Pinus edulis Engelm. Pinyon

Pinaceae Pine family

Frank P. Ronco, Jr.

Pinyon *(Pinus edulis)* is a small, drought-hardy, long-lived tree widespread in the southwestern United States. Its common name is derived from the Spanish *piñon* which refers to the large seed of *pino* (pine). For this reason the tree is known in the Southwest and throughout its range by this Spanish equivalent (49). Other common names are Colorado pinyon, nut pine, two-needle pinyon, and two-leaf pinyon *(50)*. Its heavy, yellow wood is used primarily for fuel. Because of their delicate flavor its seeds are in much demand, making them its most valuable product.

Habitat

Native Range

As a codominant with juniper species *(Juniperus* spp.), pinyon trees (fig. 1) predominate in pinyon-

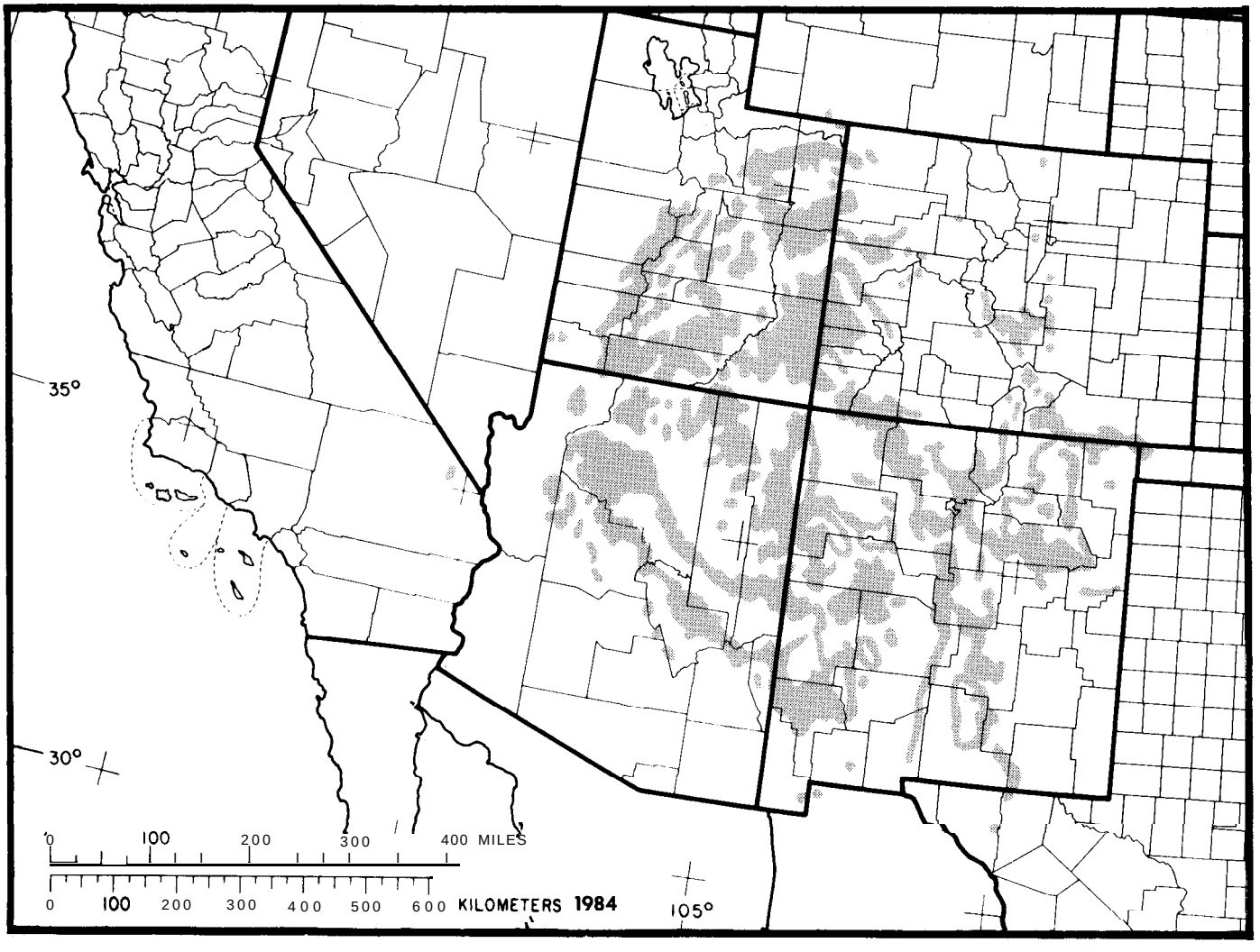

Figure *l-The native range ofpinyon.*

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juniper woodlands of the semidesert zone, which cover nearly 24.7 million ha (61 million acres), extending from Texas to California *(9)*. Woodlands in which pinyon is the major pine species cover about 14.9 million ha (36.9 million acres) in Arizona, Colorado, New Mexico, and Utah. Outliers in California, Oklahoma, Texas, and Wyoming contribute a relatively insignificant acreage to the total (48). However, the outlier in California has been considered a population of 2-needled individuals of single-leaf pinyon *(Pinus* ***monophylla),*** and more recently, a new species, California single-needle pinyon *(Pinus* ***californiarum)*** *(5,44)*.

Climate

The pinyon-juniper type occupies the lowest and warmest forested zone in the United States, with a climate generally characterized as semiarid, and locally as dry subhumid (65). Summers are hot and winters relatively cold, especially in northern locations and at high elevations. A high percentage of clear days, intense solar radiation, and windy conditions favor high evapotranspiration rates (67).

Annual precipitation, which varies widely throughout the type because of differences in elevation, topography, and geography, ranges from 250 mm (10 in) at low elevations where the type adjoins the desert or grassland vegetation to 560 mm (22 in) or higher at the upper reaches *(62,67,73)*. Locally, amounts as high as 690 mm (27 in) have been recorded, as along the Mogollon Rim in northern Arizona ***(15).***

Seasonal distribution, which also varies considerably, is related to prevailing storm patterns. In eastern New Mexico, for example, approximately 75 percent of the annual precipitation occurs during the warm season (April through September) from storms originating in the Gulf of Mexico, whereas the percentage decreases as these summer storms lose intensity during their northwesterly movement (62). Nevertheless, summer precipitation throughout much of northern Arizona and the south-central and eastern portions of Utah is still about equal to, or slightly greater than, winter moisture *(14,42)*. Furthermore, as much as one-third of the rainfall may occur during July and August *(67)*. In contrast, woodlands of Nevada and northern Utah receive more precipitation during the cool season (October through March), primarily from Pacific winter and spring storms *(13,14)*. Snow depths are not great, except at higher elevations and more northerly latitudes, but even then, melt generally occurs within a few days, especially on south-facing slopes *(62)*.

The mean annual temperature in pinyon-juniper woodlands varies from 4" to 16" C (40" to 61" F); extremes may fall to -35" C (–31° F) and reach 44" C (112° F). January means may be as low as -10" C (14" F) in the more northerly portion of the type, and about 6" C (43" F) near the southern limits. Mean July temperatures are less variable, ranging from 20" to 27" C (68" to 81" F). The frost-free period ranges from about 90 to 205 days, the shorter period typifying more northerly latitudes and higher elevations *(59,67,73)*.

Because of wide variation in temperature and the amount and distribution of precipitation, the following classification has been proposed to better characterize the climate of pinyon-juniper woodlands in Arizona and New Mexico (62):

Climate	Precipitation	
	Winter	Summer
	mm	
Cool, moist	230 to 280	180 to 230
Warm, moist	250 to 330	150 to 230
Cool, winter dry	130 to 180	180 to 230
Warm, winter dry	100 to 180	200 to 280
Cold, winter dry	100 to 150	200 to 250
Cold, summer dry	180 to 230	100 to 150
Warm, summer dry	180 to 230	100 to 150
	in	
Cool, moist	9 to 11	7 to 9
Warm, moist	10 to 13	6 to 9
Cool, winter dry	5 to 7	7 to 9
Warm, winter dry	4 to 7	8to 11
Cold, winter dry	4 to 6	8 to 10
Cold, summer dry	7 to 9	4 to 6
Warm, summer dry	7 to 9	4 to 6

Soils and Topography

Pinyon-juniper woodlands are located mainly on the more rocky plateaus, mesas, foothill terraces, and lower mountain slopes; shrubs or grasses grow on finer soils in intervening valleys, canyons, or shallow washes. Such discontinuities have been attributed to fire history and soil-related differences. The oldest pinyons are frequently found on steep, rocky sites where fire occurrence and severity are probably lower than in intervening areas, and consequently less damaging to trees *(37,41,67,73)*.

Discontinuities ascribed to soil differences may in fact be related to the greater amounts of water that coarser soils make available to the tree, as the different soils are adjacent and there are no obvious differences in climatic factors. Furthermore, pinyon-juniper woodlands are found on a wide variety of soil depths and textures that range from coarse, rocky gravels to fine, compacted clays, indicating little if

any correlation between these conditions and the presence of pinyon. Depth and texture, however, could affect productivity *(37,45,62,67).*

Woodlands also are associated with a broad range of soil Great Groups; of which Haplustalfs of the order Alfisols, Ustochrepts of the order Inceptisols, and Ustorthents of the order Entisols are the most common *(37,52,76).* Parent materials are equally varied, Sedimentary sandstones, limestones, and shales are most common, but materials of igneous origin, such as cinders and basalt, and those from metamorphic sources, also are found *(40,62,67).* In some soils, carbonates may accumulate and form a petrocalcic horizon (hardpan) that may extend as deep as 1.5 m (5 ft), but is usually much shallower. Upper layers of woodland soils generally exhibit pH values ranging from about 7 to 8.4, but at higher and wetter elevations, soils tend to be slightly acid in reaction, approaching 6.5 *(31,37,43,45,69).*

Pinyon-juniper woodlands are found between the low plains covered by grassland, desert shrub, or chaparral vegetation and the high mountains just below the zone dominated by either submontane shrubs or ponderosa pine *(Pinus ponderosa).* The lower limit of growth is probably related more to the inability of pinyon trees-especially seedlings-to tolerate water stress arising from decreasing precipitation and subsequent reduction of total moisture, rather than to soil or temperature factors. In contrast, the upper limit appears to be a function of greater biotic competition resulting from increased moisture *(10,67).*

In elevation, the woodlands lie mostly between 1370 and 2440 m (4,500 and 8,000 ft) (67). Individual pinyons, however, may extend up to 3200 m (10,500 ft) on south- and west-facing slopes in the mixed conifer forests of Arizona *(70),* while scattered juniper trees may descend to 910 m (3,000 ft) *(41).* Although the range in any given locality is considerably narrower, the elevational band occupied by woodlands is a rather uniform span of about 610 m (2,000 ft). There is a tendency, however, for the entire band to decrease in elevation in a southeasterly direction (72). In Arizona, the majority of the type is found between 1370 and 1980 m (4,500 and 6,500 ft), whereas in Colorado, the band extends from 1830 to 2440 m (6,000 to 8,000 ft). The bulk of the woodland in New Mexico and Utah occupies a zone from 1520 to 2130 m (5,000 to 7,000 ft).

Associated Forest Cover

Pinyon is a minor component of the following forest cover types *(61):* Bristlecone Pine (Society of American Foresters (Type 209), Interior Douglas-Fir (Type 210), Rocky Mountain Juniper (Type 220), Interior Ponderosa Pine (Type 237), Arizona Cypress (Type 240), and Western Live Oak (Type 241). It is an integral component in Pinyon–Juniper (Type 239) over a large area. However, as the type extends westward, pinyon is replaced by singleleaf pinyon *(Pinus monophylla)* in Nevada and some localities in western Utah and northwestern Arizona *(4,67).* Southward along the Mexican border, Mexican pinyon *(P. cembroides* var. *bicolor),* recently given separate species status as border pinyon *(P. discolor),* becomes the dominant tree in the woodlands *(6,48,49).*

Common associates of pinyon over most of its range are oneseed juniper *(Juniperus monosperma)* and Utah juniper *(J. osteosperma);* redberry juniper *(J. erythrocarpa),* also a one-seeded juniper, is confined to the southern portion. Alligator juniper *(J. deppeana)* and Rocky Mountain juniper *(J. scopulorum)* are also found in some localities *(1,4,67).* Oneseed juniper predominates in east-central Arizona and most of New Mexico, and extends into western Texas and southcentral Colorado. Rocky Mountain juniper is also a common component in northern New Mexico and the western half of Colorado, but it is found over most of the woodlands as well. It usually grows at higher elevations and is seldom dominant in the stand. Utah juniper is the codominant associate in Utah, northern Arizona, western Colorado, and northwestern New Mexico. At higher, more mesic elevations in southern and western New Mexico and westward into central Arizona, alligator juniper commonly forms a component of stands.

Although pinyon-juniper woodlands consist of relatively few tree species, stands exhibit considerable diversity in appearance and composition *(4).* Some have nearly closed canopies of a single tree species with little or no understory vegetation.

Figure *Z-The bushy form of trees in pinyon-juniper woodlands suggests an evergreen forest in which development has been stunted.*

Others are open, with widely scattered pines, junipers, or both among grasses and shrubs. A typical pinyon-juniper woodland, with its many-branched trees resembling shrubs, has the appearance of a stunted coniferous forest (fig. 2).

Any particular stand usually contains only a few different plant species, but because of the wide distribution of the type, the total flora associated with woodlands is quite varied *(4,67,73).* Common tree and shrub associates include: Gambel oak *(Quercus gambelii),* gray oak *(Q. griseu),* shrub live oak *(Q. turbinella),* true mountain-mahogany *(Cercocarpus montanus),* curlleaf mountain-mahogany *(C. ledifolius),* antelope bitterbrush *(Purshia tridentata),* big sagebrush *(Artemisia tridentata),* black sagebrush *(A. nova),* serviceberry *(Amelanchier* spp.), rabbitbrush *(Chrysothamnus* spp.), Mexican cliffrose *(Cowania mexicana),* Apache-plume *(Fallugia paradoxa),* skunkbush *(Rhus trilobata),* Mormon-tea *(Ephedra* spp.), yucca *(Yucca* spp.), opuntia *(Opuntia* spp.), broom snakeweed *(Gutierrezia sarothrae),* and buckwheat *(Eriogonum* spp.).

Some of the more important herbaceous plants are goosefoot *(Chenopodium graveolens),* rock goldenrod *(Solidago pumila),* gilia *(Gilia* spp.), penstemon *(Penstemon* spp.), segolily *(Calochortus nuttallii),* globemallow *(Sphaeralcea* spp.), white aster *(Aster hirtifolius),* hymenopappus *(Hymenopappus filifolius* var. *lugens),* Indian ricegrass *(Oryzopsis hymenoides),* dropseed *(Sporobolus* spp.), needleandthread *(Stipa comata),* squirreltail *(Sitanion hystrix),* Junegrass *(Koeleria pyramidata),* galleta *(Hilaria jamesii),* blue grama *(Bouteloua gracilis),* sideoats grama *(B. curtipendula),* ring muhly *(Muhlenbergia torreyi),* western wheatgrass *(Agropyron smithii),* bluebunch wheatgrass *(A. spicatum),* slender wheatgrass *(A. trachycaulum),* downy chess *(Bromus tectorum),* and threeawn *(Arisitada* spp.).

Life History

Reproduction and Early Growth

Flowering and Fruiting-Pinyon is considered monoecious, the male and female strobili being borne on the same tree *(67).* However, dioecy has been observed under certain environmental conditions associated with moisture stress and insect damage *(23,74).* Although ovulate cones require most of three growing seasons to mature, the stages of growth vary with elevation, weather, and individual trees. In general, winter buds containing the strobili primordia begin to form in August, and by October of the first year are fully formed. Bud growth the following year is resumed near the first of May for staminate cones, and about mid-May for ovulate cones. By mid-June, staminate cones are mature, and ovulate cones become visible and receptive to pollen. Pollination is completed by the end of June when cone scales close, and a period of rapid growth of cones and seed commences, terminating at the end of August. During the third year, conelets start growth about the first of May, and fertilization occurs in early July. Shortly thereafter, cones and seeds reach full size, and seed coats darken and harden. Seeds mature early in September, and cone opening begins during mid-month and extends for about a 50-day period.

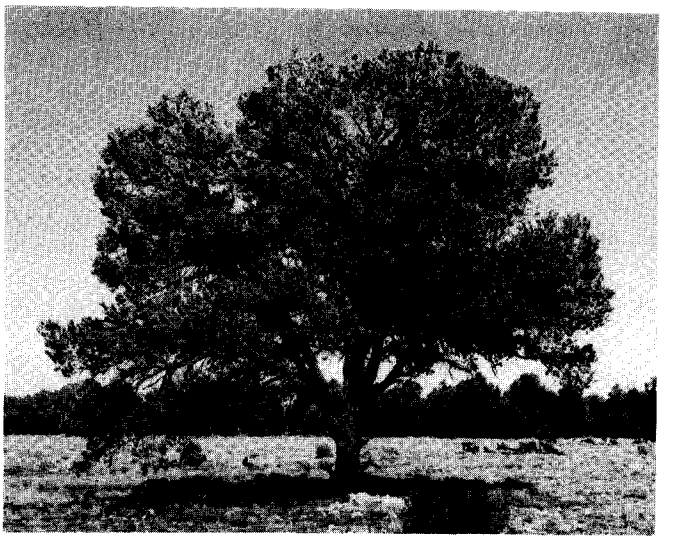

Figure *3-A mature, broad-crowned pinyon such as this should be a heavy seed producer.*

Seed Production and Dissemination-Trees reach cone-bearing age when relatively young: 25 years old and 1.5 to 3.0 m (5 to 10 ft) tall. Seeds are not produced in quantity, however, until age 75 to 100, but the long-lived pinyons continue to bear for a few centuries. A mature pinyon usually has a broad and rounded or irregular crown, which is often almost as wide as the tree height. Such trees are the heaviest seed producers, since cones are found mostly in the upper half of the crown near the ends of branches (fig. 3). Each cone contains about 10 to 20 seeds, which average only 4,190/kg (1,900/lb) because of their large size. A large tree in a good crop year may yield over 9.1 kg (20 lb) of seed, and better stands will produce an estimated 336 kg/ha (300 lb/acre). Germinative capacity of seeds may range between 83 and 96 percent; germinative energy is about 80 percent in 7 days *(9,30,67,68).*

Cone crops are either good or poor, often with cones practically absent, but seldom intermediate

(67). Although good crops tend to be localized and occur at irregular and infrequent intervals, some are found nearly every year somewhere over the widespread range of the species. Furthermore, cone bearing tends to be synchronous over large geographical areas, a condition considered to be an evolved mechanism to counteract seed predation (46). On an average, substantial crops are produced every 4 to 7 years, but shorter intervals of 2 to 5 years elapse with individual trees or in certain localities (9). Generally, crops occur more frequently on better sites over the optimum range of pinyon than at the extreme limits.

The large, wingless seeds of pinyon are not adapted to wind dissemination. Instead, seed dispersal beyond tree crowns depends upon the behavior of four corvid species of birds-Clark's nutcracker, Steller's jay, scrub jay, and pinyon jay *(8)*. Although these species eat great quantities of seed during the fall and may be greater predators than rodents, they also cache large amounts for consumption during ensuing winter months. Some of these buried seeds are not recovered by the birds, thus providing a seed source for subsequent germination and seedling establishment, particularly if caches are located in a suitable microenvironment, such as alongside shrubs or downed trees (46). Steller's and scrub jays collect seed only from open cones. In contrast, pinyon jays and Clark's nutcrackers forage from green cones, from which seeds are deftly extracted, and then from open cones as the season progresses *(8,71)*.

Clark's nutcrackers and Steller's jays probably contribute little towards regenerating existing woodland sites because their caches are located at higher elevations in ponderosa pine and mixed conifer forests or in the ecotone above pinyon-juniper woodlands (8). Thus, these species tend to expand woodlands to upper elevations. In contrast, scrub jays and pinyon jays cache seeds in woodland areas, the former in small, local territories, whereas the latter transport seeds up to 12 kilometers (7.5 mi).

Pinyon jays live in flocks of 50 to 500 birds, and it has been estimated that during a substantial seed year in New Mexico, about 4.5 million seeds were cached by a single flock (46). Even scrub jays, which do not exhibit flock behavior can be important seed dispersers-a single pair of birds may harvest and cache about 13,000 seeds from a particular crop. Pinyon jays can carry an average of up to 56 seeds in an expandable esophagus. Scrub jays lack this adaption, and the amount of seed that can be transported at one time is limited to 5 or fewer seeds held in the mouth and bill. The majority of caches by pinyon and scrub jays are single-seeded, and are located in the transition zone between mineral soil and the overlying organic material *(8,71)*.

Although rodents are known to cache seed, they should not be considered effective seed dispersers because caches are located in middens or underground chambers where conditions are not suitable for germination or seedling establishment. Instead, rodents, such as cliff chipmunks, pinyon mice, and woodrats, are major predators, caching as much as 35 to 70 liters (1 to 2 bu) of good seed *(46,67)*. Furthermore, limited data indicate that rodents consume large quantities of seeds taken from bird caches (32).

It has been suggested that pinyon trees and seed eating birds have evolved coadaptive traits that enhance survival of both organisms. The seed dispersing and caching behavior of birds appears related to certain traits of the trees: large, thin-coated seeds with high energy values, different colored seedcoats that aid visually oriented seed harvesters to distinguish edible from aborted seeds, upward orientation of cone and scale angle for increased seed visibility, and prolonged seed retention in open cones because of cone orientation and deep depressions and small flanges on cone scales (70). Furthermore, the mutual dependence of birds and trees appears more complex than just their respective roles of seed dispersing and food providing agents. Gonadal activity of pinyon jays, for example, is increased before the breeding season by the combined effect of photoperiod, the appearance of cones, and a diet of seeds (46).

Seedling Development-Natural regeneration is difficult to achieve, primarily because of unfavorable climatic conditions, but seed predation and heavy grazing pressure, especially by sheep and goats, also play a role (67). Although pinyon grows best in full sunlight and can germinate in the open, seedlings must be protected from the harsh environment *(21,31,35,46,49)*. Regeneration is usually achieved in the shade of tree canopies, under shrubs such as rabbitbrush, mountain-mahogany, and sagebrush, or alongside fallen trees.

Optimum germination temperature for pinyon seed is about 21" C (70" F). Germination is epigeal (68). Preliminary studies indicate that germination can be significantly improved by washing seeds for 48 hours in running tap water. Cold stratification for 30 or 60 days increases speed of germination but not the percentage. Treatment with hydrogen peroxide to suppress mold and enhance germination generally is not effective. Seeds germinate in spring and summer following dispersal, depending on soil moisture and temperature, with summer germination coinciding with the onset of the rainy season. Also, seedling establishment probably depends on an adequate

moisture supply during the first summer *(29,30,54,66,68)*. Growth throughout the seedling stage is extremely slow, often with only primary needles developing the first year, and subsequent height growth averaging 2.5 to 5.0 cm (1 to 2 in) per year (67).

Vegetative Reproduction-Pinyon is not known to reproduce vegetatively.

Sapling and Pole Stages to Maturity

Growth and Yield-Pinyon grows best on the higher, wetter sites of the woodland zone, just below the ponderosa pine type (40,671. At these elevations trees reach their tallest heights and tend to develop single stems (fig. 4). At lower elevations, in contrast, bushy and sprawling crowns are characteristic. Pinyons may be multistemmed, although to a lesser extent than junipers. They usually exhibit straight, but short and rapidly tapering boles, which diverge into many large sinuous branches.

Growth of pinyon, though maintained with little loss of vigor throughout the life of the tree, is extremely slow. Height growth of saplings, for example, is only about 10 to 15 cm (4 to 6 in) yearly, and mature trees grow even more slowly, averaging 5 to 10 cm (2 to 4 in) per year. Diameter growth also is slow, especially on poor sites, where 80 to 100 years can elapse before diameters at breast height reach even 10 to 15 cm (4 to 6 in). On better soils, however, 150-year-old trees may grow to a diameter of 30 cm (12 in). Mean annual diameter growth of pinyon culminates at about 1.8 cm (0.7 in) per decade, when trees are approximately 50 years old. The gross annual increment on sample plots in northern New Mexico woodlands also reflects the slow growth rate, averaging about 0.42 m^3/ha (6 ft^3/acre) for pinyon alone, and 0.66 m^3/ha (9.5 ft^3/acre) for all species. Gross cordwood increment for all species was 0.88 m^3/ha (0.14 cord/acre) *(38,66,67)*.

Pinyon is a long-lived tree, maturing in 75 to 200 years. Dominant trees in a stand are often 400 years old, and pinyons 800 to 1,000 years old have been found. Depending on the site, mature trees range between 3.0 and 15.5 m (10 to 51 ft) in height and 15 to over 76 cm (6 to 30 in) in d.b.h. Although large trees are common, especially in northern New Mexico, pinyons generally are small trees, usually less than 10.7 m (35 ft) tall and 46 cm (18 in) in diameter *(66,67)*. The largest living pinyon recorded grows in New Mexico and measures 172 cm (68 in) in d.b.h., 21.0 m (69 ft) in height, and has a crown spread of 15.8 m (52 ft) (2).

Because of the growth habit of woodland species, tree volumes are not only difficult to measure but can vary more than 300 percent for trees of the same diameter. There is less variation in well-formed trees, however, and the gross volume of a representative pinyon with a basal diameter of 30 cm (12 in) and 7.6 m (25 ft) tall is 0.22 m^3 (7.7 ft^3), measured to a 10-cm (4-in) top. Woodland volumes vary considerably, depending on species composition and density. In northern New Mexico and Arizona, mixed stands may contain cordwood volumes ranging from about 5.0 to 157.4 m^3/ha (0.8 to 25 cords/acre), with average volumes of about 69.3 m^3/ha (11 cords/acre). Cordwood volumes of nearly pure pinyon stands average about 75.6 m^3/ha (12 cords/acre). Low volumes are a reflection of the small trees generally associated with woodlands. The average size tree in

Figure 4—*Pinyons develop best at higher elevations, tending to form single stems.*

many New Mexico stands is only 15 cm (6 in) in diameter at ground line and about 2.7 m (9 ft) tall *(16,67)*.

The density of pinyon in woodlands varies considerably, ranging from few or none to several hundred stems per hectare. Nevertheless, the density in a typical northeastern Arizona stand averages about 235/ha (95/acre) in stems less than 7.6 cm (3 in) in d.b.h.; 200/ha (81/acre) from 7.6 to 15 cm (3 to 6 in) in d.b.h.; and 89/ha (36/acre) more than 15 cm (6 in) in d.b.h. (67). Mixed woodlands are denser and more productive than pure stands of either pinyon or juniper, and can approach or exceed 3,459 stems/ha (1,400/acre) *(9,57)*. The higher values have been attributed to differences in rooting habit and drought tolerance of the two species. The shallower penetrating roots of pinyons limit interspecific root competition for soil moisture in mixed stands. This, combined with the lower photosynthetic rate of pinyons compared to that of junipers at higher water stresses, allows more complete site utilization in mixed stands *(10,25,57)*. The average number of pinyons suitable for Christmas trees varies from a few trees per acre to a fairly large number.

Rooting Habit-The rooting habit of pinyon is characterized by both lateral and vertical root systems *(67)*, but roots of pinyons less than 3 m (10 ft) tall have been traced to depths 6.4 m (21 ft) in underlying rock (25). Taproots and some laterals that penetrate downward, however, grow horizontally when they encounter an impenetrable horizon or bedrock. Laterals develop at a depth of about 15 to 41 cm (6 to 16 in) and can exceed the crown radius by a factor of two or more. Taproot growth of seedlings is rapid, averaging 17 to 27 cm (7 to 11 in) in length for l-year-old seedlings (35). The extensive root system and relatively rapid rate of root elongation, especially of young seedlings, enhance the ability of pinyon to survive under arid environments.

Reaction to Competition-Pinyon is a sun-adapted plant and is classed as intolerant of shade (67). It also appears unable to compete with grasses for moisture during the seedling stage following germination (4).

Secondary succession following fire or other severe disturbance in pinyon-juniper 'woodlands appears to follow the general successional model shown in figure 5 (3). However, the first herbaceous species to become established after a fire are often those that were present in the stand before disturbance *(19)*. The shrub stage, often consisting of sagebrush, a common associate in the woodlands, becomes prominent after about 12 years *(11)*. Junipers, which appear to have a wider ecological amplitude than pinyons because of their greater drought resistance, are usually the first trees to regenerate *(10,12,75)*. They rapidly increase in density after 45 years, and dominate the site at 70 years. Thereafter, pinyons tend to succeed junipers at rates determined by available seed sources until the shrub understory is essentially eliminated. If disturbances are less severe, as when cabling, chaining, or bulldozing is used to remove tree cover for range improvement, many small surviving pinyons and junipers and newly established seedlings, reforest the site in about 2 to 3 decades *(55,56,64)*. Under some conditions, however, natural regeneration can take much longer *(60)*.

Considerable evidence has accumulated to show that the woodlands, especially those dominated by singleleaf pinyon, are invading areas below their historic elevational limits *(3,12,17,41)*. Furthermore, tree density appears to be increasing in some stands that existed before the invasion period. Pinyon–juniper woodland expansion since the time of settlement has been attributed to several factors, including possible climatic changes, control of fire, increased populations of seed-dispersing birds and mammals, and reduced competition from grasses resulting from overgrazing by livestock or the allelopathic influence of juniper foliage and litter *(20,39)*.

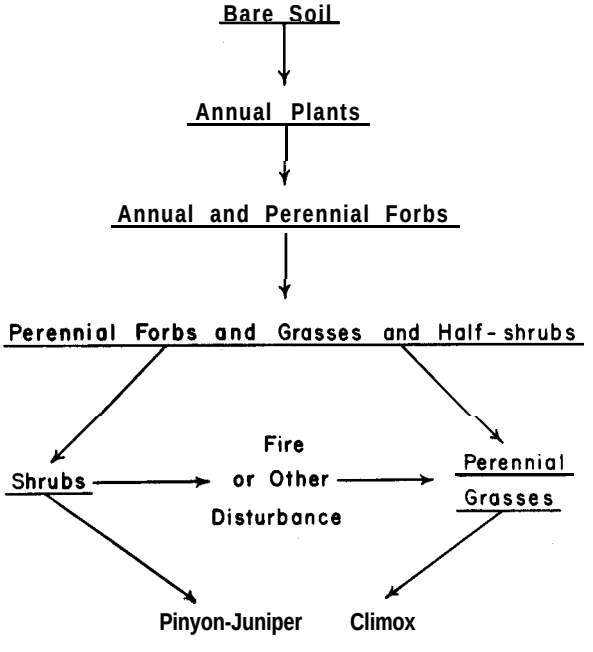

Figure *5-Possible seres and pathways of secondary succession following disturbance in pinyon-juniper woodlands (3).*

Damaging Agents-Small pinyons 1 to 2 m (3 to 6 ft) tall are readily killed by fire, but larger trees appear more resistant. Fire is generally not a serious problem, however, because stands are open and understory fuels are sparse. Where vegetation is dense and weather conditions favorable, fire has been effective as a treatment for converting woodlands to grasslands *(3,18,40)*.

Among insects most commonly attacking the vegetative portion of trees are pinyon pitch nodule moth *(Petrova albicapitana arizonensis)*, tiger moth *(Halisidota ingens)*, mountain pine beetle *(Dendroctonus ponderosae)*, pinyon sawfly *(Neodiprion edulicolus)*, adelgid *(Pineus coloradensis)*, pinyon needle scale *(Matsucoccus acalyptus)*, pine needle scale *(Chionaspis pinifoliae)*, Arizona fivespined ips *(Ips lecontei)*, pinyon ips *(Ips confusus)*, pinyon needle miner *(Coleotechnites edulicola)*, pinyon tip moth *(Dioryctria albouittella)*, and gallmidges (*Pinyonia* spp., *Janetiella* spp., and *Contarinia* spp.) *(22,24,27,28,63,67)*. The most damaging cone and seed insects include cone moths *(Eucosma bobana)* and the pinyon cone beetle *(Conophthorus edulis)*. Many species of nematodes, especially in the *Helocotylenchus, Tylenchus,* and *Xiphinema* genera, are parasitic on pinyon roots, but their effect on growth in natural stands is unknown (53).

A number of foliage diseases have been reported on pinyon, including needle casts *(Elytroderma deformans* and *Bifusella saccata)* and needle rusts *(Coleosporium jonesii* and *C. crowellii) (36,67)*. Pinyon blister rust *(Cronartium occidentale)* and pinyon dwarf mistletoe *(Arceuthobium divaricatum)* cause stem diseases, the latter being considered the major pathogen of pinyon. *Verticicladiella wagenerii*, a root rot, is also ranked high as a damaging agent; principal heart rots are red-ring rot *(Phellinus pini)* and brown cubical rot *(Fomitopsis pinicola)*. *Armillaria mellea* and *Phaeolus schweinitzii* are not particularly important diseases, but both cause root rot and butt rot.

Special Uses

Firewood is the product derived from pinyon-juniper woodlands that has been used most widely and for the longest time and it continues to be the primary energy source for the rural population of small communities in much of the Southwest *(9,60)*. Pinyon is preferred for fuelwood since it has a higher heat value than any of its associates except the oaks and burns with a pleasing and distinctive aroma.

Although pinyon has physical properties similar to those of ponderosa pine and is suitable for processing, it is not extensively used for sawn products because of poor growth form and small size *(9,51)*. Specialized woodworking shops use pinyon for novelties, and small sawmills produce mine timbers and railroad ties. The ties are used primarily in open pit mines because of their toughness and resistance to breakage during frequent rail line shifts. Pinyon has been used for pulping in the Southwest, but only to alleviate shortages of normally used mill-residue chips and pulpwood of other species. It is also occasionally processed for charcoal.

The edible nuts of pinyon are probably the most valuable product of the species and are in great demand because of their delicate flavor *(9,67)*. Annual nut crops have been estimated to average between 454 000 and 907 000 kg (1 to 2 million lb), reaching 3.6 million kg (8 million lb) in an exceptionally productive year. Commercial crops are practically nonexistant in some years, however. Nuts are commonly sold and consumed after roasting in the shell, but small quantities are sold raw. A limited retail market exists for shelled nuts, which have also been used in candies and other confections.

Pinyons have been cut for private use for Christmas trees for many years and have recently appeared on commercial lots *(9)*. In states with large acreages of pinyon-juniper woodlands, up to 40 percent of the yearly harvest in the past has been reported as pinyon. Demand has decreased since 1960, however, when 294,000 trees were harvested, ranking pinyon as 13th nationally. The decline has been attributed to an increasing supply of other plantation-grown species and the scarcity of high-quality trees in easily accessible stands.

Pinyon-juniper woodlands over the past 400 years have been, and will continue to be, grazed extensively (62). Futhermore, range improvement practices to increase forage for wildlife and livestock have removed the woodland trees over large areas. Woodland watersheds also have been mechanically cleared or chemically treated in the past, but future treatments may be limited to specific areas, because the possibility of generally increasing water yield does not appear promising *(7,9,15)*.

Pinyon-juniper woodlands provide a habitat for a varied wildlife population (26). Mule deer, white-tailed deer, elk, desert cottontail, mountain cottontail, and wild turkey provide increasing hunter recreation. Pinyon nuts are a preferred food for turkeys, but in poor seed years, juniper mast is extensively consumed (58). Similarly, deer subsist on browse species, but pinyon is a common food particularly during harsh winters with deep snows *(33,34)*.

Genetics

Population Differences

A form of pinyon that extends southeastward from northwestern Arizona into southwestern New Mexico in the mountains south of the Mogollon Rim has been classified as a taxonomic variety, *F! edulis* var. ***fallax*** (47). Others considered it a local variant of singleleaf pinyon (44). More recently, however, it has been recognized as a subspecies of a newly described species of nut pine—*Pinus californiarum* subsp. *fallax* (Arizona single-needle pinyon) (5).

Practically no information is available regarding population differences of pinyon. Considering the wide range of the species and the different environmental conditions under which it grows, differences would be expected. It has been reported that seed size is relatively consistent from year to year in individual trees but varies among trees (67). Also, some trees generally produce more cones than others, and some bear larger cones with more seeds per cone.

Races and Hybrids

No races of pinyon have been recorded. Natural hybridization has been reported between pinyon and singleleaf pinyon in three zones common to the species-the eastern edge of the Great Basin, the mountains south of the Colorado Plateau, and areas adjacent to the Colorado River and its major drainages (44). The two species also have been artificially crossed. Pinyon and the newly described Arizona single-needle pinyon also are known to hybridize (5).

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