Tree
Improvement
Branch

Cone and Seed Improvement Program
BCMoF Tree Seed Centre

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Abies Seed Problems

Abstract

The true firs (*Abies* sp.) are becoming more important to reforestation with a current planting level of approximately 10 million seedlings per year. Subalpine fir has had the greatest increase in planting from virtually none prior to 1988 to a current level of 4.2 million seedlings sown for in 1997. Several problems have plagued the successful germination of *Abies* crops in nursery culture: immature cone collections and poor post-collection handling practices, presence of resin vesicles making the seed susceptible to damage and reduced germination, the deep dormancy exhibited by Amabilis and subalpine fir, difficulty in removing dead-filled seeds and problems with seed-borne fungi.

Seed upgrading has provided seed owners with a solution to removal of dead-filled seeds and reductions in seed borne fungi, but unfortunately this does not work well on the many immature *Abies* seedlots in long-term storage. Fortunately collection timing, post-collection handling and seed processing techniques of *Abies* has improved. The split stratification regimes (stratification-redry and dryback) in addition to warmer germination temperatures have produced higher and faster germination at the nursery. The use of target moisture content calculations is recommended as a means of providing consistent seed pretreatments.

Introduction

This paper will discuss some of the problems or characteristics of *Abies* seed that make it problematic to nursery culture. The three BC species covered will be Amabilis fir (*Abies amabilis* (Dougl.) Forbes); grand fir (*Abies grandis* (Dougl.) Lindl.) and subalpine fir (*Abies lasiocarpa* (Hook) Nutt.). Amabilis fir is the most planted *Abies* species [5.4 million seedlings sown in 1997] and in 1994 a workshop addressed the problems and solutions of Amabilis fir regeneration (Konishi and Barber, 1994). The focus of this meeting is on high elevation regeneration and I will concentrate on seed problems found in subalpine fir, although many of the problems are common to all three species. Grand fir has fewer problems than the other two species. Subalpine fir has increased dramatically in importance from virtually no planting prior to 1988 to a level of 4.2 million seedlings being sown in 1997. An overview of characteristics of the three *Abies* species in storage at the Tree Seed Centre (TSC) is presented in Table 1.

Amabilis fir clearly has the most seedlots and most kilograms of seed in storage, but its large seed size requires much larger quantities of seed, compared to the other *Abies*, to produce a given quantity of seedlings. Although subalpine fir has half as much seed in storage, compared to Amabilis fir, there are about 20 million more potential seedlings in storage due to its small seed size. Considering only seedlots above 65% germination (transition point from 3 to 4 seeds per cavity) there is a 30% decrease in number of potential seedlings for all three species.

Table 1. A summary of characteristics of the three primary *Abies* species grown in BC.

	Amabilis fir	**subalpine fir**	**grand fir**
# Seedlots in Storage	227	160	55
Ave. Germination %	70	69	72
Germination % Range	8 - 84	5 - 90	17 - 88
Kg of Seed	8 714	4 384	826
Millions of Seedlings[1]	47.6	67.4	7.7
Millions of seedlings (65%+)[2]	32.3	49.2	5.5
Ave. Seeds per Gram	29	83	46
Seeds per Gram Range	18 - 40	54 - 138	35 - 57
Elevation Range (m)	20 - 1550	200 - 1970	0 - 1200

The TSC has recently completed a full physical inventory and is recommending to seed owners that *Abies* seedlots less than 40% germination and/or less than a total of 5 000 potential trees be removed from inventory. This is to ensure that our efforts in inventory and testing are directed at those seedlots more likely to be used for reforestation. Currently there are no regulations for a seedlots minimum germination and Table 1 indicates the very low germination of some seedlots in storage (e.g. 5% for subalpine fir). Some very low germination seedlots are still sown at some nurseries that are employing aggressive upgrading procedures to improve germination. For example, in 1997 a subalpine fir seedlot was sown that had a germination of 11% before upgrading (Table 2). Other nurseries are trying to convince clients of the cost-effectiveness of collecting new, higher quality collections and discarding their poor quality seedlots.

Subalpine fir is the most variable species in terms of seed size with seedlots ranging from 54 to 138 seeds per gram [18.5 to 7.2 mg per seed]. For different seedlots a variable amount of seed will be required to produce a given quantity of seedlings due to seed size differences in addition to germination differences. Subalpine fir has a large elevation range (200 - 1970 m) although most commonly a high elevation species it can grow at low elevations in the northern portion of its range. Conversely, seedlots of Amabilis fir have been collected from as high as 1550 m. Seedlots from extremes in a species range may have very different growth patterns than an average seedlot and nursery growers should be aware of a seedlots elevation and latitude in formulating a cultural regime.

Table 2. Characteristics of sowing requests of *Abies* sown in 1997.

	Amabilis fir	**subalpine fir**	**grand fir**
# Sowing Requests	320	85	42
# Seedlots Used	102	51	15
% Seedlots Used	45	32	27
Kg of Seed Used	957	297	8
Seedlings Requested	5 350 300	4 226 200	390 800
Lowest Germ %	22	11	60

[1] as calculated in the Seed Planning and Registry (SPAR) system using BCMOF Sowing Rules and assuming a 313B styroblock

[2] this variable indicates millions of potential seedlings based only on those seedlots having a germination greater than 65%

In 1997, Amabilis fir had 4X as many sowing requests, 3X as much seed used and twice as many seedlots sown compared to subalpine fir. In 1997 84% of the subalpine fir sown was destined for the Prince Rupert Forest Region. Grand fir is of less importance to reforestation, is mainly restricted to the southwestern part of the province and seems to have fewer nursery problems.

Cone Collection and Handling

Cone collection timing is a very important aspect of *Abies* collections as the seed dispersal method involves abscission of cone scales from the central axis and disintegration of the cones on the tree. In most other conifer species the scales reflex back and release the seed with the cone intact. The worst-case scenario for an *Abies* crop is that cone disintegration will occur prior to collection resulting in loss of the entire crop. *Abies* crops are collected prior to full maturity, identified by initial release of seed, compared to other conifers mainly for this reason. Actual timing of collections will vary from year-to-year based on weather conditions and buildup of degree days which is thought to play a large role in rate of seed development. Immature collections of *Abies* are a significant and primarily a historic problem which nurseries are left to deal with today. In general, collection practices have improved and more attention is being given to proper collection timing, post-collection handling, cone and seed processing and seed testing methods.

An important criteria for assessing seed maturity is the relative length of the embryo in relation to the corrosion cavity in which it sits. Currently the recommendation is that the embryo should be at least 90% of the length of the corrosion cavity. In the past the recommendation was 75% and many older seedlots would be considered immature by today's standards. Other criteria such as colour, tissue firmness and apparent moisture content are also used to assess maturity. Immature seedlots are problematic because they generally have a low germination, but they also have a high degree of variability in a wide range of attributes such as seed density, embryo length and germination speed. These immature seedlots are difficult to upgrade with existing techniques because of this variability in basic seed attributes.

Most *Abies* collections are collected via helicopter using three principle methods: aerial raking; aerial clipping /sawing or aerial topping (Camenzind 1990). Helicopter collections are expensive, but well suited to *Abies* because of the localized nature of the cones in the upper portions of the crown and the impracticalities of collecting from felled trees. A significant issue that has arisen over the past few years is an increased incidence of cold fungus (*Caloscypha fulgens*) problems at the nursery. Seeds infected with the seed fungus are killed and will not germinate, but can still infect adjacent seeds during stratification or in styroblocks.. This fungus spreads from the soil to the cones; it is likely that infected seedlots were harvested and deposited directly on the ground. To avoid this problem it is important that cone collectors use tarps or other methods to avoid direct contact between the cones and soil. *Abies* collections also tend to have a higher level of insect activity that reduces the number of filled seed per cone.

Since *Abies* are collected early it is important that post-collection conditions are optimum to mimic the natural process of cone and seed maturation. An important aspect of maturation is the gradual reduction in cone and seed moisture content. Important considerations are to provide cool conditions (10-15°C), open racks with cones spread evenly and supplemental fans or blowers to facilitate air movement and uniform drying of the seedlot. Seeds at elevated moisture levels are susceptible to damage and handling during post-collection monitoring should be minimized. The time required for dehydration of cones and seeds and disintegration of cones will be dependent on the initial moisture content and post-collection conditions in which the cones are subject to.

Cone and Seed Processing

Due to the disintegration of cones and problems with pitch, kilning is not performed with *Abies*. The disintegrated cone scales, axis' and seeds are initially separated over a vibrating screening device to remove the very large particles (axis and scales) and the very fine particles (dust and very small bits of debris). The remaining volume is then subjected to a more precise vibrating, screening device to remove any remaining impurities such as smaller cone scales, needles, rocks and loose pitch. It is important that as many impurities as possible are removed before the dewinging stage as abrasion of these particles during the mechanical removal of the seed wings can be damaging to the seed.

Dewinging is a critical stage for almost all species as this is the stage most likely to cause damage to the seed. *Abies* are dry dewinged in a cement-mixer type drum where the mechanical action of the seed, simulating a waterfall effect, causes the wings to be broken away from the seed. Dewinging is more successful with brittle seed wings that can be induced through lower moisture contents and placing seed in a cooler prior to dewinging. The duration of dewinging is minimized (10-15 minutes is typical) to avoid damaging the seed. Final cleaning is used to remove any remaining impurities and remove the non-viable seed from a seedlot. This process is based on seed density and can be performed with an air separator or gravity table, which is the preferred method at the TSC.

A significant problem with *Abies* processing is the removal of seeds that are non-viable (do not contain an embryo), but have been filled in with material. The material can be dark brown to black and is commonly referred to as resin. These seeds are unfortunately the same density as filled viable seed and cannot be removed with conventional final cleaning equipment. These seeds comprise a variable proportion of each seedlot and due to their presence the processing targets (80 to 90 % of filled seeds) are lower for *Abies* than other species. Seedlots with high proportions of these dead-filled seeds are excellent candidates for upgrading using Density Separation Processing (DSP).

Seed processing is not exact and there will always be a trade-off between seed quality (i.e. germination %), seed yield (Kg of seed obtained from a Hl of cones) and the number of processing runs required to obtain these targets. Increased numbers of runs increases the potential for mechanical damage, especially with species possessing resin vesicles. In general, I believe that more discussions between the processor and owner are required to produce the best seedlot. A simple example is whether a client would prefer 20 Kg of seed at 80% germination or 13 Kg of seed at 90% germination. For various seedlots all possible targets may not be possible due to seed maturity, susceptibility of the species to overprocessing damage and the difficulty in estimating the germination of an *Abies* seedlot without the long timeline required for testing. The seed owner should also be discussing the cost effectiveness of scenarios such as these with nurseries growing their seedlots.

Seed Biology

One of the most significant aspects of *Abies* seed biology is the presence of resin vesicles within the seed coat. In addition to *Abies* these resin vesicles are also found in western redcedar (*Thuja plicata* Donn ex D.Don), mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Resin vesicles are produced early in seed development within the outer or middle layer of the seed coat are generally more abundant on the lower surface of the seed and are easily viewed with the naked eye. A discontinuity of the seed coat on the lower surface of the seed presents a location for greater potential damage. In Table 3 the range and average number of resin vesicles are presented for each *Abies* species found in BC. Grand fir appears to characteristically have the most resin vesicles with an average of eight while both subalpine and Amabilis average six. If one considers the relative sizes of these seeds then subalpine fir has a greater concentration of resin vesicles, although those found in Amabilis fir are generally much larger.

Table 3. The range and average number of resin vesicles found in BC *Abies* species (based on 10 seeds from five seedlots)

	Amabilis fir	**subalpine fir**	**grand fir**
Ave. # Resin Vesicles	6	6	8
Resin Vesicle Range	4 - 10	3 - 9	6 - 13

Resin vesicles are poorly understood structures in terms of function. Several roles have been hypothesized: (i) prevent germination in the fall (ii) protect the embryo from drying and (iii) play a role in seedcoat dormancy. None of these have been adequately studied, but what is clear is that damage to the resin vesicles will reduce the germination of a seedlot (Gunia & Simak 1970; Kitzmiller *et al*. 1973). It must be re-emphasized that all species which contain resin vesicles should be handled with extra care to avoid damage and reductions in germination.

A second important characteristic of *Abies* is the deep physiological dormancy that is present in Amabilis and subalpine fir. Grand fir appears to have a low level of dormancy compared to these species. This physiological dormancy or embryo dormancy is widespread among conifers, but is not well understood. It is a mechanism that prevents germination in the fall to avoid seedling mortality from fall frosts. Embryo dormancy is considered to be biochemical in nature and is relieved naturally over-winter or artificially through cold stratification. To date, the most effective stratification regimes for *Abies* are what I refer to as split stratification regimes: seed is stratified for part of the total duration under a high moisture regime (≈45%) and subsequently to a lower moisture regime (≈35%). The success of this split stratification regime was popularized in 1986 with the publication of the following three research papers:

Edwards, D.G.W. 1986. Special prechilling techniques for tree seeds. J. Seed Tech. 10:151-171.

Leadem, C.L. 1986. Stratification of *Abies amabilis* seeds. Can. J. For. Res. 4:755-760.

Tanaka, Y. and D.G. W. Edwards. 1986. An improved and more versatile method for prechilling *Abies procera* Rehd. seeds. Seed Sci. Technology 14:457-464.

This type of stratification has provided an improved method of stratifying *Abies* seed, but seedlots vary in response to the treatment and it is probable that an optimal regime will vary from seedlot to seedlot. Variables in the stratification regime include the actual moisture content of the two parts and their duration. Although improvements in stratification techniques have improved *Abies* germination it is my believe that more work is required towards developing an "optimal" stratification strategy.

A third more recently identified problem in *Abies* seed biology is the presence of relatively high proportions of abnormal germinants, namely those with stunted radicles. These germinants emerge from the seed, but the radicle ceases development while the aboveground structures continue to grow. These germinants are not included in the germination capacity of a seedlot. The cause of this abnormality is unknown, but we are currently investigating its cause.

Seed Testing

Seedlots are tested based on the International Seed Testing Association rules (ISTA 1996). These rules serve as guidelines and are deviated from when evidence suggests it is advantageous (i.e. ISTA rules still only prescribe a 28 day stratification regime for *Abies* which would be disastrous to our nursery industry). Each seedlot is sampled according to a set of procedures which provides a sample that is representative of the seedlot. For each germination test performed, four replicates of 100 seeds are used to estimate the germination capacity, which for *Abies* is the % of seeds germinating after 28 days under test conditions. Each replicate is represented by a germination dish which contains kimpack (a 20-ply paper wadding material), filter paper and 50 ml of water. *Abies* are tested with a 25/15 daily temperature regime which consists of 8 hours at 25°C with lights followed by 16 hours at 15°C in the dark. Germinants are counted and removed on Monday, Wednesday and Friday allowing for the quantification of germination rate as well as capacity. For most species germinants are counted when the radicle is 4X the length of the seed coat. Due to the large size of Amabilis fir and Noble fir (*Abies procera* Rehd.) germinants are counted when the radicle is twice as long as the seed coat. More details on seed testing can be found in George Edwards publication on Methods and Procedures for Testing Tree Seeds in Canada (Edwards 1987).

Details on the germination test types for *Abies* are presented in Table 4. For Amabilis and subalpine fir two test types are initially performed on each seedlot: G44 and G64. Subsequent testing will use only the test type producing the highest germination and for *Abies* the retest frequency is 24 months. The G64 test type is a split stratification regime referred to as dryback versus the full stratification-redry which recommends a total of 84 days stratification for the second part of the regime

Table 4. Characteristics of the germination test types of *Abies* species.

Test Code	Species	Soak	Split Regime	Stratification Duration	Strat. Duration 2nd part of split regime
G32	grand fir	48 hours	N	28 days	n.a.
G44	Amabilis fir subalpine fir	48 hours	N	56 days	n.a.
G64	Amabilis fir subalpine fir	48 hours	Y	28 days @ 45% moisture content	56 days @ 35% moisture content

Some early work on subalpine fir indicated that large responses to the split stratification regime (Edwards 1981). This early work discussed stratification (high moisture content) followed by drying the seed and storing it under cool conditions (2°C). In my terminology this is equivalent to the split stratification regime with the moisture content of the seed being different for each part. There is a degree of drying in which dormancy may be reinstated, but it is thought that it is between 15 to 20% moisture content. Figure 1 presents work on subalpine fir illustrating that the greatest germination occurs with 26 weeks (6 months) of stratification at 35% moisture contents following four weeks of higher moisture content stratification, although it is only marginally better than the 13 week stratification period at 35%. The moisture content for stratification was assumed to be 45%, although moisture content and duration of this phase may also impact the success of the stratification treatment.

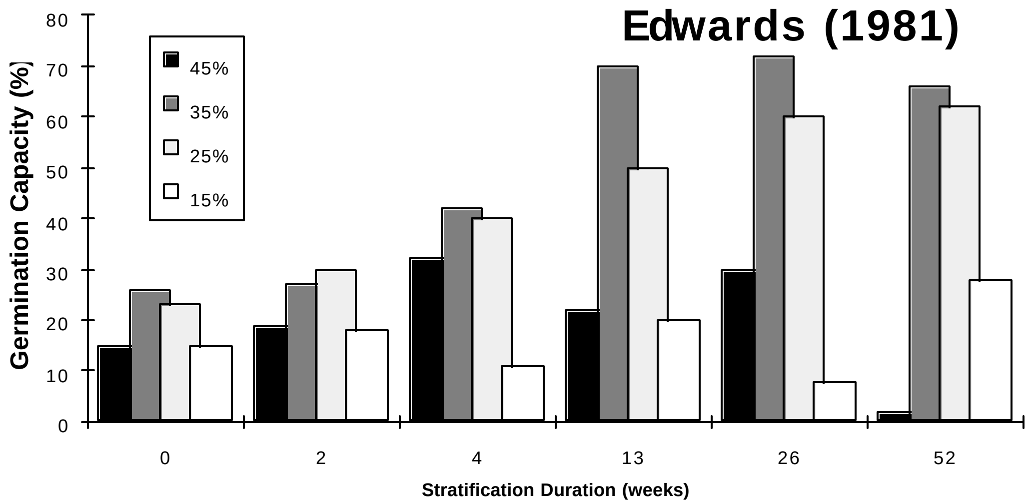

Figure 1. The impact of duration and moisture content (%) of the second portion of the split stratification regime on germination in subalpine fir (from Edwards 1981).

The TSC initiated a trial with subalpine fir to investigate variability in dormancy and response to germination temperature. The trial used 12 subalpine fir seedlots distributed through the species range and two seed treatments: a 48-hour soak and the operational dryback procedure (G64). For the dryback procedure target moisture content calculations were used to set initial moisture at 45% and subsequent, post dryback, moisture at 35% to ensure treatment consistency between seedlots. Two temperature regimes were used (20:10 and 28:22) in which the temperature ramped between these two extremes over a 24-hour period. Germination results are illustrated in Figure 2 showing the large benefit to be gained by germinating subalpine fir pretreated with the dryback procedure at higher germination temperatures . This trend was also found when the full stratification-redry treatment was performed on three different subalpine fir seedlots (Leadem 1989). Nurseries growing *Abies* are currently trying to maximize germination temperatures to obtain the greatest germination in the shortest amount of time. Quicker germination has a large impact on crop uniformity and avoidance of disease. Although nurseries recognize the importance of high germination temperatures, many northern nurseries have difficulty maintaining these temperatures during the winter months.

Dormancy is a seedlot characteristic that can be investigated by comparing the germination obtained with a stratification treatment and a soak only treatment (Figure 3). In Figure 3 ten of the twelve seedlots exhibit various degrees of dormancy. Seedlot 31134 displays no dormancy and seedlot 40271 responds quite poorly to the dryback treatment. This seedlot had initial problems in terms of seed quality and is also infected with *Caloscypha* and *Fusarium* and is considered abnormal in several respects. In the remaining ten seedlots dormancy is substantial with an average of 45 % of the seed being released from dormancy with the dryback procedure. On average, 28% of seed from these 12 seedlots have no dormancy associated with them. Variability in dormancy is evident as increases in germination, following dryback, which range from 33 to 70% of the seed. The results are based on operational seedlots as they appear in long-term storage and comparisons between seedlots reflect differences in dormancy and proportion of filled seed in each seedlot. For quantifying degree of dormancy across several seedlots testing should be performed only on filled seed. The use of x-ray analysis allows one to select only filled seeds for testing. This study will be repeated using only filled seeds, but I feel that both types of testing are valuable depending on services you provide at the nursery. If you are upgrading seed to remove most of the non-viable seed then pretreatment results based only on filled seed would be more appropriate, but if you are simply sowing the operational seedlots without further treatment the results presented here representing both viable and non-viable seed would be more useful. It is important when reading about germination results that you are clear on the material used (only filled seed vs. operational seedlots) and how each applies to your unique situation.

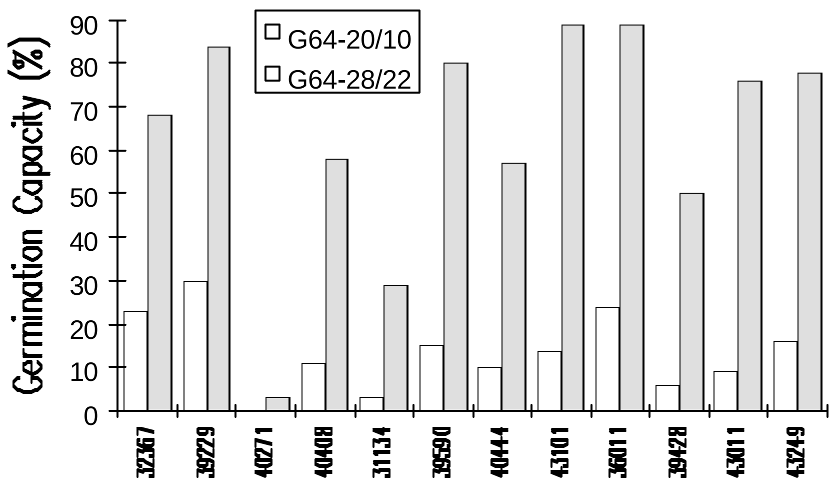

Figure 2. The impact of temperature regime on the germination of 12 subalpine fir seedlots treated with the dryback procedure.

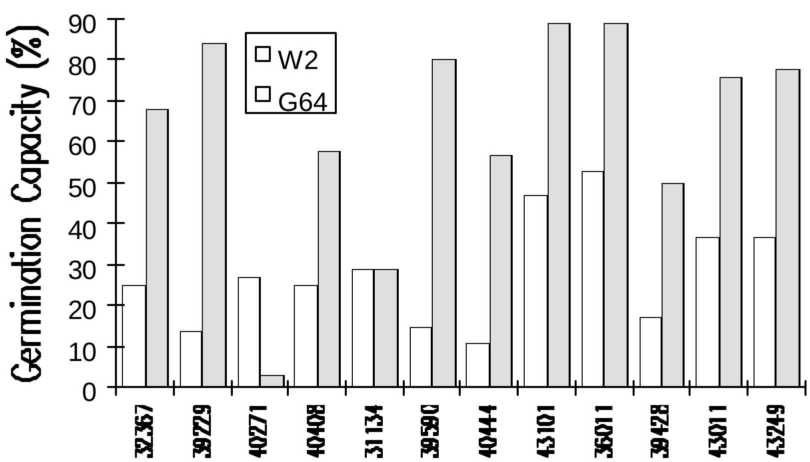

Figure 3. A comparison of the soak only (W2) and dryback (G64) pretreatment of 12 subalpine fir seedlots at the 28:22 temperature regime to investigate variability in seed dormancy.

Seed Preparation

The procedures used at the TSC for preparing seed for nursery sowing mimic the testing regimes used. A significant difference is the use of running water soaks in operational seed preparation to reduce the quantity of seed-borne fungi and possibly remove inhibitors that play a role in dormancy. For Amabilis and subalpine fir the G64 test type is superior to the G44 in over 90% of the seedlots in storage. The split stratification regime is therefore the preferred method of preparing seed for nursery sowing and for January sow dates the approved seedling requests must be in the SPAR (Seed Planning and Registry) system prior to October 1.   The full stratification-redry treatment (112 days) is recommended to increase germination rate and when nursery germination conditions are sub-optimal (Leaded and Clark 1992). The full treatment can be accomplished, if desired, by contacting the TSC and asking that the shipment be delayed or by keeping the seed in a cool (2-5°C) location at the nursery until sowing. To perform the full stratification redry treatment for January sowing the seedling requests will need to be approved by September 1. It is important once seed arrives at the nursery to inspect the seed and open bags to allow for oxygen exchange as seeds are alive. A negative aspect of longer than normal stratification is the potential for fungal buildup on the seed and problems with ease of sowing and disease.

With Amabilis and subalpine fir a large proportion of the stratification is occurring at the nursery (Table 5) to allow more flexibility in the timing of nursery sowing (the initial incentive to look at storing seed at reduced moistures) and to streamline upgrading efforts at forest nurseries which incorporate this technique prior to sowing. Partial stratification is beneficial to nurseries which wish to initiate upgrading as soon as seeds arrive on site. It also allows a consistent product arriving at the nursery as many *Abies* seedling requests are initiated before a nursery is assigned so each nurseries requested service may not be provided.

Table 5. The proportion of *Abies* seedlots shipped to the nurseries dry, with partial stratification or with full stratification for 1997 sowing.

	Amabilis fir	**subalpine fir**	**grand fir**
Dry	44%	12%	90%
Partial Stratification	48%	63%	n.a.
Full Stratification	8%	25%	10%

An important aspect of the split stratification regime is the control of the moisture level. The current procedure at the TSC is to use visible clues of seed drying and average timings, based on local experience, to obtain proper moisture levels. Most fully imbibed *Abies* seed following a 48-hour soak is greater than 45% although a large proportion of this moisture is probably on the seed coat and not within the seed. To bring the seed to 45% the seedling request is suspended in a rack system and drained for 90 to 120 minutes. When seed is dried to 35% moisture content, to initiate part 2 of the split regime, the procedure takes approximately 25 to 30 minutes with the drying set-up at the TSC. It must be emphasized that the draining time is probably similar for different facilities, but the drying time will be dependent on the system used for drying in terms of method, airflow, air temperature and whether air is dehumidified or not. Nurseries should track the drying of seedlots using their own set-up to arrive at an acceptable timing for dryback. There are no non-destructive moisture meters available for seed above approximately 15% moisture content so seed must either be sacrificed or one can estimate the moisture content based on target moisture content calculations.

Target moisture calculations allows one to accurately estimate the **average** moisture content of a quantity of seed using seed weight. There are two simple steps to using target moisture content calculations based on knowing the equation for moisture content and its various forms (equations 1 to 3). These equations utilize moisture content as a decimal rather than a percentage (i.e. 35%

moisture content is equal to 0.35) which simplifies their use. The oven dry weight is the weight of a quantity of seed with no moisture and is usually obtained through the standard moisture content test of drying seed for 17 hours at 103 °C. The fresh weight reflects seed with moisture.

(1) $\text{moisture content} = \dfrac{\text{fresh wt. - oven-dry weight}}{\text{fresh wt.}}$

(2) oven-dry wt. = fresh wt. * (1 - moisture content)

(3) $\text{fresh wt.} = \dfrac{\text{oven-dry wt.}}{\text{(1- moisture content)}}$

The first step in using target moisture content calculations is to derive the oven-dry weight of the request using equation 2. The fresh weight of the seed is on the request label and is based on the moisture content in long-term storage that can be obtained through SPAR. By plugging these variables into equation 2 we can obtain the oven-dry weight. With the oven-dry weight we can derive the moisture content of a seed sample if we know its current weight (Equation 1) or determine what the current weight should be (i.e. for drying) if one desires a specific moisture content (Equation 3). These equations can be extremely useful in *Abies* pretreatments and for quality assurance monitoring in general. I recommend that nursery managers and growers become familiar with their use.

Seed Upgrading

Seed upgrading is a valuable technique for improving the germination of *Abies* in the nursery. In 1993 the TSC initiated a program of upgrading a selected number of seedling requests using DSP. A total of 22 *Abies* seedlots were upgraded, but only four were subalpine fir (Kolotelo 1993). In most cases the results were promising with gains in germination of the best fraction and gains in potential seedlings. A disadvantage of this upgrading effort was that several fractions of differing quality were obtained making sowing at the nursery cumbersome due to several sowing factors being required for a single request. Nurseries desire to have seed of one quality for sowing.

The TSC is currently looking at upgrading on a seedlot rather than a seedling request basis for efficiency (i.e. upgrading the same seedlot once vs. several times). Upgrading of *Abies* with DSP is generally not successful if the seed has not been imbibed and then stratified for at least several days to allow the moisture content to equilibrate within the seed to allow for an efficient separation. There are serious concerns with performing DSP and then returning the seedlot to long-term storage. Several nurseries are currently performing this service on a seedling request basis just prior to sowing. At the 1993 meeting in Courtney, BC the tour to the Campbell River nursery illustrated the large benefits obtained through this type of upgrading in terms of cavity fill and crop uniformity.

Fungi

There are three significant pathogens that are assayed for by the TSC: *Caloscypha fulgens* [seed or cold fungus]; *Fusarium* sp. [that may cause damping-off or root rot] and *Sirococcus conigenus* [Sirococcus blight]. Sirococcus is not considered problematic for *Abies*, but the other two can cause substantial losses in the nursery. Results of fungal assay tests performed to date are presented in Table 6.

A much higher proportion of subalpine fir seedlots are infected with *Calosypha* (42%) and the average infection is also much greater (2.6%) compared to Amabilis fir. *Caloscypha* kills seed and will therefore reduce germination, but it can also spread between seeds during stratification or after sowing increasing the problem (Sutherland et al. 1989). Due to the relatively long stratification period for Amabilis and subalpine fir a large bulking-up of the fungus can occur. For Fusarium, % of infected seedlots follow the trend of grand fir > Amabilis fir > subalpine fir, although average infection does not vary greatly between species.

Critical levels of seed-borne fungi are difficult, if not impossible, to define as actual disease incidence will depend on the environment in which the crop is grown as well as the sowing pre-treatment. The fungal assays can be used to identify infected seedlots as potential disease problems and to prioritize seed treatments or monitoring to those seedlots showing the highest infection %. Currently no satisfactory seed treatment is available for *Abies*. Trials on the effect of various hydrogen peroxide post-stratification treatments provided a suitable treatment for coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and western larch (*Larix occidentalis* Nutt.), but no treatment provided consistent results for subalpine fir (Neumann 1997). Current trials are looking into pre-stratification hydrogen peroxide treatment as well as a biological control agent to reduce incidence of *Fusarium* and *Caloscypha* in subalpine fir.

Table 6. The results of fungal assay testing of *Abies* for *Caloscypha fulgens* and *Fusarium* sp.

Caloscypha fulgens	**Amabilis fir**	**subalpine fir**	**grand fir**
# Seedlots tested	64	73	n.a.
% Seedlots Tested	28	45	n.a.
% Seedlots Infected	13	42	n.a.
Ave. Infection %[3]	0.9	2.6	n.a.
Max. Infection %	2.0	9.6	n.a.
***Fusarium* sp.**			
# Seedlots tested	180	239	49
% Seedlots Tested	78	87	84
% Infected	33	24	37
Ave. Infection %	0.8	0.9	1.3
Max. Infection %	11.6	14.0	7.0

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[3] mean infection % of seedlots with infection % > 0.0

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