

CEDRUS—THE TRUE CEDARS

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Abstract. The true cedars (genus *Cedrus*) are valuable timber trees and striking specimen plantings in the urban landscape that grow well in a variety of soil and climatic conditions. The wood is durable and decay resistant. Cedars have been successfully introduced into areas outside of their natural range. The 4 species of *Cedrus*, 3 of which are planted to some extent in the United States, are *C. atlantica* (Atlas cedar), *C. brevifolia* (Cyprian cedar), *C. deodara* (Deodar cedar), and *C. libani* (Cedar of Lebanon). In this review, the geographical distribution, taxonomic characteristics, propagation, and adaptation to the urban landscape of cedars are discussed. This information is relevant to horticulturists, botanists, foresters, and anyone interested in the field of arboriculture.

Key Words. *Cedrus*; *C. atlantica*; *C. brevifolia*; *C. deodara*, *C. libani*; cedar.

GEOGRAPHICAL DISTRIBUTION

The true cedars consist of 4, or fewer, closely related species of tall, oleoresin-rich, monoecious, coniferous, evergreen trees, with geographically separated distributions (Maheshwari and Biswas 1970; Liberty Hyde Bailey Hortorium 1976; Arbez et al. 1978; Farjon 1990; Hillier 1991; Vidakovic 1991; Bariteau and Ferrandes 1992; Tewari 1994). The cedars are restricted to the montane or high montane zones of mountains, situated roughly between 15° W and 80° E and 30° to 40° N (Farjon 1990). This discontinuous range is composed of 3 widely separated regions in North Africa and Asia: 1) the Atlas Mountains of North Africa, in northern Morocco and northern Algeria; 2) Turkey, the mountains on Cyprus and along the eastern border of the Mediterranean Sea in Syria and Lebanon; and 3) the Hindu Kush, Karakoram and Indian Himalayas (Farjon 1990). The 4 species of *Cedrus*, *C. atlantica* (Endl.) Manetti ex Carriere, *C. brevifolia* (Hook. f.) Henry, *C. deodara* (Roxb.) G. Don in Loud., and *C. libani* A. Rich., are so closely related that habitual characteristics help differentiate the species (Farjon 1990). Isozyme analysis of *Cedrus* diploid tissue raises questions about the separation of *C. atlantica* and *C. libani* into 2 distinct species, because no distinguishing gene marker was detected (Panetsos et al. 1992). Us-

ing allozyme differentiation, Scaltsoyiannes (1999) determined that these 2 species should be separated into distinct taxa. There is disagreement as to the exact taxonomic status of the various cedars, with some authors suggesting that they be reduced to only 2 species, *C. deodara* and *C. libani*. This review examines all 4 species.

The cedars are valuable timber trees and are quite striking as specimen plantings in the landscape. The wood of *C. libani* is fragrant, durable, and highly decay resistant. On a historical note, the ancient Egyptians employed cedar sawdust (cedar resin) in mummification (Maheshwari and Biswas 1970; Demetci 1986; Chaney 1993). Upon distillation of *Cedrus* wood, an aromatic oil is obtained that is used for a variety of purposes from scenting soap to medicinal practices (Maheshwari and Biswas 1970; Adams 1991; Chalchat et al. 1994; Tewari 1994). The 4 species of *Cedrus*, 3 of which are planted to some extent in the United States, are *C. atlantica* (Atlas cedar), *C. brevifolia* (Cyprian cedar), *C. deodara* (Deodar cedar), and *C. libani* (Cedar of Lebanon).

TAXONOMIC CHARACTERISTICS

Cedrus atlantica is a large tree attaining a height at maturity of 9 to 40 m (29.5 to 131 ft), with rapid growth when young, and is closely related to *C. libani*. The Atlas cedar is distinguished by a taller crown, less densely arranged branchlets, bluish green leaves (needles) that vary from light green to silvery blue, smaller cones 5 to 8 cm in length by 3 to 5 cm in width (2 to 3 in. by 1 to 2 in.), and smaller seeds (Dirr 1990; Farjon 1990; Loureiro 1990, 1994; Hillier 1991). Young trees appear stiff, with an erect leader and an overall pyramidal shape, but with maturity this species assumes a flat-topped habit with horizontally spreading branches (Dirr 1990). *Cedrus atlantica* is hardy in U.S. zones 6 to 9, with several beautiful cultivars that differ in color and characteristic habit (Dirr 1990; Hillier 1991; Vidakovic 1991). Of special note is 'Glauca' (f. *glauca*), a spectacular tree with intense blue to silvery blue leaves, used for specimen plantings (Dirr 1990; Hillier 1991).

Cedrus brevifolia is a rare species with slow growth, but eventually develops into a medium-sized tree, attaining a height at maturity of 8 to 24 m (26 to 79 ft). The Cyprian cedar is distinguished from *C. libani* only by the habitual form, shorter leaves 0.5 to 1.6 cm in length (0.2 to 0.6 in.), and on older specimens the crown is broad and umbrella-shaped (Farjon 1990; Hillier 1991; Vidakovic 1991).

Cedrus deodara is an excellent specimen tree. The habit of the Deodar cedar is broadly pyramidal when young, with gracefully pendulous branches (Dirr 1990; Tewari 1994). It can attain a height at maturity of 15 to 50 m (49 to 164 ft). It is distinguished from the other species by its drooping leader and longer leaves that are 2 to 6 cm in length (0.8 to 2.4 in.) (Hillier 1991). Multi-stemmed crowns occasionally evolve from the higher branches turned erect, but the crown seldom becomes flat-topped, remaining conical or pyramidal (Farjon 1990). *Cedrus deodara* is hardy in U.S. zones 7 to 8, but young trees in these zones are prone to injury from frosts and cold wind (Dirr 1990). There are many cultivars of Deodar cedar, but 2 outstanding examples are 'Kashmir' and 'Shalimar'. The cultivar 'Kashmir' is a hardy form, tolerating cold winters to -30°C (-22°F), and is characterized by its silvery blue-green foliage (Dirr 1990; Vidakovic 1991). The cultivar 'Shalimar' displays good blue-green leaf color and is the hardiest cultivar planted in the United States (Koller 1982; Dirr 1990).

Cedrus libani is a majestic tree 15 to 40 m (49 to 131 ft) in height at maturity with innumerable scriptural and historical references. Cedar of Lebanon has a thick, massive trunk and wide-spreading branches and is pyramidal when young, but develops a flat-topped crown and horizontally tiered branches when mature (Dirr 1990; Farjon 1990; Hillier 1991; Chaney 1993). The dark green foliage, stiff habit, and rigidly upright cones that are 8 to 12 cm in length by 3 to 6 cm in width (3 to 4.7 in. by 1 to 2.4 in.) give this tree its splendor for landscape specimen planting. The morphological differences between *C. libani* and *C. atlantica* are small and not entirely constant (Maheshwari and Biswas 1970; Farjon 1990). Cedar of Lebanon is hardy in U.S. zones 5 to 7 (Dirr 1990; Dirr et al. 1993). A geographical form, *spp. stenocoma* (Schwarz) Davis, differs from the typical Lebanon cedar in having a broadly columnar habit, needle and cone character-

istics intermediate between *C. atlantica* and *C. libani*, and being more cold-hardy (Hillier 1991; Vidakovic 1991). There are also several dwarf cultivars of *C. libani* of interest for use in the landscape (Hillier 1991; Vidakovic 1991).

The male flowers of *Cedrus* are erect catkins, up to 5 cm (2 in.) in length, whereas the female flowers are erect, cone-like inflorescences, 1 to 1.5 cm (0.4 to 0.6 in.) long, surrounded by needles at the base (Vidakovic 1991). Male and female strobili of the true cedars are typically borne on the same tree but on separate branches (Maheshwari and Biswas 1970; Rudolf 1974; Farjon 1990). The male cones grow solitary, more or less erect from the short shoots, and bear abundant yellow pollen (Maheshwari and Biswas 1970; Farjon 1990). Depending upon the altitude, locality, and weather, the pollen is shed late in the year (autumn), relating to the late development of the female strobilus (Maheshwari and Biswas 1970; Farjon 1990). The female cones are borne singly at the tips of the dwarf shoots, stand erect, and are less abundant than the male cones (Maheshwari and Biswas 1970; Farjon 1990). Although pollination takes place in the fall, the cones do not mature until the second year, requiring about 17 to 18 months for full development (Maheshwari and Biswas 1970; Rudolf 1974; Farjon 1990).

The mature, barrel-shaped cones are resinous and characterized by numerous closely appressed, very broad scales, each containing 2 seeds (Rudolf 1974). The scales are attached to the persistent rachis with a narrowed, petiolate base and dismember from it by abscission at maturity, as in *Abies* (Rudolf 1974; Farjon 1990). The irregularly triangular mature seed is rather soft and oily, with resin vesicles present on each side of the seed, and has a membranous, broad wing several times larger than the seed (Rudolf 1974; Farjon 1990). Commercial seed bearing of *C. deodara* begins from 30 to 45 years of age, and good seed crops are usually borne every 3 years, with light crops in the intervening years (Maheshwari and Biswas 1970; Rudolf 1974; Toth 1979; Doty 1982; Tewari 1994).

PROPAGATION

Cones should be collected directly from the trees, before the cones turn brown, or cone-bearing twigs may be cut from standing or felled trees just before ripening

is complete (Rudolf 1974; Dirr and Heuser 1987; Singh et al. 1992). A cubic meter (28.4 bushels) of cones weighs from 12.2 to 15.9 kg (27 to 35 lb) and yields about 1.4 kg (3 lb) of cleaned seed (Rudolf 1974). Cones should be allowed to dry until the scales loosen and the seeds can be removed (Toth 1980a; Macdonald 1986; Dirr and Heuser 1987). It is important to avoid any more drying than is absolutely necessary, because the seeds may be killed. Cones of *Cedrus* may be soaked in warm water for 48 h to encourage them to disintegrate (Rudolf 1974; Macdonald 1986). Freezing moist cones (as a last resort) will also force the scales to open up (Macdonald 1986). After the cone scales are dry, they can be placed in a cone shaker to remove the seeds (Rudolf 1974), and seeds separated from the debris by fanning or sieving (Macdonald 1986). Dewinging is done by simply rubbing the seeds in a dry cloth (Macdonald 1986). Resin from the resin pockets in the wings can make the procedure difficult if bare hands are used (Macdonald 1986). Purity of commercially cleaned seed has ranged from 85% to 90%.

The seeds of *Cedrus* are oily and do not keep well under ordinary storage conditions (Rudolf 1974; Allen 1995). If *Cedrus* seeds are dried below a critical level, they will not imbibe water in a way that will allow the food reserves to be used by the embryo (Macdonald 1986). *Cedrus* seed has retained viability for 3 to 6 years when dried to a moisture content of less than 10%, placed in sealed containers, and held at temperatures of -5°C to -1°C (23°F to 30.2°F) (Rudolf 1974; Erkologlu 1995).

Cedrus seeds exhibit little or no dormancy and will germinate without pretreatment. However, variable degrees of dormancy may be observed within a single lot of seeds (Dirr and Heuser 1987). Seed should be stratified at 3°C to 5°C (37.4°F to 41°F) for 2 weeks (6.5 weeks for *C. brevifolia*) to give more uniform germination (Rudolf 1974; Allen 1995). Thapliyal and Gupta (1980) found that 9°C (48.2°F) was a better temperature for stratification than 3°C . *Cedrus deodara* and *C. libani* seeds are prone to damping-off disease caused by *Fusarium*, *Rhizoctonia*, and *Pythium* species. Therefore, an appropriate fungicide should be used (Mittal 1983; Tewari 1994). Gordon et al. (1991) and Suszka et al. (1996) provide extensive information on the sampling, purity, viability and germination testing, seedling evaluation, and storage of forest tree and shrub seeds. Specific procedures are presented for a number of species.

The Association of Official Seed Analysts rules for *Cedrus* (Rudolf 1974) specify germination tests of stratified seed on top of blotters for 3 weeks at 20°C (68°F) (see also Toth 1980a). International Seed Testing Association rules, however, specify diurnally alternating temperatures of 20°C at night and 30°C (86°F) during the day for a period of 4 weeks (Rudolf 1974). Light apparently is not required (Rudolf 1974). Tests may also be made in sand flats (Rudolf 1974). *Deodar* seed stratified at 4°C (39.2°F) in moist sand for 30 days germinated 45% versus 11% without stratification (Dirr and Heuser 1987). Thapliyal and Gupta (1980) also found the percentage of germination without stratification to vary from 16% to 69%. Singh et al. (1992) found that seeds from larger-sized cones exhibited higher seed germination (66%) in Himalayan cedar. Singh et al. (1997) also found significant differences between tree diameter classes in fresh and dry weight of seeds, and germination in the laboratory and in the nursery. Germination of *Cedrus* seed is epigeal.

Cedrus deodara seed should be sown in the fall or spring at a rate of 200 to 250 seeds per square meter (10.8 ft^2), in drills 10 to 15 cm (4 to 6 in.) apart, producing about 19 to 23 seedlings per 0.1 square meter (1 ft^2) for lining-out stock and for rootstocks (Rudolf 1974; Macdonald 1986). Chandra and Ram (1980) recommend sowing *Deodar* seed at a depth of 1 cm (0.4 in.). Further increase in depth results in decreased germination. Al-Ashoo and Al-Khaffaf (1997) reported that the best treatment for germination of *C. libani* seed was a 1.5-cm (0.6-in.) sowing depth, with a covering medium of clay or alluvial soil. In northern areas, fall-sown beds should be mulched over winter, with the mulch removed early in the spring and the bed racks covered with burlap on critical spring nights to prevent freezing (Heit 1968). *Cedrus* seed can be sown in containers in the fall, transplanted into other containers during the winter, and kept in shaded beds in the summer to produce $1/2$ to $1\frac{1}{2}$ -year-old planting stock (Rudolf 1974). The size of the propagation container, growth media, transplanting date, and handling of seedlings is important in container- or field-grown stock (Toth 1980b; Doty 1982; Appleton and Whitcomb 1983; Guehl et al. 1989; Puxeddu and Alias 1991; Burger et al. 1992).

Cedrus deodara 'Shalimar' can be propagated by cuttings (67% rooted) collected in late fall to early winter, when given a quick dip in 5 g/L (5,000 ppm)

indole-3-butyric acid (IBA) solution and placed in a sand:perlite medium with bottom heat maintained at 24°C (75°F) (Nicholson 1984). Shamet and Bhardwaj (1995) reported 69% rooting of *C. deodara* cuttings treated with 5 g/L indole-3-acetic acid-talc or 10 g/L (10,000 ppm) naphthaleneacetic acid-activated charcoal, both supplemented with 10 g/L captan and 10 g/L sucrose. Cuttings taken from *C. atlantica* and *C. libani* are difficult to root. Some rooting may occur on cuttings taken in late winter and treated with 8 g/L (8,000 ppm) IBA-talc (Dirr and Heuser 1987). Cultivars of *Cedrus* species are more routinely propagated by grafting (Richards 1972; Lyon 1984; Blomme and Vanwezer 1986; Macdonald 1986; Dirr and Heuser 1987; Hartmann et al. 1990; Siniscalco 1995). Two reports have been published on the *in vitro* culture of *C. deodara* (Bhatnagar et al. 1983; Liu 1990). A method for *in vitro* propagation of *C. libani* through axillary bud production, a study of bud dormancy *in vitro*, and the detection of genetic variation of *in vitro* propagated clones have also been described (Piola and Rohr 1996; Piola et al. 1998, 1999).

ADAPTATION TO THE URBAN LANDSCAPE

The diversity of conifers available for planting in the urban landscape is quite large. There are many species and cultivars with numerous ornamental characteristics, such as dwarfed, weeping, and pyramidal, and there are a vast array of needle colors. The cedars are magnificent conifers that should not be overlooked for use in the landscape as a specimen plant or lawn tree, and in gardens or parks. Cedars are exquisite trees giving beauty to any area that can afford them a little space. The cedars offer resistance to climatic stress and good growth performance. They require abundant sunlight throughout their life and will thrive in almost any moist, deep, well-drained soil. They are unsuited for shallow, rocky soils where the plants either die as a result of drought when young or remain stunted if they survive. Cedars respond well to fertilizers, mulching, and supplemental watering during drought (Chaney 1993). All the cedars are difficult to transplant to some degree and are usually sold as container-grown plants.

Cedrus atlantica was introduced into cultivation around 1840 (Dirr 1990). A fast-growing species, the Atlas cedar prefers a sunny (or partial shade) location in a well-drained, moist, deep, loamy soil. It

will tolerate sandy, clay soils if there is no standing moisture (Dirr 1990). Atlas cedar prefers an acid soil but withstands alkaline conditions (Dirr 1990). It grows well in the heat of the south and tolerates pollution and urban conditions better than *C. libani* or *C. deodara*. *Cedrus atlantica* should be planted in areas sheltered from strong, sweeping winds (Dirr 1990). It will suffer considerable needle burn and injury during cold winters when sited in windy locations. Rot caused by *Phellinus pini* A. Ames can be a potential problem (Hansen and Lewis 1997), and the Deodar weevil occasionally damages the Atlas cedar, especially in the south.

Cedrus deodara was introduced into cultivation in the United States in 1831 (Dirr 1990). The Deodar cedar prefers full sun, and a well-drained location is essential. The best growth is attained on deep, fertile soil, fairly porous, and in cooler locations (Tewari 1994). High atmospheric moisture is favorable (Vidakovic 1991). *Cedrus deodara* thrives on exposed sites, but young seedlings require side shade or light overhead cover to prevent desiccation (Tewari 1994). The Deodar cedar is affected by drought chiefly in the seedling stage (Tewari 1994). This species is generally wind firm and frost hardy (Tewari 1994), but young trees are prone to injury from frosts and cold wind. *Peridermium witches'-broom* caused by *Peridermium cedri*, and root and butt rots caused by *Heterobasidion annosum* Bref. are particularly injurious to Deodar cedar (Hansen and Lewis 1997; Tewari 1994). The Deodar weevil, *Pissodes nemorensis* Germar, can injure trees by feeding on young shoots of the crown, terminal killing, and branch-end flagging (USDA Forest Service 1985).

Cedrus libani is a majestic tree introduced into cultivation during colonial times (Dirr 1990). Cedar of Lebanon prefers full sun and a deep, well-drained loamy soil. It is intolerant of shade and needs a pollution-free, dry atmosphere (Dirr 1990). *Cedrus libani* is quite winter hardy, but grows rather slowly (Dirr 1990; Vidakovic 1991). Cedar of Lebanon is one of the most picturesque conifers in the landscape. Old specimens of *Cedrus libani* with their massive trunks, stiff habit, dark green foliage, and rigidly upright cones lend an aspect of dignity and beauty to parks and gardens (Dirr 1990; Maheshwari and Biswas 1970). There are no serious diseases or insect pests that affect Cedar of Lebanon. *Cedrus brevifolia* is a rare species seldom found in the urban landscape.

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Résumé. Les vrais cèdres (genre *Cedrus*) sont des arbres au bois de grande valeur ainsi que des spécimens surprenant lorsqu'ils sont plantés en milieu urbain en raison de leur bonne croissance dans une variété de sols et sous des conditions climatiques diverses. Le bois est durable et résistant à la carie. Cet article fait une revue de sa distribution géographique, de ses caractéristiques taxonomiques, de sa reproduction et de son adaptabilité au paysage urbain. Des quatre espèces de *Cedrus*, trois sont plantées couramment aux États-

Unis: *C. atlantica* (cèdre de l'Atlantique), *C. brevifolia* (cèdre de Chypre) et *C. libani* (cèdre du Liban).

Zusammenfassung. Die echten Zedern (Genus *Cedrus*) sind wertvolle Arten für die Holzwirtschaft und werden auch gerne in der urbanen Landschaft gepflanzt, da sie in verschiedenen Bodenarten und unter unterschiedlichen klimatischen Bedingungen gut wachsen. Das Holz ist hart und fäuleresistent. In dieser Übersicht wird die geographische Verteilung, taxonomische Charakteristika, Vermehrung und Adaption an die urbane Landschaft diskutiert. Die vier Zedernarten, von den drei mit einiger Ausdehnung in den USA gepflanzt wurden, sind *C. atlantica*, *C. brevifolia* und *C. libanii*.

Resumen. Los cedros verdaderos (género *Cedrus*) son árboles maderables de gran valor y llamativos especímenes en paisajes urbanos que crecen bien en una variedad de condiciones climáticas y edáficas. La madera es durable y resistente a la descomposición. En esta revisión, se discute la distribución geográfica, las características taxonómicas, la propagación y la adaptación de los cedros al ambiente urbano. De cuatro especies de *Cedrus*, tres son plantados con alguna extensión en los Estados Unidos: *C. atlantica* (Cedro atlas), *C. brevifolia* (Cedro chiprense) y *C. libani* (Cedro del Líbano).