PACIFIC REGENERATION TECHNOLOGIES INC.

PLANTING HANDBOOK

FOR INTERIOR REGIONS

This handbook is for all those involved in reforestation, from ordering seedlings right up to planting. The section on stock type selection is geared for the silvicultural forester or anyone else involved in ordering seedlings. The latter sections are designed for those actually planting the tree seedlings, although the information should prove useful to all involved in the forest regeneration process. As a tree planter, the goal of this handbook is to provide you with information that will enable you to consistently plant seedlings yielding high growth plantations. If you understand the principles governing seedling growth limiting factors and associated microsite influences, you will be in a better position to make the most productive decisions. Thoughtful adherence to the philosophy within these pages, in combination with careful observation of what is going on around you at the planting site, will result in many rewards for your efforts. You have now become part of a most worthwhile endeavour, that of renewing the forest for the future. The results of your contributions to this effort will be apparent and around for many generations, something in which you can take a healthy measure of pride!

If you have any questions or concerns, please ask your foreman or supervisor for further information or clarification. General information may also be obtained from your nearest PRT nursery.

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Table of Contents

PART I Introduction

PRT Background

PRT Armstrong Nursery is a member of the Pacific Regeneration Technologies Inc. (PRT) group of companies. PRT is comprised of thirteen nurseries located across Canada in Ontario, Saskatchewan, Alberta and British Columbia. PRT was an employee owned company founded in 1988 in response to the British Columbia government privatization initiative. Since 1988, PRT has increased production from 50 million to over 120 million seedlings, providing stock for western Canada, Alaska, and the US Pacific Northwest. Greenhouse capacity has increased tenfold to more than 2 million square feet. PRT also has extensive open compound growing areas, and bareroot facilities. These capital expenditures have allowed PRT to remain current in an evolving forest industry. In 1997 PRT became a public company as an Income Trust Fund on the Toronto Stock exchange.

The main services offered by PRT include:

- Seedling production - commercial forest trees and native plants
- Seed processing, storage and specialized seed treatments
- Cold (frozen) storage
- Seedling transportation
- Seed orchard management
- Seedling field performance assessment and enhancement - Field Agrologist
- Tree Planting – Frontier Resource Management (Ontario)

Location of PRT Facilities

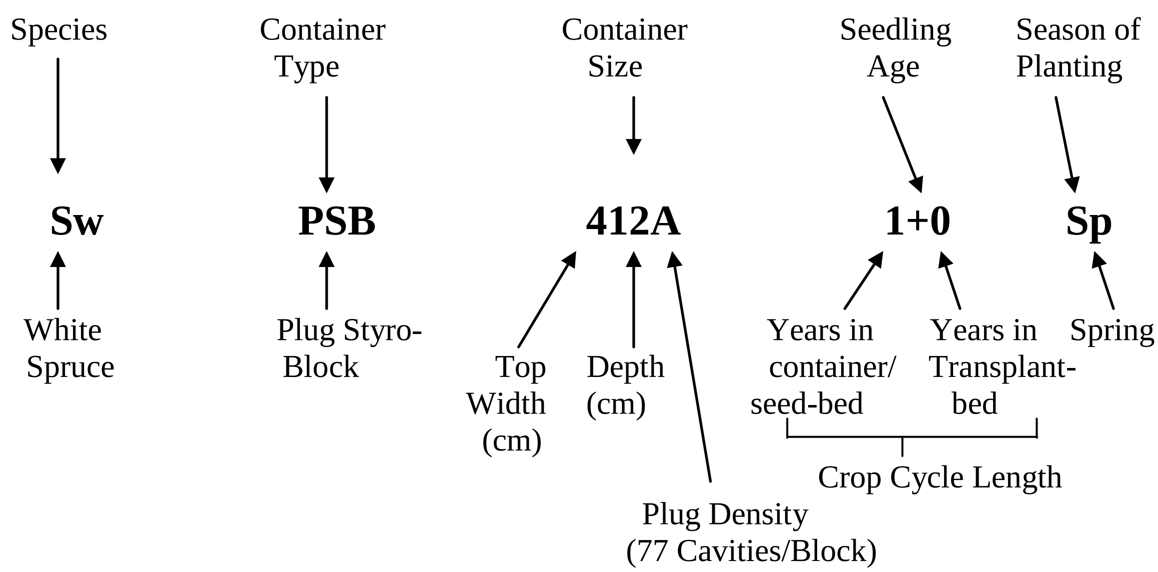
PART II Stock Type Selection

Types of Nursery Stock

- Three types of nursery stock
  1) Container – Plug Styroblock™ (PSB), Copperblock™ (PCT), Plug Airblock (PAB)
     - frozen stored vs hot lift
     - greenhouse vs open compound
     - 1+0 vs 2+0
  2) Bareroot (BBR)
  3) Plug Transplanted Bareroot (PBR)

- Two types of container stock available, although in B.C. only Styroblocks™ grown
  a) rigid-walled containers, removed before planting exposing a firm root plug
     - e.g. Styroblock™, and Multi-pot, Panth, Spencer-Lemaire
  b) soft-walled containers which remain intact at planting
     - e.g. Jiffy (first forestry use was in 1985)

Styroblock™ Stock Type Nomenclature



Container Modifications – Copper-treated Styroblock™ (Copperblock / PCT)

- Concern over toppling in planted container grown (Styroblock™) lodgepole pine in B.C. led to container modification via chemical root pruning by coating the inside of the growing container walls with copper

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- The copper promotes the formation of a more fibrous root system, which results in "softer" plugs than those grown in regular Styroblocks™.

Despite their wide acceptance, the long-term benefits of copper root pruning have never been proven. Since the introduction of Copperblocks™, vertical ribs to prevent root spiraling have been introduced; the media bulk density has decreased allowing vigorous root growth without plug compaction; and sowing dates have been refined such that stock is not held any longer than necessary, preventing rootbound plugs. [*For more information see the Copper Root-Pruning of Coniferous Forestry Seedlings article in Notes from the Field on the PRT website at http://www.prtgroup.com/customersupport/resources/field/ prtkiiskila_article5.html*].

Pine Needle Morphology – Primary vs Secondary or Mature Needles

Pine may also be ordered with primary or secondary (i.e. fascicle) foliage. Even though primary needle pine has less foliage, and thus less transpirational area, secondary needle pine is often considered more resistant to drought stress. Presently this is based more on looks than anything, as there is no significant evidence in the literature to support enhanced field performance of one needle type over the other. Along with fascicle needles, secondary needle pine has a whorl of buds at the apex vs the single terminal bud usually found in primary needle pine.

How big are the Seedlings?
Common[1] Specifications of Various Interior Spruce (SX) Stock Types

Stock	Cavity/	Volume	Age	**TARGET**		MINIMUM		MAX	Ht:
Type	Block	ml		**Ht**	**RCD**	Ht	RCD	Ht	RCD
1+0 Stock									
313B	160	65	1+0	**18**	**3.0**	11	2.2	25	60
410	112	80	1+0	**20**	**3.2**	12	2.3	28	63
415B	112	105	1+0	**22**	**3.5**	13	2.6	30	63
412A	77	125	1+0	**24**	**3.8**	14	2.8	35	63
415D	77	160	1+0	**26**	**4.0**	15	3.0	40	65
512A	60	220	1+0	**30**	**4.2**	15	3.2	45	71
615A	45	213	1+0	**35**	**5.0**	20	3.5	50	70
2+0 Stock									
415B	112	105	2+0	**27**	**4.8**	14	3.5	40	56
412A	77	125	2+0	**27**	**5.0**	15	3.8	45	54
415D	77	160	2+0	**30**	**5.3**	15	3.8	45	57
515A	60	284	2+0	**35**	**5.8**	17	4.2	50	60

[1] For comparison purposes only, actual contract specifications may differ – contact the nursery manager for more details.

Planting Season - Spring (Frozen Stored)

- Frozen stored stock can be “custom” thawed for delivery as sites are available for planting

- Once thawed, seedlings rapidly lose dormancy and hardiness and flush shortly after planting

- Prior to flushing, root activity is high, thus under favorable soil conditions roots quickly egress into the surrounding soil, reducing seedling reliance on plug conditions

- During flushing seedlings are very sensitive to stresses (e.g. drought, frost, high temperature)

- It is recommended you do not plant later than mid-June, as seedlings will be out of sync with the natural environment

Planting Season – Summer (Hot Lift)

- Seedlings are still physiologically active, thus speedy stock handling from nursery to planting site is essential

- Height growth has ceased (seedlings are generally considered too succulent for shipment during active shoot growth), and seedlings are moving into dormancy and therefore have developed some hardiness (e.g. resistance to drought, frost)

- In general, stock will not flush after planting - thus has lower water requirements and is better able to control moisture loss
  - majority of seedling resources are put into roots and stem growth

- Planting date is dictated by environmental conditions at planting

- The key to a successful summer plant is communication

Stock Type Selection

Stock type selection can be broken down as follows:
1. Identify the general site ecotype (e.g. nutrients, soil, moisture, etc.)
2. Select the desired species and seed source for the area
3. Determine the appropriate planting window for the site
4. Assess the specific site limiting factors
5. Review available site preparation methods to alleviate the limiting factors
6. Determine which stock type is best suited to the site’s limiting factors
7. Compare the cost effectiveness of the various site treatment/stock combinations

8. Select the *optimum seedling*

1. Identify the Site Ecotype; 2. Select the Desired Species and Seed Source; and 3. Determine the Planting Window

Identifying the site ecotype and selecting the appropriate species and seed source are generally done early on in the process, prior to logging. In most cases, your choices at this stage are limited and dictated by site and management factors. After the desired species and seed source has been chosen, the planting window must be determined. This will dictate whether frozen stored/overwintered stock for spring planting, or hot-lift/current crop stock for summer planting will be needed. If the planting sites have spring access, the ground never freezes or thaws early, and the probability of late spring frosts are low, then spring planting can begin as soon as feasible and continue till the summer solstice in the third week of June. For sites with late spring access (e.g. high elevation cutblocks), hot-lift stock can be planted from late June until late July, as long as the site is not subject to summer drought. In selecting a planting window, operational logistics will play a role, but they should never be allowed to compromise the seedling's biological requirements.

4. Assess the Specific Site Limiting Factors

The next step is to assess the specific factors which limit plant growth on the site in question or in the general area if it is not feasible to order stock types specifically for each individual planting site. Common site limiting factors and appropriate planting stock for these conditions are listed below:

- Vegetation Competition - select large stock
- Snow/Vegetation Press - select large, sturdy, well branched stock
- Cold Soils - select stock grown in shorter containers
- Drought - select smaller, well balanced stock
- Shallow Soils - select stock grown in shorter containers
- Frost - no stock type can fully avoid frost damage, although species differ in tolerance of frost (e.g. lodgepole pine will withstand frost much better than white spruce)
- Wet Soils - no stock type can be used to alleviate wet planting spots. In fact, the use of mechanical site preparation may be your only option of enhancing growth on very wet sites.

5. Review Available Site Preparation Methods to Alleviate the Limiting Factors

After the site limiting factors have been assessed, available site preparation methods to alleviate the growth limiting factors should be examined. Examples include tools such as chemical and mechanical site preparation, the use of which is usually governed by environmental and/or monetary factors.

6. Determine Which Stock Type is Best Suited to the Site's Limiting Factors

Taking into account the use of any planned site preparation, the stock type best suited to the site's limiting factors needs to be determined. Keep in mind that there are limits as to what any stock type can overcome. Under favourable conditions, large seedlings generally grow larger in absolute terms than comparable smaller seedlings. They do not have any additional physiological attributes to enhance performance, but simply occupy a greater area within the planting spot. A greater photosynthetic area equals quicker growth and access to the site's resources. This is coupled with a greater number of branches and buds which equals more places for new shoot growth. Once site-limiting factors (e.g. vegetation competition) are overcome, both small and large stock grow at the same rate governed by the site. However, where moisture is limited, large stock often does not survive as well as smaller stock due to the greater transpirational demand. Also, on sites with minimal or no vegetation competition, initial stock size differences are not as important as the large stock does not offer as much of an initial advantage over the smaller stock.

A clear understanding of the various types of nursery stock available will allow you to make the most productive stock selection decision. From a nursery perspective, the ideal container is one in which the nursery can economically grow seedlings of the desired size, consistently and reliably. From a field perspective, the ideal container is one which produces seedlings of a desired size capable of vigorous cost effective growth after planting. After container type and size, stock type is primarily characterized by: i) height; and ii) root collar diameter (RCD). Also, dividing height by RCD gives you the height: to: diameter ratio, which gives an indication of the seedling sturdiness. For the most part, seedling specifications typically consisting of minimum, target and maximum height, along with minimum and target RCD are included in the initial seedling contract drafted when ordering seedlings. In the nursery, there are biological limitations as to what can be produced in any given container size for each species. Taking into account seedling recovery, optimum seedling specifications reflecting what can be reliably grown in the various container sizes in a cost-effective manner have been developed. The nursery grows to the target specifications of the particular stock type, but there will always be some variation as seedlings are biological organisms (i.e. we're all familiar with the basic bell curve). Stock type selection should be based on target seedling specifications for a particular container size, specifications based on what can be produced in the nursery. If a larger seedling is desired, rather than increasing the specifications of your current stock type, a larger container size with correspondingly larger height and RCD specifications should be chosen. **In essence, after assessing the site's limiting factors and determining what size stock you require, you would order stock in the container size that has target seedling specifications which match your previously determined stock size requirement.**

7. Compare the Cost Effectiveness of the Various Site Treatment/Stock Combinations

After the stock type best suited to the site has been determined, then the cost effectiveness of the various available site treatment/stock combinations must be compared. This is the final step in determining your *optimum seedling*. To compare effectiveness we need survival and initial growth goals, which in some cases have already been set by stocking and free growing height requirements. Analysis of regeneration costs requires evaluation of these goals and cost in relation to site preparation, stock type, and post-planting vegetation control. At this point, you must remember to consider total establishment costs – initial savings upfront may result in having to spend later (e.g.

what is the cost of fill-planting?). Alternatively, initial investments in nursery culture may reduce overall costs in the long run, through a reduction in subsequent silvicultural treatments.

8. Select the *Optimum Seedling*

Finally, rank the silvicultural treatment/stock combinations by total cost per hectare. Which combination meets your free growing requirements at the lowest cost? This is the difficult part, as we usually do not have all the data we would like. Often it comes down to the level of risk you are comfortable with. Nonetheless, after comparing the above, you will be in a better position to choose your *optimum seedling* or stock type. The term *optimum seedling*, defined as the seedling which will minimize overall reforestation costs while achieving established goals for initial survival and growth, was coined by South and Mitchell in 1999.

PART III Storage and Handling

Physiological Aspects of Frozen Storage and Thawing

- Frozen storage is the least stressful way of overwintering seedlings
  - provides a stable, reliable, controlled environment

- Low storage temperatures slow, but do not stop metabolic processes such as respiration
  - frozen storage (-2°C) is used as it reduces respiration further and reduces storage molds
  - reserves are important as dark conditions of storage prevent their replenishment by photosynthesis

- Seedlings must be physiologically ready for frozen storage
  - during dormancy, conifers are most resistant to stress
  - accumulation of a couple hundred hours of low (0-10°C) temperatures (i.e. chilling hours) is required for boreal species to become frost hardy to -18°C

- Readiness for storage is determined through frost hardiness testing
  - controlled freezing to -18°C, followed by a visual assessment for foliage damage or chlorophyll fluorescence measurement

- Stock is also assessed toward the end of frozen storage well in advance of shipping
  - samples of each seedlot are potted and grown under favourable conditions in a greenhouse
  - bud flush and root growth are measured to assure viability
  - if problems are apparent, this information is reported ASAP

- After thawing:
  - seedling dormancy, hardiness and tolerance to water stress are lost rapidly

- as seedlings have previously accumulated chilling units they will break bud after sufficient heat sums have been accumulated
- between 300-400 hours of heating at 10°C is required for spring bud flush

Trees per Box – Common Amounts

	Seedlings per Box		Box Size
Container Size	Hot Lift	Frozen Storage	(length x width x height)
211A	400	400-500[1]	14 x 12 x 24
312	360	360-400	16 x 12 x 24
313B	360	360-400	16 x 12 x 24
410	270	270-360	16 x 12 x 24
415B	270	270-360	16 x 12 x 24
412A	180	180-200	16 x 12 x 24
415D	180	180-200	16 x 12 x 24
512A	120	120	16 x 12 x 36
615A	90	90	16 x 12 x 36
½ + 1½		180	16 x 12 x 36

[1] The range results from stock packaged upright vs lying down. Hot lift summer plant is packaged upright whenever possible, and no box liner is required.

Frozen Storage Guidelines

- Freezing
  - once seedlings are frozen, storage facility initially set at an ambient temperature of -5°C to ensure rapid freezing
  - ambient temperature set at -2°C
  - PRT cooler temperatures are continuously monitored by environmental computers
  - stock monitoring programs are in place at appropriate intervals

Thawing Seedlings

- Several ways of thawing seedlings:

  1) traditional slow thaw where all the stock in a particular cooler is thawed simultaneously
  2) rapid or quick thaw where particular requests are thawed a day or two before being shipped to the field
  - most stock is thawed somewhere in between these two extremes

- Good planning is essential, to be able to custom thaw orders whenever possible

- The sooner the seedlings are shipped to the field after being thawed
  - the less chance there is for the development of storage moulds and carbohydrate depletion

Slow Thaw

- Slow thaw can take up to several weeks to completely thaw container seedlings. Cooler ambient temperature is set initially at 8°C for 5-7 days, then lowered to 3°C

  - do not allow inside carton temperature to rise above 5°C
  - keep an eye on the uppermost boxes in the cooler
  - minimize seedling exposure to temperature fluctuations
  - inspect seedlings daily for temperature, disease, moisture, root and shoot activity

- Once thawed, cooler temperatures can be lowered to just above freezing to reduce carbohydrate depletion and disease potential

- Once thawed seedlings should be planted ASAP, with priority given to diseased or damaged stock

Quick or Rapid Thaw

- Rapid thawing of seedlings over a couple of days is not harmful to seedlings, but is more labour intensive

- Requires approximately 3-5 days, but can be done more quickly by removing seedlings from the boxes and repackaging after thawing.

- Larger plugs hold more water, thus take longer to thaw than stock types with less plug volume

- Various temperature regimes in use (e.g. facility ambient temperature set at 12-15°C for 2 days, then lowered to 3°C)

- Cartons are spaced 8-10 cm apart, and fans may be used to ensure there is sufficient air flow around the cartons

Thawing Seedlings in Other Facilities (e.g. Curling Rink)

- Thawing seedlings in a curling rink is no different than in a cooler (i.e. the same principles apply)
  - however, when thawing in a curling rink you lose some flexibility

- depending on how the curling rink is equipped, rapid thaw is difficult so planning and scheduling have to be good

- If you choose to thaw your stock at the curling rink:
  - place cartons 4-8 cm apart on pallets for proper air flow
  - do not place cartons directly on the floor (e.g. keep them off the ice)
  - except for inspections, keep the cartons closed
  - ensure there is continuous air movement inside the facility
  - rotate boxes as the upper boxes will thaw more quickly

Snow Cache

On sites that are difficult to reach during the spring, a snow cache may have been built to overwinter the seedlings

- The inside temperature will remain very stable at just below freezing

- The cache may be opened and seedlings removed as needed. Open the shaded side first to minimize snow melt

- Once opened, use a plastic sheet or tarp to keep the cold in

Seedling Stress

- Stress is generally cumulative, once weakened, the seedling's resistance to further stress and its ability to recover is compromised
  - however, not all stresses accumulate in the same way
  - damage from desiccation and moderate temperatures accumulate
  - damage from rough handling or very high or low temperatures occurs rapidly once a critical threshold is reached

- Stress triggers a survival response, shifting resources from growth to repair and adjustment
  - amount of stress required to cause a detectable growth reduction is related to site and weather conditions after planting
  - seedling stock type and physiological condition influence

Seedling Loading Guidelines

- Do not throw or drop cartons, or lay on their side (keep boxes upright until completely empty)
  - seedlings are live plants, handle with care

  - many small shocks are not as damaging as a few large ones - the maximum force experienced by the plant is more important

- Load all boxes with carton labels facing the rear doors for easy identification
  - to ensure that the reefer is loaded as desired, it is a good idea to supply a reefer layout map
  - mark changes in seedlots appropriately with flagging tape, spray paint, etc.

- Dunnage such as plywood, 1x4 slats, or ¼ wafer board MUST be placed between the 2nd and 4th layers of boxes to stabilize the load and prevent boxes from being crushed

- Load boxes so that there is at least 30 cm (1 ft) between the boxes and roof for proper air circulation
  - boxes directly in front of the cooling unit air flow will freeze

- Ensure cartons are well secured
  - tie down if necessary
  - drive appropriately on gravel (bumpy) roads

- Check seedling moisture in damaged boxes, and repair boxes as necessary

- Keep records (e.g. reusable HOBO Temp data loggers) of temperature during transport and while on site [*contact Mark at PRT Armstrong for more information*]

Seedling Temperature

- Respiration rates increase with increasing temperature, giving off more heat, further increasing respiration and the cycle continues
  - in a closed box, this results in a depletion of seedling carbohydrates

- Length of time that seedlings must be exposed to warm temperatures to cause a noticeable reduction in field performance depends on many factors
  - e.g. box temperatures of 20ºC for four days after thawing were found to have no measurable effect on the survival and growth in white spruce seedlings planted into a hand weeded, farm-field site
  - on a more severe site, the results may have been different

- As maintaining proper temperature is critical for shipping, especially current crop seedlings, some form of temperature monitoring and record keeping is a good idea

Monitoring Seedling Temperature

- Dial thermometers are available for inserting through seedling boxes to monitor internal box temperatures

- Min-Max thermometers are useful for monitoring temperature extremes

- Some forest companies are now using small, reusable data loggers for monitoring temperature during:

  - shipping, storage and planting
  - silvicultural treatments
  - early establishment
  - *[contact Mark at PRT Armstrong for more information]*

- If you find a data logger in your seedling box or within a seedling bundle, please return to your supervisor and collect your finders reward

Transportation Guidelines - Frozen Storage

λ Seedlings that have been freezer stored may be shipped in either frozen or thawed condition
  - frozen stock will not overheat during normal shipping, thus can be packed tight
  - typically stacked eight boxes across, five high

λ Refrigerated vans are recommended
  - mass of a trailer load of (cool) seedlings has a large effect on the reefer temperature, it will take a while to heat up, especially in an insulated reefer
  - however, use of refrigerated vans on short hauls provides extra insurance against the possibility of breakdowns and delays

λ Reefer temperatures are commonly set at –2ºC (28ºF) when transporting frozen stock, and 2-4ºC (36-39ºF) for thawed stock. Do not freeze thawed stock.

λ Roots can be damaged by temperatures of only –10ºC (14ºF), ensure that seedling roots are not exposed to these cold temperatures

Transportation Guidelines – Hot Lift or Current Crop

λ Success requires good communication between the forester, nursery, planting contractor, and trucking company

- Hot lifted seedlings should be irrigated thoroughly prior to packaging - may be the last water they get for some time

λ Depending on trailer capacity and box size, hot lift boxes are typically stacked seven boxes across, five high
  - stack boxes so that there are continuous tunnels throughout the load to allow for proper air circulation

  – Refrigerated vans should be used, with the temperature set to at 6ºC (43ºF) to maintain internal box temperatures of approximately 10ºC (14ºF)
  – hot lift stock is physiologically active, respiring and creating its own heat
  – the cooling unit on a fully loaded trailer can maintain, but not cool down warm stock

- Internal box temperatures should not be above 12ºC (54ºF) at loading
  – to avoid overheating, freshly lifted stock can be precooled by placing seedling boxes in a cooler set around 4ºC for 4 to 6 hours prior to shipping

Shipping

- Prior to loading, ask the driver to start the cooling unit and set the appropriate temperature
  – **Verify Celsius vs Fahrenheit**
  – do not load a truck with a cooling unit that cannot be started prior to loading

- During transport, operation/warning lights on the cooling unit should be checked regularly
- Ensure that proper instructions have been provided for additional pickups, the final delivery destination, and the expected time of arrival
- If the expected time of arrival will not be met, the contact MUST be informed

Transportation Guidelines – Pick-up Trucks

- Preferably use an insulated canopy (e.g. FIST), or cover the boxes securely with reflective tarps (e.g. SILVACOOL) in good condition, keeping the white side up
  – further reduce heat by insulating the truck bed from exhaust system heat
  – if possible, travel early in the morning, or late in the day

- Reflective tarps:
  – maintain existing temperature in boxes by preventing heat from entering
  – tarp effectiveness deteriorates significantly with age
  – keep tarps clean for maximum effectiveness
  – use a tarp large enough for the job
  – not all reflective tarps are created equal, tarp effectiveness has been shown to vary

Spring Plant Strategy

- Desired that root growth is initiated before bud burst, so the tree can better deal with the high moisture demands of the new flush
  – how soon the seedling flushes after planting is related to the temperatures it receives after thawing

  - seedlings exposed to warm temperatures will break bud sooner

- Warm temperatures may also result in root elongation in the box
  - root elongation prior to planting spring stock is not desired due to the sensitivity of the new root tips to breakage and desiccation

- In some instances field practitioners have purposely warmed up spring plant stock prior to planting
  - the goal is to hasten bud burst of late planted spring stock, so that it will not be out of sync with the natural environment
  - benefits of a brief conditioning period are not known

On Site Storage of Spring Plant Seedlings

- Reefers set at 2-4ºC provide ideal conditions for storage

- Field cache - select location in the shade (e.g. timber, north slope, near streams, ditch with moving water, patches of snow) with good air circulation
  - locate cache accessible to the working plant site
  - to avoid crushing, alternate box direction and don't stack too high

- If sufficient shade is not available, shelter can be provided by stringing a tarp above the cache
  - it is important to be careful how you provide shade, or you can do more harm than good
  - leave enough space (e.g. 60 –90 cm, 2-3 ft.) between the tarp and boxes to allow for air circulation
  - canvas tarps are not desired as they are very effective at trapping heat

- While internal box temperatures are low, seedling boxes can be directly covered (i.e. no air space) with a reflective tarp to maintain low temperatures

- Check daily to monitor internal box temperature, moisture content, root and shoot activity (i.e. white root tips and swelling buds), and for the presence of grey mould
  - after a while, if internal box temperatures start to rise, the reflective tarp can be removed and the seedlings treated more like hot lift current stock (e.g. overhead tarp, space, open boxes)

- If seedlings are still partly frozen, sort bundles and finish thawing in the shade, never in the direct sun or near a heat source
  - if thawed in the sun, the seedling will lose water through the foliage, but since it is unable to take up water as the roots are frozen, it will desiccate
  - do not try to separate frozen seedling bundles, as you will damage the delicate roots

On Site Storage of Hot Lift or Current Crop Seedlings

- The essence of "hot-planting" is speed
  - after lifting, ship seedlings to the field and planted ASAP

- If field cached, boxes **MUST** be opened to prevent heat buildup, facilitate watering, and allow light to reach the seedlings
  - allows photosynthesis, and prevents another blackout, which may reduce subsequent diameter and root growth after planting
  - if packaged horizontally seedlings must be placed upright

- Keep seedlings out of direct sunlight - select location for field cache under dappled light through the forest canopy, or suspend a tarp a couple feet above the boxes (allow for air circulation)
  - dark coloured interiors of most opened boxes will absorb radiation

Troubleshooting - Reefer Problems

- Reefer cooling units transporting/storing spring plant seedlings have been known to malfunction (i.e. mechanical or human error)
  - potential for seedling damage depends on the maximum or minimum temperature obtained, how long it lasted, and the seedling condition at the time of the incident

- Seedling boxes exposed to high temperatures **MUST** be removed from the reefer, spaced and opened to cool due to high seedling respiration
  - severely damaged tissue will soon show symptoms, however less severe, but still deleterious damage is difficult to detect
  - stock can be evaluated at the nursery via a potting test, but results take approximately a week
  - results can be obtained sooner via a portable chlorophyll fluorescence meter, SIVE, etc. [*contact Mark at PRT Armstrong for more information*]

Troubleshooting - Grey Mould

- Stock with a lot of dead foliage prior to freezer storage is subject to grey mould or *Botrytis* infection
  - often confused with mycorrhizal seedling roots

- Proper water management and the use of fungicides can prevent or limit its occurrence

- If it occurs, its severity must be assessed (e.g. where, how much?)

- If noticed while in freezer storage, the stock should be kept frozen, then quick thawed just before planting

- Infected stock should be planted first if at all possible
  - once planted, a light *Botrytis* infection usually burns off in a couple of hours once exposed to sunlight

Pesticides

On the whole, pesticide use in the nursery industry has declined substantially in the last ten years. However, pesticides may have to be used on stock from time to time. If this is the case, the seedling purchaser is informed, all seedling boxes are clearly marked as such, and a copy of the applicable pesticide use form is included with each seedling shipment. Although all pesticides are used according to current government regulations and have been shown to be safe if used as directed, it is recommended that gloves be worn when handling seedlings and that hands be washed before eating or going to the washroom. As well, seedling boxes should not be used for storage of personal items such as clothes.

Seedling Moisture Status in the Field

- A dry tree is a dead tree

- Desiccation stress is accumulative and interacts with other stresses

- Cooling systems dehydrate, although its usually not a problem in spring stock
  - properly close bags/boxes and repair or replace punctured boxes

- Current crop stock moisture status **MUST** be monitored closely as it may dry out, depending on storage conditions, and storage time
  - feeling the seedling plug (i.e. the "squeeze test") is subjective
  - using seedling box weights is more quantifiable
    - use average box weight per stock type like block weights [*contact Mark at PRT Armstrong for more information*]
    - don't want to plant a seedling with a dry plug, keep moist
  - overwatering is a concern
  - surplus water left in the boxes after watering should be drained

Care of Seedlings During Planting

- Follow general principles outlined for transportation and storage
  - rough grabbing from the box can break off seedling tops
  - don't handle seedlings by the leaders
  - handle and unwrap bundles gently

- do not shake or squeeze seedlings to remove excess water
- work with one tree at a time

λ Limit amount of seedlings stored outside of field cache (½ day)
- store boxes under a reflective tarp in the shade, under logs or brush, not out in the open without protection
- boxes (spring plant) should be kept shut to retain moisture
- plan breaks when planting bags are empty, or place in the shade during breaks

λ Keep planting bags in good condition
- torn or punctured bags will allow air to dry the roots
- use reflective inserts
- with exception of the feeder bag, keep closed to prevent drying
- place sponge, carpet underlay or moist layer of peat moss in bag bottom
- don't cram planting bag with too many seedlings

Handling of Bareroot and Transplant Seedlings

- The previous guidelines apply to field grown bareroot and transplant seedlings as well, but as more of their roots have direct exposure to air and have little protection from desiccation, extra care is required when working with these stock types

  - bags within the seedling box aid in conserving moisture, the opening of which may result in moisture loss, requiring that stock be misted
  - peat moss may have be placed in the box during the packaging of current crop stock at the nursery, to provide a moisture source to maintain high humidity levels within the box

- Limiting the amount of seedlings carried in the planting bag, especially during hot weather, is a good practice for transplant and bareroot seedlings

- Roots of bareroot and transplant stock are often tangled together, and must be gently separated to prevent damage.
  - this must also be done in the shade, for the only time seedlings should be exposed to direct sunlight and dry air is when they are taken from the planting bag to the planting hole

- Optional procedures for bareroot stock often consist of dipping the roots in warm water for no more than one minute prior to planting

- Similarly, rootdips have been used in hot, dry areas to protect bareroot seedling roots against exposure prior to planting; and to aid after planting by initially holding water in the seedling's root zone
  - rootdips have consisted of soil slurries, vermiculite or sphagnum peat moss slurries, and hydrophilic gels

   - a recent review of over 25 years of published literature on root dipping found that when seedlings are handled properly during storage and planting, rootdips do not increase their survival or growth

PART IV Planting

Selecting Favourable Microsites

- Specific requirements of newly planted seedlings can often be met to varying degrees on the same site

- Optimum seedling location will vary (e.g. on cold wet site - plant high… on dry, southern exposures - plant for shelter…)

- Since there is usually an allowable deviation from the prescribed spacing, it is critical that optimum planting spots are chosen, rather than adhering rigidly to some fixed spacing
   - by choosing the optimum microsite, seedling requirements can be more readily met, increasing seedling survival and early growth

- Generally, the best microsite is the easiest to plant. The key to productive planting is acquiring an eye for recognizing the best planting spots
   - microsites as little as 20 cm apart can vary drastically in their growing conditions.

Forest Floor Planting

- Forest floor or duff planting is commonly used to describe low impact tree planting where seedlings are planting directly into the forest floor without mechanical site preparation or boot screefing
   - there are numerous variations on this theme (F-layer vs H-layer vs rotten log vs live moss on a newly harvested site)
   - is practiced in conjunction with proper microsite selection, and planting depth
   - the size, depth and type of soil classified as "good planting medium" will be specified by your supervisor

- Advantages of forest floor planting
   - majority of roots are placed in a warmer, drier, more nutrient rich substrate, will result in better growth
   - maintenance of the forest floor or organic layer reduces erosion, minimizes frost heaving on silty soils, reduces the potential for desiccation on clayey soils, and retains nutrients

- If mechanical site preparation is not required (i.e. raw plant)

  - can plant in year one and get a jump on vegetation competition (for sites prone to severe vegetation competition, site preparation may be required)
  - planting and site preparation costs will be reduced
  - less site disturbance reduces the possibility of site degradation

- Exceptions:
  - on sites with a thick humus layer, it may be desirable to remove some of the feathermosses or upper organic matter
  - whether a rotten log (i.e. red rot) makes a suitable planting spot must be judged on a case by case basis, but the general rule is that the wood must be broken down enough that the structure no longer consists of cubical chunks
  - on hot, dry sites where lack of moisture is the main growth limiting factor, forest floor planting is risky and not recommended unless a portion of the root plug can be placed into mineral soil
  - leaving a shallow layer of humus on top of the mineral soil is desirable on dry sites, as it will act like a mulch, reducing drying of the mineral soil
  - on coarse loamy soils, preferred planting spots also include exposed mineral soils and mineral/organic mixtures

Structure and Moisture Characteristics of the Forest Floor or Duff

- Structure of forest floor materials (i.e. duff)
  - depends on the original litter, and the state of its decomposition by fungi or insects
  - Fermenting or F-layer has loose structure and large pore spaces, Humus or H-layer has smaller pore spaces, and rotten wood is more variable but similar to the H-layer
  - the duff has low bulk density (125 - 170 kg/m^3) compared to mineral soil (1,500 kg/m^3), which allows for better root egress

- Moisture characteristics of the forest floor or duff
  - depends on its thickness
  - the forest floor has low water holding capacity compared to mineral soil
  - the forest floor has low hydraulic conductivity because of its large pore spaces

- Nutrient characteristics of the forest floor
  - depends on its state of decomposition (e.g. the Carbon:Nitrogen ratio of a rotten log may be > 100:1 vs 30:1 for mineral soil)
  - nutrients increase from: F-layer and rotten wood > H-layer > mineral soil
  - duff has a high cation exchange capacity (i.e. it has a high nutrient holding ability)
  - there is increased biological activity and abundant mycorrhizae in the duff

Planting Near Stumps

- Why?
  - stumps are raised microsites, which on cold, wet sites equals a warmer planting spot

- there is reradiation of heat
- they can help in preventing vegetation press and snow creep
- they help in preventing animal (e.g. cattle) trampling

- Distance from stumps
  - depending on the stump size (larger stumps may have air pockets at their base), seedlings may be planted quite close to the stump (e.g. 15 cm), but never on the stump
  - depending on the species and planting site, this practice is not always recommended due to the potential for root rots
  - there has been some concern over poor root asymmetry resulting in instability leading to toppling, although the actual risk is not known at this time

Planting Spot Selection Summary

- Choice of substrate is not as important as its temperature and moisture conditions which are influenced by microsite (i.e. duff planting places seedlings into warm/dry spots)

- Evaluate growth limiting factors on a site-by-site basis

- Are the required number of plantable spots available?

- Spacing of microsite planting is more irregular
  - this makes it mentally more difficult for planters and checkers
  - minimum spacing becomes the main concern

Planting Depth

- Studies from the early 1900’s warned against planting too deeply - “the greatest hazard to plantation survival”
  - more recent literature based primarily on pines in the southern U.S. recommends deep planting, due to increased stability, drought avoidance and protection of the root collar from heat damage

- The current thought in boreal regions is to plant to the depth of the root collar (i.e. so that the seedling will grow at the same depth it did in the nursery)
  - when discussing planting depth, your point of reference must be established (i.e. mineral soil vs H-layer vs F-layer vs litter layer)
  - on hot, dry sites where the duff layer is left intact to act as a mulch, the root collar should be planted flush with the surface of the underlying mineral soil

- Deep planting (e.g. “two fingers”)
  - is recommended where there is potential for soil sloughing (e.g. mechanically prepared planting spots such as mounds or berms on trenches)
  - has been recommended on dry sites to increase seedling access to water, although proper stock type selection and possible site preparation are better options in the long run

- Certain species such as spruce put out adventitious roots on the stem and branches if planted deeply, aiding in anchorage and nutrient/water uptake
  - however, if the proper stock type for the site is planted correctly in warm, moist, well drained nutrient rich substrates, then the benefit to the new root system from additional adventitious roots will be minimal
  - as most pines do not put out adventious roots, the decision to deep plant must be carefully considered

- Shallow planting
  - if the proper stock type has been selected and suitable planting equipment is being used, there are no reasons to shallow plant
  - however, as peat (i.e. the duff or forest floor) has large, non-capillary pores which impede the upward movement of water, having the top of the plug exposed does not necessarily mean that the seedling will dry up and die

Closing the Planting Hole

- Concern about poor root-soil contact leading to moisture stress has resulted in stomping around the seedling to close the planting hole (i.e. “The Death Stomp”)
  - if you see your boot tread, you’re applying too much pressure
  - stomping breaks down forest floor texture leading to soil compaction, which reduces subsequent seedling growth
  - stomping also increases the possibility of damaging the root collar and lower branches

- Evaluation of planting firmness on conifer seedlings includes the “three needle test”, in which the seedling is pulled by grabbing onto three needles, which should tear off from the seedling rather than move the seedling from the ground

- A balance between the use of excessive force and the creation of air pockets must be reached
  - air pockets are not desirable, as they reduce the amount of root:soil contact, which is necessary for the seedling to access soil water and nutrients
  - depending on the soil type, the planting hole may be adequately closed through gentle pressure from your shovel, toe of your boot, or hand
  - gentle backcuts may be used to close the planting hole, and in no circumstances should they be left open (this shows the planting checker that an effort was made)

- the seedling plug should not be flattened, so that it is less than three quarters of its original dimension

Fertilization-at-Time-of-Planting

- Limited height growth for the first couple of years after planting compromises plantation productivity. Suppressed seedlings may also be damaged by competing vegetation, insects, animals
  - possible causes include nutrient poor soils, cold wet soils, improper handling, and poor planting spot selection and/or technique

- As seedlings often become chlorotic after planting, fertilization-at-time-of-planting (FAP) has been prescribed to minimize planting check, as well as ameliorate the site limiting factors of nutrient deficiency and vegetation competition

- FAP is generally carried out on nutrient demanding species such as spruce

- Areas of artificially induced low nutrient availability including landings, roadways, and mechanical site prepared planting spots such as mounds are also considered candidates for FAP

- In some instances, increased animal damage has been reported after FAP
  - future implications depend on the type of damage (e.g. girdling vs browse)
  - FAP may result in greater seedling biomass which may be better able to recover from browse

- FAP is not recommended on hot, dry sites due to risk of fertilizer burn
  - there have been instances of high mortality in the past

- At planting, individual seedlings are fertilized as they only occupy a small portion of the total site
  - at present, most common method of FAP involves placing controlled release fertilizer in or adjacent to the planting hole at the time of planting
  - various products are available (e.g. *tea bags*, planting tabs, loose controlled release fertilizer prills)
  - to be most effective, fertilizers must be placed within the area of root growth (i.e. don't put fertilizer in bottom of planting hole on a cold, wet site)
  - nutrient release governed by temperature or microbial decomposition
  - FAP is an expensive option

- Alternative – long term release controlled release fertilizer incorporated in-the-plug at the nursery (NUTRI-PLUG™)
  - ensures correct fertilizer placement
  - no additional labour required at planting
  - less costly