# Effect of Plant Date on Stand Establishment

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## Introduction

The likelihood of successful reforestation via planting seedlings is influenced by many factors such as seedling quality, planting practices, and planting site environmental conditions. For the most part, planting dates are determined by the environmental conditions most likely to be encountered during planting and for the first few critical months thereafter. For while the planting site environment can be altered somewhat through site preparation, the prevailing climate can not. Any discussion on the current planting windows for container seedlings in British Columbia (B.C.) must also include seedling stock type, as different planting windows require the use of stock at different stages of phenological development.

There are currently two major planting windows used in the interior of B.C. Spring planting with overwintered stock, and summer planting with physiologically active stock. Spring planting begins in mid- to late April, finishing by June 21. There is some overlap between the spring and summer planting windows, as summer planting with active stock often begins as early as mid-June, although the majority is planted after July 1. In some areas there is also a fall planting window, beginning mid-August and running until early October. Preliminary numbers suggest that 264 million seedlings will be planted in B.C. in 2005. At 50 million (i.e.,19%), the percentage of summer plant seedlings has declined in recent years, partly due to replanting of lower elevation sites from the 2003 forest fires, where summer planting is not feasible due to environmental conditions. Also, recent summer droughts resulting in lower survival have decreased the summer plant's popularity, especially in the southern B.C. interior (S. Joyce, pers. comm., 2005).

## Stock Types

With the advent of container stock and freezer storage, seedlings could be reliably harvested in the fall and held in frozen storage till planting the following spring. While bareroot seedlings could also be kept frozen over the winter, rainy weather during the fall often kept the harvesting equipment off the fields, thus delaying harvest till the following spring. Bareroot and/or plug-transplant field stock are currently used very little in B.C., thus this discussion will pertain to container stock, although some of the principles are applicable to planting bareroot seedlings. Seedlings harvested in the fall and stored over the winter are referred to as frozen stored or overwintered stock, and the planting window is referred to as a "spring plant". This refers more to the seedling stock type than the actual season, as a late spring plant can actually take place in the summer. As the nursery climate is in most cases quite different from that of the planting site, keeping the seedlings at -2°C until shortly before planting allows the seedlings to be in sync with the environment of the reforestation site at planting. Frozen stored one-year-old (1+0) seedlings such as interior spruce (*Picea glauca x engelmannii*) are commonly sown in a greenhouse in March or April, or in the case of lodgepole pine (*Pinus contorta*), outside in late April or May. Seedlings are grown over the spring and summer, and in most cases the naturally decreasing daylength is relied upon to induce budset and dormancy prior to lifting in the fall.

The "summer plant" with hot-lift, fresh or current stock was originally developed for high elevation, moist sites, which often had access problems due to a late snowmelt. This planting window has also gained popularity in northeastern B.C. and northern Alberta, areas which receive significant precipitation during the summer. Extending the planting window with hot-lift stock offers many logistical advantages such as spreading out the workload and eliminating stock overwintering frozen storage costs (Mitchell et al. 1990). While summer planting with hot-lift bareroot spruce was tried in an attempt to extend the planting window (Revel and Coates 1975), lifting the seedlings from the field during budflush reduced future growth potential. The use of container seedlings in conjunction with the horticultural practice of blackout, whereby the ambient photoperiod is artificially shortened, has allowed the operational production of stock phenologically suited to planting from mid-June onwards. Although hot-lift stock used in summer planting is still physiologically active, it has set a terminal bud, and has developed some degree of hardiness. Hot-lift stock is greenhouse sown in January or February, where it usually remains until the last month prior to lifting, at which time the greenhouse covers may be removed, exposing the crop to full sunlight. Hot-lift stock does not break bud the year of planting, instead it concentrates it resources on stem diameter and root growth.

While summer planting is a great tool for some sites which can not be spring planted, it is not feasible on all sites. In general, newly planted seedlings typically have restricted root placement and poor root-soil contact, resulting in limited water uptake and various levels of water stress, depending on the range of growth limiting factors present (Grossnickle 2000). Thus, sites that commonly experience root-zone water deficits and high atmospheric evaporative demand during late June and July should not be summer planted, as the seedlings will experience potentially severe stress levels. Thus, these sites must be spring planted when air temperatures are lower and soil moisture is higher. As an alternative, fall planting in interior regions such as the Sierra Cascade Mountains in California (Livingston 2000) and high elevation sites in the B.C. interior (Kiiskila 2004) have recently garnered renewed interest. However, in contrast to the current operational fall planting programs on the Pacific coast, current planting guidelines do not advise fall planting in the B.C. interior (Eastham et al. 1998). In the past, major problems with interior fall planting have included insufficiently hardened off stock (Revel et al. 1990), a high probability of frost heaving (Crossley 1956), and winter desiccation on sites with low annual snow cover (Krasowski et al. 1995, Krumlik 1984). Improvements in stock quality along with the switch to forest floor planting in conjunction with less “deep” planting have resulted in greater initial root growth in the organic/mineral soil interface (Heineman 1998), thus lessening the chances of frost heaving and winter desiccation (Krasowski et al. 1995). An interior “fall plant” is carried out with hardened off hot-lift stock.

## Spring Plant

For the most part, the prevailing climate and environmental conditions at the planting site determine the planting window. While greenhouse growers now have close to total control over nursery stock, obviously the seedling must be at an appropriate phenological stage for the planting site and time of year. For example, although air temperature and soil moisture may be ideal for planting in early September, one would not want to plant a seedling in the boreal without some degree of frost hardiness. There are also logistical concerns, such as the availability of frozen storage and staff for thawing, and the availability of planters.

The general strategy with a spring plant is to get the seedlings in the ground early while soil moisture is adequate, to ensure the seedlings will have a chance to establish new roots prior to budflush. The start date of spring planting with frozen stored stock usually depends on access and when the ground is free of snow and/or frost, although it is recommended that soil temperature be above 4°C (Mitchell et al. 1990). With up to 100 million seedlings planted in the interior each spring, it is logistically impossible to plant all sites at the “optimum” time, with some cutblocks being planted simply because they are scheduled next. Another factor to consider when starting spring planting is the date of the last hard frost.

To ensure that frozen stored seedlings have sufficient time to flush and develop hardiness before the onset of fall frosts, it is currently recommended that spring planting be finished by June 21 (Eastham et al. 1998). While that calendar date may sound late, often planters are following the snow off north aspect, high elevation blocks which could not physically be planted any sooner. Lack of soil moisture at the later spring planting dates may also be a concern. It is recommended that soil moisture tension is less than 0.1 MPa (Mitchell et al. 1990), although it is doubtful that this parameter is actually checked during operational planting programs.

As frozen stored stock can be kept more or less in a state of suspended animation, site conditions and the length of the growing season are the primary determinants of initial field performance of frozen stored stock (assuming similar stock handling and planting practices). As the thawing method influences timing of budflush and root growth, the previous “slow” thaw procedure meant that the phenology of spring plant stock at the time of planting was variable, depending on how long and at what temperature it had been thawed. The “slow” thaw method consisted of raising the temperature of the entire refrigeration unit, which meant the last planted stock may have been thawed and exposed to warm temperatures for weeks at a time, sometimes resulting in stock flushing in the box. Seedling budflush in the spring is determined by the amount of exposure to warm temperatures (Grossnickle 2000); thus compared to a slow thaw the current practice of “quick” thawing stock a few days prior to shipping (Rose and Haase 1997) delays budflush, allowing time for new root development before budbreak. Therefore, when evaluating the field performance of a specific spring planting date, the thawing regime must also be considered.

## Summer Plant

As summer planting takes place at a time of year with the potential for environmental extremes, several constraints have been recommended by Mitchell and others (1990). These include a soil moisture tension threshold of less than 0.1 MPa, a recommended air temperature of less

than 18°C and a wind speed of less than 30 km/hr, along with consideration of the dryness of the air, or vapour pressure deficit. However, under operational conditions, summer planting is seldom suspended for these reasons, primarily due to the fact that the physiologically active hot-lift stock does not store well in boxes. Although on-site refrigerated units can keep the stock cool, the general rule of thumb is not to keep seedling boxes closed for greater than 48 hours. While not proven, some reforestation practitioners feel that a long dark period in a box may approximate a long blackout in the nursery, which has been shown to result in reduced stem diameter (Hawkins 1996). On the positive side, the use of container stock and improved stock handling practices have lessened the potential for seedling damage such as drying of the root tips when planting during hot, dry weather.

In comparison to frozen stored spring plant stock, which is basically kept dormant until planting, the morphology and physiology of hot-lift stock is changing rapidly during the summer lifting window (Grossnickle and Folk 2003). These changes occur primarily in response to a decrease in daylength, either naturally or more commonly via a blackout treatment, causing bud initiation. Seedlings are commonly shipped five to six weeks after blackout, although the criteria by which stock is judged acceptable for shipping is vague. Along with morphological height and root collar diameter (RCD) specifications, the only other parameter assessed is the subjective measure of shoot succulence (Eastham et al. 1998).

The start date of summer planting is determined more by logistical, rather than biological reasons. Depending on the location, the majority of spring planting is finished by early June, and the planting contractors want to start summer planting soon after, for fear of losing their planters. While planting contractors push for early summer planting with hot-lift stock, the nurseries usually struggle to produce stock ready for planting in mid- to late June. There are limits to how much a seedling can grow within the five to six month period between sowing and lifting. Due to low light levels in December and the cost of heating a greenhouse at that time of the year, there is not much gain in sowing trees much before the beginning of January. It is possible to produce a larger seedling earlier in the year by manipulating a two-year-old or reflush crop. However, by applying blackout even earlier in the year to initiate budset, you would be putting the stock even further out of sync from the normal phenological cycle of established spruce on the planting site. That is, blackout to initiate budset would be applied during a period of increasing daylength, when established spruce on the planting site may not have even broken bud yet.

No definite “must be completed by” calendar date has been defined for summer planting with hot-lift stock, although it is commonly felt by most B.C. reforestation practitioners that earlier planting dates are better, with most planting currently completed by the end of July. When discussing hot-lift planting dates, to ensure that you are not comparing apples to oranges, you should also be aware of the number of weeks since bud initiation. Five to six weeks after the start of bud initiation (i.e. blackout) is generally considered the optimum time to lift and plant hot-lift stock. Seedlings lifted earlier would have a higher root growth potential, although they would be less tolerant to frost, drought and handling, and their bud primordia would be less developed. Seedlings lifted later would have increased frost and drought tolerance and greater development of their bud primordia, but less root growth potential. To ensure the greatest likelihood of reforestation success, hot-lift stock should be lifted at the nursery and planted at the previously requested delivery date. Holding the stock in the nursery results in the seedlings moving further along their phenological cycle (i.e., moving towards dormancy), resulting in a further reduction in root growth potential and the chance for successful seedling establishment. However, a positive trade off of holding seedlings in the nursery is that stem diameter continues to grow, such that when planted these seedlings are usually more sturdy.

Considering that fall planting in the interior often begins as early as mid-August, the line separating hot-lift summer and fall plant stock is not clear. As seedlings are planted later into the fall, the need for a greater level of frost tolerance increases. However, frost tolerance increases as seedling move towards dormancy, during which time their root growth potential decreases. If the seedlings receive sufficient snow cover during their first winter, poor root growth during the first fall may not be as detrimental. However, if the snow cover is minimal or nonexistent, then seedlings with initially little or no root growth would be more subject to desiccation (Krasowski et al. 1995). Thus stock for fall planting should have just enough frost tolerance for the specific site and date, but no more — the trick is to reduce root growth potential no more than necessary.

### Spring vs. Summer Plant

In comparing frozen stored spring plant with hot-lift summer plant seedlings, the frozen stored stock is initially larger at the end of the first planting season as its buds flushed and it grew in height and diameter. Also, frozen

stored spring plant seedlings often have greater RCD than hot-lift summer plant seedlings grown in the same container size, as they are held in the nursery longer after budset allowing them more time to grow stem diameter. Needle primordia for the second season growth of the spring plant stock are developed in the field, usually under less than ideal conditions. In contrast, needle primordia development of hot-lift summer plant stock supposedly occurs under ideal nursery conditions, which in theory should allow the summer plant to "catch up" to the spring plant stock (Grossnickle and Folk 2003). However, current operational trials in B.C. (see Fig. 1) suggest that the hot-lift summer plant does not catch up to the frozen stored spring plant seedlings, which have actually been found to be much more vigorous. This may be partially due to the fact that rather than ideal conditions, nursery growers often stress the hot-lift crop by reducing water and fertilizer to encourage budset and/or prevent the buds from reflushing. It has also been noted in some cases that the terminal buds of hot-lift interior spruce do not flush and/or flush abnormally the first spring after planting, although the cause is not known (Hawkins 1998, MacDonald 1998). There is speculation that problems with the terminal buds may be due to the fact that in some cases artificially induced bud initiation via blackout takes place at a time of the year when daylength is increasing and the seedlings would normally be actively growing. That is, they are receiving mixed signals. Another cause for relatively poor vigour with hot-lift summer plant seedlings is that they are sometimes planted much later than their optimum lifting date according to when the planned bud initiation took place. For seedlings held in the nursery past their originally scheduled delivery date would have reduced root growth potential and their establishment could suffer, especially under dry conditions.

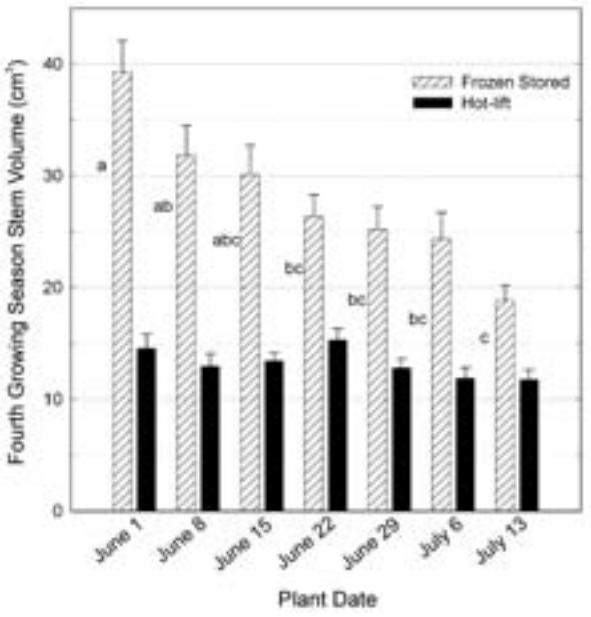


***Figure 1.*** *Fourth season stem volume ($cm^3$) of frozen stored and hot-lift interior spruce planted once a week for seven weeks at 1,550 m elevation in the Montane Spruce dry mild biogeoclimatic subzone near Princeton, B.C. Means with the same letter are not significantly different (p=0.05) from one another. Vertical bars are standard errors of the mean.*

## Conclusions

The best time to plant depends of course on the site. With the use of quick thawing procedures, spring plant stock is now for the most part in better condition when planted later in the season. Thus it is worthwhile to examine the current rule of thumb stating that frozen stored seedlings should not be planted past June 21. The use of hot-lift summer plant seedlings is a great tool for extending the planting season on appropriate sites. However, the use of physiologically active hot-lift stock requires a greater level of coordination between the nursery, forester, and planting contractor. The growth benefits of early summer planting have not been proven, and in fact may be indirectly responsible for terminal bud abnormalities observed in interior spruce. It is suggested that as a guideline summer planting of hot-lift stock not begin prior to July 1, which would ensure that the planted stock is more in sync with the normal phenological cycle of established spruce on the planting site. Although millions of hot-lift summer plant seedlings have been planted to date, more questions still need to be answered regarding their field performance in relation to frozen stored spring plant stock. To ensure the best possible seedling establishment, it is also recommended that greater effort be made to plant hot-lift stock as close to the originally requested delivery date as possible.

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