Juniperus silicicola (Small) Bailey Southern Redcedar

Cupressaceae Cypress family

L. P. Wilhite

Southern redcedar ***(Juniperus silicicola),*** also called redcedar, coast juniper, sand-cedar, and eastern redcedar, has not been well studied. Until more work is done, the fragmentary information available should be supplemented, though cautiously, with information in the literature about eastern redcedar *(J. virginiana)*. The two species are similar in many respects. Generally, eastern redcedar has ascending or horizontal branches, male cones 3 to 4 mm (0.12 to 0.16 in) long, and female cones 5 to 6 mm (0.20 to 0.24 in) long containing one to four seeds. In contrast southern redcedar generally has more slender, pendulous branches, male cones 5 to 6 mm (0.20 to 0.24 in) long, and female cones 3 to 4 mm (0.12 to 0.16 in) long containing only one or two seeds *(5,11)*.

Habitat

Native Range

The native range of southern redcedar (fig.l) extends from coastal North Carolina through northern Florida and across the Gulf Coast to eastern Texas. Except in the center of the Florida peninsula and in outliers in Louisiana and Texas, the species is found within 50 km (30 mi) of saltwater.

On the range map, the inland boundary of the species should not be considered exact because it touches or overlaps the southern boundary of eastern redcedar, which so resembles southern redcedar that the two often are confused.

Climate

Two climatic types, humid and moist subhumid, are present within the range of southern redcedar. Normal precipitation increases from about 1200 mm (48 in) per year in the Carolinas to more than 1600 mm (63 in) along the central Gulf Coast, then decreases to about 1000 mm (40 in) in eastern Texas. Length of growing season varies from about 240 days in North Carolina, Louisiana, and Texas to more than 330 days along both coasts of central peninsular Florida. Southern redcedar is found from slightly north to slightly south of U.S. Department of Agriculture Plant Hardiness Zone 9, which is defined by a range in average minimum temperatures from -7" to -1" C (20° to 30" F).

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Soils and Topography

Southern redcedar is mostly restricted to the nearly flat outer Coastal Plain, so its establishment and growth in relation to topographic factors are not well understood.

Along the Atlantic and Gulf Coasts, southern redcedar is associated with limestone outcroppings and Indian shell middens bordering tidal marshes, and on sea islands on the leeward side of dunes, where salt spray is minimal. On the Gulf Coast, the species often is found in a narrow zone between the tidal marsh and the pine flatwoods (7). Also along the Gulf Coast, it often colonizes dredge spoil islands *(3)*.

Inland from the coast, scattered individuals of the species can be found from the broad, flat ridges between streams to the flood plains of these streams. In areas of abandoned rice fields in South Carolina, the species is found more frequently on the tops and sides of the old dikes than in the poorly drained flats between them.

The natural range of southern redcedar includes soils belonging to the orders of Alfisols, Entisols, Inceptisols, Spodosols, and Ultisols *(14)*. Redcedars usually are found on soils that are moist or wet, but not saturated. In general, the species appears to prefer sites of high base saturation, as indicated by its presence near sources of limestone or on Alfisols.

Associated Forest Cover

Southern redcedar is the predominant species in the forest cover type Southern Redcedar (Society of American Foresters Type 73), in which it occupies a plurality (20 to 50 percent) of the basal area (4). Common overstory associates in this type are live oak ***(Quercus virginiana)***, sand live oak *(Q. virginiana* var. ***germinata),*** cabbage palmetto *(Sabal **palmetto),*** slash pine *(Pinus elliottii)*, southern magnolia ***(Magnolia grandiflora)***, laurel oak ***(Quercus laurifolia)***, redbay *(Persea **borbonia),*** and American holly *(Ilex **opaca).*** Common understory species are yaupon ***(I. vomitoria)***, southern bayberry *(Myrica **cerifera),*** devilwood ***(Osmanthus americanus),*** Carolina laurelcherry *(Prunus **caroliniana),*** beautyberry *(Callicarpa **americana),*** bumelia *(Bumelia* spp.), tree sparkleberry *(Vaccinium ar-*

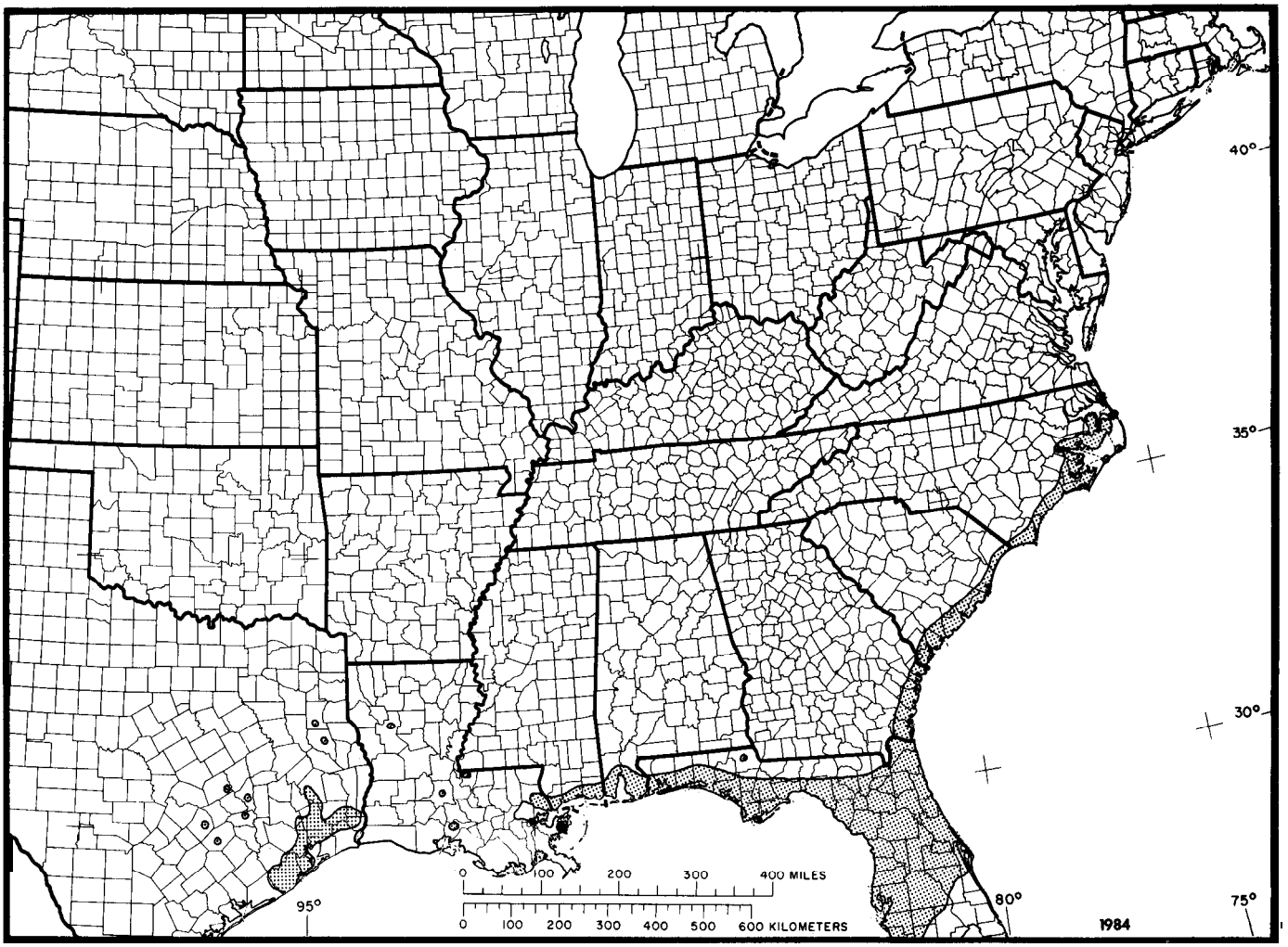

Figure *l-The native range* ***of*** *southern* redcedar.

boreum), muscadine grape *(Vitis rotundifolia),* and greenbriers *(Smilax* spp.).

Southern redcedar was virtually eliminated as an overstory species during the 19th century by harvesting, primarily for the manufacture of pencils. Live oaks and other associated trees were not cut at that time, and their competition presumably has retarded the reestablishment of cedar-dominated stands. Consequently, Southern Redcedar (Type 73) is quite similar to Cabbage Palmetto (Type 74). Both of these types are variants of a general maritime forest.

Inland from this maritime forest, the Southern Redcedar type sometimes intergrades with Sweetbay-Swamp Tupelo-Redbay (Type 104). Southern redcedar is listed as a minor species in Slash Pine (Type 84), and it has been found in Loblolly Pine (Type 81). In these pine types, redcedars seldom reach the overstory, possibly because of competition from the pines and associated hardwoods.

Life History

Reproduction and Early Growth

Flowering and Fruiting-Southern redcedar is dioecious. The male cones shed pollen in January to February, and the berrylike female cones, dark blue and covered with a glaucous bloom, mature in October to November of the first year *(11).* Seeds often have dormant embryos, and germination may not occur until the second or third spring after seed maturation (2). Cold stratification, however, hastens germination, and so might stratification of the seed by passage through the digestive system of an

animal. Germination is epigeal. Southern redcedar should be sown in fall or cold-stratified and sown in either fall or spring *(13)*.

Seed Production and Dissemination-There is considerably more information on the reproduction of eastern redcedar than on southern redcedar. Eastern redcedar produces some seeds nearly every year with irregular heavy seed crops. Its seeds are dispersed in the fall, usually by birds. Seeds may be stored as dried fruits or after extraction with a macerator. Cleaned seeds range from 81 600 to 121 300/kg (37,000 to 55,000/lb). A citric acid soak preceding cold stratification increases germination more than cold stratification alone *(13)*.

Seedling Development-Stratified seeds of eastern redcedar sown in the spring should be in the ground early enough to ensure complete germination before air temperatures exceed 21° C (70" F), and complete germination requires 4 to 5 weeks. Juniper seeds are usually drilled into rows 15 to 20 cm (6 to 8 in) apart and covered with about 0.6 cm (0.25 in) of firmed soil. The beds should be mulched with straw, sawdust, burlap, or plastic film, and the mulch removed as soon as germination starts. Light shade should be provided during the first growing season. Eastern redcedar is planted as 2-0, 3-0, l-l, l-2, 2-1, or 2-2 stock. Potting or balling for field planting increases survival over bare-root planting during dry years *(13)*.

Vegetative Reproduction-Southern redcedar can be propagated by cuttings of nearly ripened wood (2). The closely related species, eastern redcedar, can be propagated by rooted cuttings, but there is much variability among varieties within the species as to ease of rooting. Rooting success has been increased by treatments with indolebutyric acid, naphthalene acetic acid, and Phygon XL talc. Because of the difficulties and inconsistencies in rooting juniper cuttings, grafting has long been the standard method of propagating clonal material of eastern redcedar *(18)*.

Sapling and Pole Stages to Maturity

Growth and Yield-Little is known about the growth of this species. It has been reported to be moderate in growth rate *(1)* or to be long lived and slow growing *(17)*. Mature height has been reported to be about 8 m (25 ft) *(1,2,19)* or about 15 m (50 ft) *(9,12)*. The largest southern redcedar recorded by the American Forestry Association was 21 m (70 ft) tall and 145 cm (57 in) in d.b.h. in 1976 *(10)*. **Some of** the virgin timber along Apalachee Bay in Florida may have been more than 30 m (100 ft) tall *(3,4)*. Perhaps the second-growth timber of this long-lived species has not yet reached its mature height on its best sites (fig. 2).

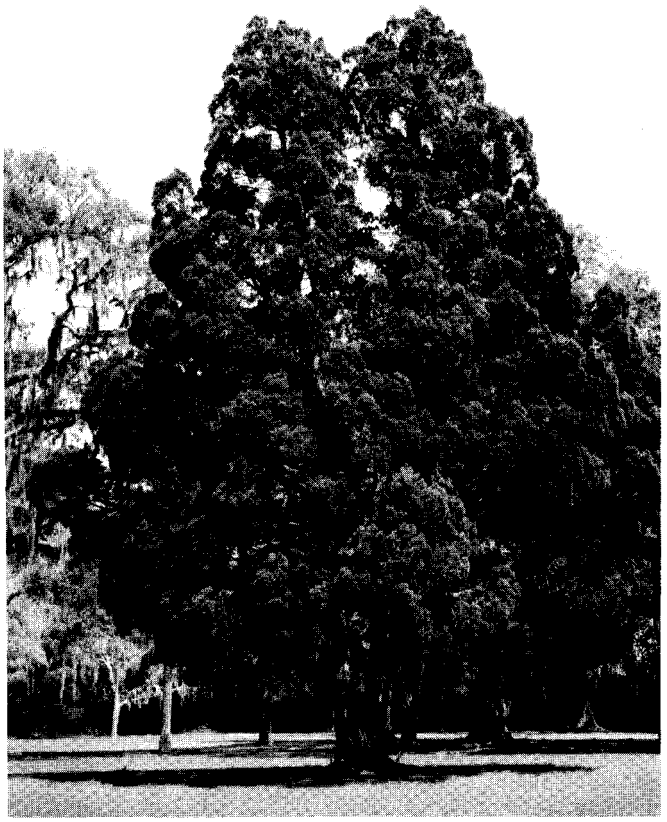

Figure 2—*A mature southern redcedar on Cape Romain Migratory Bird Refuge, SC.*

Rooting Habit-The species has been reported to have a shallow root system *(17)*.

Reaction to Competition-Brief statements in the literature, plus observations, indicate that southern redcedar can become established and will grow in sun or partial shade. Competition, however, may retard reestablishment of cedar-dominated maritime forests because of the dense shade cast by live oaks and associated hardwoods. Southern redcedar, like eastern redcedar, is classed as intolerant to very intolerant of shade. The fact that southern redcedar often grows on the margins of tidal marshes indicates that it is fairly tolerant of salt spray, wind, and flooding *(1,12,17)*.

Damaging Agents-Fire is deleterious to this thin-barked species, but the forest cover type

Southern Redcedar, which is generally found on sea islands or immediately inland from salt marshes of the mainland, rarely experiences fire. Farther inland, where southern redcedar occurs as a minor species and fires are more frequent, it suffers damage and mortality. Fire damage may be less prevalent now than in the past. Control of wildfires has allowed eastern redcedar to come back to sites within its natural range where it has not existed for a long time *(18)*, and conditions are similar for southern redcedar within its natural range.

Cedar-apple rust *(Gymnosporangium juniperi-virginianae)* attacks southern redcedar *(6)*, and bagworms *(Thyridopteryx ephemeraeformis)* have been observed feeding on its foliage. Other agents that damage eastern redcedar, such as cedar blight *(Phomopsis juniperovora)* and various wood rots *(15)*, probably damage southern redcedar also.

Special Uses

Southern redcedar lumber is used in the manufacture of chests, wardrobes, closet linings, flooring, and scientific instruments. Because the heartwood of redcedar is very resistant to decay, it is used for fence posts *(16)*. Young southern redcedars are sold as Christmas trees (2).

Junipers, including southern redcedar, furnish fruit, browse, and protective and nesting cover for many species of wildlife (8).

In landscaping, southern redcedar is used as a background, windbreak, or hedge in parks and along roadsides or around homes *(1,2)*. Although usually found on moist soil, it will grow in dry, sandy, or rocky land, and this hardiness, plus its salt tolerance, makes it desirable for ocean bluffs and seaside plantings.

Genetics

Southern redcedar apparently hybridizes freely with eastern redcedar *(18)*. The literature contains nothing else on the genetics of southern redcedar.

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Juniperus virginiana L. Eastern Redcedar

Cupressaceae Cypress family

Edwin R. Lawson

Eastern redcedar *(Juniperus virginiana),* also called red juniper or savin, is a common coniferous species growing on a variety of sites throughout the eastern half of the United States. Although eastern

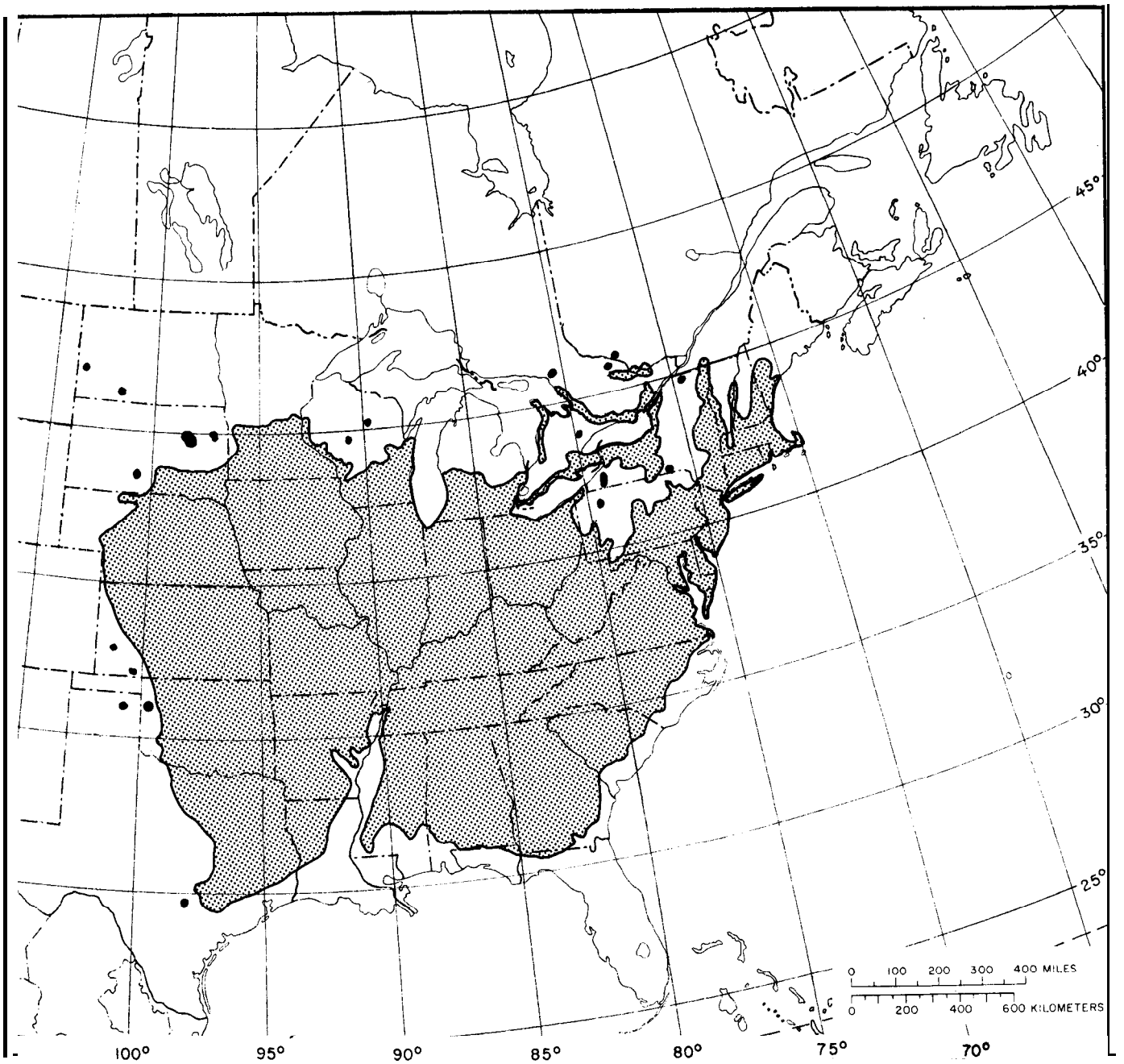

Figure l-The *native range of eastern redcedar.*

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redcedar is generally not considered to be an important commercial species, its wood is highly valued because of its beauty, durability, and workability. The number of trees and volume of eastern redcedar are increasing throughout most of its range. It provides cedarwood oil for fragrance compounds, food and shelter for wildlife, and protective vegetation for fragile soils.

Habitat

Native Range

Eastern redcedar (fig. 1) is the most widely distributed conifer of tree size in the Eastern United States and is found in every State east of the 100th meridian. The species extends northward into southern Ontario and the southern tip of Quebec (27). The range of eastern redcedar has been considerably extended, especially in the Great Plains, by natural regeneration from planted trees *(47)*.

Climate

The wide natural distribution of eastern redcedar clearly indicates its ability to grow under varying and extreme climatic conditions. Average annual precipitation varies from about 380 mm (15 in) in the northwestern section to 1520 mm (60 in) in the southern parts of its range *(40)*. Throughout the eastern redcedar range, average precipitation from April through September measures from 380 mm (15 in) to 760 mm (30 in). This suggests that summer precipitation may be more limiting to the species than average annual precipitation. Average annual snowfall ranges from a trace to more than 254 cm (100 in).

Table l-Site classes for natural stands of eastern redcedar in northern Arkansas

Item	Site class			
	I	II	III	IV
Soil character	alluvial	upland	upland	upland
Soil depth, cm	61+	61+	30 to 58	less than 30
Soil depth, in	24+	24+	12 to 23	less than 12
Site index[1]				
Open stand, m	16.8	13.7	10.7	7.6
Open stand, ft	55	45	35	25
Closed stand, m	18.3	15.2	12.2	9.1
Closed stand, ft	60	50	40	30

[1]Adjusted to base age 50 years

Average annual temperatures vary from about 4" C (40° F) in the north to 20° C (68° F) in the southern part of the botanical range, Average annual maximum temperature ranges only from about 32" C (90° F) to 41° C (105" F), but average minimum temperature ranges from -43" C (45" F) to -7" C (20" F). The growing season varies from about 120 to 250 days.

Soils and Topography

Eastern redcedar grows on a wide variety of soils, ranging from dry rock outcrops to wet swampy land *(15)*. The most common soils fall within the soil orders Mollisols and Ultisols. No attempt will be made here to describe all of them. Like most species, eastern redcedar grows best on deep, moist, well-drained alluvial sites, where its height may reach 17 to 18 m (55 to 60 ft) in 50 years. On the better sites, however, hardwood competition is so severe that the species rarely becomes dominant. Eastern redcedar also grows well on deep, upland soils, particularly abandoned farmland. A 0.4-hectare (l-acre) plantation established in Arkansas from wildlings, with spacing of 1.8 by 1.8 m (6 by 6 ft), yielded a basal area of 37.4 m^2/ha (163 ft^2/acre) and an estimated 196 m^3/ha (2,800 ft^3/acre) of merchantable volume in 44 years *(11)*.

The species is frequently associated with areas commonly called glades, characterized by thin rocky soils and intermittent rock outcrops; soil depth is difficult to determine because soil rock content and depth of rock fissures vary *(11,16)*. Soils on the poorest glade sites are less than 30 cm (12 in) deep, medium sites are usually less than 61 cm (24 in) deep and have large crevices, and good sites have deeper soil. Arend and Collins (3) developed the site classification system shown in table 1.

Eastern redcedar grows on soils that vary widely in acidity. Soils found in natural stands range in pH value from 4.7 to 7.8. Although the species will grow on sites that are slightly alkaline, it is not particularly tolerant to higher pH levels. Eastern redcedar is, in fact, among the least alkali-tolerant of drought-hardy trees and shrubs. Soils in eastern redcedar stands tend to become neutral or slightly alkaline because the high calcium content of the tree's foliage can change the pH of the surface soil in a relatively short time. This condition also increases earthworm activity, with an increase in incorporation of organic matter, a lower volume weight, and an increase in pore volume and infiltration rate *(11,15)*.

Eastern redcedar grows on ridgetops, varying slopes, and flat land and is frequently found on dry, exposed sites and abandoned fields. Aspect also in-

Figure *2-Nearly pure stand* ***of*** *eastern redcedar on an upland site.*

fluences eastern redcedar development. In the western part of its range, the species may be found on north-facing slopes and along streambanks where there is some protection from high temperatures and drought. Although the most desirable elevation is not clearly delineated, eastern redcedar is found most often growing between 30 m (100 ft) and 1070 m (3,500 R). It is notably absent below the 30 m (100 ft) elevation zone in the southern and eastern parts of the species range *(15,27)*.

Associated Forest Cover

Pure stands of eastern redcedar are scattered throughout the primary range of the species. Most of these stands are on abandoned farm lands or drier upland sites (fig. 2). The forest cover type Eastern Redcedar (Society of American Foresters Type 46) is widespread and therefore has many associates *(10)*. Variants of the type are eastern redcedar-pine, eastern redcedar-hardwood, and eastern redcedar-pine-hardwood. The eastern redcedar-pine variant is composed of eastern redcedar and either shortleaf pine *(Pinus echinata)* or Virginia pine *(P. virginiana)* and is found throughout the southern half of its range. The eastern redcedar-hardwood variant is found throughout the central part of its range and includes a mixture of red *(Quercus rubra)* and white *(Q. alba)* oaks, hickories *(Carya* spp.), black walnut *(Juglans nigra)*, and other hardwoods. The third variant, eastern redcedar-pine-hardwood, includes all of the above species associations *(15)*. Eastern redcedar appears as a minor component of several other forest cover types.

Eastern redcedar is among the first to invade abandoned fields and areas cleared for pasture (25). On deeper soils, persimmon *(Diospyros virginiana)*

and sassafras *(Sassafras albidum)* are associated invaders and may crowd it out. In cedar glades, the species is commonly associated with blackjack oak *(Quercus marilandica),* winged elm *(Ulmus alata),* fragrant sumac *(Rhus aromatica),* Carolina buckthorn *(Rhamnus caroliniana),* rusty blackhaw *(Viburnum rufidulum),* and Alabama supplejack *(Berchemia scandens).* Little bluestem *(Andropogon scoparius),* big bluestem *(A. gerardi),* yellow Indiangrass *(Sorghastrum nutans),* switchgrass *(Panicum virgatum),* dropseed *(Sporobolus* spp.), and numerous composites and legumes are common herbaceous plants.

Life History

Reproduction and Early Growth

Flowering and Fruiting-Eastern redcedar is a dioecious species, and trees probably reach sexual maturity at about 10 years. Staminate strobili or conelets begin to develop on male trees at the tips of axillary branches of new scale-leaves. Pollen grains are formed by late September in conelets having 10 to 12 entire-margined sporophylls. Staminate strobili turn a conspicuous yellowish brown when they reach maturity during winter, and thus male trees are readily distinguished from ovulate ones.

Small green conelets begin to develop by early fall or late summer on ovulate trees but grow very little during the winter. They are borne terminally on axillary branches of the new scale-leaves but do not become conspicuous until late February to early spring. At this time the microsporangial walls of the staminate conelets split longitudinally, discharging the mature pollen. Pollen grains lodge at the end of the micropyle of the many ovules in the conelet. Pollination is complete in a few days when the conelet closes.

Growth of the pollen tube is slow at first but becomes active by late May or mid-June. Fertilization occurs in June and the mature embryo is full grown in about 2 months, anytime from late July to mid-November, depending on location. As the ovulate cone develops, greenish fruit-scales form the outer fleshy protective coat of the berrylike cone. Cones change color from green to greenish white to whitish blue and finally to bluish as the season progresses.

Each cone or fruit contains one to four (occasionally more) rounded or angled brownish seeds, 2 to 4 mm (0.08 to 0.16 in) long, often with longitudinal pits. The seed coat has a thick and bony outer layer and a thin, membranous inner layer *(23,47).*

Seed Production and Dissemination-Mature eastern redcedar trees produce some seeds nearly every year, but good crops occur only every 2 or 3 years. The cones do not open and will remain on the tree through the winter, although many are eaten and dispersed by animals. Most remaining cones are dispersed in February to March. Mature fruits are usually collected in the fall by hand-stripping or shaking onto canvas. Seeds may be stored as dried fruits or cleaned seeds.

After fanning to remove leaves, twigs, and other debris, the seeds can be extracted by running the fruit through a macerator and floating the pulp and empty seeds away. Dried fruits should be soaked in water several hours before macerating. Since eastern redcedar fruits are resinous, they should be soaked in a weak lye solution for 1 or 2 days. The soaking helps separate the oily, resinous pulp from the seeds and aids further washing, flotation, and stratification. This treatment should be followed by thorough washing (45). The cleaned seeds are ready for use, or they can be dried to 10 to 12 percent moisture content for storage at -7" C (20° F) to 4" C (40° F). The number of cleaned seeds per kilogram ranges from 81,570 (37,000/lb) to 121,250 (55,000/lb) and averages 96,120 (43,600/lb) (23). If seeds are to be sown in the spring, they should be soaked in a citric acid solution (10,000 ppm) for 96-hours, placed in moist-warm stratification at 24" C (75" F) for 6 weeks, and finally placed in moist-cool stratification at 5" C (41" F) for 10 weeks. Germination is best if fresh seeds are used. If desired, dry, stored seeds may be sown in mid-July, which accomplishes moist-warm stratification, and the over-winter period accomplishes moist-cool stratification for early spring germination (46).

In nursery practice, eastern redcedar seeds are broadcast or sown in rows spaced 15 to 20 cm (6 to 8 in) apart in well-prepared seedbeds and covered with about 6 mm (0.25 in) of firmed soil or sand. Stratified seeds should be sown in the spring early enough to allow completion of germination before air temperatures exceed 21" C (70° F). Germination of stratified seed usually begins in 6 to 10 days after sowing and is completed in 4 to 5 weeks. Untreated seeds may be sown in the fall and mulched until germination during the second spring after planting (23); but when fruits are depulped, dried, and stored at -16" C (4° F), seeds germinate the first spring after summer sowing (46). Germination is epigeal.

Fruits are eaten by birds and other animals, which are important vectors for seed dissemination (20). Seeds that pass through animal digestive tracts and those that remain on the ground beneath the trees may germinate the first or second spring. Most of the

natural germination of eastern redcedar seed takes place in early spring of the second year after dispersal.

Eastern redcedar may also be established by hand direct-seeding or machine-sowing (29). Both hand and furrow seeding are successful when stratified seeds are used at the rate of 1.35 kg/ha (1.2 lb/acre). Seedling catch is best where the amount of litter has been reduced and hardwood competition has been completely removed. The rate of sowing may be adjusted to allow for variations in germinative capacity of the seeds and degree of competition control.

Seedling Development-Eastern redcedar seedlings grown in nurseries may be transplanted from seedling beds after 1 or 2 years. Spacing in transplant beds ranges from about 15 by 3 cm (6 by 1 in) to 20 by 5 cm (8 by 2 in), depending on locality. The age at which trees are outplanted varies from area to area. Generally, eastern redcedar is field planted as 2-0, 3-0, l-l, 1-2, 2-1, or 2-2 stock (numbers refer respectively to growing seasons in seedling beds and transplant beds).

Survival and growth of planted stock can be improved by grading the seedlings just after lifting from the nursery beds. Seedlings that are relatively small, topheavy, oversized, damaged, diseased, or insect-infested are discarded (37). Culling after lifting from transplant beds is usually 1 to 3 percent, compared to 5 to 20 percent from seedling beds. Eastern redcedar seedlings should have a stem diameter of at least 4.0 mm (0.16 in>, but preferably 5.6 mm (0.22 in), at the ground line. It is also desirable for seedlings to have top green weights that are no more than 3 to 4 times heavier than the roots *(26,36)*. Seedlings having higher top-to-root ratios are more likely to die under environmental stress.

Survival of eastern redcedar plantations has been variable, with low survival being attributed to poor seedling quality, low site quality, and competition. If these factors are considered carefully, however, eastern redcedar plantations can be successfully established. One early plantation established from hand-pulled wildlings had 84 percent survival. In a Nebraska plantation, established with 2-O seedlings from 204 sources of eastern redcedar and Rocky Mountain juniper, first-year survival averaged 95.1 percent. Four other plantations from these sources averaged more than 85 percent survival, although one in Oklahoma had only 19.7 percent *(11,38)*.

Most natural eastern redcedar regeneration takes place on relatively poor hardwood or pine sites, along fence rows, or in pastures that are not burned or mowed. Seedlings are commonly established in rather open hardwood stands, adjacent to older seed-bearing eastern redcedar trees, as a result of birds eating the fruit and subsequent deposition of seeds (34). On very dry sites, most seedlings are found in crevices, between layers of limestone, and in other protected places where the microclimate is most favorable. Seedling development is relatively slow on these adverse sites, although eastern redcedar seedlings withstand drought rather well *(4,22)*. First-year seedlings do not produce much height growth but develop a long fibrous root system (15). Plantings from 2-O stock showed good growth in some areas, however, exceeding 45 cm (17.8 in) in height after one growing season (38). If competition from an overstory is rather severe, eastern redcedar seedlings may not survive. Once established, however, eastern redcedar survives for extended periods under severe competition *(15,28)*. Eastern redcedar also competes very well in shelterbelts, where it is the most common natural reproduction (43).

Vegetative Reproduction-Eastern redcedar does not reproduce naturally by sprouting or suckering, but the species may be propagated by grafting, by air-layering, or from cuttings *(6,15,33,44)*.

Sapling and Pole Stages to Maturity

Growth and Yield-Growth rates of eastern redcedar depend largely on site quality, competition from other species, and stand density. These factors probably reflect competition for available soil moisture on most sites. Trees 20 to 30 years old are generally 5 to 8 m (18 to 26 ft) tall and 6 to 8 cm (2.3 to 3.0 in) in d.b.h. Mature trees are usually 12 to 15 m (40 to 50 ft) tall and 30 to 61 cm (12 to 24 in) in d.b.h. On good sites, trees may reach 37 m (120 ft) in height and 122 cm (48 in) in d.b.h. (25).

Some of the earliest data on diameter growth in natural eastern redcedar stands is presented in table 2 (3). Site classes mentioned are those described in table 1. Analysis of these data provided equations to compute the height-age relationships in table 3. The relation of height of dominant and codominant trees to d.b.h. and stand density was also determined, after pooling of data for age and site classes ***(11)***. Height growth, a reflection of soil depth and fertility, increases with stocking density (fig. 3).

Other studies in Arkansas have shown that growth and yield are affected by stand density and hardwood competition. In a 45-year-old eastern redcedar stand, highest volume growth was obtained in unthinned stands from which hardwoods had been removed. Volumes averaged 1.96 m^3/ha (28 ft^3/acre) per year during a 14-year period. This was double the growth of stands where hardwoods were left. A stand con-

Table S-Average annual diameter growth of dominant eastern redcedar by site class and stand density[1]

Stand character	Site class			
	I	II	III	IV
		mm		
Under-stocked	7.6	8.1	4.6	3.6
Well-stocked		8.1	4.3	3.0
Over-stocked	—	3.8	2.5	1.8
		in		
Under-stocked	0.30	0.32	0.18	0.14
Well-stocked	—	0.32	0.17	0.12
Over-stocked	—	0.15	0.10	0.07

[1]Based on increment core measurements of 456 trees (3).

Table 3—Total height of eastern redcedars by age[1] and site class

Growth rings	Site class			
	II		III	
	m	*ft*	*m*	*ft*
10	4.6	15	3.7	12
15	5.5	18	5.2	17
20	7.6	25	6.1	20
25	8.5	28	7.3	24
30	9.8	32	7.9	26
35	10.7	35	8.8	29
40	11.3	37	9.4	31
45	12.2	40	10.1	33
50	12.8	42	10.7	35

[1]Age was computed using the total number of growth rings; false rings make accurate determinations difficult.

taining 432 crop trees per hectare (175/acre), 7.6 cm (3.0 in) d.b.h. and larger grew nearly the same volume after 14 years when 80 percent of the competition was removed as an unreleased stand of 988 trees per hectare (400/acre) *(11)*.

Over a lo-year period in northern Arkansas, completely released stands averaged higher growth in d.b.h., basal area, and volume than stands where only crown competition was removed. The greatest mean d.b.h. growth, 6.4 cm (2.5 in), occurred with the lightest stocking, 124 crop trees per hectare (50/acre). As stocking increased, mean d.b.h. growth decreased. Basal area increase was greatest in stands having 988 crop trees per hectare (400/acre), and as stocking decreased, basal area and volume growth decreased. An initial stocking of 988 eastern redcedar crop trees per hectare (400/acre), averaging about 7.6 cm (3 in) d.b.h., produced over 28 m^3/ha (2,000 fbm/acre) in 10 years. A stocking of 432 trees per hectare (175/acre), averaging 10.2 cm (4 in) d.b.h., produced slightly more volume during the same period on similar sites *(11)*.

On most sites eastern redcedar grows slowly, and long rotations are required to produce conventional sawlogs. Because the wood is used for small items, however, and there is wide latitude in acceptable defects, shortening of rotations and intermediate harvesting of merchantable wood are possible. About 20 to 30 years are required for posts and 40 to 60 years for sawtimber *(11,25)*.

Maintaining relatively dense stands can maximize post production. Thinning one or more times before harvest cut hastens sawlog production but may not increase total yield. The ideal density for growing sawlogs is not known, but excessive thinning may promote excessive formation of sapwood and growth of lower branches.

Rooting Habit-On shallow and rocky soils, eastern redcedar roots are very fibrous and tend to spread widely. Even first-year seedlings begin developing a long fibrous root system, often at the expense of top growth *(15)*. If soil conditions permit, eastern redcedar trees develop a deep, penetrating taproot.

Root development is greatly influenced by the size of soil-filled fissures. Eastern redcedar roots are known to grow extensively in soils in which limestone rocks make up more than 52 percent of the total soil volume *(11)* (fig. 4).

Reaction to Competition-Eastern redcedar has been classed as intolerant to very intolerant of shade *(11,30)*, but trees that have lived for decades beneath

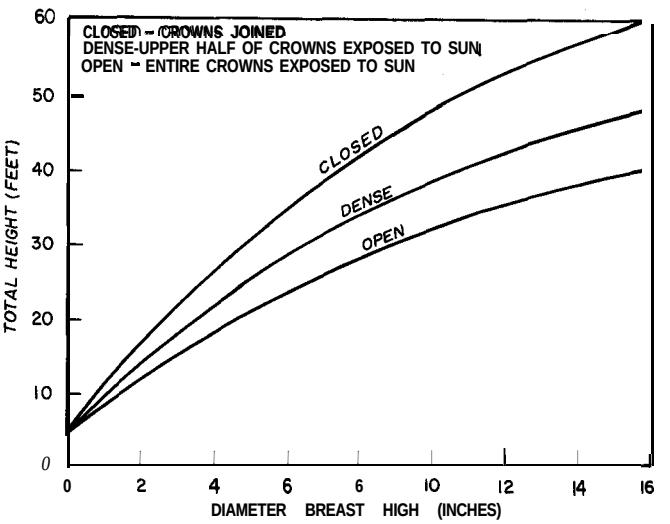

Figure *3-Relation of height to d.b.h. by stocking class.*

a full canopy of hardwoods or pines on medium- to low-quality sites have been observed. Apparently, eastern redcedar has an inherent low capacity for water loss and the ability to sustain stomata1 opening at low water potentials, which help the species adapt to dry environments *(4)*. Eastern redcedar can also conduct photosynthesis when overstory hardwoods are leafless and perhaps even reduces its light requirements for photosynthesis by adjusting to shaded conditions *(17,24)*. Eastern redcedar is a pioneer species on surface-mined areas (fig. 5), old fields, or pastures that are protected from fire; and it is the primary natural reproduction in many shelterbelts. However, stands formed through invasion of old fields may deteriorate at around 60 years of age as hardwoods or other competing species become established. Eastern redcedar grows well and faster than associated species because it is sun-adapted, drought-resistant, and has a long growing season. On most sites, eastern redcedar is temporary and is eventually replaced by more tolerant hardwoods and pines. However, clusters of eastern redcedar established beneath hardwoods have survived longer than the competing hardwood trees, possibly due to an allelopathic effect, or the species may be a better competitor for water and nutrients (34). The species is more permanent on poor sites having thin, rocky soils, such as the glades of the Ozarks of Missouri and Arkansas and the Nashville Basin in central Tennessee. Eastern redcedar invasion of pastures is a problem on areas converted from poor hardwood sites in the Ozarks and western areas of its range *(9,31)*, and the species is likely to persist for a long time if left to grow (7).

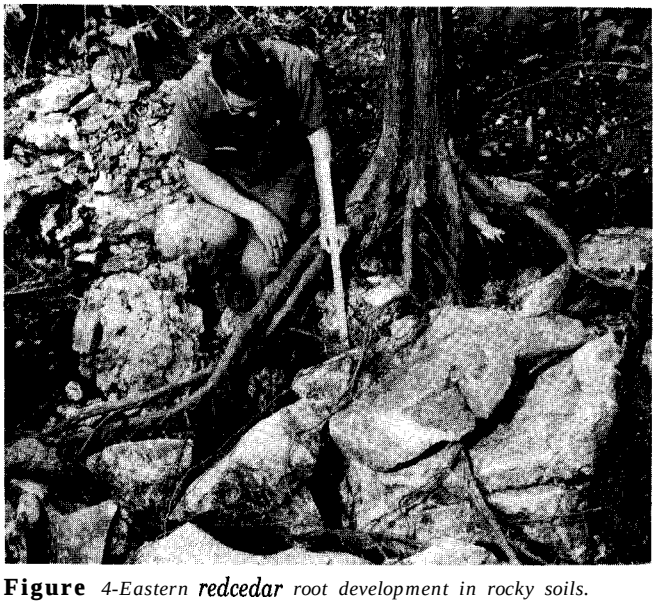

Figure *4-Eastern redcedar root development in rocky soils.*

Eastern redcedar should be managed in even-aged stands, judging from studies conducted in northern Arkansas *(11)*. Good growth rates can be maintained by controlling competition and stand densities.

Damaging Agents-Fire is probably the worst enemy of eastern redcedar. The thin bark and roots near the ground surface are easily injured by fires. Some natural protection against fire exists because its foliage does not burn well and litter accumulation is minimal under stands on thin soils *(11,15)*.

Several insects damage eastern redcedar trees but rarely cause serious permanent damage (5). Roots of seedlings are very susceptible to attack by nematodes and grubs. The foliage is eaten by bagworms ***(Thyridopteryx ephemeraeformis)*** and spruce spider mites ***(Oligonychus ununguis),*** both of which can completely defoliate trees. The eastern juniper bark beetle ***(Phloeosinus** dentatus)* attacks the species but usually does not kill trees except when the attack is associated with the root rot fungus, ***Heterobasidion annosum.*** Another bark beetle ***(Phloeosinus** canadensis)* may feed on eastern redcedar. Several boring insects, including the black-horned juniper borer *(Callidium **texanum),*** cedartree borer ***(Semanotus ligneus)***, cypress and cedar borer ***(Oeme rigida)***, and pales weevil ***(Hylobius pales)*** will attack eastern redcedar. The juniper midge *(Contarinia **juniperina)*** is a gall insect pest of redcedar which bores into the twigs at the base of needles and kills the portion beyond the entrance hole. In addition to pales weevil, two other weevils, the arborvitae weevil ***(Phyllobius intrusus)*** and the strawberry root weevil *(**Otiorhynchus ovatus),*** feed on roots of eastern redcedar. The latter two weevils are also leaf feeders, along with the juniper webworm *(Dichomeris marginella)*; a wax moth *(Coleotechnites juniperella)*; a leaf roller *(Choristoneura houstonana)*, a pest of windbreak and ornamental plantings; and a sawfly *(Monoctenus mel-*

Figure *5-Development of redcedar on surface-mined areas.*

liceps). The Fletcher scale *(Lecanium fletcheri)* and juniper scale *(Carulaspis **juniperi**)* are two other commonly occurring insects that attack junipers.

Eastern redcedar, especially when weakened by stress or insects, is very susceptible to damage by the root rot fungus, ***Heterobasidion annosum.*** This disease is thought to cause the greatest damage over much of its range. Cubical rot fungi ***(Fomes subroseus*** and ***Daedalea juniperina)*** and juniper pocket rot fungus ***(Pyrofomes** demidoffii)* enter eastern redcedars through dead branch stubs and attack the heartwood. Several other minor heart-rot fungi infect eastern redcedar *(21)*.

The major stem and foliage diseases of eastern redcedar are fungi known as cedar rusts in the genus ***Gymnosporangium.*** The most commonly known and widely spread species is cedar apple rust ***(G. juniperi-virginianae),*** which attacks trees in all stages of development. Because it is an alternate host to this disease, the presence of redcedar is a problem to apple growers. Other common species are G. ***clavipes, G. globosum, G. effusum,*** and ***G. nidus-avis.*** The latter fungus is widely distributed and produces witches' brooms (21). Important foliage diseases include Phomopsis blight ***(Phomopsis juniperovora)*** and ***Cercospora sequoiae*** blight, which also attack seedlings. Phomopsis blight has been difficult to control in nurseries, but newer developments show promise *(12,32)*. Both blights can cause major losses to eastern redcedar in the field, but Phomopsis blight is not a serious problem after seedlings reach age 4.

Newly established seedlings are subject to frost-heaving, and foliage may occasionally be damaged by winter injury (23). Mice and rabbits may damage young eastern redcedar seedlings. Livestock generally avoid biting seedlings or trees but may trample the plants and their roots while grazing. During times of scarce food, deer will heavily browse eastern redcedar and destroy most reproduction *(11,20)*. Redcedar withstands the weight of snow fairly well, but it has only moderate resistance to ice damage (8). Although the species is generally very tolerant to drought and temperature extremes, the author observed considerable mortality in west central Arkansas associated with the extremely hot, dry summer of 1980.

Special Uses

Eastern redcedar is important to wildlife. As an evergreen, it provides good nesting and roosting cover for many birds *(18,39)*. Dense thickets provide good escape cover for deer, and the abundant foliage, although low in quality, provides emergency food for them during times of stress. Fruits are high in crude fat and crude fiber, moderate in calcium, and very high in total carbohydrates, Eastern redcedar fruits are eaten by many wildlife species, including waxwings, bobwhite, quail, ruffed grouse, pheasant, wild turkeys, rabbits, foxes, raccoons, skunks, opossums, and coyotes (20).

Eastern redcedar is among the best trees for protecting soils from wind erosion and reducing the desiccating effects of wind. It ranks high in the Great Plains shelterbelt plantings because of its ability to withstand extremes of drought, heat, and cold *(15)*. In Nebraska, eastern redcedar was the most suitable species among five combinations tested for single-row field windbreaks (42). The fibrous root system also helps to hold soil in place, especially on shallow soils. Many varieties of eastern redcedar are used as ornamental plantings *(19,35)*. The species is also ranked among the top five for Christmas trees (25). Eastern redcedar is also important as a source of cedarwood oil, which is a natural product for direct use in fragrance compounding or as a source of raw material producing additional fragrance compounds *(1)*.

Genetics

Population Differences

Eastern redcedar displays great diversity in phenotypic characteristics such as tree form, foliage color, and crown shape. Van Haverbeke's study *(41)* included a total of 43 gross morphological, foliage, cone, and seed characteristics and biochemical data derived from cone pulp. He points out that much of the research on morphological characteristics of eastern redcedar has been in the central and western parts of the species' range. More recently, however, information on genetic variation in natural stands in the eastern part of its range has been obtained *(13)*. Natural variation in the species may have been modified by past commercial exploitation of natural stands and by the selection, propagation, and distribution of clones (47).

Races and Hybrids

Two distinct varieties have been recognized in the United States. ***Juniperus virginiana*** var. ***crebra*** (Fernald) is a northern form having a narrow crown and slightly pitted seeds. The other variety, ***J. virginiana*** var. ***ambigens,*** is an intermediate form between eastern redcedar and creeping juniper, ***J. horizontalis*** Moench *(1 5)*.

Although there are no recognized hybrids at this time, evidence is mounting that hybridization does

occur. Population studies, especially in the western part of eastern redcedar's range, suggest that considerable introgression and perhaps blending of genetic differences have occurred whenever species' ranges overlap; and that *J. virginiana* readily hybridizes with *J. scopulorum, J. horizontalis,* and *J. ashei,* resulting in juniper populations that contain the germ plasm of two or three species *(15).* Research in the Ozarks, however, showed no evidence of introgression into *J. ashei* by *J. virginiana* where *J. ashei* was surrounded by *J. virginiana (2).*

The relatively strong influence of *J. scopulorum* germ plasm in the western part of the eastern redcedar population suggests that the entire population in the area studied is of hybrid origin (41). This west-to-east *flow* of *J. scopulorum germ* plasm was further supported by Flake, Urbatch, and Turner *(14),* who sampled many of Van Haverbeke's sample trees for terpenoid analysis. He proposed an alternative hypothesis that eastern redcedar of eastern and central North America may have been derived from the western juniper complex.

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