Restoring Atlantic White-Cedar Swamps: Techniques for Propagation and Establishment

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There has been much recent interest in restoring white-cedar swamps along the Atlantic Coast of the United States. Awareness of the ecological role of wetlands in keeping our environment healthier has combined with demand for cedar products to produce a drive to develop better methods to propagate and establish young cedars. This paper discusses unique features of cedar swamp ecosystems, natural regeneration methods, protection from deer, the use of herbicides, and nursery propagation and cedar swamp restoration by planting seedlings or rooted cuttings. Current research is noted, with references. Tree Planters' Notes 46(3):78-85; 1995.

Atlantic white-cedar, *Chamaecyparis thyoides* (L.) B.S.P (figures 1 and 2), is an obligate wetland species occupying swamps along the Atlantic Coast from central Maine south to Florida and westward along the Gulf Coast to the southeastern corner of Mississippi (figure 3). The western Florida population is sometimes regarded as a separate subspecies, ssp. *henryae* (Li 1962; Little 1966, 1979). Most cedar swamps lie along the Coastal Plain from New Jersey southward, but a few are perched atop mountains at some distance inland, as at High Point, New Jersey (1,500 feet elevation, 90 miles inland). The largest natural areas containing cedar swamps are in eastern North Carolina, southeastern New Jersey; and northwestern Florida (figure 3).

Currently, the area occupied by cedar swamps or wetlands (5 to 95% cedar) rangewide is about 115,000 acres, according to foresters and conservationists surveyed in spring 1995. This includes typical cedar swamps from the Carolinas to Maine and sandy streamside forests in western Florida and the Mobile Bay area (Ward and Clewell 1989). At the time of European settlement, there was much more, perhaps 500,000 acres.

What happened to most of it? In North Carolina, which probably had more than half of the original cedar, much of the Great Dismal Swamp and the lands along the Alligator River were drained for agriculture beginning in the late 18th century. One of the early land speculator– agriculturists who joined a consortium to drain 40,000 acres of the Dismal Swamp was George Washington, who also bought land there in his own

Figure 1— *The New Jersey record Atlantic white-cedar—located at Nixon Branch, Cumberland County, in southern New Jersey—is 9 ft, 6 inches in circumference at breast height. This battered old tree (age is estimated at 300 years) grows not far inland from Delaware Bay and has lost its top at least once to hurricane winds. Most Atlantic white-cedars grow to 70 to 80 feet in height, with a trunk diameter of 2 to 4 feet. Few forest trees grow in denser stands, and trees in such stands have long straight trunks and narrow crowns (Collingwood and Brush 1974).*

name (Frost 1995). Farming the drained lands met with varying success, and problems arose as the upper levels of the organic peat subsided because of oxidation.

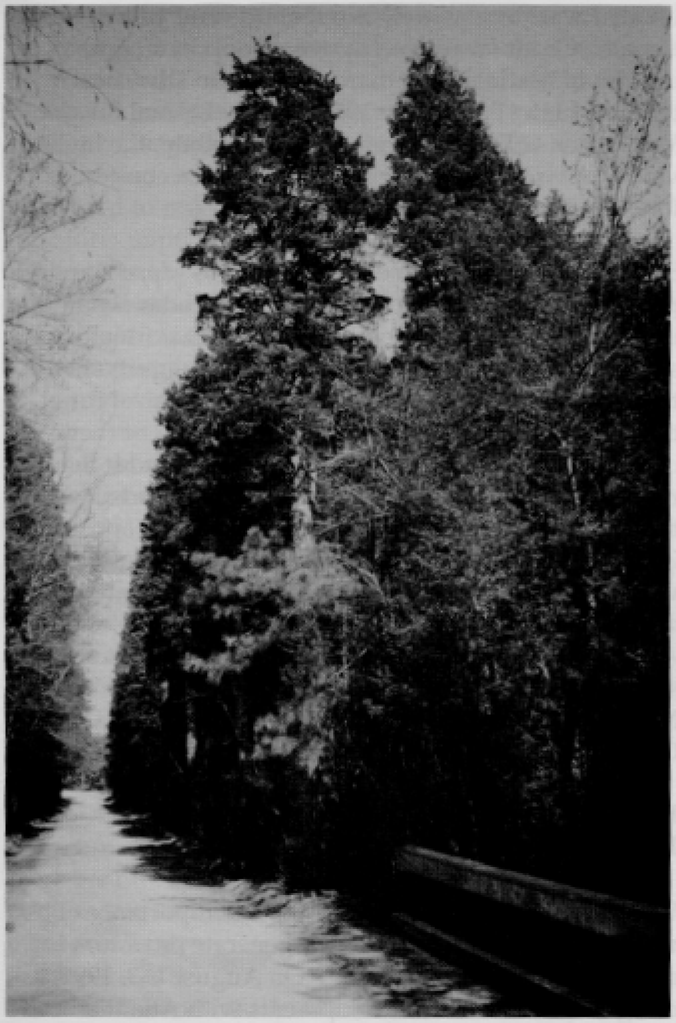

Figure 2— *A stand of 70-ft Atlantic white-cedars in Lebanon State Forest, New Jersey. Although cedars are usually small (a 14-inch diameter is a good size), better stands have trees with 18-inch diameters and 60-to 70-foot heights at ages of 75 to 100 years.*

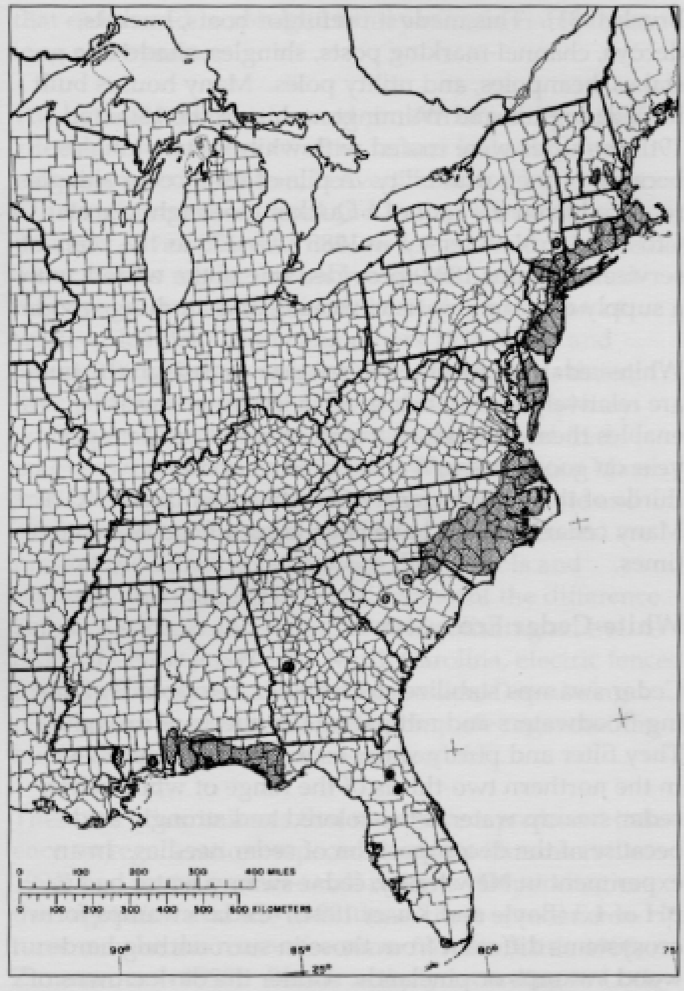

Figure 3— *Range of Atlantic white-cedar (Little 1971).*

Hydrologic changes in the Dismal Swamp made water levels too low (or in some cases too high) for cedar, and logging without fire allowed stump-sprouting hardwoods to replace cedar. Dismal Swamp was essentially mined rather than managed for cedar as a renewable resource. Today much of the Great Dismal Swamp and the low-lying lands along the Alligator River have become national wildlife refuges, and active white-cedar revegetation programs are underway in both areas (Brownlie 1995, Johnson 1995, L. Smith 1995, S. Smith 1995, Wicker 1995).

In Massachusetts and New Jersey, many cranberry bogs were once cedar swamps (Korstian and Brush 1931); in the latter state, 5,500 acres of cedar swamps in the Hackensack meadowlands were burned in 1791 to eliminate hiding places for pirates who preyed on shipping in Newark Bay (Kantor and Pierson 1985, Schmid 1987). Lakes have been built, swamps drained, stream channels straightened (allowing saltwater penetration to kill cedars), beavers have raised water levels in some swamps, highway construction has changed water levels, and logged cedar swamps have become hardwood or brush swamps after cedar regeneration has failed because of heavy deer browsing (Little and Somes 1965).

Wood Characteristics

For the first three-and-a-half centuries after European settlement, people were interested in cedar swamps mainly for the fragrant, rot-resistant wood that could be harvested from them. The decay resistance of Atlantic white-cedar is better than that of white pine, yellow pine, yellow-poplar, and oak although probably not as good as that of redwood or chestnut (Korstian and

Brush 1931). This made it useful for boats, buckets, decoys, channel-marking posts, shingles, shade-tree stakes, beanpoles, and utility poles. Many houses built in Philadelphia and Wilmington during the 18th and 19th centuries were roofed with white-cedar shingles because of their durability. A pile of used cedar shingles removed from the roof of a Quaker meetinghouse at Crosswicks, New Jersey, in 1985 after 175 to 185 years of service (Williams 1992) provided one of the writers with a supply of crisp, dry fishsmoking and kindling wood.

White-cedar is a productive species. Although the trees are relatively small, their growth in dense stands enables them to produce a cord of wood per acre per year on good sites in North Carolina or about two-thirds of this in New Jersey (Korstian and Brush 1931). Many cedar swamps have been logged from two to five times.

White-Cedar Ecosystems

Cedar swamps stabilize streamflows, temporarily storing floodwaters and mitigating the effects of droughts. They filter and purify water as it flows through them. In the northern twothirds of the range of white-cedar, cedar-swamp water is teacolored and strongly acid because of the decomposition of cedar needles. In an experiment in New Jersey, cedar-swamp water had a pH of 4.3 (Boyle and Kuser 1994). Cedar swamps form ecosystems different from those in surrounding hardwood swamps or pinelands. Under the dark crowns of the cedars it is 6 to 8/F cooler in summer and almost windless (Wander 1980). Occasionally the canopy is dense enough to shade out most undergrowth, but most of the time one has to struggle through tangles of greenbrier *(Smilax rotundifolia L.)*, sweet azalea *(Rhododendron viscosum* (L.) Terr.), rhododendron (*R. maximum* L.), highbush blueberry *(Vaccinium corymbosum* L.), and sweet pepperbush *(Clethra alnifolia L.)* in order to go anywhere in the swamp.

Cedar swamps are prime habitat for endangered swamp pinks, *Hellonias bullata,* in New Jersey and the Delmarva Peninsula (Zappalorti 1994, Dill and others 1987). Around the edges of cedar swamps, fringed orchids, *Habenaria* spp., turkey-beard, *Xerophyllum asphodeloides,* and curly-grass fern, *Schizaea pusilla,* can be found.

Bird species nesting in cedar swamps in New Jersey include black-throated green warblers, black-and-white warblers, brown creepers, ovenbirds (Wander 1980), and hermit thrushes (Zappalorti 1994). In North Carolina, cedar swamp nesters include prairie, prothonotary, and hooded warblers, as well as ovenbirds and yellowthroats. Cedar swamp ecosystems support a higher density of nesting birds than maple-gum sites, nearly twice as high (Terwilliger 1987). In the Dismal Swamp, Van Velzen (1981) observed 1,312 nests/km^2, the highest value for birds nesting in any of 12 eastern coniferous forest habitats.

Southern red-backed voles, *Clethrionomys gapperi,* are the predominant small mammals in mature cedar swamps in New Jersey. The presence of mycorrhizal fungal spores in the fecal pellets of these voles suggests that they may play a role in dispersal of mycorrhizal fungi that may be important for successful growth of the cedars (Craig and Dobkin 1993). Hollows under the roots of cedars growing along streams are used as winter dens by Pine Barrens rattlesnakes (Reinert and Zappalorti 1988). The best known amphibian associated with cedar swamps is the Pine Barrens treefrog, *Hyla andersonii.* One butterfly, Hessel's hairstreak, uses Atlantic white-cedar exclusively; it inhabits bogs and swamps close to white-cedar from New Hampshire and Massachusetts south to North Carolina and the Gulf Coast of Florida (Zappalorti 1994, Pyle 1981).

Bringing Atlantic White-Cedar Back— the "Cedar Initiative"

With growing public awareness of the importance of wetland ecosystems, efforts to regenerate or restore cedar swamps have increased. On August 1-3, 1995, a conference on current developments with Atlantic white-cedar management drew 75 researchers, foresters, and nursery managers to Goldsboro and Washington, North Carolina. Many papers on natural and artificial regeneration were presented, and a tour was given to sites with natural regeneration, planted seedlings, planted cuttings, and a cedar sawmill. Methods of regeneration are discussed below with references to current or recent research.

Natural Regeneration

The natural regeneration of white-cedar depends on a source of seed and the factors influencing its presence, germination, and subsequent survival. The main abiotic factors influencing seed germination are moisture, light, and temperature (Korstian and Brush 1931, Little 1950). In the field the primary limiting factor seems to be moisture. A continuous supply of moisture is critical to germinate white-cedar seed. For the seedling to survive the water supply cannot be too little or too much (Akerman 1923, Little 1950). There is also a critical interaction between moisture and substrate for successful germination. Field observations by Little (1965) and experiments by others (Greenwood 1994) have shown that cedar seed germination is earlier and more complete on sphagnum than on mineral soil. The differences in germination between substrates cannot be attributed to moisture-holding capacity or absolute moisture; unpublished experiments by Zimmermann (1993) have shown striking differences in germination between the substrates to persist when moisture is held above field capacity. The pH of the substrate is not a factor in germination (Boyle and Kuser 1994).

The amount of light needed for white-cedar germination, establishment, and growth has been the center of conflicting reports through the years (Korstian and Brush 1931, Little 1950, Hickman and Neuhauser 1978). Recent experiments with different logging slash levels by Zimmermann (1995) show cedar germination to be the densest in areas where slash is completely removed thus allowing maximal light. However, following the first year subsequent survival and growth is statistically significantly higher where slash is not removed. Indeed there is still adequate cedar regeneration and growth where logging slash has been doubled. Whether the second and subsequent year's survival and growth of cedar are due to a shift in its shade tolerance or whether there are other factors (nutrients, less inter-specific competition, etc.) remains to be seen as the 5-year experiment and analyses are finished.

These facts— combined with white-cedar's delayed germination (Moore 1939, Little 1950), variable seed crops, difficulties in obtaining adequate seed, and recent field experiment observations (Zimmermann 1995)— have led to recommendations that are contrary to those of Little (1965), who said that direct seeding can be successful more often than not. Indeed, in New Jersey, recent success has been too variable even on optimal sites (good moisture, good substrate, etc.) to recommend direct seeding.

Natural regeneration of white-cedar from seed already present in the seed bank (usually a sphagnum substrate) is, however, another matter. In New Jersey the highest probability for successful regeneration and restocking at adequate levels occurs when choosing areas where cedar was present or is near enough that the seed bank has accumulated adequate seed (Zimmermann 1995). Although Zimmermann is currently in the fifth year of a long-term experiment on cedar seed viability, field observations and experiences by Little (1990) suggest that cedar seed in sphagnum may remain viable for as long as 14 years.

The natural regeneration and growth of white-cedar are affected by a number of other factors including fire, interspecies competition, beaver, browsing by a variety of animals, rising sea level and human disturbance (cutting and development). In New Jersey the prime reason cedar fails to regenerate and reestablish after clearcutting or similar disturbance is the high population of white-tailed deer (Little and others 1958, Little and Somes 1965, Zimmermann 1995). During the winter, deer will browse white-cedar partially or completely while leaving primary competitors untouched (red maple, *Acer rubrum* L.; blackgum, *Nyssa sylvatica* Marsh.; and sweet pepperbush). Indeed where adequate and effective deer exclosures (electric or woven fences) are present the differences between the controls and exclosed areas are striking and represent the difference between success and failure in reestablishing whitecedar. In New Jersey and North Carolina, electric fences (usually five-stranded and solar-powered) are being used where necessary to insure adequate regeneration, but in many cases they are not affordable.

There are other animals that may have a profound influence on regeneration, especially rabbits (Summerville 1994) and various other small rodents. Depending on the vegetation and site conditions, these smaller creatures may be the reason for some failures (Little 1950, Zimmermann 1995). Beaver activity according to Little (1950) may have had a major role in holding natural succession back and perpetuating white-cedar.

The role of fire in regeneration depends on a number of factors including the structure, history, and size of the cedar stand as well as the intensity and type of fire (Little 1950, Motzkin and others 1993). Frost (1995) considers cedar to have been a fire species in the Great Dismal Swamp, with nearly pure stands dependent on fire return intervals of 75 to 300 years.

In New Jersey and North Carolina, wetlands-approved herbicides have been used to control competing vegetation that may arise either from differential deer browsing or a natural consequence of successional trends in the ecosystem. In New Jersey, Arsenal® is the most commonly used herbicide providing adequate control over troublesome species like red maple while avoiding (at proper dosages) "burning" of the cedar foliage.

Artificial Regeneration

Before planting seedlings or stecklings comes into widespread use, it will be useful to increase our knowledge of the genetic architecture of *Chamaecyparis thyoides:* differences among populations, uniqueness of any populations, how far propagules may be moved from their site of origin, differences in growth rate, cold tolerance, and other characteristics among populations, stands, and clones. Variation in heterozygosity may be estimated by isozyme frequency analysis, while comparisons of growth rates, hardiness, tree form, and disease resistance require classical provenance experiments which are just being established now. Eckert (1995) has compared isozyme frequencies in different swamps in New Hampshire and Maine and estimated degrees of relatedness among cedar populations. Kuser and others (unpublished data) have compared isozyme frequencies at four swamps in New Jersey and two in North Carolina.

Provenance testing. In North Carolina, Summerville (1995) established a provenance test on two sites in spring 1993, using seedlings grown from 77 single-tree collections. In New Jersey, Kuser and Spaziano (unpublished data) planted a test of rooted cuttings of 29 clones from 10 swamps on several test sites belonging to Clayton Sand Co. at Lakewood, NJ, in May 1995. We are also comparing survival and growth of cuttings from selected tall cedars vs. random cedars vs. juvenile (3 to 4 ft) cedars, vs. seedlings from three different swamps. When results are known in 5 to 10 years, it should be possible to estimate differences in cedar growth rates due to provenance, clone, maturity state of ortet (cuttings), and method of propagation (seedlings vs. cuttings).

Seed propagation. Seed viability and germination vary widely among seedlots from different swamps (Laderman 1989, Boyle and Kuser 1994). Cedar seed is tiny, difficult to collect, and notorious for delayed germination (Schopmeyer 1974). In North Carolina, Summerville is experimentally collecting seed from a Christmas tree plantation using a cone rake. Greenwood (1994) and Jull and others (1995) have found that larger plants can be produced in less time at 30ºC with high-nitrogen fertilization. Currently, bareroot seedlings furnished by the New Jersey state nursery are 2+0, 6 to 12 inches tall, and 5/32 inch in diameter, and supply is not adequate. In North Carolina, the state nursery is producing 13,000 1+0, 4-in bareroot seedlings and would produce more if possible. The best planting season in New Jersey is thought to be April/May, and in North Carolina March/April.

Stecklings (rooted cuttings). Nursery managers have been propagating cultivars of related species of *Chamaecyparis* as stecklings for a long time, and the advent of modern mistbed technology together with the use of rooting hormones has made it easy (figure 4). Recent research at North Carolina State University (Hinesley and others 1994) and Rutgers University (Boyle and Kuser 1994) aims to optimize techniques for rooting cuttings. With a mistbed, rooting hormones, and bottom heat during cooler months, our experience has been that cedar can be rooted with about 90% success at any time of year. Commercial production of stecklings is well underway in North Carolina, where Weyerhaeuser can produce up to 400,000 a year, 6 to 8 in high, in tubes and bareroot. Within the last year or two, experiments in North Carolina have shown that mistbed rooting of cedar can be accomplished outdoors using sandy soil and fogging/ irrigation spray regulated by evapotranspiration sensors (Hinesley 1995). Outdoor mist--rooting is also being done by Weyerhaeuser, using a different technique (Miller, personal communication).

Planting and establishment. If the site is a swamp where natural regeneration has failed or is inadequate, the first step is reduction of competing vegetation by cutting and applying herbicide (if there are small cedar seedlings underneath brush, herbicide alone may work). Seedlings or stecklings should be planted at medium elevation on hummocks (Ehrenfeld 1995) where the root collar will be dry but the lower ends of roots moist. Cedar is "picky"— it tolerates neither inundation nor drought. If the site is a hardwood swamp slated for conversion or mitigation, the hardwoods must be controlled first because cedar is intolerant and will not grow up underneath them. If the site is a newly constructed lakeshore (such as along worked-out sandpits) or stream-edge, the planter should match as closely as possible the microsite conditions under which cedar naturally and often aggressively colonizes such places: the roots must be within easy reach of water, but the stem never inundated.

After planting, young cedars must be protected against deer and/or rabbits. In small plantations or where rabbit clipping may be a problem, plastic mesh collars (figure 5) are effective. In larger plantations with high deer populations, fencing is necessary exactly as with natural regeneration.

Figure 4 — *Cedar cuttings in a mistbed at Rutgers University.*

Seedlings vs. stecklings. Comparison of the growth of outplanted seedlings and stecklings (rooted cuttings) in North Carolina showed that seedlings usually grew somewhat faster but not always so (Gardner and Summerville 1992, Phillips and others 1993). In New Jersey, we planted seedlings and stecklings resulting from Boyle's experiments (Boyle and Kuser (1994), averaging 4 to 7 cm high in June 1992 in a swamp at the Jackson tree nursery. In November 1995, 41 stecklings averaged 131 cm tall and 24 seedlings averaged 128 cm after four growing seasons. The most obvious difference between the two groups was in winter color: all seedlings were copper-maroon on 20 March 1995, but 36 of 40 stecklings were green. The 3 tallest plants in the plot were all seedlings, (246, 227, and 205 cm).

One advantage of seedlings is that no two are exactly alike, and thus would seem less likely to be affected by pathogens such as those that have decimated single-clone plantations of hybrid poplar. If stecklings are planted, this risk can be minimized by planting blocks of up to 20 selected clones or a multiclone mixture.

Several advantages of stecklings are that cuttings are easy to collect, easy to root, and the supply does not depend on variable pollination, seed production, and viability.

In British Columbia, the entire provincial reforestation program with Alaska yellow-cedar, *Chamaecyparis nootkatensis* (D. Don) Spach, has switched from seedlings to stecklings in the last 10 years, and currently produces about 750,000 per year. Russell and others (1990), Karlsson and Russell (1990), Grossnickle and Russell (1993), and Russell (1993) provide good summaries of this situation. In North Carolina, Weyerhaeuser's white-cedar cutting/rooting facility at Trenton had doubled its capacity to 400,000 stecklings/year in April 1994. It was then providing year-old rooted cuttings of North Carolina, Delaware, and New Jersey clones.

Which will be the method of choice in the future for white-cedar? The verdict is not in, but the British Columbia and Weyerhaeuser examples may foreshadow

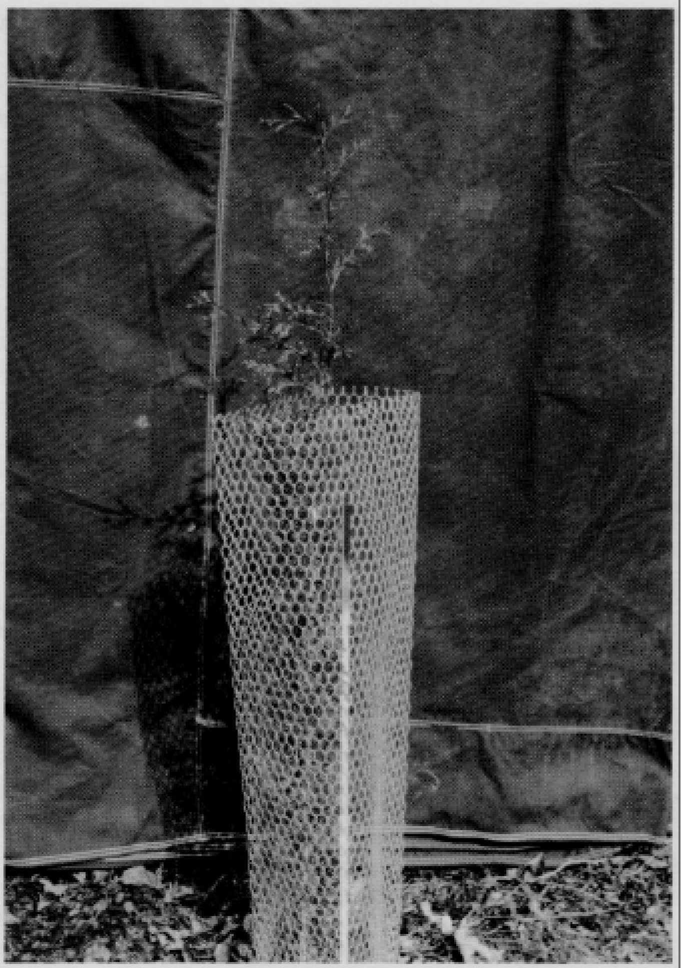

Figure 5— *Plastic mesh collars around cedar seedlings at Clayton Sand Co., Lakewood, New Jersey.*

future mass regeneration techniques of known genetic material.

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