PACIFIC REGENERATION TECHNOLOGIES INC.

PLANTING HANDBOOK

FOR NORTHERN REGIONS

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PRT has compiled this handbook 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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PRT Background

PRT Beaverlodge 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 July of 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

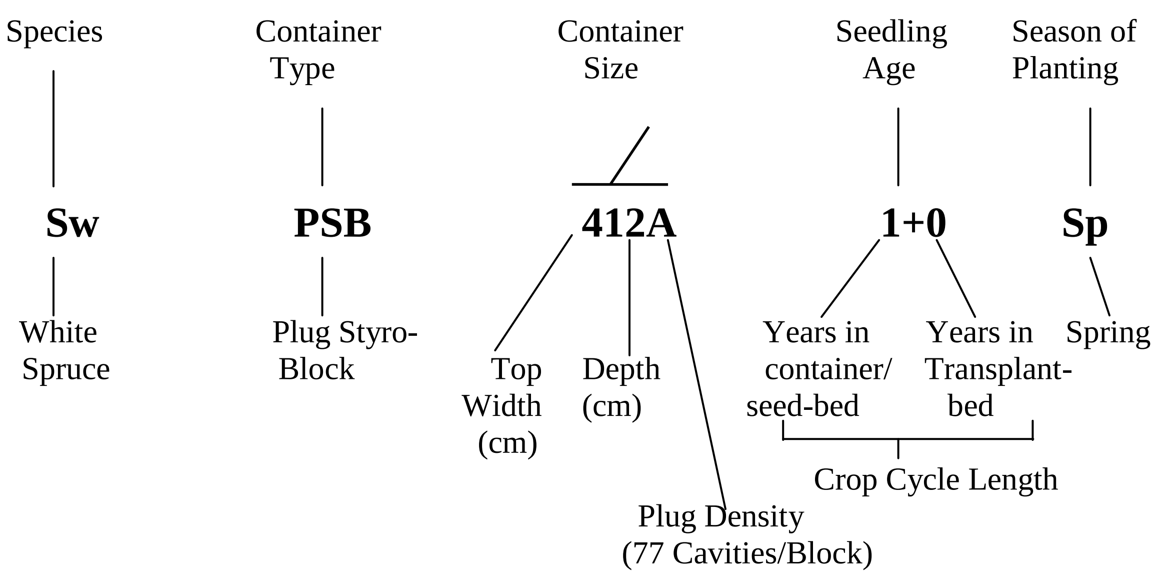
Location of PRT Facilities

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

- 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 root bound plugs.

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

Stock Type	Cavity/ Block	Volume ml	Age	**TARGET** **Ht**	**RCD**	MINIMUM Ht	RCD	MAX Ht	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

Site Limiting Factors to Seedling Growth

- Vegetation Competition
- Snow/Vegetation Press
- Frost Damage
- Soil Moisture - excess or deficit
- Pest Damage
- Shallow Soils

Management of Site Limiting Factors

- Vegetation competition
  - plant ASAP after harvest
  - select large, vigorous stock types (2+0 are also desirable)
  - site preparation (e.g. mechanical, chemical)

- Snow/Vegetation Press
  - select large, sturdy, well branched stock types which are more resistant and likely to recover
  - practice obstacle planting (i.e. plant adjacent to stumps, logs, etc.)
  - brush and weed as required to ensure prompt establishment

- Frost damage
  - site avoidance (e.g. gullies, dense grass cover)
  - practice microsite selection - (e.g. next to stump, in nurse crop)
  - mechanical site preparation to create raised planting spots

- Wet soils
  - practice microsite selection (e.g. avoid depressions)
  - species selection (e.g. black spruce)
  - mechanical site preparation to create raised planting spots

- Drought
  - select large (woody), well balanced stock that is well-hardened
  - practice microsite selection (e.g. shaded spot behind log)
  - time planting to avoid the drought period

- Shallow soils
  - select a shorter stock type (e.g. PSB 310B, 410A)

Physiological Aspects of Frozen Storage and Thawing

- Frozen storage is the least stressful way of over wintering 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 -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 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 which are difficult to reach during the spring, a snow cache may have been built to over winter 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
  - 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 & weather conditions after planting
  - seedling stock type and physiological condition influence

General Transportation Guidelines

- Do not throw or drop cartons, or lay on their side
  - many small shocks are not as damaging as a few large ones - the maximum force experienced by the plant is more important
- Dunnage such as plywood is commonly used between the layers of boxes to stabilize the load and prevent boxes from being crushed
- Boxes usually loaded in such a way that space is left between boxes and the front bulkhead for proper air circulation

- Ensure cartons are well secured
  - drive more slowly on gravel (bumpy) roads

- Keep records (e.g. reusable HOBO Temp data loggers) of temperature during transport [*contact Glenn at PRT Beaverlodge 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, 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

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

Transportation Guidelines - Frozen Storage

- Seedlings that have been freezer stored may be shipped in either frozen or thawed condition

- 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

- Reefer temperatures are commonly set at –2ºC when transporting frozen stock, and 2-4ºC for thawed stock

- Roots can be damaged by temperatures of only -10ºC, ensure that seedling roots are not exposed to these cold temperatures

Transportation Guidelines – Hot Lift or Current Crop

- 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

- Refrigerated vans should be used, with the reefer temperatures set to maintain internal box temperatures of approximately 10ºC

- To avoid overheating, freshly lifted stock can be precooled by placing seedling boxes in a cooler set around 4ºC for 4-6 hours prior to shipping

Transportation Guidelines – Pick-up Trucks

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

- Reflective tarps:
  - tarp effectiveness deteriorates significantly with age
  - not all reflective tarps are created equal, recent FERIC study reported that for one reflective tarp, seedling box temperatures were not significantly different from leaving the boxes unprotected in the sun

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, patches of snow) with good air circulation
  - to avoid crushing, don't stack boxes 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 –100 cm) 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 covered with a reflective tarp to maintain low temperatures

- Check daily to monitor internal box temperature, moisture content, root and shoot activity, and for the presence of disease
  - after a while, if internal box temperatures start to rise, the reflective tarp can be removed and the seedlings treated more like 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
  - seedlings with frozen plugs could theoretically be planted, but under our current packaging regimes, frozen seedling plugs can not be separated without damaging the 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 should 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 should be removed from the reefer, spaced and opened 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 Glenn at PRT Beaverlodge 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 dry

- Desiccation stress is accumulative and interacts with other stresses

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

- Current crop stock moisture status should 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 Glenn at PRT Beaverlodge for more information*]
    - don't want to plant a seedling with a dry plug, keep moist
  - over watering 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
  - handle and unwrap bundles gently
  - work with one tree at a time

- 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
  - during breaks, put planting bags in the shade

- 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 - prevent drying
  - place sponge or moist layer of peat moss in bag bottom

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

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
  - micro sites 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, should 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 equals less governmental violations

- Exceptions:
  - on sites with a thick humus layer, it may be desirable to remove some of the feather mosses or upper organic matter
  - on hot, dry sites where lack of moisture is the main growth limiting factor, forest floor planting is risky and not recommended
  - on hot, dry sites, if 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 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 mycorrhizal in the duff

Planting Near Stumps

- Why?
  - stumps are raised micro sites, which on cold, wet sites equals a warmer planting spot
  - there is eradication of heat
  - they 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)
  - 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

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 adventurous 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")
  - stomping breaks down forest floor texture leading to soil compaction, which reduces subsequent seedling growth

- 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 back cuts may be used to close the planting hole, and in no circumstances should they be left open

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^{TM})**
  - ensures correct fertilizer placement
  - no additional labour required at planting
  - less costly
  - [*contact Glenn at PRT Beaverlodge for more information*]

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 Mike at Red Rock 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