Atlantic White-Cedar Propagation by Seed and Cuttings in New Jersey

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Atlantic white-cedar— Chamaecyparis thyoides *(L.) B.S.P.---propagation was tested using seeds and cuttings. Photoperiod played an important role in seed germination. Under 16-hour daylength, 31.9%* of *fresh seeds germinated, compared to 0.7% under 10-hour daylength. Cold stratification and gibberellin treatments could substitute for the photoperiod requirement. There was great variation in viability among seedlots from different cedar swamps. For seed propagation, 30-day stratification on sphagnum at 4 ºC is recommended. Optimal rooting (97.5%) was obtained on cuttings 6 to 7 cm (2.3 to 2.7 in) long taken from juvenile trees in November, dipped in powdered Hormodin #2, and stuck in a well-drained mix of Pro-Mix BX, peat moss, and sand under intermittent mist with bottom heat (24-26 ºC). Sturdy, well-developed root systems developed within 3 months.* Tree Planters' Notes 45(3): 104-111; 1994.

Atlantic white-cedar *(Chamaecyparis thyoides* (L.) B.S.P.) is one of eastern North America's most unique wetland species. Ranging along the eastern seaboard and gulf coast of the United States (figure 1), it is important both economically for its timber and ecologically as a habitat for many species of flora and fauna not common to other freshwater wetlands (Kantor 1976). Natural regeneration of cedar is difficult because of deer browsing, competing hardwoods, and variable seed germination rates (Little 1950). Much has been written about cedar germination variability due to poor seed quality and set, insect damage, and varying degrees of embryo dormancy (USDA 1974; Laderman 1987). Cedar, an intolerant species, needs disturbance to reestablish; yet disturbance often results in the conversion of cedar swamps to other wetland types (Roman and others 1987).

We compared sexual and asexual propagation techniques that could assist regeneration and reforestation efforts in places where Atlantic white-cedar has failed to regenerate or cedar swamp establishment is desired for wetland mitigation. Seed propagation is relatively inexpensive, requires little technology, and promotes genetic diversity. But seed germination varies greatly among seedlots from different swamps, and cedar seeds may not germinate until 2 or 3 years after seedfall (Laderman 1989). Rooted cuttings capture a tree's full genetic potential, allowing for the selection of desirable individuals. However, vegetative propagation may be more expensive, requiring facilities such as hedge orchards and a greenhouse.

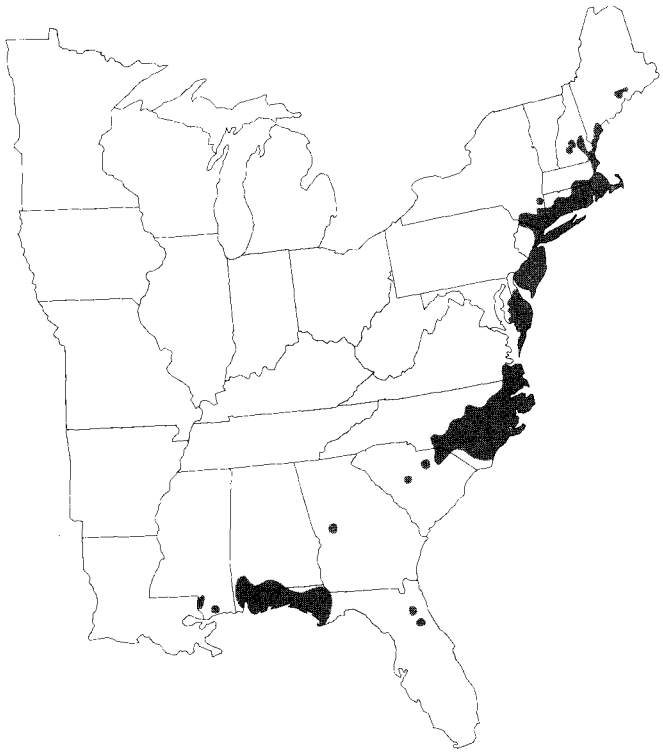

Figure 1—*Range of Atlantic white-cedar* (Chamaecyparis thyoides *(L.) B.S.P.) (Little 1971).*

We addressed the following questions: Does daylength make a difference in germinating seeds? What length of stratification is needed? Can gibberellins substitute? Is pH important? Can potassium nitrate increase germination? For rooting of cuttings, does soil type matter? Can cuttings be rooted without mist? Does misting improve rooting? Do auxins

increase rooting success? Does the age of the donor tree influence rooting success? What are the relative advantages and disadvantages of seed propagation and rooting of cuttings?

Materials and Methods

A two-part design was implemented for this study. The first part dealt with seed viability and germination, and the second part with vegetative propagation.

Seed propagation. Cedar cones were collected in fall 1991 from eight different swamps in New Jersey (table 1, figure 2). In six swamps (Belleplain, Double Trouble, Greenwood, Lebanon, Manchester, and Penn), the cones were collected from a mix of trees of varying sizes: greater than 6 m (20 ft), about 3 m (10 ft), and 1.5 m (5 ft) or less. These were often found on the edges of swamps or near blowdowns, because the best cone production was in full sun. The cones were collected with a pole pruner, or if a tree was large enough it was climbed. At Cheesequake, cones were collected from a single midsized tree, the only tree heavily coning. At High Point, all cones were collected from old even-aged trees, because no others were available. Seeds were collected from early October through early November.

Seed extraction was accomplished by heating the cones in an oven at 35 to 37 ºC until they opened (USDA 1974). Most seeds could easily be removed at this point, but in some cases cones had to be soaked

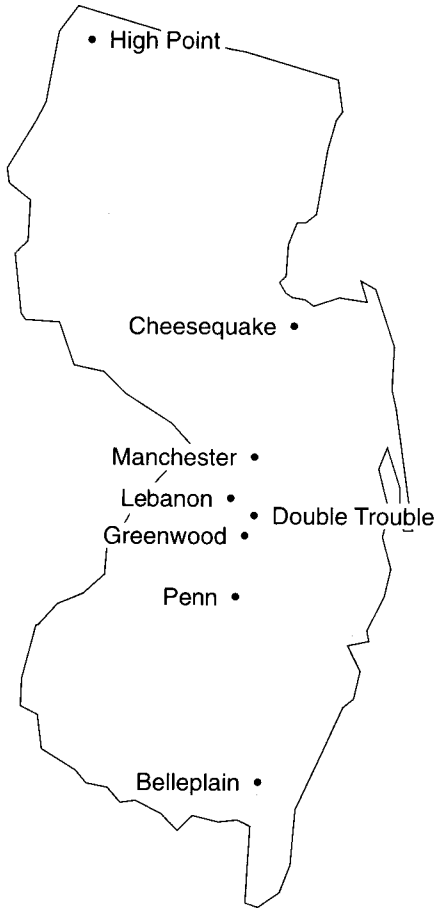

Figure 2—*Atlantic white-cedar swamps sampled.*

Table 1 -*Viability and germination of Atlantic white-cedar seed by New Jersey swamp of origin*

	Viability					Germination	
Swamp	Bad seed[1]	Insect damage	Empty seed	Rate(%)	*T*-grouping[2]	Average rate[3] (%)	*T*-grouping[2]
Belleplain	70	0	0	30	C	7.3	F
Cheesequake	47	2	0	51	AB	21.0	CD
Double Trouble	32	15	11	42	BC	24.5	C
Greenwood	36	2	0	62	A	17.5	DE
High Point	2	0	43	55	AB	46.7	A
Lebanon	35	6	1	58	A	13.2	E
Manchester	1	0	39	60	A	30.0	B
Penn	39	1	9	51	AB	19.7	CD

[1] Brown or deformed embryos present.

[2] Percentages with the same T-group letter are not significantly different.

[3] Average germination rate for all experiments conducted on seeds from the indicated swamp.

overnight in water and reheated. Cedar seeds are very tiny, with a diameter of 2 to 3 mm (0.8 to 1.2 in), and removal of seed debris proved difficult. Attempts were made to pass the seeds through a metal mesh straining screen, but debris the same size as the seeds remained. The most effective method proved to be gently shaking the seeds across a Styrofoam plate. Static electricity helped keep the debris on one side of the plate while the heavier seeds slid to the other.

The cleaned seeds were then grouped by swamp into lots of 100. Tetrazolium seed tests for viability were attempted as prescribed by the International Seed Testing Association, but were difficult to read and often inconclusive. (However, the National Tree Seed Laboratory has successfully conducted tetrazolium studies on North Carolina seed.) Because of this difficulty, seed viability was estimated by dissection. One hundred seeds from each swamp were dissected. Seeds with fresh-looking embryos were counted as viable, whereas empty seeds or those with insect-damaged or discolored embryos were counted as nonviable.

Germination tests were conducted under various conditions, including daylength, stratification, and additional liquid treatments with water at pH 7 (as a control), water at low pH levels, potassium nitrate, and gibberellin. One hundred seeds from each test lot were placed on filter paper in a petri dish. In preliminary tests with apparently viable seed on filter paper that was merely moist, germination had usually not occurred. Adding extra water seemed to facilitate imbibition, so treatment liquid was added until the seeds floated. As the liquid in the dishes dried out, water was added until the seeds refloated. The dishes were moved every 5 days to minimize the effect of position within the germinator. The germinator contained 6 "Gro and Sho" lights producing 645,840 lumens m^2 (lux) and was kept at a temperature between 22 and 26 ºC. All germination studies were done under this light and temperature regime. At 3 weeks, as germination was beginning, the germinants were counted and removed. Remaining seeds were checked daily, and subsequent germinants were counted, added to the totals, and removed. Germination rates were recorded for a period of 2 months, or until fungal or bacterial contamination stopped the experiment.

Daylength.. A trial testing 16-hour ("long-day") photoperiod was conducted on seeds from seven different swamps (there were insufficient seeds to conduct the test for Cheesequake). Two petri dishes were prepared for each swamp (14 dishes in all), each containing 100 seeds. An identical trial was conducted under a 10-hour ("short-day") photoperiod. These tests were performed with water alone, not in combination with potassium nitrate or other additives. Short-day seeds that did not germinate after 2 months were exposed to long-day conditions. Data comparing germination of seeds from the seven swamps under 16-hour daylength were tested by pairwise chi-square analysis, and data on germination under 10-hour daylength were tested by chi-square analysis comparing one swamp (where some seeds germinated) to six other swamps (where none germinated).

Stratification. *To* test the effect of cold stratification, three groups of test seeds were prepared (one group for each time period to be used). In each group, about 500 seeds from each of four swamps (Greenwood, Lebanon, Manchester, and Penn) were used. The seeds were first placed on moistened sphagnum in plastic bags in a cold box at 4 ºC. The first group of seeds was removed after 30 days, the second after 60 days, and the third after 90 days. After removal from the cold box, the seeds were washed off the sphagnum, and four replicate dishes were prepared for each of the four swamps (16 dishes in all). Each dish contained 100 seeds, floated as described above. Two dishes from each swamp were tested under the 16-hour photoperiod and two others from each swamp under the 10-hour period. As the liquid in the dishes dried out, water was added until the seeds refloated; dishes were moved within the germinator every 5 days.

Liquid treatments. Experiments with seven different liquid treatments were performed under the germinator conditions described above. Seeds from each swamp were used, although not enough seeds from High Point were available to perform all seven tests. Seeds were tested with three replications per swamp, each dish containing 100 seeds. The seven treatments included pH 7 (control water), pH 3, pH 4, pH 5, cedar swamp water (pH 4.3), 0.2% potassium nitrate, and gibberellin. Tap water was used for the pH 7 control (preliminary tests had shown that distilled water made no difference). The three lower pH values were achieved by titration with hydrochloric acid to the desired level. In the gibberellin test, a 3,000-ppm gibberellic acid solution was added to the petri dishes for 24 hours. The dishes were then drained, and water was added. Seeds were floated in all seven treatment liquids, and water was added when solutions evaporated. All treatments were performed under 16-hour daylength at 22 to 26 ºC; the gibberellin treatment was also done under short-day conditions.

A generalized linear model (SAS GLM procedure) with least significant difference T-grouping test ($P = 0.05$) was used to statistically test the effects of cold

stratification, pH, potassium nitrate, and gibberellin treatments on germination rate and to determine significance of variation among seeds from different swamps (SAS 1990).

Rooting of cuttings. The second part of the experiment examined methods of vegetative propagation of cedar. Only two swamps (Greenwood and Manchester) were used for the cutting experiments. Half of the cuttings were from mature wood (branches that carried cones), and the other half were from juvenile trees about 1 m (3.3 ft) high and without cones. All cuttings were from the ends of branches (laterals and terminals) and were taken from current-season growth. Cuttings averaged 5 to 7 cm (2.0 to 2.7 in) in length and were taken with an extra "heel" (a piece of woody tissue at the base) (Hartman and others 1975). Cuttings were taken in early October (Dirr 1990) and again in November. They were placed in plastic bags to prevent desiccation and stored at 4 C until they were stuck.

The first experiment, run in the greenhouse without mist, was designed to compare (1) cutting sources (Greenwood and Manchester); (2) maturity states (adult and juvenile); (3) times of year (October and November); (4) rooting medium (Pro-Mix BX; peat moss and sand; and equal parts Pro-Mix BX, peat moss, and sand); and (5) rooting hormones (powdered Hormodin dips: Hormodin #1 (active indole-3-butyric acid 0.1%); Hormodin #2 (IBA 0.3%); and Hormodin #3 (IBA 0.8%)). Twenty cuttings were tested in a full factorial design combining swamp, maturity state, time of year, rooting medium, and rooting hormone. Cuttings were stuck in individual Leach tubes (10-in^3 Supercells) filled with medium and placed in 98-tube racks. Each treatment other than medium was randomly selected for spacing in the rack. Racks were moved around the greenhouse weekly to minimize position effect. Temperatures in the greenhouse ranged from 16 to 21 ºC at night to 18 to 22 ºC during the day. Ambient light was used, with daylength at our latitude varying from 11.5 hours in early October to 9.25 hours on December 21.

A second rooting experiment was done using mist. The rooting medium was made up of equal parts sand, peat moss, and Pro-Mix BX. The same variables were examined, including cutting sources (Greenwood and Manchester), maturity states (adult and juvenile), times of year (October and November), and rooting hormones (Hormodin #1, #2, and #3). The design was full factorial, with 20 individual cutting replicates made for each combination of swamp, maturity, month, and rooting hormone. Because Leach tubes were not compatible with bottom heat, flats were used in a propagating bench with bottom heat (24 to 27 ºC) and intermittent mist (6 seconds every 6 minutes).

All cuttings were evaluated for rooting after 3 months, and a generalized linear model (SAS GLM procedure) was used for the analysis of variance in rooting experiments. The model related the percentage rooted to cutting source (swamp), maturity state, month of collection, rooting medium, hormone, and whether or not mist was used.

Results

Seed viability and germination rates. Seed dissections showed variation in viability among seeds from different swamps (table 1), due principally to occurrence of brown or deformed embryos in some seedlots. Generally, it took about 3 weeks of soaking to penetrate the cedar seed coat and induce germination. Although most long-day seeds germinated in 3 weeks, sporadic germination continued thereafter throughout the 2-month period in the germinator. There was significant variation in germination rates among seedlots from different swamps. Seeds from High Point had the highest germination rate (table 1).

Photoperiod played an important role in seed germination (table 2). Under long-day conditions, germination equaled or exceeded 40% in seeds from Double Trouble, High Point, Lebanon, and Manchester swamps, whereas germination was 19% or less in seeds from Belleplain, Greenwood, and Penn. Pairwise chi-square analysis showed that these were two significantly different groups. Under short-day conditions, only 7 of 1,400 seeds (0.5%) germinated, all from High Point; no seeds from the other six swamps germinated. Chi-square analysis showed the 7-seed germination from the High Point seedlot to be significant. After 2 months, when short-day seeds were exposed to long-day conditions, many of them germinated (including 39 more seeds from High Point), although total germination was not as high as for seeds originally exposed to long-day conditions.

Liquid treatments other than water at pH 7 were not particularly effective (table 3). Only the combination of gibberellin and short daylength yielded significantly higher germination rates than water alone; low pH and cedar swamp water produced lower rates of germination. But results varied among swamps (table 4): two seedlots (from Greenwood and Penn) that did not germinate well on water alone showed some improvement under other treatments.

The GLM statistical procedure produced an r^2 of .8573 ($P \leq .0001$). The highest germination rates were achieved for short daylength with 30-day cold stratifi-

Table 2-*Germination rates of fresh Atlantic white-cedar seed on water (pH 7), by New Jersey swamp of origin and daylength*

	16 hours		10 hours	
Swamp	Germination rate (%)	Pairwise chi-square	Rate	Chi-square
Belleplain	18	B	0%	B
Double Trouble	40	A	0%	B
Greenwood	19	B	0%	B
High Point	43	A	3.5%[1]	A
Lebanon	45	A	0%	B
Manchester	45	A	0%	B
Penn	15	B	0%	B

[1] Seven seeds germinated.

Table 3-*Germination of Atlantic white-cedar seed from eight New Jersey swamps, by liquid treatment*

Treatment[1]	Germination rate (%)	*T*-grouping[2]
Gibberellin		
10-hour daylength	22.7	A
16-hour daylength	16.1	BC
Water (pH 7)	19.9	AB
Potassium nitrate	18.2	AB
pH5	15.8	BC
Cedar swamp water (pH 4.3)	14.7	BC
pH3	11.9	C
pH4	11.6	C

[1] Daylength was 16 hours for every liquid treatment except gibberellin.
[2] Percentages with the same T-group letter are not significantly different.

cation, and for long daylength with 30- and 60-day cold stratification (table 5). There was no significant difference among these treatments. Cold stratification for 90 days could not be analyzed, because bacterial contamination became so serious that none of the seeds germinated. Other treatment effects are shown in tables 3 and 4.

Rooting of cuttings. The r^2 of the GLM model was .7897, with an F-value of 25.87 ($P < 0.0001$) (table 6). The most important variable was the month when the cutting was taken: only 19.9% of cuttings taken in October rooted, whereas 84.2% of the November cuttings did. A significant difference was also noted between juvenile cuttings (which rooted at a rate of 34.9%) and mature cuttings (which rooted at 26.4%). There was no statistically significant difference in rooting rates for the two swamps (Greenwood rooted at 33.8% and Manchester at 27.5%). For rooting without mist, differences among media were significant: Pro-Mix BX produced a rooting rate of 40.4%; ProMix/peat/sand, a 36.1%; sand, 25.4%; and peat moss, 9.6%. Although no rooting occurred without hormone treatments, there was no statistical difference among the three kinds: averaged across month, maturity state, and rooting medium, Hormodin #3 yielded a rooting rate of 34.4%; Hormodin #2, 29.6%; and Hormodin #1, 27.9%. Cuttings under mist with bottom heat (not shown in the tables) rooted more often (at a rate of 53.9%) than cuttings without mist (19.7%). The best rooting was obtained in November under mist, with juvenile cuttings averaging 94% (Hormodin #1, 92.5%; #2, 97.5%; and #3, 92.5%), and mature cuttings averaging 74% (Hormodin #1, 60.0%; #2, 72.0%; and #3, 90.0%).

Discussion

Seed viability and germination. The superior germination of High Point seed may be related to maturity of the large trees found in this swamp. High Point is not a mixed-age swamp and has the largest trees of any swamp tested. Historically, more mature trees are credited with producing more viable seed (Laderman 1989). The low germination of Belleplain seed may be partially explained by the amount of bad seed (70%) found in this seedlot. Viability rates for Greenwood and Manchester seedlots were both high (62 and 60%, respectively), but germination rates for these seedlots (17 and 30%, respectively) differed

Table 4-*Germination rates of Atlantic white-cedar seed, by New Jersey swamp of origin and liquid treatment[1] (percent)*

Swamp	Water	Cedar swamp water	pH 3	pH 4	pH 5	$KN0_3$	GA_3 16-h	GA_3 10-hr
Belleplain	14.2	9.7	2.7	4.0	3.3	5.7	10.0	13.0
Cheesequake	25.3	27.0	19.0	23.3	20.3	21.3	7.6	15.0
Double Trouble	45.5	36.5	10.0	11.3	26.3	20.3	20.0	28.0
Greenwood	7.9	9.0	9.7	8.3	12.0	12.7	12.5	9.0
High Point[2]	51.0	n.a.	n.a.	n.a.	n.a.	42.5	33.0	48.0
Lebanon	18.6	2.0	2.3	2.7	10.7	17.7	4.0	37.0
Manchester	20.4	13.3	28.3	16.3	24.3	18.0	33.0	27.0
Penn	8.4	12.7	11.0	15.3	13.7	15.3	13.5	17.0

n.a. Not applicable (test not conducted).

[1] Daylength was 16 hours for every liquid treatment except gibberellin. For gibberellin, daylength was 10 hours and 16 hours.

[2]Insufficient seed was available to conduct all experiments.

Table 5-*Germination of Atlantic white-cedar seed from eight New Jersey swamps, by stratification*

Stratification	Germination rate (%)	*T*-grouping[1]
30-day		
10-hour daylength	46.8	A
16-hour daylength	46.7	A
60-day		
10-hour daylength	45.4	A
16-hour daylength	37.3	B
90-day [2]		
10-hour daylength	0	C
16-hour daylength	0	C

[1]Percentages with the same T-group letter are not significantly different.

[2] 90-day stratification had bacterial contamination.

Table 6-*Rooting for Atlantic white-cedar cuttings from two New Jersey swamps, by treatment*

Treatment	Average rooting rate[1] (%)	*T*-grouping[2]
Month of cutting collection		
November	84.2	A
October	19.9	B
Maturity state of cutting		
Juvenile	34.9	A
Mature	26.4	B
Swamp		
Greenwood	33.8	A
Manchester	27.5	A
Rooting medium		
Pro-Mix BX	40.4	A
Pro-Mix BX/peat/sand	36.1	AB
Sand	25.4	B
Peat moss	9.6	C
Rooting hormone		
Hormodin #3	34.4	A
Hormodin #2	29.6	A
Hormodin #1	27.9	A

' Figures for each treatment were averaged over other treatments. Figures for rooting medium were for no-mist only, but averaged over other treatments.

[2]Percentages with the same T-group letter are not significantly different.

sharply, suggesting that mechanisms other than light were at play.

The importance of photoperiod in controlling germination of Atlantic white-cedar seed is shown by the failure of nearly all fresh seeds to germinate under short-day conditions, and by their subsequent germination when exposed to long daylength. The behavior of Atlantic white-cedar seed is consistent with phytochrome response to red light and farred light. The seed dormancy exhibited by cedar is an important delaying mechanism, allowing seed to wait before germinating for favorable conditions to develop that will increase the likelihood of successful establishment.

For example, cedar is an intolerant tree that would benefit from a mechanism preventing germination under dense shade, likewise, a germination strategy

oriented toward daylength would ensure that seeds germinate at the right time of year. Many plants with small seeds need light to germinate. The small Atlantic whitecedar seeds may not have sufficient stored energy to push through the soil if buried too deeply. Light is an absolute requirement for germination in many swamp species (Deno 1994). For germination to occur, seeds from these species may need to be on the top of a hummock where both light and moisture conditions are right.

Several conifers have seeds that require light to germinate; most of these seeds have coat-imposed dormancy (Bewley and Black 1985). The phytochrome response can occur only in fully imbibed seeds. This interaction between light and the water-penetrability of the seed coat may control germination.

Cold stratification is known to affect the phytochrome response and could substitute for the photoperiod requirement. Chilling is thought to increase the production of gibberellins; we attribute the 23% germination of gibberellin-soaked seed (table 3) to the phytochrome-gibberellin interaction.

The fact that liquid treatments with cedar swamp water and at pH3, pH4, and pH5 did not improve germination indicates that low pH by itself does not stimulate germination. In each case, bacterial and fungal contamination became a problem, preventing whole petri dishes from germinating.

Rooting of cuttings. It was not surprising that cuttings from younger, more juvenile twigs rooted better than those from mature wood. Nursery managers have long used hedging and pruning to produce juvenile sprouts, and these techniques could probably be used on Atlantic whitecedar. Time of year when cuttings are taken is often the most important variable in rooting; endogenous hormone levels dictated by daylength and the number of cold days influence rootability (Hartman and others 1975).

In the no-mist rooting experiments, we compared rooting media to determine whether a low-tech approach (without greenhouse or mist bed) might work. Most narrow-leaved evergreen cuttings benefit from moist conditions that prevent the excess evapotranspiration that leads to death. Pro-Mix BX without mist gave relatively good results, with rooting averaging 40.4% and replicates rooting at rates varying from 10 to 75%. Further work on time of year and environmental temperature and humidity conditions may produce optimal rooting without the need for a greenhouse and mist bed. With mist, however, Atlantic white-cedar appears to root easily at more than one time of year (Hinesley and others 1994).

Conclusion

How does this information translate into practical applications for the propagator? For seed propagation, 30day stratification on sphagnum at 4 ºC is recommended. The seeds should be washed off the sphagnum and floated in a container with water under longday conditions for about 3 weeks, until radicles appear. Then they should be spread onto a flat of ProMix BX, but they should not be covered with soil, because they need exposure to light. Instead, they should be poured out and gently pressed into the medium. Special care should be given to watering; until true leaves emerge, a light mist nozzle should be used to avoid knocking down the tiny seedlings. Atlantic white-cedar seedlings grow very slowly and require months to reach outplanting size.

Vegetative propagation can be utilized where reforestation depends on mass-producing stecklings of plantable size (Russell 1993). This method can be combined with plus-tree selection to capture superior trees' genetic potential, and then a mixture of plus clones can be planted. Rooting rates of more than 97% can be achieved with cuttings 6 to 7 cm (2.3 to 2.7 in) long taken from juvenile trees in November, dipped in powdered Hormodin #2; and stuck in a well-drained mix of sand, peat moss, and Pro-Mix BX under mist (6 seconds every 6 minutes) with bottom heat (24 to 26 ºC). Sturdy, well-developed root systems fully occupy the containers within 3 months. Cuttings started in November are 7 to 8 cm (2.7 to 3.1 in) tall and actively growing by early June. By contrast, seedlings started during the same winter are only 2 cm (0.8 in) tall. But there is some evidence that seedlings may grow faster than cuttings after outplanting (Gardner and Summerville 1992), so there is room for work on both approaches.

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Literature Cited

Bewley JD, Black M. 1985. Seeds, physiology of development and germination. New York, NY: Plenum Press. 367 p.

Deno N. 1994. Seeds of a new theory. American Nurseryman (June 1994):42-52.

Dirr MA. 1990. Manual of woody landscape plants: Their identification, ornamental characteristics, culture, propagation, and uses. Champaign, IL: Stipes Publishing Co. 1,007 p.

Gardner WE, Summerville KO. 1992. Summary of Atlantic whitecedar. Tour and meeting; 1992 March 4-5; Plymouth, NC. Raleigh, NC: North Carolina Cooperative Extension Service. 18 p.

Hartman K, Hudson T, Kester DE. 1975. Plant propagation principles and practices. Englewood Cliffs, NJ: Prentice Hall. 662 p.

Kantor RA. 1976. The values of Atlantic white-cedar to New Jersey. Trenton, NJ: New Jersey Department of Environmental Protection, Office of Coastal Zone Management, Division of Marine Services. 15 p.

Laderman AD. 1987. Atlantic white-cedar wetlands. Boulder, CO: Westview Press. 401 p.

Laderman AD. 1989. The ecology of Atlantic white-cedar wetlands: A community profile. Biol. Rep. 85(7.21). Washington, DC: U.S. Fish and Wildlife Service, National Wetlands Research Center. 144 p.

Little EL. 1971. Atlas of United States trees, vol. 1: Conifers and important hardwoods. Misc. Publ. No. 1146. Washington, DC: USDA Forest Service. 312 p.

Little S Jr. 1950. Ecology and silviculture of white-cedar and associated hardwoods in southern New Jersey. Yale University School of Forestry Bulletin 56:1-103.

Roman CT, Good RE, Little S Jr. 1987. Atlantic white-cedar swamps of the New Jersey Pinelands. In: Laderman AD, ed. Atlantic white-cedar wetlands. Boulder, CO: Westview Press: 35-40.

Russell, J. 1993. Clonal forestry with yellow-cedar. In: Ahuja MR, Libby, WJ, eds. Clonal Forestry Il. Berlin, Germany: Springer-- Verlag: 188-201.

SAS. 1990. SAS users guide. Cary, NC: SAS Institute. 1,686 p,

USDA. 1974. Seeds of woody plants in the United States. Ag. Hdbk. No. 450. Washington, DC: USDA Forest Service. 883 p.