams and on bottom lands from southern Quebec westward into North Dakota and southwestern Manitoba, south to central Texas, and east to northwestern Florida and Georgia. The north-south distribution extends from latitude 28° N. to 46° N. It is absent from the higher Appalachian areas and from much of Florida and the Gulf Coast except along rivers. The western boundary is not well defined because eastern cottonwood intergrades with var. *occidentalis*, plains cottonwood, where the ranges overlap. Altitude is a primary determiner of the western boundary.



-The native range of eastern cottonwood.

Climate

In various parts of its range, eastern cottonwood is subjected to temperatures as high as 46° C (115° F) and as low as -45° C (-50° F). Average January temperatures vary from -10° C (14° F) to 8° C (46° F). It occurs in areas with from less than 100 to more than 200 consecutive frost-free days per year. Rainfall ranges from less than 380 mm (15 in) in the northwest corner of the range to more than 1400 mm (55 in) in the southern part of the range. In the dryest parts of its range, eastern cottonwood receives most of its moisture from streams, making rainfall requirements meaningless. In the lower Mississippi Valley, more than one-third of the rain falls during the growing season, following a full subsoil recharge during the winter. Flooding often provides additional water. Nevertheless, there is usually inadequate moisture for optimum growth during the latter part of the growing season.

Soils and Topography

The species survives on deep, infertile sands and clays but makes its best growth on moist, welldrained, fine sandy or silt loams close to streams. The soils of most cottonwood sites are in the soil orders Entisols and Inceptisols. The best sites are characterized by absence of mottles in the upper 46 cm (18 in), water tables from 60 to 180 cm (24 to 72 in), bulk density of less than 1.4 g/cm³ (0.8 oz/in³), pH of 5.5 to 7.5, and greater than 2 percent organic matter (1). Sites frequently meet the requirements for good growth, but because of competition or lack of proper seeding conditions, planting is necessary for stand establishment.

Eastern cottonwood is not often found as a well-formed tree at an elevation of more than 4.6 to 6.1 m (15 to 20 ft) above the average level of streams. In the lower Mississippi River Valley, the best sites are in the batture, the land between the levees and the river. Here the species grows on the front land ridges, the high land or banks of present or former stream courses, on well-drained flats, the general terrain between low ridges, and rarely on abandoned fields on well-drained ridges in the first bottoms (17). Where it occurs on slopes, it is confined to the lower ones that remain moist throughout the growing season. An example is the brown loam bluff area of loessial soil along the eastern side of the lower Mississippi River flood plain. Fine cottonwood specimens are frequent in the bottoms and on the lowest slopes bordering the small water-courses emerging from the bluffs.

Associated Forest Cover

Eastern cottonwood is the key species in the forest cover type Cottonwood (Society of American Foresters Type 63) and is an associate in the following types (6): Black Ash-American Elm-Red Maple (Type 39), Bur Oak (Type 42), River Birch- Sycamore (Type 61), Silver Maple-American Elm (Type 62), Sweetgum-Willow Oak (Type 92), Sycamore-Sweetgum-American Elm (Type 94), and Black Willow (Type 95).

Other tree associates of eastern cottonwood are hackberry *(Celtis occidentalis),* sugarberry (C. *laevigata),* green ash *(Fraxinus pennsylvanica),* box elder *(Acer negundo),* river birch *(Betula nigra),* white ash (F *americana),* slippery elm *(Ulmus rubra),* blackgum *(Nyssa sylvatica),* American hornbeam *(Carpinus caroliniana),* and eastern hophornbeam. *(Ostrya virginiana).*

In the area where cottonwood attains its best development, roughleaf dogwood *(Cornus drummondii)* and swamp-privet *(Forestiera acuminata)* are major noncommercial tree and shrub associates.

Life History

Reproduction and Early Growth

Flowering and Fruiting- Eastern cotton wood is dioecious. The sex ratio is about 1 to 1 (8). Floral buds form in the summer prior to opening the next spring. Male buds develop somewhat earlier than female buds and are much larger. Flowering occurs from February to April before leaves appear. Male flowers are only 8 to 13 cm (3 to 5 in) long. They have 40 to 60 stamens and are reddish in color and more conspicuous than the female flowers. Female flowers elongate to 15 to 30 cm (6 to 12 in). Males tend to flower a few days earlier than females. Flowering varies by as much as a month among trees in a stand (9). As a result, early-flowering trees do not have the opportunity to cross with late-flowering trees. Trees as young as 4 to 5 years old have flowered. Northern trees flower at lower temperatures than do southern trees. Seeds develop 30 to 60 per capsule on short stalks on long catkins. Each capsule has 3 or 4 valves.

Seed Production and Dissemination- Seed production starts when the trees are 5 to 10 years old, increasing rapidly in amount as the trees become older and larger. Estimates of annual seed production of a single open-grown tree have been as high as 48 million seeds (3). Good seed crops are the rule. About 35 liters (I bushel) of fresh fruit yields 1 kg (2.2 lb) of seeds, or about 770,000 cleaned seeds (19).

Seed dispersal follows flowering by about 2 months in southern populations and a somewhat shorter period in the North. It is characterized by considerable variation among trees as well as a lengthy dispersal period for some individual trees (9). Seed dispersal occurs from May through mid-July in the South and June through mid-July in the North (19). The dispersal pattern results in abundant deposits of seeds along water courses as spring flood waters recede. Seeds may be carried several hundred feet by the wind, aided by the "cotton" attached to the seed. Seeds falling in water may be carried a long distance from the parent tree before being left on silt deposits.

Seedling Development- Unless floating on or immersed in water, cottonwood seeds must reach a favorable seedbed and germinate very soon after falling. Germination of fresh seeds may exceed 90 percent. Seedlings are delicate for the first few weeks. Rains, very hot sunshine, and damping-off fungi kill many of them. Very moist, exposed mineral soils, such as fresh silt deposits, are required. Germination is epigeal. Growth rate of the fragile seedlings is slow for the first 3 weeks but may be very rapid after that. Full sunlight for a substantial part of each day is required after the first few weeks.

Fully mature seeds that are dried promptly to 5 to 8 percent moisture and stored at temperatures just above freezing maintain viability for several months. Storage at -20° C (-4° F) may prolong viability for 5 or more years (20). It is best to increase the moisture content gradually when attempting to germinate

very dry seed.

Vegetative Reproduction- Satisfactory sprouting has occurred on low-cut stumps of trees as old as 25 years of age (22). Reproduction by root suckers is not common. Artificial propagation of the species normally involves use of cuttings from 1-year stem growth from nursery trees (23). These may or may not be rooted before outplanting.

The planting season in the North is short, coinciding with the beginning of the growing season. Rooted cuttings commonly are used under these conditions.

In the Southern United States, unrooted cuttings 30 to 50 cm (12 to 20 in) long provide a satisfactory, economical means of planting (15). Survival rates of 70 to 90 percent are normally achieved, depending on the genetics of the clones, quality of cuttings, and field conditions. Root-inducing hormones normally are not used. Rooted or unrooted long cuttings are sometimes used to reach moisture, to reduce damage from deer, to permit less intensive site preparation and to provide greater flood tolerance. Because operational use of asexual propagation of cottonwood permits immediate and complete utilization of superior genotypes, rooting ability is of great importance.

Propagation from 1-year-old wood from older trees is often difficult, but some success is usually achieved. Repropagation from the resulting material is often satisfactory. Clones tracing back to older trees normally have the smooth, somewhat thin, bark characteristics of the tops of older trees.

Sapling and Pole Stages to Maturity

Growth and Yield- Eastern cottonwood is one of the tallest species east of the Rocky Mountains. Heights of 53 to 58 in (175 to 190 ft) and diameters of 120 to 180 cm (48 to 72 in) have been reported (17), as have age 35 stand volumes exceeding 420.0 m^3/ha (30,000 fbm/acre) of sawed lumber (5,10,14,22).

The most phenomenal growth has been from trees planted on favorable sites in the South and receiving adequate weed control. Scientists have recorded heights of 13 in (43 ft) at age 3 and more than 30 in (100 ft) at age 9 on individual trees. In one plantation, unpruned trees at wide spacing averaged 29 cm (11.4 in) d.b.h. at age 5 (11). The best yields with close spacing of unimproved clones without irrigation in the South has been about 138.6 m^3/ha (1,980 ft^3/acre) total volume at age 4 with 2,700 stems per hectare (1,100/acre) (21).

Rooting Habit- Root growth of new seedlings is so slow that the plants are easily dislodged by rain droplets. After the first 3 weeks, root growth accelerates and lateral root growth may exceed height growth for the first year. Most of the roots are in the uppermost, best aerated layer of soil (2). They are nearer the surface in clay soils than in loam soils. Following siltation, roots develop on the covered portion of the stem. Cottonwood trees planted from conventional 20 to 60 cm (8 to 24 in) cuttings have fewer deep roots and are not as well anchored against root lodging as those established naturally or as

deep-planted seedlings or rooted cuttings.

Reaction to Competition- Cottonwood is classed as very intolerant of shade. It is more intolerant of shade than any of its associates except willow. Although the two frequently seed in together, pure stands of one or the other are the general rule after the first few years. Willow survives on the wetter sites and cottonwood on the slightly higher, drier sites. Its faster growth allows cottonwood to crowd out the willow except where prolonged deep flooding drowns the cottonwood component of the stand.

Cottonwood responds poorly to release following crowding. Only those trees with the best crowns respond. In natural stands, uneven spacing and size permit some trees to become dominant, and natural thinning allows production of large trees. Under plantation conditions and particularly when only clones with similar growth rates are used and all trees get off to a good start, stagnation can occur quickly. Spacing and timing of thinning become critical under these conditions. Optimum growth of individual trees requires very wide, seemingly wasteful, spacing. On the best sites in the South, cottonwood planted initially at a spacing of 3.7 by 3.7 m (12 by 12 ft) should be thinned by removing half of the trees at age 3 and again at age 5 if rapid growth rate of individual trees is to be maintained.

Damaging Agents- Although cottonwood grows rapidly under ideal conditions, numerous agents can disrupt its schedule and cause death or loss in tree quality or growth rate. These include insects, disease organisms, flood, fire, and various animals. At least 10 insect species and 12 diseases cause major damage to eastern cottonwood throughout its range (16).

A clearwing borer, *Paranthrene dollii dollii,* attacks the lower stem. Another clearwing borer, *P. tabaniformis,* attacks terminals and small branches causing breakage of terminals. The poplar borer, *Saperda calcarata,* attacks trunks of trees 3 or more years old and may riddle portions of the trunks with tunnels, causing serious degrade or breakage. The cottonwood borer, *Plectrodera scalator,* attacks the root collar and roots of both large and small trees. Small, closely-spaced trees break off easily from this damage. The cottonwood twig borer, *Gypsonoma haimbachiana,* causes stunting, forking, and other malformations in young cottonwood. The cottonwood leaf beetle, *Chrysomela scripta,* defoliates and kills terminals, producing forked stems. The poplar tentmaker, *Ichthyura inclusa,* can cause repeated defoliation, resulting in mortality.

Numerous disease organisms attack cottonwood. *Septoria musiva* causes a small canker that opens a path for other canker organisms. *Cytospora chrysosperma* causes a canker where sites are adverse and tree vigor is low. *Fusarium solani* enters wounds, particularly after major floods, to cause a canker. Two other canker-producing organisms are *Phomopsis macrospora* and *Botryodiplodia theobromae.* On vigorous trees, cankers usually callus over. *Melampsora medusae* causes leaf rust which results in premature defoliation and reduced growth rate. *Marssonina brunnea* causes a leaf spot that also results in early defoliation. *Septoria musiva,* in addition to causing a canker, causes a leaf spot. New leaves may be infected from old leaves or cankers.

Since cottonwood grows primarily in relatively low areas near streams it is subjected to frequent

flooding. Floods during the dormant season or floods of short duration during the growing season may benefit cottonwood trees by fully recharging subsoil moisture and providing some degree of vegetation control. Floods that overtop newly sprouting cuttings or established trees for prolonged periods during the growing season or that result in stagnant water pools are harmful.

Cottonwood of all ages is very susceptible to fire. A very light burn kills younger trees, while burns of greater intensity kill or wound larger ones. Butt rot, a common result of fire injury, is uncommon in cottonwood, however (13).

Seedlings and young trees are browsed by rabbits deer, and domestic stock. A substantial portion of the trees can recover from this damage. Beavers cut sapling and pole-size trees for food and for dam construction. The resulting ponds may drown cottonwood trees.

Special Uses

Eastern cottonwood is frequently planted to give quick shade near homes. Male clones, which have none of the objectionable "cotton" associated with seed, are preferred. Windbreaks are occasionally established with cottonwood as a component. Cottonwood is suitable for soil stabilization where soil and moisture conditions are adequate, as along stream or ditch banks. Deep planting permits reforesting of nonproductive fields with sandy soils having available moisture beneath a dry surface layer.

There has been considerable interest in cottonwood for energy biomass, because of its high yield potential and coppicing ability. There has also been interest in growing it for inclusion in cattle feed, since it is a good source of cellulose relatively free of undesirable components, such as tannins. The new growth is high in protein and minerals.

Genetics

Population Differences

Eastern cottonwood tends to be linearly distributed along streams. Differences in climate, soils, day length, and exposure to pests result in genetic differences among these populations. Gene flow to downstream portions of the population may occur as a result of seeds floating in the current. The cottonwood in the lower reaches of the Mississippi River may contain genes from many tributaries.

Races and Hybrids

Some scientists recognize three subspecies of eastern cottonwood (7). These include *angulata,* a southern strain, *missouriensis,* a central or intermediate strain, and *monilifera,* a northern strain. These divisions are based upon minor differences in morphological traits. Plains cottonwood *(Populus deltoides* var. *occidentalis),* discussed in the next paper, appears to be a legitimate race or subspecies,

growing at higher altitudes under more adverse conditions.

Eastern cottonwood hybridizes freely with plains cottonwood and crosses with several other species either naturally or artificially. It is most noted for its excellent hybrids with *Populus nigra.* Hybrid swarms with P. *balsamifera, P. tremuloides,* and P *grandidentata* are reported (18), as well as natural hybrids with P *trichocarpa (4).* The following natural interspecific hybrids are recognized (12):

Populus x acuminata Rydb. *(P. angustifolia x deltoides)*
Populus x bernardii Boivin *(P. deltoides x tremuloides)*
Populus x jackii Sarg. *(P. balsamifera x deltoides)*
Populus x polygonifolia Bernard *(P. balsamifera x deltoides x tremuloides)*

In addition, many hybrids between eastern cottonwood and other poplars have been produced artificially.

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PLAINS COTTONWOOD

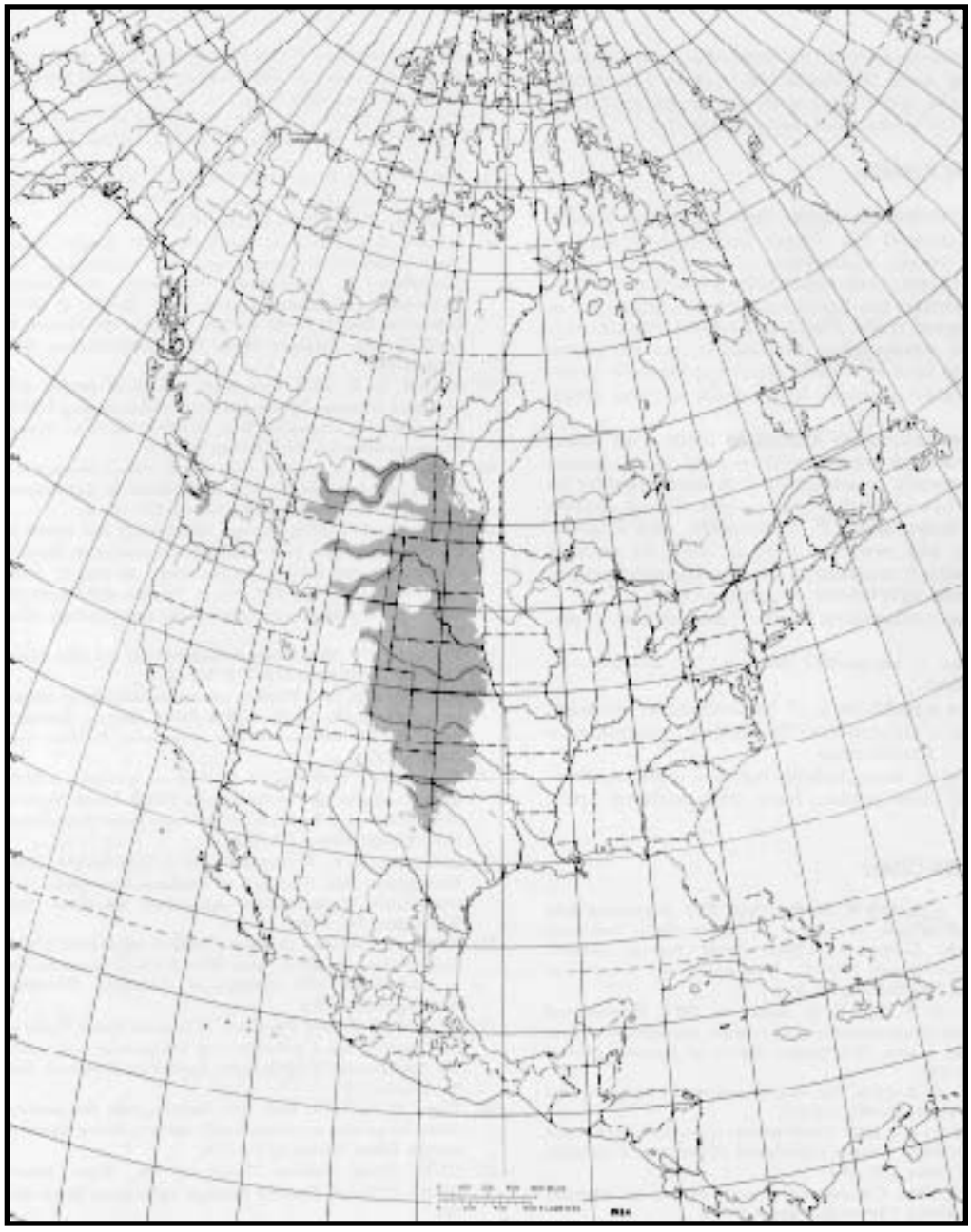
Plains cottonwood (Populus *deltoides* var. *occidentalis)* also has other common names with geographical and topographical connotations: Texas cottonwood, river cottonwood, western cottonwood, and plains poplar.

Habitat

Native Range

The range of plains cottonwood encompasses a broad, irregular-shaped band approximately 800 km (500 mi) wide and 2400 km (1,500 mi) long, extending south southeasterly from the southern prairie provinces of Canada into the high plains of northern Texas. This range spans approximately 20° in longitude (92° to 115° W.) and 25° in latitude (30° to 55° N.) (14,19).

Specifically, plains cottonwood grows from southern Alberta, central Saskatchewan, and southwestern Manitoba in Canada, south through the Great Plains in North Dakota, South Dakota, Nebraska, Kansas, western Oklahoma into northcentral Texas and extreme northeastern New Mexico; north in Colorado, eastern Wyoming, and eastern Montana. The eastern limit of the range is not well defined because it integrades with the western limit of the range of the typical variety, eastern cottonwood (var. *deltoides)* (13,14).



-The native range of plains cottonwood.

Climate

The climate of the Great -Plains, the region in which plains cottonwood grows, is distinctly continental. The region is characterized as dry subhumid to semiarid, with extremes and rapid fluctuations in temperature, unpredictable and limited precipitation, frequent and cyclic droughts, and strong persistent winds (3).

Average annual precipitation varies from about 250 mm (10 in) in the northern and western Great Plains to about 760 mm (30 in) in the extreme southeastern part of the species range. About 75 percent of the annual precipitation occurs during the growing season. Drought periods of 35 to 60 consecutive days may be expected annually, and periods of 60 to 70 days without rainfall may occur once in 10 years. Infrequent drought periods of 90 to 120 days have been recorded in the northern and southern plains, respectively. Drought hazard is greatest in the autumn and winter in the northern plains, and in the winter in the southern Great Plains where snowfall is less. High-velocity winds occur in all seasons but are strongest and most persistent during winter and early spring (29).

Average January temperatures vary from -15° C (5° F) in the North to 4° C (40° F) in the South. Minimum temperatures range from -46° C (-50° F) in the north to -18° C (0° F) in the South, with maximum temperatures of 38° C (100° F) to 46° C (115° F) throughout the region. The frost-free period varies from 100 d in the North to 220 days in the south (29).

Soils and Topography

Plains cottonwood grows along most of the rivers and streams that flow through the loessial soils of the Great Plains on sites that are 2.4 to 3.7 m (8 to 12 ft) above the water table. The taxon predominates on the level, narrow stringers of the river floodplains and stream bottom lands that cross the region. It is common in pure stands on river sandbars and on overflow land in the bends of large rivers but is also found in the beds of intermittent streams (1).

Plains cottonwood grows on soils of the order Entisols, mainly along alluvial streams, and on soils of the orders Mollisols, Alfisols, and Inceptisols on stream terraces, in drainage ways, and in bottom lands and subirrigated valleys. Best development is on deep, rich, well-drained loams; however, the species also grows on level subirrigated uplands of deep, sandy soils (1). Soil texture and fertility seem to be of lesser importance than moisture, however, in determining its occurrence.

Plains cottonwood grows between elevations of about 300 m (1,000 ft) near its eastern limit to about 1830 m (6,000 ft) in the foothills of the Rocky Mountains. It is seldom found above 2130 m (7,000 ft) (27).

Associated Forest Cover

Plains cottonwood can grow in pure stands, but it is frequently found as an associate in three forest cover types: Bur Oak (Society of American Foresters Type 42), Cottonwood (Type 63), and Cottonwood-Willow (Type 235) (22). Black *willow (Salix nigra)* and peachleaf willow *(S. amygdaloides)* are the most common associates. Other associates on the better sites include American elm *(Ulmus americana),* slippery elm *(U. rubra),* hackberry *(Celtis occidentalis),* boxelder *(Acer negundo),* green ash *(Fraxinus pennsylvanica),* red mulberry *(Morus rubra),* black walnut *(Juglans nigra),* American sycamore *(Platanus occidentalis),* eastern redcedar *(Juniperus virginiana),* and silver maple *(Acer saccharinum)* (1,17,30).

Associated shrubs and vines include sandbar willow *(S. exigua),* red-osier dogwood *(Cornus stolonifera),* indigobush *(Amorpha fruticosa),* coralberry *(Symphoricarpos orbiculatus),* wild grape *(Vitis* spp.), poison-ivy *(Toxicodendron radicans),* smooth sumac *(Rhus glabra),* and American plum *(Prunus americana).* In the western Plains, shrubs are scarce in the cottonwood stands, and several species of grasses and forbs are found in their place. These include sand dropseed *(Sporobolus cryptandrus),* buffalograss *(Buchloe dactyloides),* sunflowers *(Helianthus* spp.), lambs-quarters *(Chenopodium album),* and Russian-thistle *(Salsola pestifer) (1).*

Life History

Reproduction and Early Growth

Flowering and Fruiting- Plains cottonwood's dioecious with only occasional deviations. Staminate and pistillate flowers are borne on twigs of the previous year's growth, appearing in early spring (April and May) before the leaves develop (20,27). Pollination is by wind. Following anthesis, the staminate catkins dry and fall within 2 weeks. Four to 6 weeks, ranging from June through August, are required for seed maturation (9,20).

The flowering period seems to be regular within the limits of geographic zones, but differences can occur in time of anthesis between stands and among trees within stands. Differences in date of flowering from year to year apparently depend upon temperatures. The ratio of staminate to ovulate trees is believed to be about 1 to 1. In the lower Mississippi Valley the ratio was reported to be 54 to 46 percent (10).

Seed Production and Dissemination- Minimum seed-bearing age of plains cottonwood is about 10 years, and fair to large seed crops can be expected annually. The seeds are very small, yet relatively large for the genus; they range from 551,000 to 1,056,000 seeds per kilogram (250,000 to 479,000 lb). Seeds have a tuft of "cottonlike" hairs attached and are dispersed primarily by wind, but also by water, over long distances a few days after ripening. Seedfall among trees within a locality varies greatly and may extend for 6 weeks or longer (9,20).

Seedling Development- The viability of fresh seeds is high; 98 percent germination has been attained during the first 5 days following dispersal (9,20). Longevity of poplar seeds under natural conditions has

been reported to be 2 weeks to 1 month. Vitality of fresh, unstored seed drops rapidly, however, if they are not kept moist. There is no evident dormancy.

Poplar seeds can be stored successfully and viability is prolonged if the moisture content is reduced to 4 or 5 percent. Air-dried *P. deltoides* seeds, stored in sealed containers at 1° to 4° C (34° to 39° F), were 100 percent viable after 6 months (9,20). Seeds of some poplar species have been similarly stored in vacuum-packed jars at 0° C (32° F) for as long as 3 years (11). Recently, it was demonstrated that *P. deltoides* seed stored at -20° C (- 4° F), either at normal air pressure or under vacuum, showed significantly higher germination than the same seed stored at 5° C (41° F) under vacuum (in sealed containers), after 6 months of storage. Thereafter, germination at -20° C (-4° F) remained unchanged during a 6-year study period, whereas germination of seed stored at 5° C (41° F) was considered unsatisfactory after 3.5 years. Eastern cottonwood seed should always be stored at below freezing temperature, even for short-term storage (28). Germination is epigeal.

Plains cottonwood seed germinates within 48 hours after dispersal on proven mediums such as moist silt, sand, or fine gravel in full sunlight. The aboveground portion of the seedling develops rapidly and vigorously. Constant moisture is required for at least several weeks to ensure the establishment and survival of the slower developing root systems of the seedlings (5,9).

The best planting sites are moderately welldrained, permeable, and fertile deep loam soils on bottom lands. Very sandy soil is suitable if the water table is within 3.7 to 4.6 rn (12 to 15 ft) of the surface. Even upland sites are satisfactory if they are fertile, not too shallow, and if rainfall is abundant and well-distributed. Full sunlight, freedom from competition of weeds and grass (particularly sod), and abundant moisture throughout at least the first growing season are essential to seedling survival and establishment (27).

Although initial establishment is usually good and growth is rapid on coarse sands and gravels of river bottom lands, periods of drought and fluctuating water tables make subsequent development uncertain (17). Establishment of plains cottonwood on meander lobes of rivers in southern Canada is positively correlated with flood flows during seed dispersal (June 1-July 10) (2). Floods during the seed-dispersal period recur in southern Alberta and northern Montana about every 5 years.

Vegetative Reproduction- Plains cottonwood is easily reproduced by stem cuttings from 1-year-old "ripened" wood. Since this species, like other members of the genus, sprouts vigorously from both roots and stumps of young trees, clonal "stool" beds are commonly established for the production of these cuttings. Cuttings can also be taken from pollards, 1-year-old plants, or epicormic branches of old plants (11).

Healthy, straight, lignified wands without bark injuries approximately 2 m (6.6 ft) long and 3 to 30 mm (0.1 to 1.2 in) in diameter are cut from stool beds with a sharp knife during the dormant season (October to March), treated with fungicide, and placed in cool 50 C (410 F), moist storage (11). The wands are divided into cuttings approximately 25.4 cm (10 in) long and 10 to 20 mm (0.4 to 0.8 in) in diameter at

midpoint and inserted in a mist-sprayed greenhouse rooting bench containing moist sand as a medium.

Recent greenhouse and field tests in Nebraska demonstrated that cuttings taken from the basal end of wands produce significantly more roots than those taken from the upper portion. Also, cuttings from clones of Nebraska and Minnesota-Wisconsin origins produced significantly higher numbers of roots than those of other geographic sources (33). About 4 to 6 weeks are required for rooting and subsequent field establishment. Rooted cuttings of *R deltoides* are not root-pruned when field-planted.

Unrooted cuttings can also be field-planted. In wetter climates and in heavier soils, 25.4 cm (10 in) cuttings are satisfactory. In drier climates and in sandy soils, cuttings 50 to 80 cm (20 to 31 in) long have been more successful. In both situations, dormant cuttings are planted in the early spring and are completely buried except for the top bud and 3 to 5 cm (1 to 2 in) of the wand. Difficult-to-root clones can also be grafted (11).

Experiments in Utah have shown that Populus *deltoides* (of unknown, but presumed eastern origin), *R balsamifera,* and *R angustifolia,* as well as *R tremuloides*, produce abundant shoots (suckers) and roots from root cuttings (segments). New shoots and roots originate from pre-existing suppressed buds embedded in the periderm along the surface of the root cutting and from the region of the exposed cambium at the cut ends. The presence of lateral root increased shoot growth, and the development of shoots and lateral roots responded to the inherent polarity of the root segments (18). The probability that the closely related plains cottonwood will react similarly would seem to be high.

Sapling and Pole Stages to Maturity

Growth and Yield- Young plains cottonwood trees grow 1.8 to 3.7 m (6 to 12 ft) per year in height under favorable conditions, surpassing other native species of the Great Plains region in height and diameter growth. Growth is most rapid in the first 25 to 30 years, by which time the trees can reach 15.2 to 22.9 m (50 to 75 ft) in height and 61.0 to 91.4 cm (24 to 36 in) in diameter. Cottonwood sources from Missouri *(P. deltoides)* and Nebraska (Sioux-land), along with silver maple (Acer saccharinum), ranked highest among seven species tested for the production of biomass during a 2-year study in Kansas (12).

Plains cottonwood usually attains maximum development in about 40 to 50 years. Mature trees can be 24.4 to 27.4 m (80 to 90 ft) tall, with diameters of 1.8 to 2.4 m (6 to 8 ft), and with clear holes for 9.1 m (30 ft) or more. The trees are usually single-stemmed with an open, spreading, symmetrical crown of massive horizontal branches and stout, more or less angled branchlets and twigs. While plains cottonwood is relatively short-lived, it can remain vigorous for 80 to 90 years under favorable conditions (21,27).

Survival and growth of cottonwoods on the Great Plains is directly dependent upon availability of moisture. Mortality during the drought of the mid-1930's was 59 percent along intermittent streams, 55 percent near springs that failed during the drought, and only 6 percent along continuously flowing streams (1).

Fully stocked cottonwood stands along creek and river channels and overflow land in Kansas are estimated to yield 168.0 to 210.0 m^3/ha (12,000 to 15,000 fbm/acre) at 25 to 30 years of age (21). In North Dakota, 30-and 50-year-old plantation yields were 59.5 to 219.8 m^3/ha (4,250 and 17,500 fbm/acre) gross merchantable volume, respectively, Scribner log rule (26).

Plains cottonwood 94 cm (37 in) in diameter outside bark and 19.8 to 22.9 m (65 to 75 ft) tall, growing in the South Platte River bottom, Morgan County in eastern Colorado, attained gross volumes of 8.0 m^3 (283 ft^3) inside bark (8). One could expect trees growing on more fertile and wetter sites along the Platte and Missouri River bottom lands in the eastern part of the range to achieve volumes in the magnitude of 11.3 m^3 (400 ft^3).

Rooting Habit- Early diameter and height growth of plains cottonwood surpasses that of other species native to the Great Plains region (17). Growth and penetration of poplar seedling roots immediately following germination is reported to be relatively slow, however. About 5 days are required after germination for the primary root to begin downward growth, and after 12 days the root may be only 1.5 mm (0.06 in) long (19). Growth continues slowly for 3 weeks to 1 month, at which time taproots of the cultivar Petrowskyana, for example, grown indoors in fairly strong light, averaged only 2.5 cm Q in) in length at the end of I month. This growth pattern explains the critical need for continuous moisture during the seedling stage. Subsequent root growth is much more rapid.

Ninety-eight percent of the roots of a 43-year-old northern cottonwood *(Populus monilifera),* 19.8 m (65 ft) tall, were found to be in the top 1.2 m (4 ft) of a prairie clay soil near Fargo, ND (31). Roots of this and other non-drought-tolerant species formed shallow roots on dry sandy sites but had a tendency to grow deep vertical roots on very moist (nonsaturated) sandy sites. Similar trends of root development were revealed in excavations of plains cottonwood trees growing in silty loam soils in eastern Nebraska, where (1) a 14-year-old tree, 18.3 m (60 ft) tall, developed only shallow, widespread, and fibrous roots over and down to a water table 0.8 m (2.5 ft) deep; (2) a 16-year-old tree, 11.3 m (37 ft) tall, developed a moderately heavy root system downward to a water table 4.3 m (14 ft) deep and then branched outward; and (3) a 49-year-old tree, 21.3 m (70 ft) tall, developed a distinct and heavy taprooted pattern over an unreachable water table 18.3 m (60 ft) deep (24).

Reaction to Competition- Plains cottonwood requires full sunlight for maximum growth. It is classed as very intolerant of shade and intolerant of root competition (21). It grows either in pure stands, which thin naturally and rapidly, or in open mixed stands, both of which are nearly always even-aged (17). After pioneering on alluvial sites, often with the willows, it is gradually replaced with other broadleaf species that can then become established under the forest conditions so created. Cottonwood does not normally regenerate until the overstory has broken up.

Damaging Agents- Prolonged periods of severe environmental stress, such as drought, weaken trees physiologically and increase their susceptibility to disease and insect pathogens. Plains cottonwood, with its high water requirement is especially vulnerable (1). *P. deltoides* var. *occidentalis* trees, considered water-tolerant, showed 47 percent high stress rate and 18 percent mortality when inundated late in the

growing season in the Central Plains (15).

Leaf rusts and stem cankers are the most widespread and damaging diseases. Leaf rusts cause premature defoliation of trees. This defoliation not only causes growth losses; it weakens the trees and increases their susceptibility to infection by other pathogens, which cause cankers and mortality.

Melampsora leaf rust caused by *Melampsora medusae* is one of the most serious leaf diseases of plains cottonwood. Others include Septoria leaf spot, caused by *Septoria musiva, Marssonina brunnea* leaf spot, and Alternaria leaf and stem blight, caused by *Alternaria tenuis* (16).

The most serious of the canker pathogens is Cytospora canker *(Cytospora chrysosperma),* which often results in wind-breakage at the wound area. Other canker pathogens include those caused by *Septoria musiva, Fusarium solani, Phomopsis macrospora, Botryodiplodia theobromae, Cryptosphaeria populina,* and *Pleurotus ostreatus.* Root and butt rots may be due to *Ganoderma lucidum, Armillaria tabescens,* and *Scytinostroma galactinium* (16).

The insects most damaging to plains cottonwood are the defoliators and wood borers; the former cause loss of vigor, the latter reduce the quality of lumber. Some of the more important defoliating insects include the cottonwood leaf beetle *(Chrysomela scripta),* cottonwood dagger moth *(Acronicta lepusculina),* forest tent caterpillar *(Malacosoma disstria),* poplar leaffolding sawfly *(Phyllocolpa bozemani),* fall cankerworm *(Alsophila pometaria),* and the fall webworm *(Hyphantria cunea)* (25).

Important boring insects include the poplar borer *(Saperda calcarata),* cottonwood borer *(Plectrodera scalator),* flatheaded wood borer *(Dicerca divaricata),* carpenterworm *(Prionoxystus robiniae),* poplar-and-willow borer *(Cryptorhynchus lapathi),* and the bronze poplar borer *(Agrilus liragus)* (25).

Several species of mites and aphids infest plains cottonwood, but their effects are not usually fatal.

Special Uses

Plains cottonwood is an important component of windbreak plantings in the Great Plains. It is frequently used as an ornamental to provide quick, if rather temporary, esthetic and protective effects. Plains cottonwood can produce an effective windbarrier 12.2 to 15.2 in (40 to 50 ft) tall in 15 to 20 years on stream lowlands and on deep, sandy, subirrigated lands (17).

The wood of plains cottonwood is coarse, odorless, soft, and lightweight, yet relatively strong. The heartwood is pale yellowish brown, the sapwood nearly white. The wood frequently warps on drying and is not durable in contact with soil and other moist conditions. It nails without splitting, is clean appearing, and takes printing and stenciling well.

The wood is used primarily for pallets, rough construction lumber (farm buildings), interior parts of

furniture, excelsior, crating, and wood pulp (21,27). The pulp produces a very high-grade gloss paper.

New and potentially important commercial uses of the wood include roughage food for livestock and the production of fiber and reconstituted wood products derived from short-rotation (2- to 8-year) biomass operations (6,23).

Genetics

Races

Within the large and climatically diverse north-south range of plains cottonwood, subtle but recognizable differences in the population have evolved by natural selection. What is here called Populus *deltoides* var. *occidentalis* has received at least nine names denoting either specific or varietal rank over the past two centuries (14).

Recently, the eastern cottonwood *(Populus deltoides)* complex has been treated as a group of three intergrading subspecies showing random or clinal variation or both within each subspecies (7). Plains cottonwood, on the basis of taxonomic affinities to the poplars of the Great Lakes region, was recognized as *P. deltoides* ssp. *monilifera* (Ait.) Eckenwalder. This treatment, supported by recent provenance evaluations in Nebraska, seems to be a more tenable interpretation. In these provenance evaluations the poplars of Kansas, Nebraska, and South Dakota, with smooth bark, small branches, small leaves with a few or no glands and few serrations, and prolific rooting habit tended to be similar to poplars of Minnesota. and Wisconsin origin (32).

Hybrids

The eastern members of plains cottonwood *(Populus deltoides* var. *occidentalis)* intergrade with western-most eastern cottonwoods (P. *deltoides* var. *deltoides);* therefore, the literature reveals no named hybrids between these very closely related populations (14).

Interspecific hybrids have been reported, however, between plains cottonwood and named species to the north and west. In southern Alberta, Canada, plains cottonwood is reported to cross and introgress readily with balsam poplar (Populus *balsamifera* L.), narrowleaf cottonwood (P *angustifolia* James), and possibly quaking aspen (P *tremuloides* Michx.) (4). Lanceleaf cottonwood (P. x *acuminata* Rydb.) is regarded as an interspecific hybrid between narrowleaf cottonwood (P. *angustifolia* James), which occurs from northern New Mexico, Nebraska, and North Dakota to southern Alberta, and plains cottonwood (P *deltoides* var. *occidentalis)* (14). Other reported interspecific hybrids involving plains cottonwood include *Populus x jackii* Sarg. (P *balsamifera x deltoides* var. *occidentalis),* and Populus x *polygonifolia* Bernard (P *balsamifera x deltoides* var. *occidentalis x* tremuloides (4).

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