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UNIVERSITY OF ALASKA FAIRBANKS
College of Rural Alaska
Cooperative Extension Service

Trees as Crops in Alaska Profile

With an Emphasis on Spruce

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Production Facts

Growing trees in Alaska can be difficult. This document addresses basic questions regarding growing tree seedlings as an agricultural crop. Whether growing a few seedlings or thousands, many of the basic questions for production are the same.

From the standpoint of tree seedling production there are three basic regions in Alaska: Southeast, Southcentral and the Interior. Producing high quality tree seedlings is achievable in all three regions; however, care must be taken to match tree species requirements with local environmental conditions. Through the efforts of the University of Alaska Fairbanks and the Agriculture and Forestry Experiment Station, many tree species have been evaluated over the past 100 years for their performance in Alaska. Results from these species trials have led to the listing of tree species, growth characteristics and site requirements found in Table 1.

Demand

Interest in tree production can vary from growing trees for your yard or property to full scale outdoor or greenhouse, bareroot or container nurseries. Tree planting and tree sales continue to be of considerable interest to the public although there are no large-scale commercial tree nurseries currently operating in Alaska.

A state tree nursery was once operated in the Matanuska Valley area, but has been closed. Reasons for the closure were based upon the high cost of producing seedlings in Alaska versus what it would cost to import them from nurseries outside the state and also the overall operational difficulties and risks associated with an Alaska nursery program. This has resulted in the demand for seedlings being provided largely by Canadian and northwestern U.S. producers.

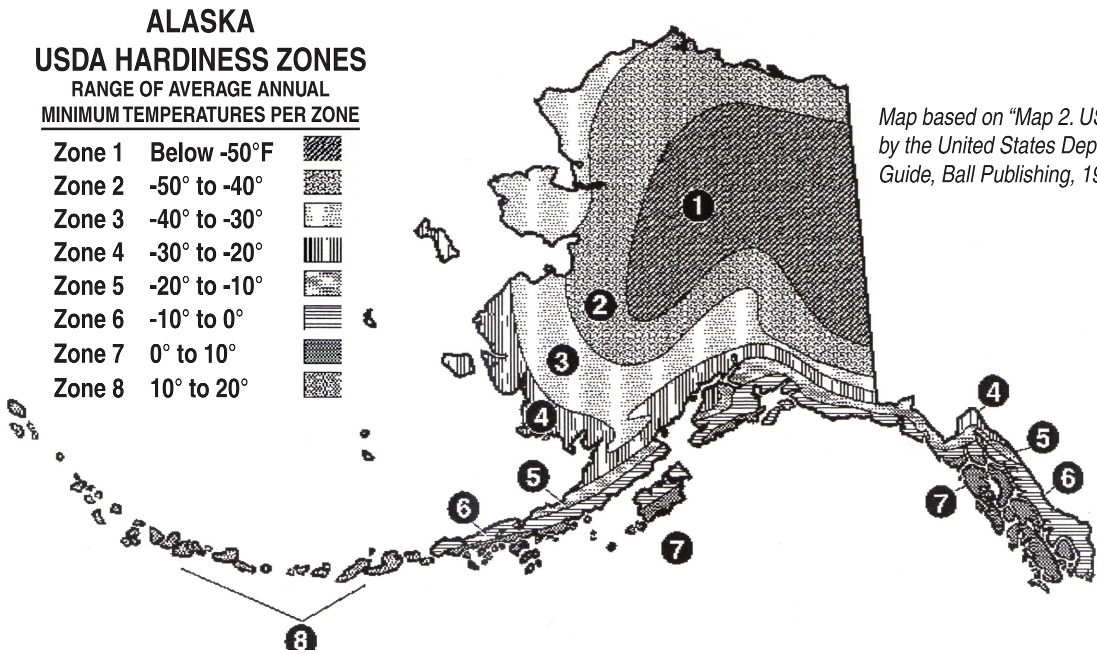
Estimates of annual planting demand are difficult to determine due to the number of nurseries contracted. More than 40,000 seedlings are estimated to be planted on private property (non-native corporation lands) in Alaska annually. The demand for seedlings has been further enhanced by the efforts of the Anchorage and Kenai boroughs to reforest land devastated by the spruce bark beetle.

As a result, current contracts are underway to produce more than 1 million seedlings. Additionally, it is estimated that more than 40,000 woody shrubs are planted annually in Alaska by private landowners based upon statistics from out-of-state nurseries.

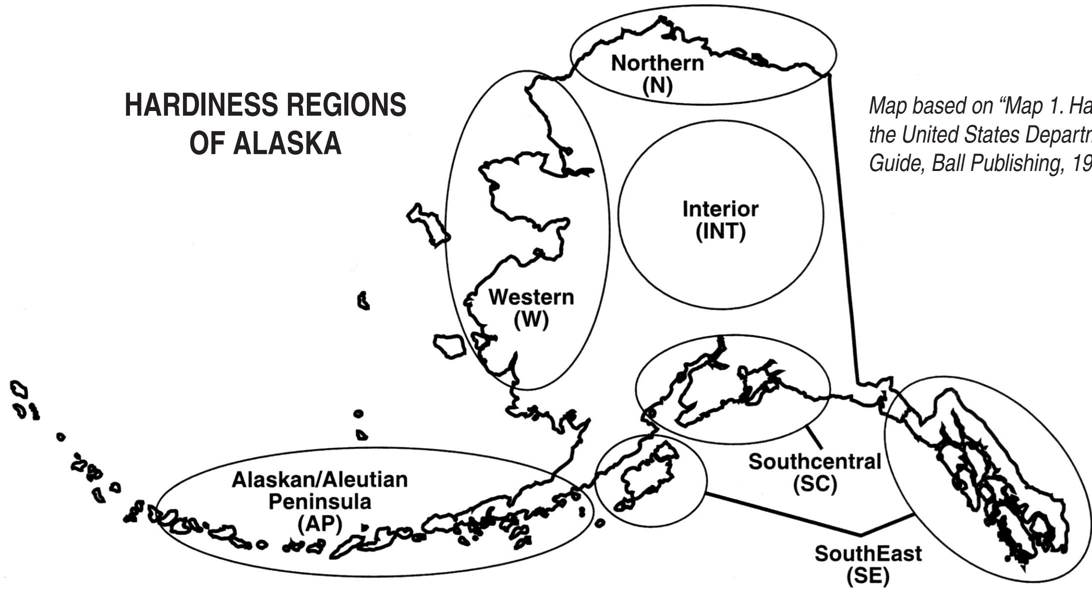
Tree sale in Soldotna, Alaska. May 2003.

In addition to tree seedlings for reforestation, Christmas tree sales account for more than 50,000 trees sold each year statewide. Christmas tree plantations have been attempted in Alaska with limited success.

A typical Christmas tree of the 6- to 7-foot class will take about eight to 12 years to develop. Christmas tree species for Alaska plantations include lodgepole pine, Scotch pine, jack pine, Siberian fir and Colorado blue spruce.



Map based on "Map 2. USDA Hardiness Zones of Alaska" by the United States Department of Agriculture Ball Culture Guide, Ball Publishing, 1993.



Map based on "Map 1. Hardiness Regions of Alaska" by the United States Department of Agriculture Ball Culture Guide, Ball Publishing, 1993.

Tree Planting By Region

Tree hardiness zones have been developed for Alaska and are summarized in the following diagram. Hardiness zones help select tree species for your area by matching the hardiness zone recommendations with the specific tree species of interest.

Non-Native and Native Tree Species Growth Comparisons

Considerable interest and concern has been expressed in recent years regarding the planting of non-native tree species in Alaska. Concern for the accidental release of invasive plants has lead to the development of invasive species lists for Alaska. Although most tree species would not likely become noxious or invasive in nature it is helpful to know what species might be of concern. John Alden's report *Naturalization and Growth of Non-native Conifers in Alaska* indicates that 20 year height and diameter growth of both lodgepole pine and western Siberian larch were significantly greater than that for white spruce when grown on the same site (Alden 2003). The average height growth of the white spruce was exceeded by Siberian larch, lodgepole pine, Scotch pine, jack pine, Dahurian larch, paper birch and balsam fir. There is some evidence to suggest that the growth of white spruce may eventually exceed some of the early fast growing species. Alden estimates that lodgepole pine and Siberian larch will soon become established as naturalized non-native conifers in Alaska. For a list of non-native and invasive plants in Alaska contact your local Extension office, or the website established by the Alaska Committee for Noxious and Invasive Plants Management at www.cnipm.org.

Table 1: Listing of Trees Adapted to Alaska Environments

Species	Common Name	Hardiness	Height (ft.)	Seeds per lb.	Pre-germination
Conifers:					
Abies concolor	White fir	SC, SE (Zone 3)	30–130 ft.	11,100	28 days on moist medium at 34–41°F
Abies lasiocarpa	Subalpine fir	SC, SE (Zone 2)	20–80 ft.	34,800	28 days on moist medium at 34–41°F
Abies sibiric	Siberian fir	INT, SC, SE (Zone 1)	80 ft.	unknown	28 days on moist medium at 34–41°F
Chamaecyparis nootkatensis	Alaska yellow cedar	SC, SE (Zone 4)	40-100 ft.	108,000	moist medium for 30 days at 68°F followed by 30 days at 40°F
Larix decidua	European larch	SE, SC (Zone 2)	30–70 ft.	70,000	None required
Larix gmelinii	Dahurian larch	INT, SC, SE (Zone 1)	60–70 ft.	120,000	None required
Larix laricina	Eastern larch	INT, SC, SE (Zone 1)	40–80 ft.	318,000	None required
Larix russica (sibirica)	Siberian larch	INT, SC, SE, W (Zone 1)	40–100 ft.	44,000	None required
Picea abies	Norway spruce	SC, SE (Zone 2)	100–200 ft.	64,000	None required
Picea englemannii	Englemann spruce	SC, SE (Zone 2)	100–165 ft.	135,000	30 days at 34–41°F after soak for 24 hours
Picea glauca	White spruce	INT, SC, SE, W (Zone 2)	40–115 ft.	226,000	None required
Picea mariana	Black spruce	INT, SC, SE, W (Zone 2)	15–70 ft.	404,000	7 days at 41°F in water
Picea pungens	Colorado blue spruce	SC, SE (Zone 2)	80–150 ft.	106,000	30 days on moist
Picea sitchensis	Sitka spruce	SC, SE (Zone 7)	80–225 ft.	210,000	2 days on moist medium at 34–41°F
Picea x *lutzii*	Lutz spruce	SC, SE (Zone 3)	55–100 ft.	200,000	None required
Pinus albicaulis	White-bark pine	SC, SE (Zone 3)	20–100 ft.	2,600	90 days on moist medium at 34–41°F
Pinus aristata	Bristlecone pine	SC, SE (Zone 3)	8–50 ft.	18,100	30 days on moist medium at 34–41°F
Pinus banksiana	Jack pine	INT, SC, SE (Zone 2)	35–100 ft.	131,000	7 days on moist medium at 34–41°F
Pinus cembra	Swiss Stone pine	INT, SC, SE (Zone 4)	30–70 ft.	2,000	90 days on moist medium at 34–41° F after mech. scarific.
Pinus contorta var. latifolia	Lodgepole pine	INT, SC, SE, W (Zone 5)	30–80 ft.	94,000	30 days on moist medium
Pinus contorta var. contorta	Shore pine	SE (Zone 7)	20–30 ft.	135,000	20 days on moist medium at 34–41°F
Pinus flexilis	Limber pine	INT, SC, SE, W (Zone 2)	20–80 ft.	4,900	30 days on moist medium at 34–41°F
Pinus mugo	Mugo pine	INT, SC, SE, W (Zone 2)	6–40 ft.	69,000	None required
Pinus sibirica	Siberian stone pine	INT, SC, SE (Zone 3)	50–90 ft.	1,800	Cold moist strat.
Pinus sylvestris	Scotch pine	INT, SC, SE (Zone 2)	60–130 ft.	75,000	30 days on moist medium at 34–41°F
Pseudotsuga menziesii var. menziesii	Douglas fir	SC, SE (Zone 4)	150-200 ft.	39,500	21 days on moist sponge at 32–41°F
Thuja occidentalis	Northern white cedar	SC, SE (Zone 2)	40–100 ft.	346,000	None required
Tsuga heterophylla	Western hemlock	SC, SE (Zone 6)	100–150 ft.	260,000	21 days on moist medium at 34–41°F
Tsuga mertensiana	Mountain hemlock	SC, SE (Zone 4)	25–125 ft.	114,000	90 days on moist medium at 34–41°F

Table 1 continued: Listing of Trees Adapted to Alaska Environments

Species	Common Name	Hardiness	Height (ft.)	Seeds per lb.	Pre-germination
Deciduous:					
Acer glabrum var. douglasii	Douglas maple	SC, SE (Zone 3)	20–30 ft.	13,400	Warm followed by cold strat.
Acer negundo	Boxelder maple	SC, SE (Zone 2)	30–75 ft.	13,400	60 days on moist medium at 34–41˚F
Acer platanoides	Norway maple	SC, SE (Zone 3)	40–100 ft.	2,800	90 days on moist medium at 34–41˚F
Acer rubrum	Red maple	SC, SE (Zone 3)	40–90 ft.	22,800	None required
Acer saccharinum	Silver maple	SC, SE (Zone 3)	50–90 ft.	1,780	None required
Acer tataricum	Tatarian maple	SC, SE (Zone 3)	15–20 ft.	11,300	90 days on moist medium at 34–41˚F
Acer tataricum var. ginnala	Amur maple	INT, SC, SE (Zone 2)	multi-stem	unknown	90 days on moist medium at 34–41˚F
Alnus crispa	Mountain alder	INT, SC, N (Zone 2)	3–13 ft.	1,280,000	60 days on moist medium at 34–41˚F
Alnus sinuata	Sitka alder	INT, SC, SE, W (Zone 2)	5–40 ft. multi stemed	unknown	60 days on moist medium at 34–41˚F
Alnus tenuifolia	Thinleaf alder	INT, SC, SE (Zone 2)	15–30 ft.	675,000	None required
Betula glandulosa	Shrub birch	INT, N, SC, SE, W (Zone 1)	1–10 ft.	3,839,000	None required
Betula nana	Dwarf arctic birch	INT, N, SC, SE, W (Zone 2)	3–5 ft.	unknown	unknown
Betula papyrifera	Paper birch	INT, SC, SE, W (Zone 2)	20–80 ft.	380,000	None required
Betula pendula	European white birch	SC, SE (Zone 2)	40–50 ft.	795,000	None required
Cornus canadensis	Dwarf dogwood	INT, SC, SE, W (Zone 2)	3–12 in.	67,000	Cold strat. for 3–4 months
Cornus stolonifera	Red-osier dogwood	INT, SC, SE (Zone 2)	3–12 ft.	18,500	Cold strat.
Cotoneaster acutifolius	Peking cotonester	INT, SC,SE (Zone 4)	5-8 ft.	24,194	Cold strat. for 1–3 months
Crataegus succulenta	Fleshy hawthorn	INT, SC,SE (Zone 3	25 ft.	20,600	Cold strat. for 4–5 months
Fraxinus pennsylvanica	Green ash	SC,SE (Zone 3)	50-60 ft.	17,260	warm strat. for 60 days and cold for 6 months
Malus sp.	Apple varieties	INT,SC,SE (Zone 3)	10-25 ft.	up to 60,000	30 days alter. warm days and cold nights
Populus balsamifera	Balsam popular	INT, N,SC,SE, W(Zone1)	30-50 ft.	unknown	None required
Populus tremulides	Quaking aspen	INT,SC,SE (Zone1)	40-80 ft.	3,600,000	None required
Populus trichocarpa	Black cottonwood	SC,SE (Zone 3)	80-100 ft.	300,000	None required
Prunus maackii	Amur chokecherry	INT,SC,SE (Zone 2)	35-45 ft.		
Prunus padus	European birdcherry	INT,SC,SE (Zone 3)	30-40 ft.	8,900	Cold strat. for 3 months
Prunus virginiana	Chokecherry	INT,SC,SE (Zone 2)	20-30 ft.	4,790	Cold strat. for 3-4 months
Pyrus ussuriensis	Ussurian pear	INT,SC, SE, (Zone 3)	30-40 ft.	9,100	Cold strat. 38°F for 60 days
Sorbus acuparia	European mtn. ash	INT, SC,SE, W (Zone 2)	15 ft.	Unknown	Cold strat. for 2–4 months

Tree Nursery Site Assessment—What are the Conditions?

Selecting an outdoor bareroot nursery site requires attention to the environmental conditions and fluctuations that may occur year-round. Problems with seedling mortality caused by insects, diseases and environmental conditions can be minimized by careful consideration of site conditions. To produce economical high-quality seedlings for sale to the public, careful attention to site conditions is also essential. Tree seedlings can be impacted by both biological (biotic) and non-biological (abiotic) factors (Table 2). Consideration should be given to these factors when determining a location for seed production.

Table 2: Listing of Biological and Non-biological Factors Effecting Nursery Site Selection

Non-biological Factors:	Biological Factors:
Cold Temperatures: Cold or frozen soils and permafrost or partial permafrost conditions. Be concerned about slope aspect and elevation and precipitation patterns. Seedlings lifted from frozen soil or root pruning can cause damage.	Fungal infections, including evidence of root rots, molds and other related fungal conditions affecting roots and leaves. Avoid boggy wetlands or poorly drained soils.
Wind: Exposed areas with high wind potential should be avoided. Wind can be a cause for several problems including excessive moisture stress and mechanical damage to seedlings.	Bacteria and viruses that can cause mortality or defoliation. Avoid species that are known to be highly susceptible. Seedlings can be very susceptible to damping-off disease and other disorders that can destroy large numbers of trees.
Soil Condition: Poor quality soils with nutrient deficiencies, high or low pH, salt. Be sure to do soil sampling for the entire plantation area. Soils low in nitrogen and other nutrients can be augmented if necessary. Be careful of poor drainage that may cause contamination such as salt from roads. Avoid areas of low pH below 4.0 or exhibiting metal toxicity.	Soil nematodes can damage seedling root systems. Consult the local Extension agent on nematodes and control options.
Mechanical Injury: Muddy or boggy soils may cause machinery problems that could cause damage to seedlings. Coarse textured sandy soils are best for lifting seedlings without damaging the root systems.	Areas of high browse can cause severe damage unless fenced and controlled. Damage by browsing animals can cause loss of trees and value. Consider how to control pests, possibly by fencing.
Heat: Avoid sites with excessive heat exposure which may cause problems with costs for irrigation and associated plant moisture stress and loss of seedling growth.	Birds can consume seed as well as damage seedlings. Does the area have a bird problem?
Avoid dry or water logged soils: Excessive moisture stress and wet root conditions can cause seedling mortality. Wet soils are also sources of fungal infections.	Weeds and weed control measures. Be aware of herbicide and pesticide application limitations for the nursery area.
	Alaskan forest soils can be prone to mosses and algae that can be damaging to seedlings or difficult to control.

An Example of High-Quality Spruce Seedling Production

If you are interested in producing commercial quality seedlings for sale in Alaska, consult the American Standards for Nursery Stock, originally published in 1923 by the American Nursery and Landscape Association. The latest edition of the standards is ANSI Z60.1-1996 and is available upon request directly from the ANLA or their website http://www.anla.org.

Seeds for Planting: There are several national and international seed companies that can provide seed for growing seedlings. However, care must be taken to consider the source of the seed and whether or not it is certified seed. Certified seed has documentation for proof of source location to further assist in determination of seed origin and seed zone classification.

Variations in local and regional environmental conditions limit where seeds can be grown successfully. Variations in climate and environment throughout a region are the basis for the development of seed transfer zones. Some rules to follow regarding seed collection include:

1. Maintain a record of the source location of the seed used. Include the seed zone, aspect and elevation of the seed source and keep this information on a tag with the seed storage bag at all times.

2. Collect seeds from at least 30 well-distributed and high-quality trees throughout the area of collection.

Colorado blue spruce are well-suited for growing in parts of Alaska. Nurseries, like this one in Oregon, grow bareroot (left) and potted (right) trees for shipment throughout the United States, including Alaska.

3. Try to collect seeds from sites similar to where you will be planting them (features including elevation, soil type, amount of moisture available and slope aspect).

4. Try to avoid transfer of seeds from upland areas to lowland or riparian sites and vice versa. Try to avoid transfer of seedlings beyond natural barriers such as mountain ranges or above treeline.

5. Restrict seed transfer to within 500 feet in elevation of the collection source.

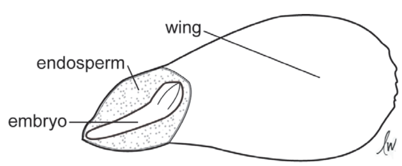
Collecting Seeds

White, Sitka and black spruce cones all mature in the fall (late August through September) in Alaska. Squirrels collecting cones can be an indicator of seed ripeness. However, you can better estimate seed ripeness by cutting several cones in half lengthwise and examining the seeds that have been cut in half. Seeds with embryos extending at least 80 to 90 percent of the length of the seed cavity are considered to be sufficiently ripe to be viable.

Care in collecting tree seed is important since molds and excessive moisture and/or high temperatures can damage the ability of seeds to germinate. Also, care should be taken to assure that the cones are not collected too early, since this can significantly reduce seed viability. If the cones are collected too late, many of the good seeds may have already been shed, since the cone scales open during cone ripening releasing the seeds.

White spruce canopy with cones, Fairbanks, AK.

Tree seeds can be collected from standing trees, felled trees or from squirrel caches. The seeds can be stored on racks in open mesh bags such as gunny sacks that allow the cones to dry while limiting the formation of molds. Each bag should be carefully tagged with information about the species, location of collection and date of collection of the cones. The bags of cones should be filled only half full and should be stored in a covered, dry, well-ventilated location. A few weeks to a month of drying, depending on environmental conditions, will be required before the cones open to release the seeds. Collect and cleanse the seeds using a screen box to sift debris from the cone bags and isolate the tree seeds.



White Spruce Seed
Embryo cross section with wing

Seeds should be dewinged and stored in dry plastic bags or sealed containers and refrigerated. The containers must be sealed against moisture.

Contact Forestry Specialist Robert Wheeler, Cooperative Extension Service, for information on non-spruce tree seedling production:

phone (907) 474-6356; fax (907) 474-5139

e-mail ffraw@uaf.edu

PO Box 756180, University of Alaska Fairbanks, Fairbanks, AK 99775-6180.

Seedling Production

Tree seedling producers must make a choice whether to produce bareroot seedlings using native soils in an outdoor environment or whether to produce container seedlings planted in artificial medium usually under controlled environmental conditions in a greenhouse. Bareroot seedlings will tend to have larger, more developed root systems and can be grown in place for two or more years before outplanting. Culturing techniques such as bed wrenching and root pruning can be used with bareroot stock to enhance the quality and mass of roots and modify the shoot to root ratios. However, Alaskan environments can create problems for bareroot nurseries due to the short growing seasons and cold soils, which can make it difficult to manage and lift seedlings at needed times.

Container seedlings have several advantages over bareroot stock. These include ease of processing seedlings for mass production and development of uniform seedlings that are easier to plant in harsh environments and the convenient, controlled application of mycorrhizal inoculation of root systems. Container seedlings are more easily grown inside greenhouses where it is easier to control day and night temperature regimes, day length and light intensity, watering and fertilizing, and carbon dioxide concentrations. Some drawbacks of container seedlings are that they are more prone to frost heave, they tend to be a smaller seedling at outplanting than bareroot seedlings, they have a higher potential for root binding, they may be prone to more transplant shock and moisture stress.

There are a number of forest tree seedling containers on the market, several of which have been used in Alaska and generally occur in the form of either plastic tubes, styrofoam blocks, or pre-formed plugs. Nurseries and greenhouses can be contacted to purchase supplies of these container types. Tree containers vary greatly in size and design depending upon the size of the seedling being produced, root system developed and planting medium being used. Commonly used tree containers include the Ray Leach Single Cell (tubes), plastic dibble tubes, styrofoam blocks and Spencer-Lemaire Root Trainers.

Production of white spruce seedlings in Alaska for Alaskans shows great promise. Here, white spruce in square pot containers are being grown at an Oregon nursery.

When transferring the container seedlings to the field for planting, it is common to remove the tree seedlings from their containers, wrap them in plastic wrap and transport them in a damp and shaded enclosure or bag to the field for planting.

Growing Medium for Container Seedlings

There are many alternative potting mixtures available for planting seed or seedlings in containers. Commercially prepared media are available in convenient bulk wrapped cubes but are more expensive than self-prepared media which can be easily made from ingredients available at most commercial nursery/greenhouse retailers. Commonly used mixtures include 1 to 3 parts of medium textured peat moss to 1 part coarse to medium horticultural grade vermiculite mix. Also use of 0.3- to 0.5-parts Perlite can be added to the mixture, as well as fertilizer and micronutrients. The addition of magnesium sulfate and Dolomitic lime may also be needed, however too much can cause seedling nutrition problems. The use of peatmoss adds acidification which acts as a buffer that will hold the soil mixture at about 5.5 pH even after considerable lime is added. Conifer species prefer an acidic soil pH which also helps to reduce seedling losses to damping-off disease. Growers are cautioned that mineral soil should never be used for container media.

Seedlings and Temperature Control

Cold stratification of tree seeds, a practice used to enhance germination success has been found not to be necessary for white and black spruce and fresh lodgepole pine seeds (stored lodgepole pine are recommended to have a 30 day pretreatment of 33° to 41°F on moist medium).

Conifer seeds will germinate best in 60° to 70°F conditions. Germination of seed will be inhibited if temperatures exceed 75°F. After the seedlings emerge, the recommended temperatures for seedling growth are 75°F to 80°F during the light period (day) and 65°F to 70°F during the dark period (night). Temperatures above 85°F to 90°F will inhibit seedling growth and survival. Care must be taken to assure that sufficient air circulation is provided for greenhouse environments. For guidance on germinating tree seeds consult the pregermination requirements shown on Table 1 (Landis, Tinus and Barnett 1998).

Maintaining proper temperatures for growing seedlings is especially critical for young seedlings. Excessive temperatures can lead to plant moisture stress within seedlings along with the shutting down of photosynthesis under higher temperatures and increased respiration energy costs to the seedlings. Higher temperatures in greenhouses can be controlled by venting such as by convection or fan driven or by use of a water-cooled baffle system to draw moist air into the greenhouse which provides cooling by evaporation. Alternatively, cooling can also be achieved by use of shading or use of shade cloths to cover the seedlings or greenhouses to increase reflectance of solar radiation. A variety of materials can be used to provide shade including wooden lath and shade cloths. Examples of temperature control are provided by Table 3 (Landis, Tinus, McDonald and Barnett 1992).

Table 3: Example of Temperature Control by Use of a Shade Cloth

Shading Type	Light Intensity Micromoles/s/m2	Light Intensity ft-candles	Air Temp. °C	Air Temp. °F	Leaf Temp. °C	Leaf Temp. °F
No Shading	1,370	70,200	36	97	40	105
50% Shade Cloth	525	27,000	32	90	32	90

Additionally, cooling of seedlings especially within greenhouses can be achieved by use of short burst of mists during the hottest period of the day. Combining misting with the use of light-colored mulch rock or material can effectively help to control heat damage to the stem area of the seedling.

Significant young seedling losses due to damping-off syndrome can be a serious problem resulting in significant losses of seedlings (see pest control section).

Once the seedlings have grown to 8 inches tall, gradually reduce the growing temperatures 5 to 10 degrees per week (especially if possible during the dark period) in order to prepare them for being transplanted. Reduced temperatures, shorter day lengths (photoperiod), and perhaps lower light intensities are necessary to induce dormancy and the hardening of seedlings for eventual transplantation. Cool temperatures and even mild frost during the night periods can be beneficial to completion of the hardening process for over-wintering container grown seedlings.

Illumination Requirements

Conifer seeds germinate well at low-light intensities and germination can even occur in full darkness. The minimum photoperiod and light intensity recommended for the seedling emergence phase at latitudes north of 60° are 20 hours at 350 micromoles/m2/sec or one-third full sunlight. Optimum average light intensities are likely in the 900 to 1,200 micromoles/m2/sec range during the period of rapid seedling growth. Maximum outdoor light intensity on a clear day in mid-June at Fairbanks is about 1800 micromoles/m2/sec. Consequently, if possible, it is recommended that some form of shading be used to control light intensity by as much as 30 percent. Various shade cloth materials are available for use in shading which vary depending upon the thickness and color of the cloth. Germinating seedlings are especially susceptible to high-light intensities and may require additional shading to further reduce light down to the level of 200-350 micromoles/m2/sec before being placed under higher light intensities during their rapid growth phase.

Once the seeds have germinated and the seedlings begin the period of rapid elongation (usually lasting about 60 days) it will be necessary to maintain a 20- to 22-hour light period. As the time approaches for outplanting or hardening it will be necessary to reduce the photoperiod back to a minimum of at least 12 hours. Most nurseries harden seedlings under natural conditions of light and temperatures. Artificial darkness is often required to reduce photoperiods and harden low latitude seedlings (seeds derived from southern latitudes) during late summer at high latitudes (60° to 68° North). The problem of growth cessation, dormancy and winter hardening of stock in the nursery is avoided if the seedlings can be transplanted to the field by June or early July (Wheeler and Alden 1998).

Fertilizer Recommendations

Bareroot Seedlings (seedlings grown and managed in field soils)**:** Fertilizing seedbeds is very important to maintain the health and vigor of seedlings. Applications of fertilizer can be made either by top dressing over the seedbed or by incorporating it directly into the planting media. You will need to determine how much and what kind of fertilizer is needed. Both nitrogen (N) and potassium (K) are soluble and can be carried to the root zone of the seedlings via the irrigation water and consequently can be spread on the surface of the seedbed. Phosphorus (P) is much less soluble and so must be incorporated into the soil in granular form or applied as liquid fertilizer.

Once the seedlings have emerged and grown beyond 8 centimeters (3 inches) you will need to apply an application of a balanced formula fertilizer such as 10:10:10 (N:P:K) at the recommended rate of 7 ounces per 100 square feet of bed space (Alden 2003). This should be applied twice in the summer (i.e. June and July) but discontinued after July 15. You will need to apply water immediately after fertilizing to flush off any fertilizer adhering to the foliage and facilitate its transport to the root zone. Intensive fertilization schedules are available for bareroot seedlings, depending upon soil pH. For soils that are acidic or have pH's less than 7.0, select either ammonium phosphate (11:52:0) or ammonium nitrate (34:0:0). If basic soils contain pH's higher than 7.0 then use ammonium sulfate (21:0:0:26) as the nitrogen source which will also help to lower the soil pH over time.

Container Seedlings: Fertilizer recommendations for container seedlings can vary depending upon the soil medium characteristics such as pH. Commercially prepared soil mediums commonly include a starter fertilizer incorporated in the medium.

Trays of six-month-old Western red cedar seedlings in an Oregon greenhouse.

For preparing self-mixed growing medium, slow release fertilizers such as Osmocote (17-7-12) are suggested along with additions of MagAmp and Micromax for macronutrient and micronutrient needs. The practice of nutrient loading is commonly used to reduce transplanting shock by applying fertilizer after the seedlings enter dormancy and before being outplanted.

Seedbed Development and Planting Recommendations

Bareroot tree nurseries generally use raised seed beds (i.e. 4 feet wide and raised 3 to 6 inches). This approach promotes better soil drainage and soil warming. Wet soils can contribute to damping off and other diseases for the developing seedlings.

Seeds are usually sown in rows at a density such that each seedling will be able to grow without excessive competition. This approach also makes it easier to monitor and achieve uniform seedling survivial and growth. Seedling rows are commonly planted at 6 inches or 12 inches between rows for the production of 2+0 seedlings (trees grown for two years in the same seed bed without being transplanted to a transplant bed). A general goal for seed bed density is to achieve approximately 25 seedlings per square foot with seedling spaced about 1 to 1.5 inches apart. Consideration must be given seed germination rates that are less than 100 percent so that additional seeds are planted to account for losses in seed germination. For example, if seed germination rates are only estimated to be about 65 percent then instead of planting 25 seed per square foot as would be used for 100 percent germination, plant about 38 seeds per square foot. It may be necessary to test the seed to determine germination rates before planting nursery beds (Quarberg and Jahns 2000). Germination rates can decline rapidly with older stored seeds.

Irrigation of Seedlings

To maximize seedling growth, photosynthesis and seedling vigor it is necessary to minimize the level of plant moisture stress in the seedlings caused by inadequate irrigation, high temperatures and excessive seedlings transpiration. Watering is important, but don't oversaturate the soil, as excessively wet soil can promote pathogenic fungi, especially "damping-off." Initially, it is best to provide repeated light mistings. Once the seedlings have emerged and grown approximately one month, you can begin to irrigate the soil deeper, but not excessively. Watering can be done with an oscillating yard sprinkler as long as a consistent application of water is achieved. Drip irrigation and permanent sprinkler systems can be more effective in giving even applications of water, but may involve more cost and maintenance. A soaker hose can also be effective at providing irrigation water to the seedlings, although their delivery is often uneven at best.

Transpiration losses increase rapidly as the seedlings grow larger, increasing the potential for moderate to heavy plant moisture stress. It will become necessary to irrigate more frequently with multiple applications per day. As it becomes closer to the time of transplanting or outplanting, you will want to develop some hardiness in the seedlings to limit transplanting shock. Hardiness can be developed by reducing the growth of the trees which may require lower temperatures, light and water. Full dormancy and hardiness are not required for seedlings outplanted in late June or July, but to avoid stem breakage during the handling of the seedlings it would be helpful to partially harden them off so they are not as succulent and tender.

For container seedlings, keep the growing medium between field capacity (standing water at the surface) down to 70 percent of field capacity. As the seedlings grow, much more transpiration occurs, and watering as often as several times daily may occur. To initiate hardening of the seedlings, it may be necessary to reduce water, temperatures and light.

It is best to water seedlings early in the day with a deep watering. This will stimulate better root development and a better root to shoot ratio. During hot days, brief light misting during peak afternoon temperatures can lower the risk of damage to seedlings by higher temperatures. Having a good mulch cover for the soil or container media can also improve water retention and uptake by the seedlings.

Harvesting and Transport

When harvesting seedlings the following guidelines should be observed (Chastagener 1997 and Dumroese, Landis and Wenny 1998)

1. Be careful when lifting and handling the seedlings to make sure they are not exposed to excessive warm temperatures or drying of the roots. Preferred lifting temperatures (removal from the seed bed) should be in the 40° to 50°F range.

2. Seedlings should be stored and transported in protective bags such as polyethylene bags, waxed boxes, or open-ended peat moss bales. The interior of the bags should be kept moist by adding wet sphagnum moss.

3. Keep the seedlings cool or refrigerated during transport and while awaiting planting. Once the seedlings have broken bud do not refreeze them (storage temperature should be kept around 35° to 40°F).

CONTROL OF PESTS AND PESTICIDES

Note: A more comprehensive review of insects and diseases of Alaska tree species can be found in: Insects and Diseases of Alaskan Forests. USDA Forest Service publication. 2001. R10-TP-87.

Spruce: (*Picea abies* – Norway spruce, *Picea mariana* – black spruce, *Picea pungents* – Colorado blue spruce, *Picea glauca* – white spruce, *Picea sitchensis* – Sitka spruce)

Spruce plantations in Alaska risk potential infestation and damage by the following agents. Careful monitoring and prescribed pesticide applications can provide control of damage and reduction of potential tree value losses.

Integrated Pest Management Practices

Although commercial spruce tree seedling production does not currently exist in Alaska, many woodlot managers, foresters and landscapers utilize some form of IPM practices. Alaskan forests are relatively free of many major pests that persist in Lower-48 forests, however due to Alaska's expansive spruce monocultures, the destructive pests that are present have caused extensive damage. The quarantining of new plant materials and the monitoring of existing stands for newly introduced pest species continue to provide timely information in helping to avoid damage and subsequent reduction of valuable plantings. Thoughtful site selection for future stand development, combined with careful thinning and pruning practices, add value to healthy forest plantings.

Diseases

- **Damping-Off**
- **Spruce Needle Rust**
- **Rhizosphaera Needlecast**

Note: Although rusts and needlecast typically attack older trees there is evidence to suggest that they can be a problem in plantations and nurseries. A more detailed description of spruce container diseases and insects can be found in Landis, Tinus, McDonald and Barnett 1989.

Damping-Off (*Pythium/Phytophthora*)**:** Although damping-off syndrome can be caused by either fungal infections or abiotic factors such as chemicals and fertilizers, their symptoms are somewhat similar in that seedlings tip over at ground level (root collar). It is important to monitor young seedlings for evidence of damping-off syndrome and remove any dying or dead seedlings in order to reduce the risk of further contamination. Fertilizer applications and watering may need to be reduced if losses by damping-off are not controlled. Contaminated or moldy seedlots exhibiting high germination losses to damping off disease may need to have the seeds treated with a 3 percent solution of hydrogen peroxide for four hours prior to germination to increase seedling survival. In some cases, a preplant chemical treatment may be required to minimize the effects of damping-off disease.

Spruce Needle Rust (*Chrysomyxa ledicola Lagerh.*)**:** This is a fungal disease that infests only the current years' spruce needles but requires an alternate host to complete its life cycle (Labrador tea – *Ledum spp*). The infections are characterized by the presence of pale orange spore masses which erupt from the needles. The spruce needle rust has an alternative host, Labrador tea, which must be present in the environment for the lifecycle of the rust to be completed. Control of Labrador tea within the ground vegetation around the trees out to about 1,000 feet will provide some protection from further infections. The SNR can cause trees to be weakened and defoliation to occur but the infections are cyclical and dependent upon cool moist conditions for spore formation.

Control is possible by fungicides for high value trees or seedlings where appearances are of concern.

Spruce Needle Blight or Needle Cast: There are three diseases in this class of needle fungal infections that affect spruce needles: (*Lirula macrospora* (Hartig) Darker), (*Lophodermium picea* (Fckl.) V.Hohn.) and (*Rhizosphaera pini* (Corda) Maubl.). Spruce needle cast or blight is usually not fatal to trees unless there are several successive years of attack. Outbreaks follow wet weather patterns that allow the spores to spread via rain splash. Infected trees are often localized but if control becomes necessary carefully timed applications of fungicides have been shown to be effective. Nurseries may need to limit the time that the needles are wet.

Spruce needle cast is a fungal infection that usually only appears on one-year old needles, however, older needles on trees under stress can also be infected. The infection actually begins with an initial infection of the new year's growth of needles by spores which then don't become pronounced until after the needles are one year old. Symptoms usually first appear on the tree's lower branches and then progressively move upward in the tree. Black fruiting bodies will appear as dark spots or patches on the underside of the needles. Fungicide control of needle cast can be successful, but careful timing is required to apply the fungicide just as the needles are starting to emerge after bud break. Delayed application of fungicides will likely be much less successful in controlling the infection. Control may require planting alternative tree species that are not susceptible to spruce needle cast.

Table 4: Chemical Options for Control of Damping-off Disease

Fungicide	Product Rate	a.i. Rate
Captan 50WP	2 lb/100 gal H_2O apply 15 gal of spray per 1,000 square ft Work into top 3–4 inches of soil	1 lb ai/100 gal H_2O

Table 5: Chemical Options for Control of Spruce Needle Rust

Fungicide	Product Rate	a.i. Rate
Protect T/O	1–2 bags (3 lb/bag)/100 gal	2.4–4.8 lb/100 gal

Table 6: Chemical Options for Control of Spruce Needle Cast or Blight

Fungicide	Product Rate	a.i. Rate
Bravo Weather Stik	2–5.5 pt/A	1.5–4.125 lb/A
Kocide 2,000	1.5–3 lb/A	0.81–1.61 lb/A
Protect T/O	1–2 bags (3 lb/bag)/100 gal	2.4–4.8 lb/100 gal
Spectro 90 WDG	1–2 lb/100 gal	0.9–1.8 lb /100 gal

Insects

- **Spruce Spider Mite**
- **Spruce Budworm**
- **Spruce Aphid**

Spruce Spider Mite (*Oligonychus ununguis*)**:** The presence of spruce spider mites is indicated by yellow or bronzish stippling beginning near the needle bases. Infestations usually begin on older needles of the lower branches and spread upwards as the mite population increases. Damaged needles may turn brown or reddish-brown. Fine webbing may cover the needles and twigs. The actual spider mites are very small and vary in color from greenish to orange, dark green or black, with orange legs. Spruce spider mites attack many species of conifers. They are usually spread by wind. These mites are often worst on dusty roadside trees.

Spruce Budworm (*Lepidoptera: Tortridcidae; Choristoneura*)**:** This is a pest found throughout Alaska. They feed on foliage and buds of true firs, spruce and Douglas fir. Mature larvae are green-brown and up to an inch in length. They destroy buds, new foliage, cones and seeds. They typically attack the newer needles but repeated infestations can result in damage to older needles as well. Symptoms include defoliation or thinning of the upper canopy of the tree. Brown caterpillars emerge in mid-May and begin feeding on new needles. Large infestations show reduction in radial growth with top kill being common. Monitoring population buildups through trapping and visual observation along with a timely application of chemical controls if needed can be used to control defoliation and cone reduction.

Although this is not a common problem for seedling production in Alaska, it was felt that it would be beneficial to include control measures for existing trees ranging from seedling to fully mature. The present epidemic of eastern spruce budworm has caused considerable concern for landowners that are interested in planting and growing spruce seedlings.

Table 7: Chemical Options for Control of Spruce Spider Mites

Insecticide	Product Rate	a.i. Rate
Insecticidal soap	2.5 fl oz/gal	0.16 lb ai/gal
Kelthane	0.50–1.00lb/A	0.25–0.5 lb ai/A

Spruce Aphids (*Homoptera: Aphididae; Elatobium abietinum*) and **Spruce Gall Aphids** (*Homoptera: Phylloxeridae; Adeligidae*)**:** They are found in Southeast Alaska up through the Interior. Population increases are directly related to mild winter temperatures and available soluble nitrogen. Stressed trees are more susceptible to damage, so with careful production practices the populations could be kept at a reasonable level. Removal of galls from high value trees is an efficient control method if done before adult emergence in summer. Commercially available insecticides are also effective.

Table 8: Chemical Options for Control of Spruce Budworm

Insecticide	Product Rate	a.i. Rate
Biobit HP	0.25–0.75lb/100 gal	0.145–0.436 lb/100 gal
Sevin SL	0.75 fl oz/1,000 sq ft	0.02 lb/1,000 square ft
Confirm 2F	4.0–8.0 oz/A	0.06–0.12 lb/A

Table 9: Chemical Options for Control of Spruce Aphids

Insecticide	Product Rate	a.i. Rate
Azatin XL	21 fl oz/A	0.04 lb/A
Talstar N	5–10 fl oz/A	0.025–0.05 lb/A
Biflex*	0.26–1.28 fl oz/10 gal	0.004–0.02 lb/10 gal
Tempo	1.5–5.4 oz/100 gal	0.012–0.042 lb/100 gal
Insecticidal soap	3–5 fl. oz gal	0.014–0.024 lb/gal
Endeavor 50WG**	2.5–5 oz/100 gal	0.078–0.156 lb/100 gal

*10 gallons per 4,356 square ft
**Do not apply more than 48 oz/A per year

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