United States
Department of
Agriculture

Forest
Service

Agriculture
Handbook 654

Silvics of North America

Volume 1. Conifers

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Agriculture Handbook 654

(Supersedes Agriculture Handbook 271,
Silvics of Forest Trees of the United States, 1965)

Forest Service
United States Department of Agriculture

Washington, DC

December 1990

For sale by tho Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

Burns, Russell M., and Barbara H. Honkala, tech. coords. 1990. Silvics of North America: 1. Conifers. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol. 1, 675 p.

The silvical characteristics of about 200 forest tree species and varieties are described. Most are native to the 50 United States and Puerto Rico, but a few are introduced and naturalized. Information on habitat, life history, and genetics is given for 15 genera, 63 species, and 20 varieties of conifers and for 58 genera, 128 species, and 6 varieties of hardwoods. These represent most of the commercially important trees of the United States and Canada and some of those from Mexico and the Caribbean Islands, making this a reference for virtually all of North America. A special feature of this edition is the inclusion of 19 tropical and subtropical species. These additions are native and introduced trees of the southern border of the United States from Florida to Texas and California, and also from Hawaii and Puerto Rico.

Oxford: 174, 181 (082, 7).
Keywords: Silvics; forest types; conifers; hardwoods.
Library of Congress Catalog Card Number: 86-600518.

Cover art: Natural stands of southern pine and cypress bordering a lake in Noxubee County, MS.

Juniperus scopulorum Sarg. Rocky Mountain Juniper

Cupressaceae Cypress family

Daniel L. Noble

Rocky Mountain juniper *(Juniperus scopulorum)* is one of 13 junipers native to North America. It is similar to eastern redcedar *(Juniperus virginiana)* but requires 2 years for seed maturity, compared to 1 year for its eastern relative. Other common names for the typical variety include Rocky Mountain redcedar, redcedar, western redcedar, river juniper, cedro rojo, and sabino *(23,42,49)*. Rocky Mountain juniper varies in size from a shrub to a small tree. The largest specimen grows in the Cache National Forest in Utah. It measures 198 cm (78 in) in d.b.h. but is only 11 m (36 ft) tall. Much information is available about Rocky Mountain juniper as a member of a variety of habitat associations; however what is known about the silvics of the species is more limited *(41)*.

Habitat

Native Range

Of 11 junipers native to the United States normally reaching tree size, Rocky Mountain juniper (fig. 1) is the most widely distributed in western North America *(22,49)*. Within its range the distribution is considerably scattered; however, the concentrations, from central British Columbia and southern Alberta through northwestern Montana and southeastern Idaho into Colorado and northern New Mexico, generally follow the Rocky Mountains. In addition, there are fairly extensive concentrations in western portions of the northern Great Plains, in the Uinta and Wasatch Mountains of Utah, and in a band approximately 100 km (62 mi) wide beginning near the Grand Canyon in northwest Arizona and following the Arizona Plateau southeast into the Black Mountains of southwestern New Mexico.

Climate

The climate generally associated with Rocky Mountain juniper is dry and subhumid. The range of climatic conditions is broad, however, extending from maritime to subalpine to semiarid (table 1). Temperature extremes range from 43° to -37" C (110° to -35" F), but conditions are more favorable to the species when minimum temperatures exceed

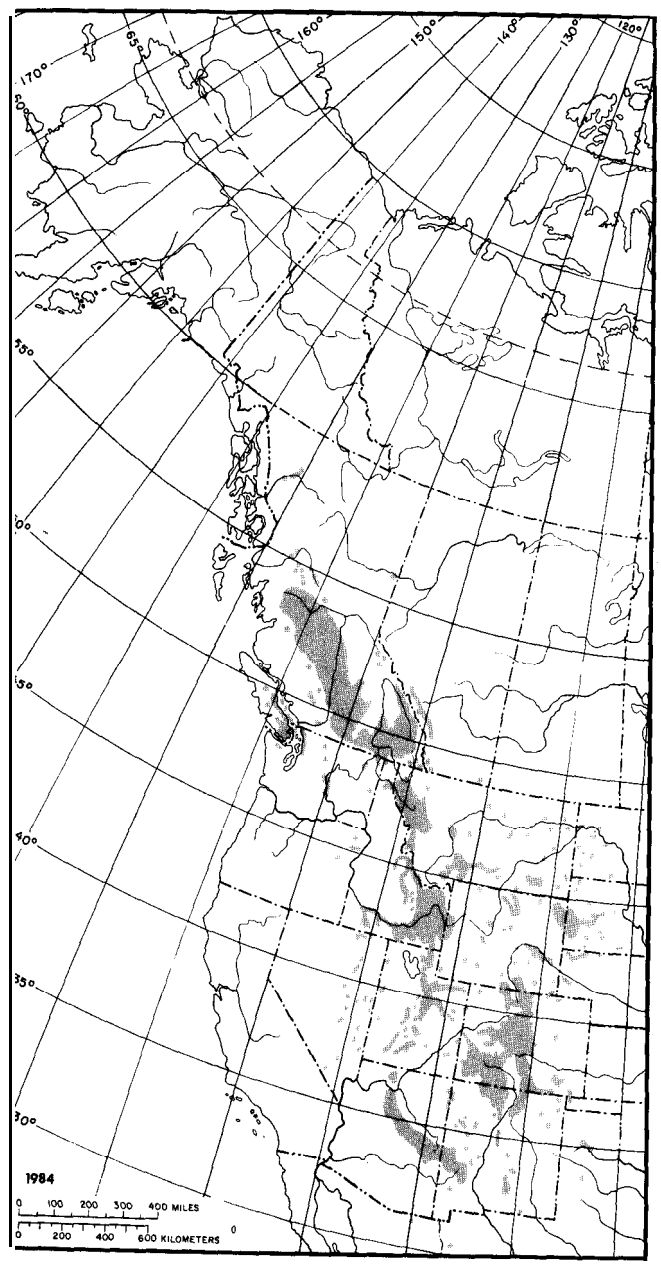

Figure *l-The native range of* **Rocky Mountain juniper.**

-23" to -21" C (~ 10" to -5" F). Average July temperatures in different areas vary from about 16" to 24° C (60" to 75" F), and average January temperatures from about -9" to 4" C (15" to 40" F). Average number of frost-free days varies from 120 days in parts of the

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Table l-Climatic data from six regions within the range of Rocky Mountain juniper

Region	Average temperature			Frost-free	Average annual precipitation	
	Annual	July	January	period	Rain	Snowfall
		°C		days	mm	cm
Pacific Coast	10	17	3	200+	810	20
Rocky Mountains						
Northern	4	14	-8	120	840	135
Central	7	20	-6	130	330	130
Southern	10	22	-2	150	250	76
Northern Great Plains						
Western area	7	22	-7	140	410	107
Great Basin and						
Southwest	9	21	-1	170	360	147
		°F		days	in	
Pacific Coast	50	63	38	200+	32	8
Rocky Mountains						
Northern	40	58	17	120	33	53
Central	44	68	21	130	13	51
Southern	50	72	28	150	10	30
Northern Great Plains						
Western area	45	72	20	140	16	42
Great Basin and						
Southwest	49	70	30	170	14	58

northern Rocky Mountains to 175 days at lower elevations in Arizona and New Mexico. The longest growing season is near sea level in the Puget Sound area *(36,39,42)*.

Average annual precipitation varies in amount, distribution, and type. Over much of the Rocky Mountain juniper range, precipitation averages 380 to 460 mm (15 to 18 in), with variation from 305 mm (12 in) in areas of the Southwest, Great Basin, and eastern slope of the Rocky Mountains in Colorado to 660 mm (26 in) on Vancouver Island. More than half of the precipitation occurs in late fall or early winter on the Pacific coast and west of the Continental Divide in the northern Rocky Mountains. In the northern Great Plains and east of the divide in the northern and central Rocky Mountains, the period of heaviest precipitation is spring and early summer, but this period is late summer and early fall in the Great Basin, Southwest, and southern Rocky Mountains. In general, snow accounts for about one-third to one-half of the total annual moisture, but the amount is highly variable depending upon location *(44)* (table 1).

Recent paleobotanical studies indicate the macroclimate covering much of the Rocky Mountain juniper range has changed from mesic to more xeric conditions. Rocky Mountain juniper is a drought-enduring species and it is more hardy than eastern redcedar; however it is generally less drought-resistant than other western tree juniper species, and the climatic change has not been favorable for regeneration or growth. Ten-thousand years ago, during the Holocene, the species was present in the Wisconsin forests. As recently as 1,000 years ago, extensive stands of Rocky Mountain juniper were present in Western Nebraska and in the Laramie Basin of Wyoming, with specimens often reaching 131 cm (52 in) d.b.h. *(38,42,45,47)*.

Soils and Topography

Edaphic factors for Rocky Mountain juniper can be characterized as nonspecific and variable, as evidenced by the broad ecological range of the species and its adaptability to a wide variety of soils and conditions in shelterbelt reclamation and landscape plantings. Within pinyon-juniper woodlands in Arizona and New Mexico there are 5 soil orders., 10 great-groups, 40 subgroups, and 150 soil families *(3,16,25,34)*.

Rocky Mountain juniper is most often associated with soils derived from basalt, limestone, and shale throughout its natural range, particularly in semiarid regions. Soils in the order Mollisols are commonly associated with this species. Generally, the soils are poorly developed, stony, shallow, have low mois-

ture-holding capacities, and are easily eroded, so that in many places little or no topsoil is present. Some of the soils are calcareous or adobic, often high in clays; are slightly alkaline; and have limy, cemented subsoils. The pH of these soils is generally around 8.0 and moisture availability to plants is low *(21,43)*.

Geology and physiography associated with Rocky Mountain juniper are varied. Throughout its range, it is often found on open exposed bluffs, rocky points, and southern exposures. It does best in sheltered areas, however, along ravines, and in canyons and draws. Its range extends from glaciated valleys in central British Columbia through the foothills of the Rocky Mountains to mesas and tablelands of the southwestern United States, and south into the Sierra Madre in Sonora, Mexico. It is found on lava beds in Idaho and eastern Washington, on limestone cliffs in southwestern Montana, on outcroppings of sandstone and limestone in the central Rocky Mountains, and on high limestone plateaus in South Dakota and Wyoming. It is common on northern aspects in the "badland" topography of both North and South Dakota. In the southern parts of its range, Rocky Mountain juniper is often found on malpais derived from lava flows, and on Kaibab limestone plateaus in northern Arizona *(42)*.

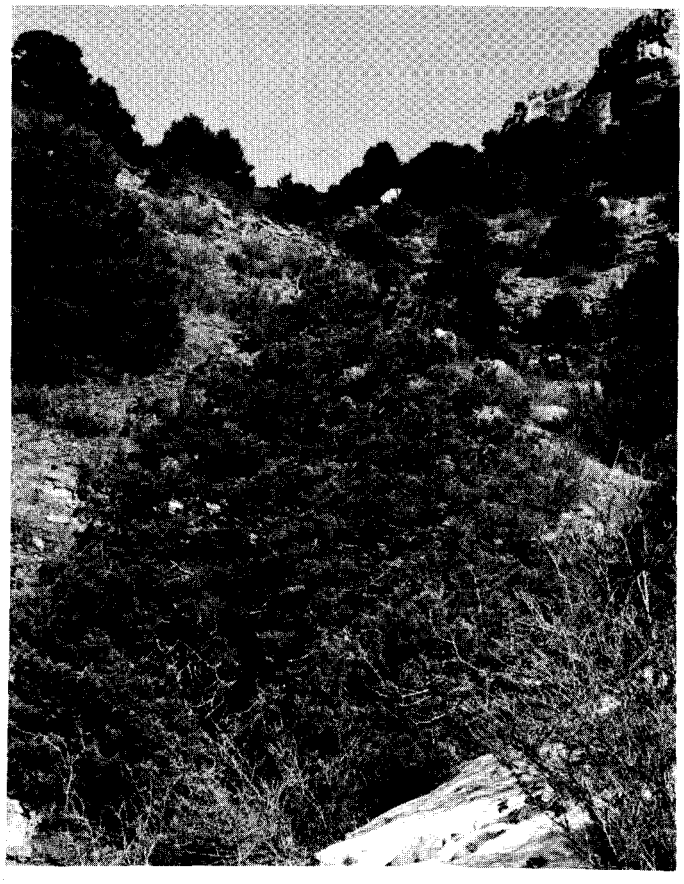

Figure 2—*Pinyon–Juniper (Type 239) near Fort Collins, CO. This is the northern limit for this forest cover type.*

The elevational range of Rocky Mountain juniper is from near sea level to 2740 m (9,000 ft); following the general plant geography rule of decreasing elevation with increasing latitude, the range varies considerably with latitude and local climate. Aspect also has an effect on local elevations, southern exposures generally having a wider range than corresponding northern exposures. For example, in Utah and Nevada, Rocky Mountain juniper has been reported ranging generally from 1070 to 2260 m (3,500 to 7,400 ft) on southern exposures and from 1160 to 1400 m (3,800 to 4,600 ft) on northern exposures *(14,42)*.

Associated Forest Cover

Rocky Mountain juniper is most common as a component of the foothills or woodland coniferous zone; in some areas it extends into the montane zone in significant amounts. It forms a distinct forest cover type, Rocky Mountain Juniper (Society of American Foresters Type 220), from northern Colorado and Utah northward. Southward it becomes associated with Pinyon–Juniper (Type 239) (fig. 2) *(27,36)*.

Rocky Mountain juniper, because of its scattered distribution over a broad range, is often found in complex transition zones or growing on exposed or severe sites within other forest types (27,361. In these situations, however, it is rarely more than a minor component of the forest association. Rocky Mountain juniper is found in the following forest cover types, among others:

206 Engelmann Spruce–Subalpine Fir
208 Whitebark Pine
209 Bristlecone Pine
210 Interior Douglas-Fir
212 Western Larch
216 Blue Spruce
217 Aspen
218 Lodgepole Pine
219 Limber Pine
221 Red Alder
233 Oregon White Oak
235 Cottonwood-Willow
236 Bur Oak
237 Interior Ponderosa Pine
240 Arizona Cypress
241 Western Live Oak

Differences in elevation, latitude, physiography, and soils, which affect temperature, precipitation, soil moisture, and nutrient conditions, in combina-

tion with phytozoological interactions, influence the composition of forests in which Rocky Mountain juniper grows. Furthermore, fire has influenced the development of regional differences for Rocky Mountain juniper distribution, associated complexes, and related biotic associations. Only in the northern parts of its range, at middle and lower elevations, does it form pure stands *(14,21,48)*.

Throughout its range south to northern New Mexico and Arizona, Rocky Mountain juniper intermingles with ponderosa pine *(Pinus ponderosa)* on southern and western exposures and with interior Douglas-fir *(Pseudotsuga menziesii* var. *glauca)* on northern and eastern exposures where it is more abundant. At higher elevations, Rocky Mountain juniper is occasionally associated with Engelmann spruce *(Picea engelmannii),* subalpine fir *(Abies lasiocarpa),* lodgepole pine *(Pinus contorta),* and limber pine *(P. flexilis)* throughout the Rocky Mountains. In its central and southern range, Rocky Mountain juniper has been reported with white fir *(Abies concolor),* blue spruce *(Picea pungens),* aspen *(Populus tremuloides),* and narrowleaf cottonwood *(Populus angustifolia);* at higher elevations it is occasionally or rarely found with bristlecone pine *(Pinus aristata) (36,42)*.

At higher elevations, in British Columbia, Alberta, Idaho, and western Montana, Rocky Mountain jumper is occasionally found with subalpine larch *(Larix lyallit),* western white pine *(Pinus monticola),* limber pine, or whitebark pine *(P. albicaulis).* It is associated with whitebark pine at higher elevations in western Wyoming. In the Pacific Northwest, Oregon white oak *(Quercus garryana)* and red alder *(Alnus rubra)* are commonly associated with Rocky Mountain juniper, along with Douglas-fir at slightly higher elevations on Vancouver Island, the San Juan Islands, and the inland area around Puget Sound *(20,36,42)*.

Rocky Mountain juniper grades into variations of the pinyon-juniper complexes at middle to lower elevations, southward from Nevada, Utah, and Colorado. Within these complexes, Rocky Mountain juniper generally decreases in density in relation to pinyon species with an increase in elevation. The usual junipers are Utah juniper *(Juniperus osteosperma),* one-seed juniper *(J. monosperma),* and alligator jumper *(J. deppeana).* The pinyons may be pinyon *(Pinus edulis),* Mexican pinyon *(P. cembroides),* or singleleaf pinyon *(P. monophylla).* This association is well developed on the Coconino Plateau in Arizona, where it is referred to as the pygmy conifer biome *(14,26,29)*.

Rocky Mountain juniper is often associated with open-grown scrubby ponderosa pine or bur oak *(Quercus macrocarpa)* growing on severe sites in the rough, broken tableland topography of western North and South Dakota and eastern Montana and Wyoming (27). Occasionally in this area, it forms small but almost pure stands (fig. 2). Along stream bottoms and in protected draws, it is occasionally found with a variable but generally incomplete mixture of deciduous trees that may include cottonwood *(Populus* spp.), willow *(Salix* spp.), green ash *(Fraxinus pennsylvanica),* American elm *(Ulmus americana),* boxelder *(Acer negundo),* bur oak, and hackberry *(Celtis occidentalis).* In the Black Hills, it may, rarely, be found with white spruce *(Picea glauca).*

Because of Rocky Mountain jumper's association with a wide range of forest-shrub-grassland types, a complete list of understory vegetation would be too long to include here. Sparse understories are a characteristic of Rocky Mountain juniper stands, however, particularly on dry sites and where the species is dominant or codominant. Some of the shrubs reported as understory components are *American* plum *(Prunus americana),* antelope bitterbrush *(Purshia tridentata),* chokecherry *(Prunus virginiana),* creosotebush *(Larrea tridentata),* cliffbush *(Jamesia americana),* cliffrose *(Cowania mexicana),* red-osier dogwood *(Cornus stolonifera),* fernbush *(Chamaebatiaria millefolium),* mountain-mahogany *(Cercocarpus* spp.), rabbitbrush *(Chrysothamnus* spp.), currant *(Ribes* spp.), rose *(Rosa* spp.), sagebrush *(Artemisia* spp.), serviceberry *(Amelanchier* spp.), skunkbush sumac *(Rhus trilobata),* snowberry *(Symphoricarpos* spp.), winter-fat *(Eurotia lanata),* and shadscale saltbush *(Atriplex confertifolia).* Also, it shares sites with common jumper *(Juniperus communis)* throughout its range and with creeping juniper *(J. horizontalis)* in the Dakotas, Wyoming, Montana, and Alberta (20).

Common grass and grasslike associates of Rocky Mountain juniper at lower elevations in its northern range include wheatgrass *(Agropyron* spp.), fescue *(Festuca* spp.), needlegrass *(Stipa* spp.), grama *(Bouteloua* spp.), and bluegrass *(Poa* spp.). In the southern Rocky Mountains, it is found with grama, galleta *(Hilaria* spp.), and tobosa *(Hilaria mutica).* Along its eastern distribution from North Dakota to Texas, Rocky Mountain juniper grows with wheatgrass, grama, buffalograss *(Buchloe dactyloides),* bluestem *(Andropogon* spp.), and sandreed *(Calamovilfa* spp.) *(20,26)*.

Life History

Reproduction and Early Growth

Flowering and Fruiting-Rocky Mountain juniper is dioecious. Both pistillate and staminate flowers are small and are borne on the ends of short branchlets or along the branchlet from mid-April to mid-June. The greenish-yellow female flowers usual-

ly contain one or two ovules and become more conspicuous during late summer, opening the following spring before pollination. Pollen is disseminated primarily by wind from inconspicuous yellow male flowers on short branchlets, each flower usually containing six stamens. Female flowers are composed of three to eight pointed scales which become fleshy and fuse to form small indehiscent strobili, commonly called "berries" *(15,18)*.

The berries ripen the second year after pollination from mid-September to mid-December and remain on the tree until March or April of the following spring; however, some fruits may persist on the tree for as long as 3 years *(18)*. Immature berries are green and glaucous; ripe berries are bluish purple and covered with a conspicuous white, waxy bloom. The rounded fruit is resinous with a thin coat and averages about 5 to 8 mm (0.2 to 0.3 in) in diameter.

Seed Production and Dissemination-Rocky Mountain juniper may begin bearing seed at 10 years of age, under favorable conditions. The optimum age for seed production is 50 to 200 years. Trees that are open grown, stunted, or under stress often are prolific seed producers. Rocky Mountain juniper is rated as a good to prolific seed producer throughout most of its range, but in parts of Idaho and Montana, production is reported as only fair. The interval between heavy seed crops varies from 2 to 5 years, but some seed is produced almost every year. Rocky Mountain juniper is as good a seed producer as its other tree associates, with the possible exception of Utah juniper and singleleaf pinyon. It is a better producer than common or creeping juniper *(18,42)*.

Each Rocky Mountain juniper fruit usually contains one, sometimes two, and rarely three brownish seeds, and 100 kg (220 lb) of berries yields 11 to 28 kg (24 to 62 lb) of seeds. The angular, lightly grooved seeds are about 5 mm (0.2 in) in length and 3 mm (0.1 in) in thickness; they average about 59 700/kg (27,100/lb) but range from 39 200 to 92 800/kg (17,800 to 42,100/lb) *(18)*.

Rocky Mountain juniper is considered to have a high proportion of unfilled seeds, but the number varies widely from tree to tree and from season to season. Interacting factors causing filled or unfilled seeds are only partially understood; some of the most important are stand age, structure, density, and species composition; physiography; and favorable or unfavorable weather conditions for flower development, pollination, and seed development *(8,18)*.

Viability of Rocky Mountain juniper seed is only fair and, except for alligator juniper, is not as good as other juniper or pinyon species with which it grows. Recent studies indicate that average germinative capacity is 22 percent, with maximums rarely exceeding 35 percent; however, in one study germination averaged 45 percent and varied from 32 to 58 percent. In another study, seed stored in less than ideal conditions had 30 percent germination after 3.5 years. Under proper storage conditions, at least some of the seed may remain viable for several years *(14,18)*.

Rocky Mountain juniper seeds are disseminated primarily by birds, secondarily by gravity and water. A few mammals play a minor role. The berries are eaten mostly during fall and winter months, when other foods are relatively scarce. Bohemian waxwings are known to eat large numbers of berries. Cedar waxwings, robins, turkeys, and the jays—Mexican, pinyon, scrub, Stellar's, and blue-have all been known to feed on the berries at times. As domestic sheep feed on juniper berries, propagation is noticeable along trails between grazing ranges *(30)*. Bighorn sheep and deer occasionally eat the berries, but they normally browse juniper only under stress conditions. Dissemination of seeds by small mammals is thought to be insignificant *(30,33,42)*.

Thus, natural distribution patterns are affected by bird and animal populations, their daily and migratory movements, location and prevalence of berries, and availability and desirability of other foods. These variables, combined with specific site and weather conditions for germination and establishment, are largely responsible for the scattered distribution of Rocky Mountain juniper within its total range.

Artificial regeneration of Rocky Mountain juniper is commercially significant, and large amounts of seed are required to produce the nursery stock needed for planting in shelterbelts, parks, and landscapes, and on mine spoils or other disturbed sites. Fruits should be collected early enough in the fall to avoid losses to birds and animals, but immature fruits should not be gathered because they are difficult to separate from mature fruits *(18)*. Seeds may be stored either in the dried fruits or as cleaned seeds. A moisture content of 10 to 12 percent is considered satisfactory for long-term storage, and the clean seeds or dried fruits should be stored in sealed containers at -7" to 4" C (20° to 40°F).

Normally, Rocky Mountain juniper seeds germinate the second spring after a 14- to 16-month "after-ripening" period that breaks embryo dormancy. Low germination percentages and slow germination, with germination sometimes being delayed more than 2 years, are not unusual, however. These problems result from a combination of chemical factors in the embryo and physical factors, such as the thick, hard, outer layer of the two-layered seedcoat,

which has only a very small permeable area in the hilum *(1, 6)*.

Specific effects of passage through the digestive tract of a bird or animal on germination of Rocky Mountain juniper are not known; however, it could improve germination, as digestion acts as a scarification and acid treatment. A report on the pinyon—juniper type states that germination of juniper (species not indicated) was materially improved by such passage (30). Germination is epigeal *(18)*.

Figure *S-Three-year-old seedling, 30 cm (12 in) tall, showing immature, acicular foliage. This seedling was outplanted from 2-O containerized stock. Under natural conditions, at least 8 years of growth are needed to reach this size.*

Seedling Development-Under natural conditions, Rocky Mountain juniper seedlings become established more readily on moist sites under partial shade; in fact, the characteristic sparseness of Rocky Mountain juniper regeneration is due partly to its inability to establish itself on drier sites. The moist sites favored by Rocky Mountain juniper often are conducive to frost-heaving, however, which can take a heavy toll of seedlings. In nurseries, seedlings are best established on mulched seedbeds under partial shade *(2,18,42)*.

The seedlings, characterized by acicular foliage (sharp-pointed leaves) (fig. 3), develop slowly under natural conditions. They are reported to reach a height of 30 cm (12 in) in 8 years in northern New Mexico and Arizona. Their growth is more rapid in nurseries, where they often reach 15 cm (6 in) or more in 3 years. The preferred age for nursery stock for field plantings depends on the area and includes 2-0, 3-0, l-l, 1-2, 2-1, or 2-2 stock. Potting or

Figure *4-Fibrous, stringy bark, characteristic of mature Rocky Mountain juniper.*

balling Rocky Mountain juniper for field planting increases survival over bare root planting during dry years but adds considerably to the cost. During the fall, seedlings often change from the normal green to a bluish purple because of freezing weather, less precipitation, or changes in light intensity *(18,42)*.

Seedlings in the juvenile stages are sometimes confused with common juniper seedlings, but they do not have the basally jointed leaves of that species *(15)*.

Vegetative Reproduction-Rocky Mountain juniper does not reproduce naturally by sprouts or layering. Cuttings can be grown satisfactorily in a rooting medium if they are given a basal treatment of indolebutyric acid in talc and misted intermittently for 3 s/min *(12,42)*.

Sapling and Pole Stages to Maturity

In the sapling stage, Rocky Mountain juniper has mature foliage characterized by small, somewhat obtuse, scalelike leaves. The sapling bark is usually reddish brown and slightly rough and scaly, but not stringy and fibrous as when mature (fig. 4) *(14,15)*.

Mature Rocky Mountain juniper can vary from shrub size to small trees, with wide variation in crowns. Typically, it has a central trunk and a conical crown, slightly more rounded than eastern redcedar with which it is often confused (37). Branches are spreading, normally extending to ground level; small branches often droop slightly. Mature trees, as well as saplings, vary in color from light green or a yellowish green to dark green. The presence of mature fruits can give the tree a bluish-green or gray appearance.

Growth and Yield-Rocky Mountain juniper grows slowly and rather uniformly throughout its range; however, rates of growth have not been thoroughly studied. In the Southwest, average height at 40 years of age has been reported to be about 4 m (13 ft), indicating a growth rate of 10.3 cm (4.1 in) per year. At age 40, height growth declines to about 3.4 cm per year (1.3 in) until age 80, at which time trees average about 5 m (18 ft) tall. Thereafter, height growth is fairly uniform at 1.8 cm per year (0.7 in), producing trees 9 m (30 ft) tall at about 300 years of age. Diameter growth measured at 30 cm (12 in) above the ground (basal diameter) was also reported as slow, with a growth rate of 0.2 cm (0.08 in) per year, This growth rate is fairly uniform until the trees are about 170 years old or average about 33 cm (13 in) in basal diameter. The rate then declines over a period of about 40 years to another constant rate of about 0.08 cm (0.03 in) per year when the tree is 210 years old. This growth rate may be sustained until the tree is 300 or more years old. Basal diameters of trees 300 years old averaged 43 cm (17 in). The species is long lived, with ages of 300 years not uncommon. A relic specimen in western South Dakota was estimated to have been 750 years old when it died; one unusual specimen in Logan Canyon, UT, is reported to be 3,000 years old (4,421.

Tree growth varies considerably with location and site condition. In Canada, the trees usually grow to 30 cm (12 in) in basal diameter and 3 to 4 m (10 to 12 ft) tall, although a few trees reach 9 m (30 ft) in height. Trees on the north rim of the Grand Canyon are 5 to 6 m (15 to 20 ft) tall and 30 to 46 cm (12 to 18 in) in basal diameter. Heights of 6 to 15 m (20 to 50 ft) and basal diameters up to 46 cm (18 in) are reported from other areas of the Southwest *(14,42)*.

Rocky Mountain juniper is not recognized as a commercial timber species, so limited volume and growth prediction data are available. Stand yield prediction equations have been developed for the species in Colorado, Idaho, Utah, and Wyoming. Most information available is generalized and related to harvesting for fenceposts and firewood and to management of stands for watershed, range, wildlife, and shelterbelts. It is a fragile forest type and overcutting or improper management for livestock use reduces wildlife habitat and damages watershed *(5,30)*.

The future management of Rocky Mountain juniper as a forest type, of which only about 22 percent is in national forests, is unclear; furthermore, present conditions for management are not well known. As an associate of the pinyon-juniper type, the species is recommended for 200-year-rotation management and both even- and uneven-aged silvicultural systems can be applied. In the past, harvesting varied from light-cutting and high-grading to excessive overcutting; in recent years pinyon-juniper has been removed from large areas by chaining to increase forage for livestock. Except in limited areas in rather inaccessible places, few so-called virgin stands remain *(1,10,30)*.

Rooting Habit-Rocky Mountain juniper is considered to have a shallow but fairly extensive lateral root system, particularly where trees are growing over cemented subsoils or in rocky areas that limit depth of root penetration. The species develops a deeper root system along bottom lands with deeper soils. In the nursery, undercutting of third-year seedlings stimulates strong lateral root development *(18)*.

Reaction to Competition-Rocky Mountain juniper normally is a component of long-term seral

or near-climax vegetation. It is relatively shade-tolerant during the seedling and sapling stages, but it later becomes more intolerant and is unable to endure as much shade as eastern redcedar-its eastern counterpart. Rocky Mountain juniper requires top light for height growth and crown development, and trunk branches die out when it develops in overly dense, pure stands or under deep shade of other tree species. In the northern Rocky Mountains, it is considered less tolerant of shade than ponderosa pine, limber pine, or lodgepole pine but is reported to endure considerable shade from broadleaf trees in protected canyons and sheltered sites on the Pacific coast *(26,42)*. Overall, it is most accurately classed as a very shade-intolerant species.

In Utah, junipers have been observed to invade sagebrush stands under certain conditions; pinyon generally follows and has a tendency to replace the juniper. Pinyon-juniper may encroach into grasslands that have been overused or disturbed in some manner, as juniper germination and establishment are favored by mineral soil. Rocky Mountain juniper also has allelopathic properties that can inhibit establishment of competing grasses, forbs, and shrubs. Herbicides can be used to kill individual trees, to keep chained areas from revegetating, and to restore recently invaded grasslands. However, Rocky Mountain juniper and one-seed juniper are the most difficult of the juniper species to kill *(17,24,26,28,42)*.

Controlled burning to reduce competition from juniper species has had varied results. Insufficient ground-fuel and wide topographical and meteorological variables make it difficult to use fire throughout the entire range of Rocky Mountain juniper. Generally, fire has been more successful in the southern areas of the species' range (48).

Once established, Rocky Mountain juniper competes well with understory vegetation for water and minerals. In a shelterbelt study, its height growth exceeded Siberian pea shrub, green ash, boxelder, or American elm when competing with undisturbed sod-forming grasses. Removal of the sod did increase juniper growth, but not significantly (34).

Apparently no silvicultural guidelines or cutting methods have been developed for Rocky Mountain juniper. Its shade tolerance when young would tend to rule out the clearcut method. Development of shade intolerance with maturity might suggest a three- or four-step shelterwood system, should a need develop to grow and harvest Rocky Mountain juniper in pure stands.

Damaging Agents-Rocky Mountain juniper is susceptible to loss from erosion simply because it often becomes established on exposed sites where soils are readily eroded. Overuse of ranges by livestock, bison (in North and South Dakota), and occasionally deer can accelerate the erosion process.

Because animals use the trees as "rubbing posts," they cause considerable physical damage to stems and roots, including wounds that may admit pathogens. In addition, they browse the foliage when range conditions are poor and animal concentrations are high. This browsing, called "high-lining," reduces crown size, ultimately affecting growth and vigor.

Rocky Mountain juniper is attacked by a complex of arachnids, insects, and nematodes *(11,37)*. ***Two*** species of spider mites ***(Oligonychus ununguis*** and ***Eurytetranychus*** *admes)* feed on foliage and occasionally develop epidemic populations. Two species of juniper berry mites *(**Trisetacus quadrisetus*** and *T. **neoquadrisetus)*** that destroy the fruits have been reported in British Columbia and Oregon (35). A small red false spider mite ***(Pentamerismus erythreus),*** sometimes called red spider, is not rated as a forest pest but can be a serious problem in shelterbelts and landscape plantings.

Rocky Mountain juniper is host to several species of Coleoptera (true insects), Lepidoptera (butterflies and moths), Diptera (flies and midges), and Psyllids (jumping plant lice) that damage the roots, bole, twigs, foliage, and berries.

A nematode, ***Pratylenchus penetrans,*** has injured Rocky Mountain juniper seedlings by causing root lesions. The damage has been reported only in the nursery, where populations of the nematode have reached high levels (13).

A broad range of diseases associated with Rocky Mountain juniper attack the roots, stems, and foliage; but the most serious disease probably is a blight caused by ***Cercospora sequoiae.*** Some shelterbelts in the Great Plains have lost most of their junipers from this disease. Rocky Mountain juniper is also an alternate host for a cedar-apple rust *(**Gymnosporangium juniperi-virginianae)*** which can be a serious problem in the apple industry. The most conspicuous stem diseases are rusts caused by *Gymnosporangium* spp. and by mistletoes *(Phoradendron* spp.). These infestations generally are noted by the formation of twig excrescences, woody galls, and witches' brooms *(13,19)*.

Seedling diseases of Rocky Mountain juniper have not been thoroughly studied. It is normally resistant to damping-off fungi; however, *Rhizoctonia* ***solani*** has caused losses in Texas ***(12).*** Phomopsis blight ***(Phomopsis juniperovora)*** can destroy seedlings in the nursery and reduce survival of outplanted seedlings from partial blighting of the foliage. This blight is seldom found on trees older than 4 years; the

disease does not thrive under the dry conditions prevailing on most juniper sites. In some nurseries, juniper cultivars have developed magnesium-deficiency symptoms that were similar to symptoms of Phomopsis blight.

Ectotrophic mycorrhizae are rare on the Cupressaceae. Most *Juniperus* species examined have been primarily endomycorrhized. No fungi have been reported to form mycorrhizae with Rocky Mountain juniper. *Tuber griseum* and *T. melanosporum* have been reported with juniper species in general, however, and *Elaphomyces granulatus* had been reported for common juniper *(13,40)*.

Rocky Mountain juniper is susceptible to death or severe injury from fire, primarily because the fibrous, stringy bark is thin, and the lower branches contain significant amounts of volatile oils and normally extend to the ground *(13)*.

Special Uses

The early Indians made some use of juniper berries for food and decoration; the bark was woven into cradles and similar products as well as being used for torches. The most important use of Rocky Mountain juniper, however, was as firewood for cooking and heating, and today this is still a major use. Fuelwood volume tables that include Rocky Mountain juniper have been developed *(14,30)*.

The wood is fine grained, with white sapwood and deep red heartwood with faint purplish and whitish streaks. It is slightly lighter in weight and not as hard as that of eastern redcedar, but in color, odor, figure, and strength it could be substituted for its eastern counterpart. When cured, the wood, especially the heartwood, is resistant to decay; it has been cut heavily for fenceposts, particularly before the advent of steel fenceposts *(14)*.

The small size and rapid taper of the stems, with the consequent high cost of producing usable sawn material, have discouraged use for lumber. However, some sawn material has been cut from Rocky Mountain juniper for such use as closet lining, custom-built furniture, inlays, and cedar chests. The products are attractive; the colored heartwood also has been used for carvings and novelties, but only on a small scale *(14,30)*.

Genetics

Population Differences

Information on population variability of Rocky Mountain juniper is incomplete. Undoubtedly, any species with its scattered distribution and wide elevational and latitudinal range will show differences between subsets of the total population in such features as growth, morphology, phenology, and resistance to heat and cold. Recent studies on variations of terpenoids, other volatile oils, and isozymes are providing more information about differences not only among individuals but among segments of the population *(31)*. A study on the overlapping populations of Rocky Mountain juniper and eastern redcedar in the Missouri River Basin indicates that secondary inter-gradation (allopatric introgression) is occurring rather than primary intergradation (allopatric divergence), and the gene flow is primarily in an easterly direction (9).

Races and Hybrids

Hybridization and the development of races of Rocky Mountain juniper are complex. The whole population within the Missouri River Basin is reported to be a hybrid swarm of Rocky Mountain juniper and eastern redcedar, with neither of the extreme parental types being found; also, the trees tend increasingly toward Rocky Mountain juniper in a line from the southeast to the northwest. It has been shown that controlled hybridization between these two species is possible. A triparental hybrid swarm that includes horizontal juniper and eastern redcedar *(J. virginiana)* has also been reported in western portions of the northern Great Plains. In the Southwest, hybridization with alligator juniper has been reported *(7,8,14,46)*.

No subspecies have been identified for Rocky Mountain juniper. Two naturally occurring varieties have been reported. *J. scopulorum* var. *columnaris,* a columnar form, is found only in North Dakota. A depressed shrub, *J. s.* var. *patens,* found in Wyoming and Alberta, is considered to be a hybrid with horizontal juniper *(32,42)*.

Several horticultural and ornamental varieties have been reported. Most of these have been developed from the natural columnar variety in North Dakota and from the ornamental variety *J. scopulorum* var. *viridifolia,* called "Chandler Blue" and "Hill Silver" *(16)*. Other varieties include "Medora," a bluish, semicolumnar compact form; "Moffet," similar to Medora but somewhat less compact; "Welch," a blue-green pyramidal type with upright branches; "Pathfinder," a silver-blue type of more open form; "Color-green," a reasonably compact green variety; and "Hillborn Globe," a broad, blue-green pyramid form. Most of these varieties have been introduced into the horticultural trade as grafted specimens.

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