Genera Profiles

The genera profiles section provides illustrations and descriptions of the individual species within each genus commonly grown in western Canada for reforestation. The genera in the Pinaceae family are covered first followed by the Cupressaceae.

The importance of interior spruce and lodgepole pine to reforestation in B.C. cannot be overemphasized: they consistently account for 75% of the reforestation in the province. Due to their similar small size and lack of wing remnants, these species are sometimes confused, but upon closer examination differences are obvious (FIGURE 47). Lodgepole pine seed are generally larger, heavier, quite dark (almost black), while spruce seed are smaller, brownish, and more variable in colour, usually with a mottled surface. At the extremes of both species there is an overlap in seed size, weight, and colour.

In FIGURE 48 a comparison of longitudinal seed sections of the four major reforestation species are presented. Combined, these account for about 87% of the seedlings grown in B.C. This diagram illustrates some of the differences in seed length, width, and embryo size between these species. A striking feature is the reduced size of the megagametophyte and presence of persistent wings in western redcedar. The increased ease of handling the larger Douglas-fir seed is often offset by the presence of wing remnants, which can reduce purity and decrease sowing precision.

Each species has unique attributes (TABLE 2). The seed size attributes can be useful in screening or sizing seed to maximize the efficiency of sowing with some seeders.

FIGURE 47

A comparison of seed coat morphology between interior lodgepole pine and interior spruce.

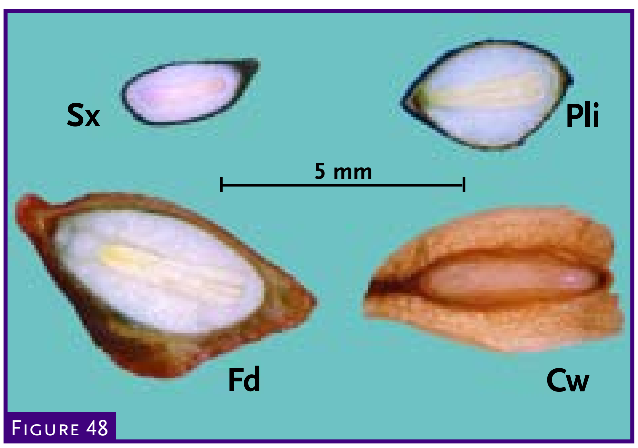


FIGURE 48

A comparison of longitudinal sections of interior spruce, interior lodgepole pine, Douglas-fir, and western redcedar.

Table 2 Seed and embryo attributes for B.C. reforestation species. Measured variables are based on 10 seed from 5 seedlots and are presented with means and (ranges) in millimetres.

Common name	Code	Seed per gram	Seed length	Seed width	Embryo length	Cotyledon number	Resin vesicle number
Amabilis fir	Ba	29	10.4 (8–12)	4.4 (3–5)	6.7 (4–8)	4.6 (4–6)	6.2 (4–10)
grand fir	Bg	46	9.6 (7–13)	5.5 (4–9)	6.5 (5–8)	5.2 (4–6)	8.4 (6–13)
subalpine fir	Bl	83	6.4 (5–8)	3.4 (3–4)	4.8 (4–6)	4.2 (3–5)	5.9 (3–9)
coastal Douglas-fir	Fdc	91	6.6 (5–8)	3.4 (3–4)	3.6 (3–5)	6.7 (5–8)	n.a.
interior Douglas-fir	Fdi	103	5.2 (4–7)	3.1 (2–4)	3.6 (3–4)	6.8 (6–8)	n.a.
mountain hemlock	Hm	461	3.6 (2–5)	1.8 (1–2)	2.2 (1–3)	3.3 (3–4)	2.8 (1–5)
western hemlock	Hw	494	3.1 (2–4)	1.9 (1–2)	2.3 (2–3)	3.0 (2–4)	3.8 (1–7)
western larch	Lw	283	4.4 (3–6)	2.2 (2–3)	2.1 (2–3)	5.7 (4–8)	n.a.
coastal lodgepole pine	Plc	375	3.2 (2–5)	1.8 (1–2)	2.5 (2–3)	3.5 (3–5)	n.a.
interior lodgepole pine	Pli	346	3.4 (2–5)	1.9 (1–2)	2.5 (1–3)	3.6 (3–5)	n.a.
western white pine	Pw	52	6.8 (5–8)	3.9 (3–5)	4.4 (3–6)	8.1 (6–10)	n.a.
ponderosa pine	Py	20	8.9 (7–12)	5.7 (4–8)	7.8 (6–10)	8.9 (6–12)	n.a.
Sitka spruce	SS	412	3.1 (2–4)	1.9 (1–2)	2.0 (1–3)	5.4 (4–6)	n.a.
interior spruce	Sx	439	2.8 (2–4)	1.7 (1–2)	2.0 (1–2)	5.6 (4–7)	n.a.
hybrid Sitka spruce	SxS	458	2.8 (2–4)	1.6 (1–2)	2.0 (1–3)	5.5 (4–7)	n.a.
western redcedar	Cw	788	5.2 (4–7)	2.8 (2–4)	2.9 (2–4)	2	7.7 (4–12)
yellow-cedar	Cy	225	4.4 (3–6)	4.7 (3–6)	2.7 (2–3)	2	n.a.

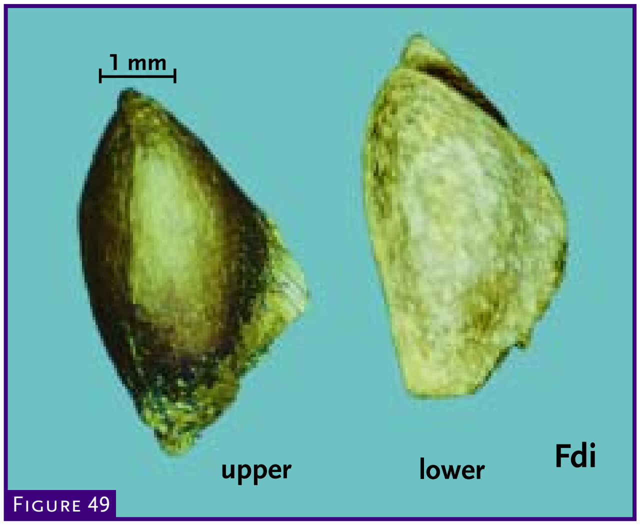


Figure 49

A comparison of the morphological features between the upper and lower surface of a Douglas-fir seed.

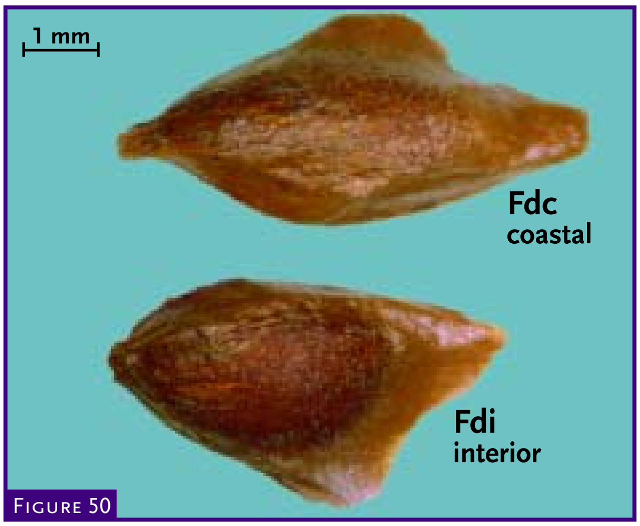


Figure 50

A comparison of the external seed morphology of coastal and interior Douglas-fir.

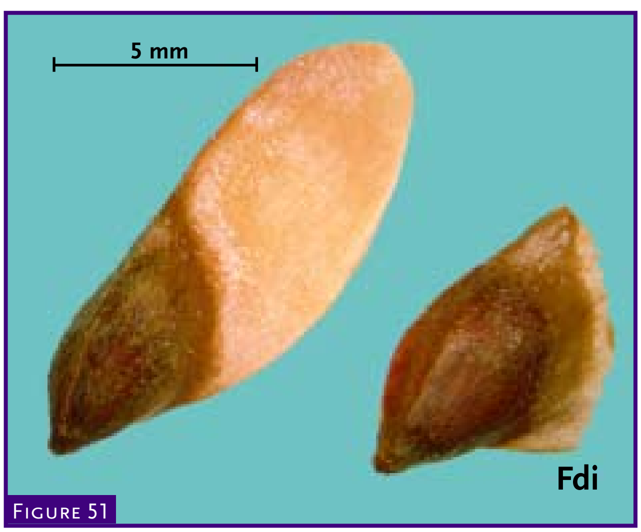


Figure 51

A comparison of a winged and dewinged Douglas-fir seed.

Douglas-fir

Pseudotsuga genus

Pinaceae family

Additional Douglas-fir photos	
Figure#	Page#
3	5
10	10
18	15
22	17
30	24
35	26
45	29
48	30

The seed of Douglas-fir is relatively easy to identify by its size and distinct upper and lower surfaces. The upper surface is rounded and dark brown while the lower surface is light coloured, mottled, and much flatter (Figure 49). In studies of the effect of seed orientation on germination, it was found that seed with their lower (lighter coloured, mottled) surface facing upwards germinated 1.7 days earlier under laboratory conditions. The practical application of these results is difficult to imagine, but suggest that characteristics such as seed orientation can affect germination. It was also observed that coastal Douglas-fir seed from environments with the shortest growing seasons germinate quickest[53].

In western Canada, Douglas-fir is subdivided into a coastal **variety** (var. *menziesii*) and an interior variety (var. *glauca*). The varieties can be distinguished by shape and presence of markings on the seed coat. The coastal variety generally has longer and narrower seed with a pointed tip that is pinched in at the micropylar end. It also has a more pronounced ridge on the darker side that is wrinkled near the micropylar end. The interior variety is broad and more circular in shape. Its seed coat is often brighter and commonly the dark side is marked by stripes that may continue into the seed wing[2] (Figure 50).

Removal of the seed wing is important to improve seeding efficiency and is performed on all species in the Pinaceae family. In Douglas-fir, the seed wing and seed are integrally connected and dewinging is accomplished by breaking the wing as close as possible to the seed coat. A winged and dewinged seed of interior Douglas-fir illustrate the persistent remnants of the wing attached to the seed coat (Figure 51). Incomplete dewinging can result in decreased **purity** over time due to the continual breakage of wing remnants. This wing material may be sown instead of a seed resulting in an empty cavity. The seed wing of

FIGURE 52

A longitudinal section of an imbibed Douglas-fir seed.

Douglas-fir is composed of two layers of sclerenchyma cells, both of which develop from the ovuliferous scale and not the ovule. The outer layer is continuous with the outer layer of the seed coat[39]. This seed wing origin and structure is considered typical of the Pinaceae although the integrity of the seed to wing attachment varies by species.

In FIGURE 52 an imbibed longitudinal section of a Douglas-fir seed is presented. The embryo is characteristically yellow in dry seed and gradually grows paler following imbibition (FIGURE 10, page 10, FIGURE 30, page 24). The dry megagametophyte is a grey-cream colour that changes to white following imbibition (FIGURES 10, 30). This colour change following imbibition is characteristic of most conifer seed. In coastal Douglas-fir the megagametophyte accounts for 65% of the dry weight of the seed followed by the seed coat (28%) and embryo (7%).

Seed of the coastal variety are generally larger, but embryo lengths of both varieties were found to be equivalent (TABLE 2, page 31). The more rapid germination found in interior Douglas-fir may be due to its proportionately larger embryo. A suspensor is usually obvious at the micropylar end of the seed.

The anatomy of Douglas-fir seed has been intensively studied in Canada. The classic work of Allen and Owens[1] in 1972 has opened the door to studies on many other conifers and today we are gaining an understanding at greater levels of detail about the conifer seed[27,38,56,57]. Many of these details are beyond the scope of this text.

Spruce

Picea genus

Pinaceae family

ADDITIONAL SPRUCE PHOTOS	
FIGURE#	PAGE#
7	8
13	11
14	12
17	14
25	19
26	19
27	19
31	25
40	27
47	30
48	30

The species in the spruce genus are considered together, as their seed are quite similar in anatomy and morphology (FIGURE 53) (TABLE 2), although their ecological niches vary considerably. The species represented in B.C. include Sitka spruce on the coast and interior spruce (a species complex including white spruce at lower elevations; Engelmann spruce at higher elevations; and hybrids between the two species at intermediate elevations). Along the north coast, Sitka spruce also hybridizes with interior spruce and these seedlots are designated SxS. In the boreal part of the province black spruce is also present, although currently not planted to any extent in B.C. Black spruce can be identified by its small, dark seed (FIGURE 54).

The morphology of a spruce seed coat appears mottled (FIGURE 55), although it can be predominantly dark or light. Notable differences between upper and lower seed surfaces are not as apparent

FIGURE 53

A comparison of seed morphology between interior spruce, Sitka spruce, and hybrid spruce.

FIGURE 54

A comparison in the seed morphology between interior spruce and black spruce.

FIGURE 55

A magnified view of the surface morphology of an interior spruce seed.

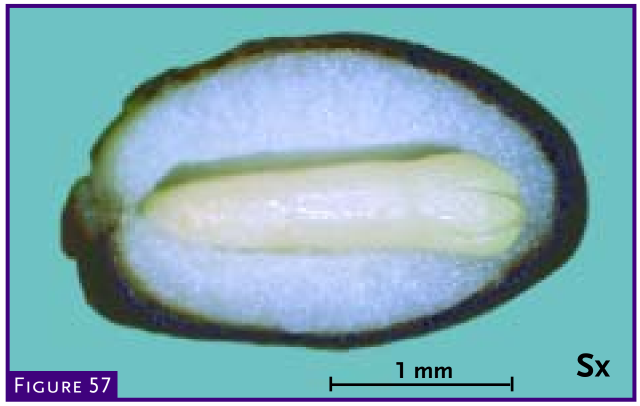


FIGURE 57

A longitudinal section of an interior spruce seed with the embryo unsliced.

as other genera. FIGURE 56 illustrates seed of interior spruce from two different trees. Both were fully mature and germinable, but very little pigmentation is present in the light-coloured seed. In Finland, Norway spruce seed are consistently darker from the north, but no such findings have been reported for Canada. In FIGURE 57, a typical imbibed seed of interior spruce in longitudinal section is displayed. The cream-coloured embryo has not been sectioned to present its three-dimensional morphology with three distinct cotyledons.

A comparison of the upper and lower surfaces of winged spruce seed is presented in FIGURE 58A. The seed wing, derived from the ovuliferous scale, is continuous with the upper surface of the seed. The lower surface of the seed is exposed due to a separation layer which forms beneath the seed before fertilization (FIGURE 58B)[34]. The lower seed surface sits imbedded in the surrounding ovuliferous scale. With the addition of water the seed wing expands and is easily removed from the seed (FIGURE 58C) resulting in very clean dewinging. Compare the complete wing removal of spruce with the incomplete breaking that must occur with Douglas-fir (FIGURE 51, page 32).

FIGURE 56

Comparison of interior spruce seed from two mother trees.

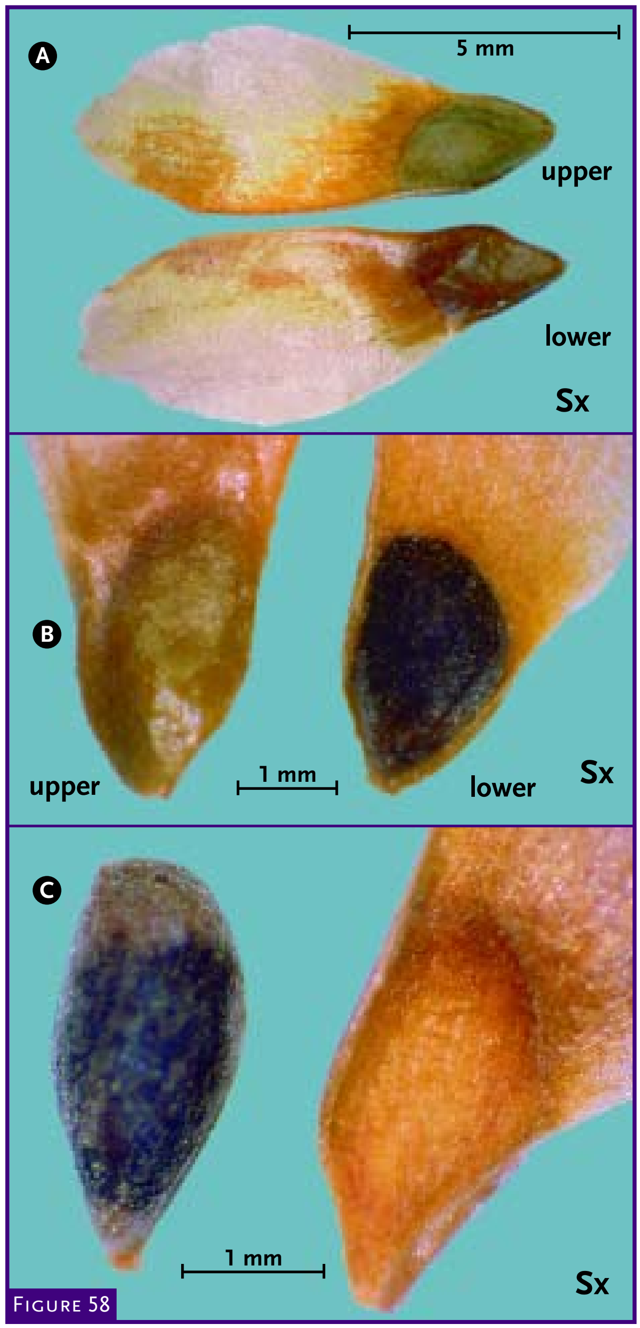


FIGURE 58

A comparison of (A) the upper and lower surfaces of winged interior spruce seed, (B) a magnified view of wing attachment, and (C) a seed removed from the adjacent wing attachment.

Pine

Pinus genus

Pinaceae family

Additional Pine Photos	Figure#	Page#
Pli	6	7
	39	27
	44	28
	46	29
	47	30
	48	30
Pw	8	8
	12	11
	13	11
	24	18
Py	5	7
	10	10
	15	12
	32	25
	36	26
	41	27

This section will concentrate on the three pine species used for reforestation in the province: lodgepole pine, ponderosa pine, and western white pine (Figure 59). The pines we will discuss all have seed wings, but pine seed larger than 90 mg are generally bird dispersed and wingless[7]. In ponderosa pine and white pine the attachment of the wing to the seed is usually similar to spruce (Figure 60). The connection of the wing to the seed coat is relatively weak and in this example incomplete, allowing for its easy separation. In lodgepole pine and sometimes ponderosa pine the attachment is pincer-like where the cells from the wing do not cover the upper surface or lower surface of the seed, but clasp the seed at the junction of upper and lower seed surfaces (Figure 61). In either case the addition of moisture ensures efficient dewinging.

Lodgepole pine is subdivided into a coastal variety (var. *contorta*) and an interior variety (var. *latifolia*). Seed differences are not great, although the interior variety has slightly larger seed and about one hundred times more are planted in B.C. Both varieties germinate very quickly. A longitudinal section of a lodgepole pine seed shows numerous cotyledons and a well-defined cylinder of the procambium and pith (Figure 62). The embryo is cream coloured in this seed, but characteristically lodgepole pine has a distinct white embryo. The megagametophyte accounts for a large proportion

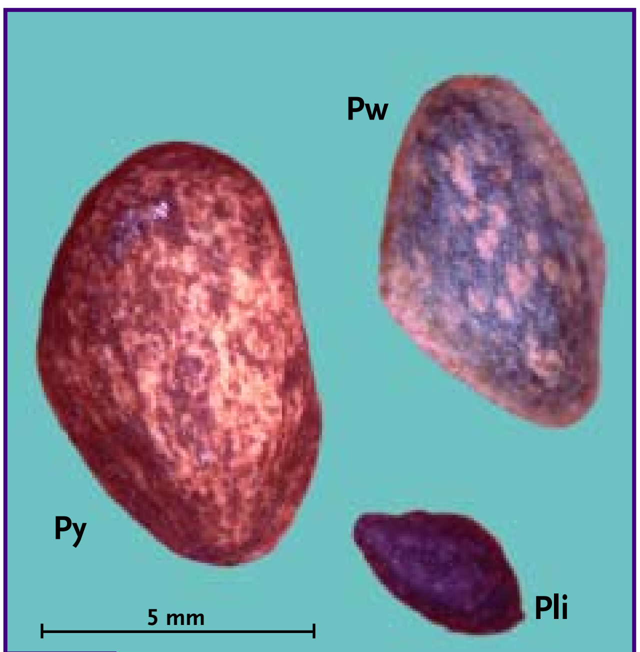


Figure 59

A seed morphology comparison between lodgepole, ponderosa, and western white pine.

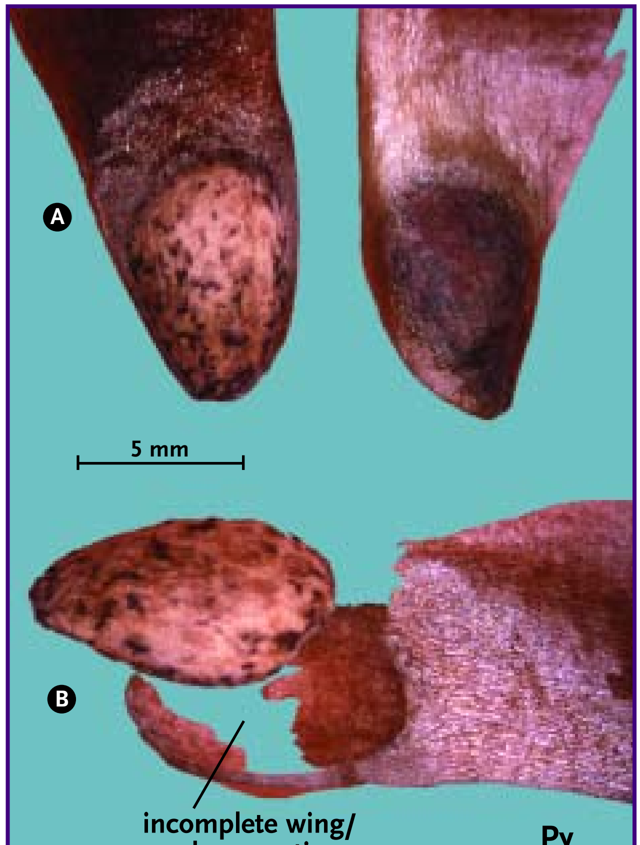


Figure 60

Method of wing attachment in ponderosa pine illustrated by (A) the upper and lower surfaces of a winged seed, and (B) the morphology of structures following dewinging.

Figure 61

The morphology of the seed wing attachment in lodgepole pine.

of the seed. In estimates of the energy invested in seed, the megagametophyte and embryo account for 77.6%, the seed coat 13.7%, and the seed wing 8.8%[51].

Ponderosa pine have the heaviest seed with thick seed coats that may act to constrain the megagametophyte and embryo (Figure 63). The seed coat weight is lightest in the interior of the range and heaviest with increasing elevation. This indicates seed coat dormancy is greater at higher elevations in the interior portion of the range[4]. The greatest number of cotyledons are found in ponderosa pine (ranging from 6 to 12) giving the species a large base for photosynthesis before leaves are initiated. Other literature on the southern pines would probably be applicable to ponderosa pine as their general anatomy and morphology are similar.

Western white pine is well known for its low and erratic germination. The species requires a long stratification period (deeply dormant) and has shown variability in the degree of physical and physiological dormancy between seedlots. A longitudinal section of a western white pine seed is shown in Figure 64. The embryo occupies a large portion of the seed and a prominent micropylar plug is commonly seen. The seed coat layers can be clearly seen at the chalazal (cotyledon) end of the seed (see also Figure 8, page 8).

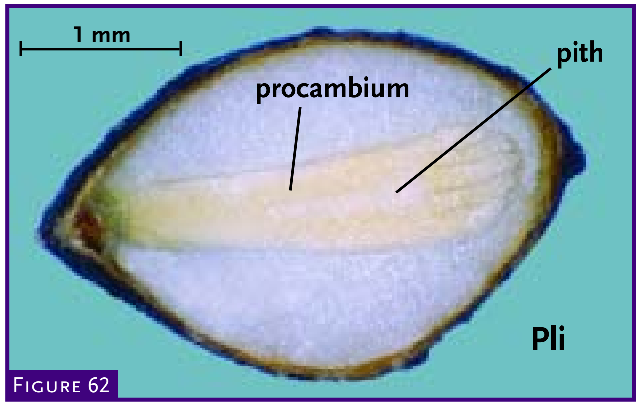


Figure 62

A longitudinal section of an imbibed interior lodgepole pine seed.

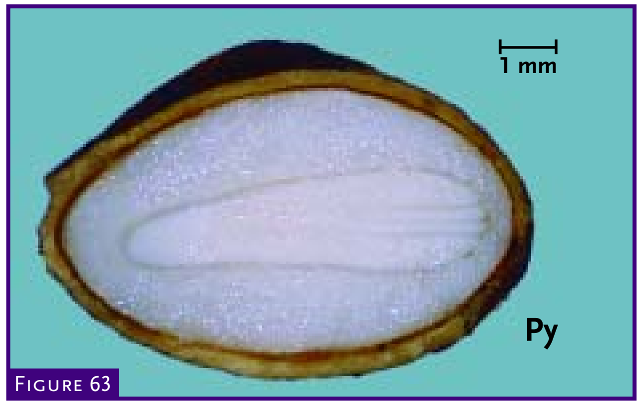


Figure 63

A longitudinal section of an imbibed ponderosa pine seed.

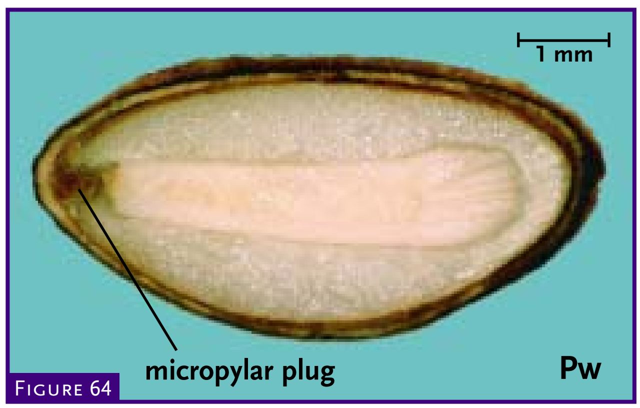


Figure 64

A longitudinal section of an imbibed western white pine seed.

True firs

Abies genus

Pinaceae family

Additional True firs photos	Figure#	Page#
Ba	20	17
	21	17
	45	29
Bl	34	26
	37	27

The true firs are represented in B.C. by Amabilis fir, subalpine fir, and grand fir. All of the *Abies* spp. have cone scales that abscise from the cone axis. Therefore, kilning is not required for seed extraction. An example of an abscised cone scale with one seed attached is displayed in Figure 65. Note the continuity of the seed wing and outer seed coat over the upper surface of the seed and the relatively large size of the seed wing compared to other conifers.

A comparison of the upper and lower seed surfaces of grand, subalpine, and Amabilis fir are presented in Figure 66. Species can usually be identified based on seed morphology without much difficulty. Amabilis fir seed is tan-coloured, quite large, and elliptical in shape; subalpine fir is relatively small, triangular, and can have a purple coloration (Figure 67); Grand fir is intermediate in size, triangular, and contains the most resin vesicles. The lower surface of the seed is characterized by a discontinuity in the outer seed coat layer (Figure 66) as a result of the separation of the seed from the ovuliferous scale. This discontinuity exposes some of the resin vesicles on the lower seed surface to potential damage.

All *Abies* spp. have resin vesicles that form within the integument during seed development. The resin vesicles, which appear outside the stony layer of the seed coat in Amabilis fir[33], subalpine fir[48], and grand fir[49], are more common on the lower surface of the seed and cause depressions in the megagametophyte. The stony layer is reduced in size under the resin vesicles. If processing is excessive, the entire outer seed coat layer and wing tissue can be removed exposing a larger number of resin vesicles to potential damage. An Amabilis fir seed without its outer seed coat layer illustrates a recently damaged resin vesicle (Figure 68). Seed with damaged resin vesicles can be identified by a sticky or pitchy feel, presence of resin, and a characteristic odour and dark grey colour. The outcome of resin vesicle damage is a reduction in germination[17,21].

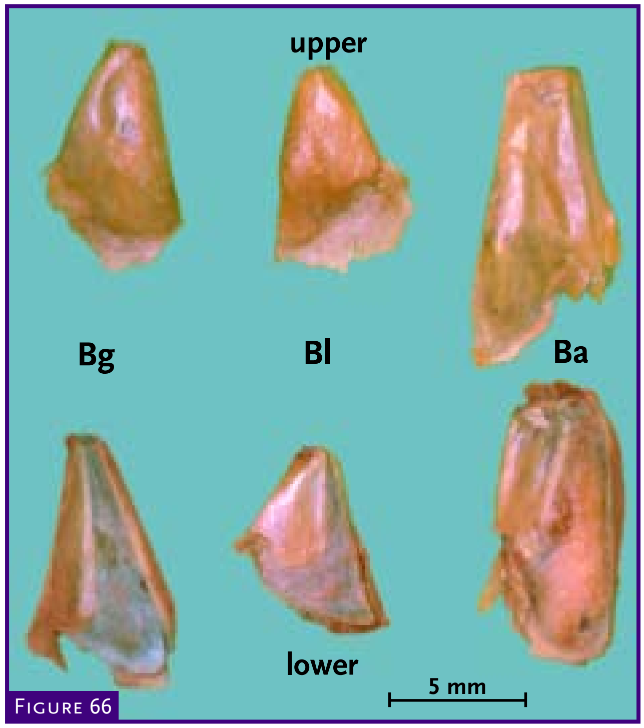


Figure 66

The upper and lower surfaces of the seed of grand fir, subalpine fir, and Amabilis fir.

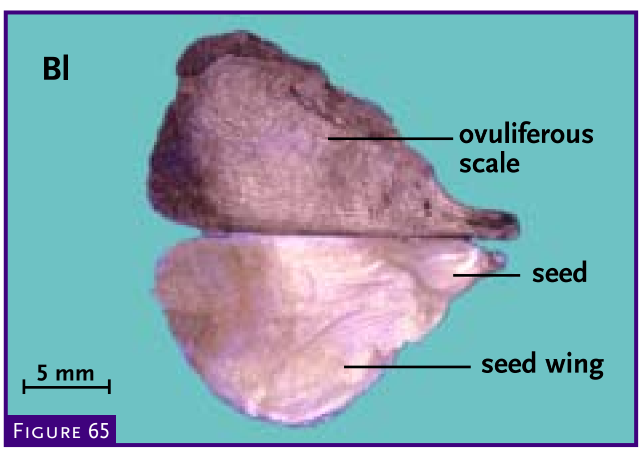


Figure 65

An ovuliferous scale of subalpine fir with one winged seed present.

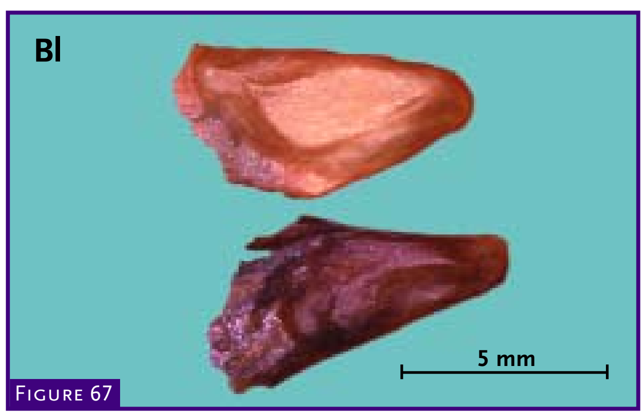


Figure 67

Different morphologies of mature, viable seed of subalpine fir.

Seed of grand fir contain the greatest number of resin vesicles; five are obvious in Figure 69 causing depressions in the megagametophyte. Grand fir seed are also considered less dormant than the other species which is reflected in its shorter stratification regime (Appendix 4). The smaller seed of subalpine fir have the least number of resin vesicles in the true firs (average is 4) and only one is visible in Figure 70 at the chalazal end of the seed. A longitudinal section of an Amabilis fir seed is displayed in Figure 71. The characteristically yellow-cream coloured embryo occupies nearly the entire length of the seed, cotyledons are large and well developed and the procambium is visible. Remnants of the seed wing can be seen. A short vascular strand was reported to be found in the seed coat, at the chalazal end, during seed development[41].

Details on cone and seed processing are beyond the scope of this volume, but an overview of changes in the morphology of material present in a subalpine fir seedlot during processing is presented to provide an overview (Figure 72).

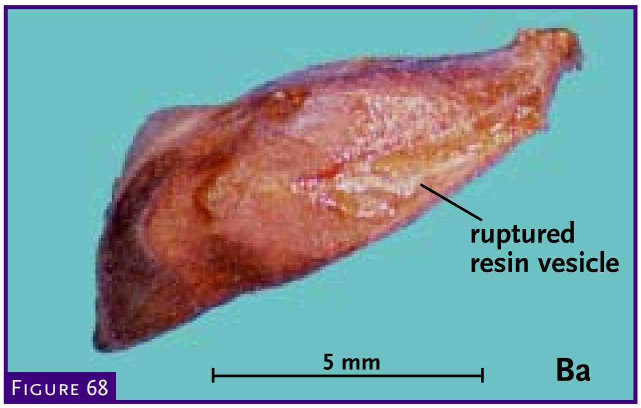


Figure 68

A damaged resin vesicle in an Amabilis fir seed.

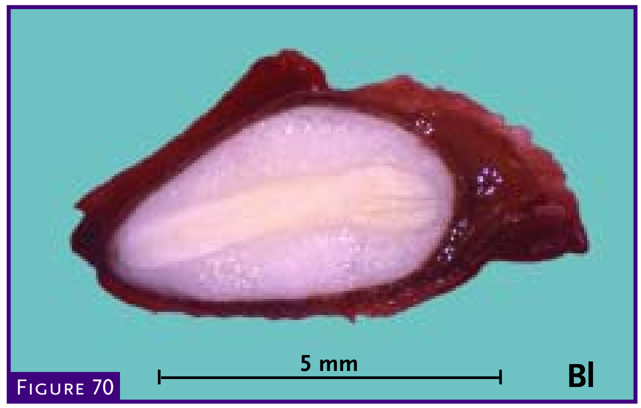


Figure 70

Longitudinal section of an imbibed subalpine fir seed.

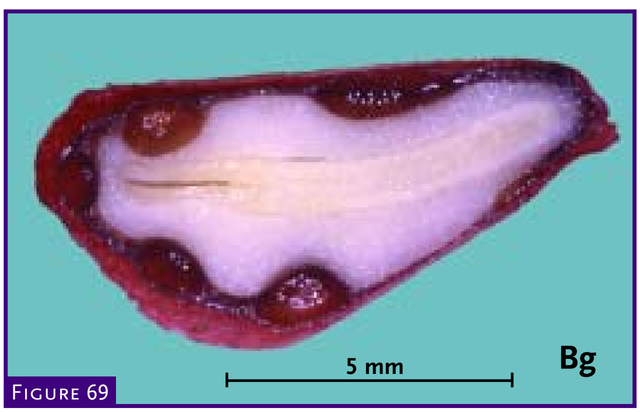


Figure 69

Longitudinal section of an imbibed grand fir seed.

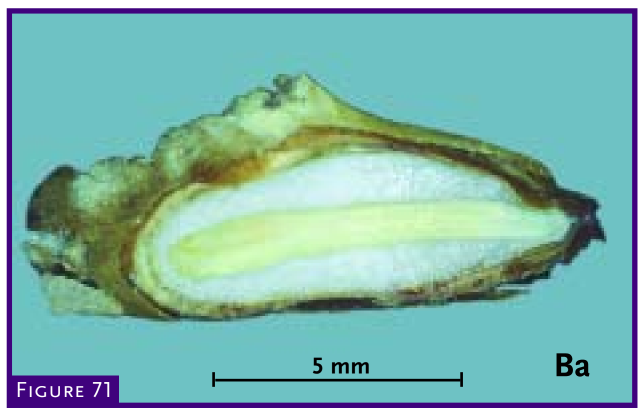


Figure 71

A longitudinal section of an imbibed Amabilis fir seed.

The cones are slowly dried until they are completely broken up (Figure 72a). A large amount of debris (cone axis, scales, and fine debris) are removed first by screening the material (Figure 72b). The remaining material will be scalped (more refined screening) to further purify the seed and remove debris that may cause mechanical damage (Figure 72c). Dewinging seed using a rotary drum is the next processing step, and similar to Douglas-fir the wings are broken off because of the integral connection with the seed coat (Figure 72d). Dewinging is a critical point in processing as it is best to remove as much wing material as possible while not damaging the seed coat or resin vesicles through excessive tumbling. The final stage of cleaning is to run the seedlot over a fanning mill, gravity table, and/or pneumatic separator to remove any non-viable seed and remaining impurities (Figure 72e).

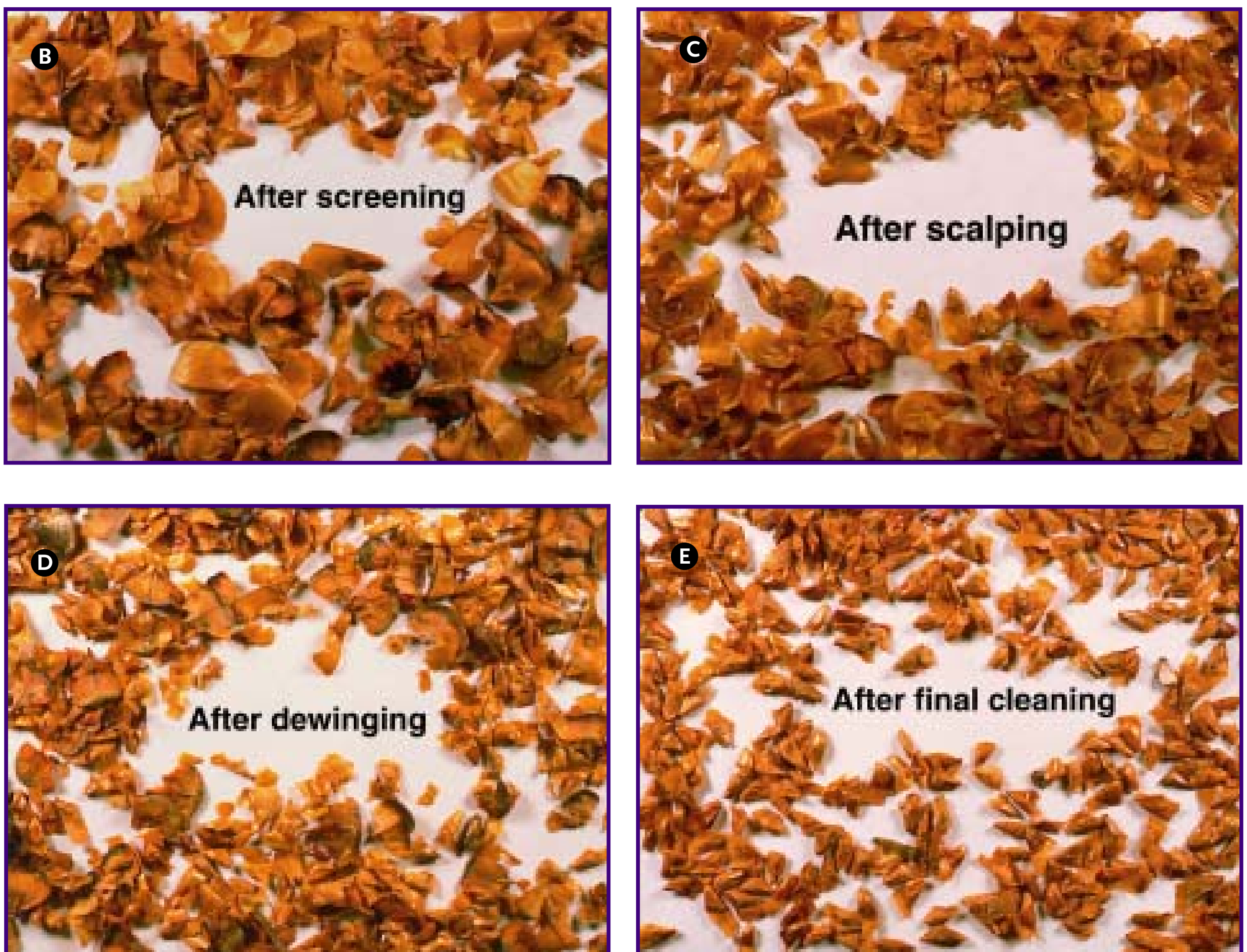


Figure 72 *Morphological differences in a subalpine fir seedlot during processing: (a) before processing, (b) after screening, (c) after scalping, (d) after dewinging, and (e) after final cleaning.*

Hemlock

Tsuga genus

Pinaceae family

ADDITIONAL HEMLOCK PHOTOS	
FIGURE#	PAGE#
9	9
33	25
38	27

This genus is represented by western and mountain hemlock in B.C. Mountain hemlock seed are considerably larger and darker in colour than western hemlock (FIGURE 73). The seed of western hemlock is very small and only western redcedar is lighter in weight. Both *Tsuga* spp. have resin vesicles which only occur on the lower surface of the seed (FIGURE 74). Although western hemlock seed are smaller, they contain more resin vesicles than mountain hemlock.

Like western redcedar, western hemlock is considered to have a low level of seed dormancy. Stratification of four weeks is used, but it is considered a treatment to increase the germination rate rather than the capacity[12]. The longitudinal section in FIGURE 75 reveals the main components. However, anatomical details are difficult to distinguish; this is typical of the hemlocks. The longitudinal section of mountain hemlock is from a dry seed (FIGURE 76). Cotyledons are prominent, but no shrinkage is present as is found with other species in the dehydrated state. The megaspore cell wall surrounds the megagametophyte in western hemlock, but in mountain hemlock only a few irregular cells occur and a continuous sheath is not formed[26].

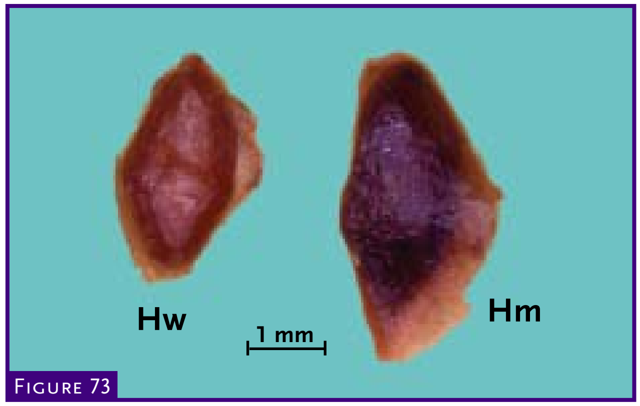


FIGURE 73

The morphological differences between a western and mountain hemlock seed.

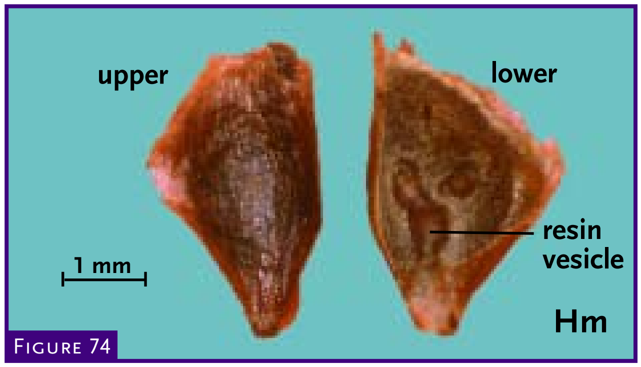


FIGURE 74

The upper and lower surfaces of mountain hemlock seed.

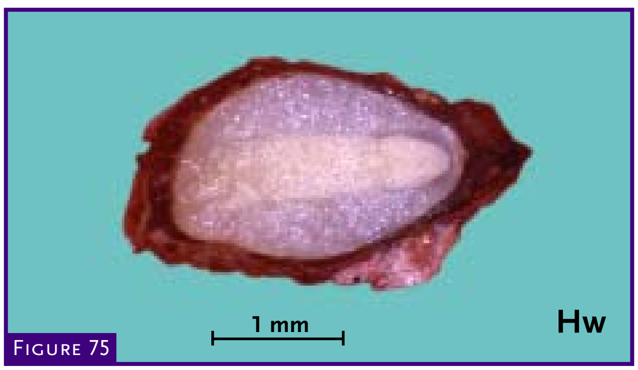


FIGURE 75

Longitudinal section of an imbibed western hemlock seed.

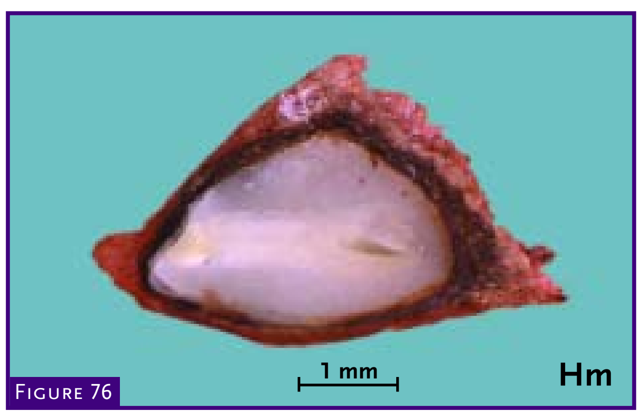


FIGURE 76

Longitudinal section of a dry mountain hemlock seed.

Larch

Larix genus
Pinaceae family

There are three larch species in western Canada: western larch, subalpine larch, and tamarack, but only western larch is currently used for reforestation in B.C. Western larch seed have a dark, raised upper surface and a mottled lower surface. A larger than average seed wing remnant is displayed in the lower seed (FIGURE 77). Dewinging is performed on dry seed, but it is a difficult species on which to achieve consistently thorough dewinging. Empty seed are common in western larch as the ovule and seed coat are well developed at fertilization relative to other conifers[35]. Western larch, although much smaller, is quite similar to Douglas-fir in terms of shape and differences between the upper and lower seed surfaces (FIGURE 78). The mottled appearance of the lower surface as well as the obvious tip of the seed at the micropyle are common to both species (FIGURE 78A). The upper surface shows similarity in form, although colour varies considerably and the western larch seed appears more rounded (FIGURE 78B).

These two species also show higher susceptibility to pre-emergence damping-off caused by *Fusarium* spp. in nurseries. Some of the anatomical characteristics that the species share may allow the fungi a relatively easy entry into the seed or provide the spores with suitable sites for attachment. Recent work has shown that treatment with hydrogen peroxide (3% for 4 hours) is an effective means of reducing *Fusarium* spp. without negatively affecting germination in these species[25].

FIGURE 79 displays a longitudinal section of an imbibed western larch seed. The prominent micropyle and wing remnant resemble Douglas-fir, but the seed is fatter with more megagametophyte tissue relative to its size. Within the embryo the cotyledons are visible and are beginning to turn yellow. Just prior to emergence, these will turn green. No anatomical details are observable within the embryo. Western larch and the hemlock species present the greatest challenge for viewing anatomical details of the embryo with cutting tests.

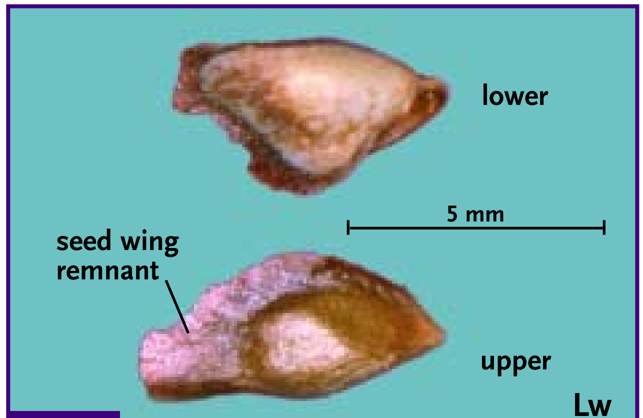


FIGURE 77

The morphological differences on the lower and upper surfaces of western larch seed.

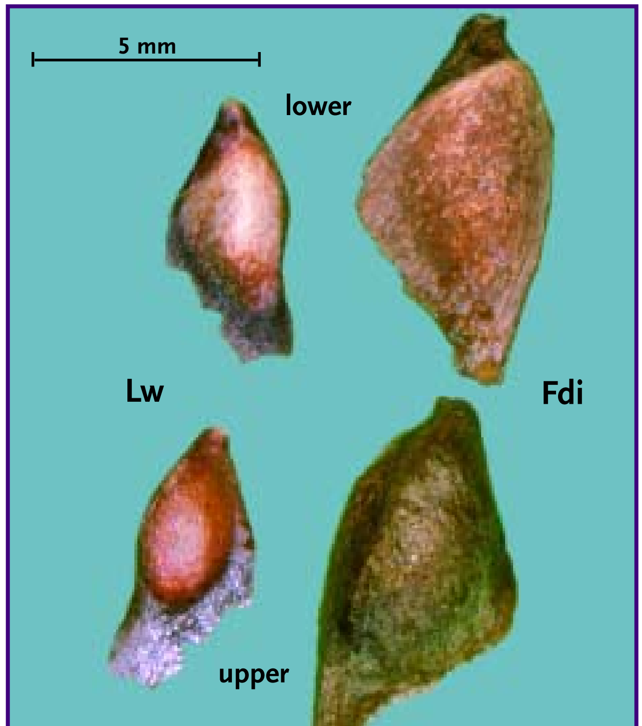


FIGURE 78

The morphological differences and similarities between seed of western larch and Douglas-fir on (A) lower and (B) upper surfaces of the seed.

FIGURE 79

A longitudinal section of an imbibed western larch seed.

Western redcedar

Thuja genus

Cupressaceae family

ADDITIONAL REDCEDAR PHOTOS	
FIGURE#	PAGE#
6	7
42	28
43	28
45	29
48	30

Western redcedar is the only species from this genus in western Canada. As illustrated in Figure 80, the seed is quite different from other conifer seed: the wings are an integral part of the seed, resin vesicles are linear in appearance and reduced in size compared to *Abies* and *Tsuga* spp., and the seed is extremely light in weight. The seed coat is very thin and consists of three layers that are thickened at points of attachment to the persistent wings[37]. Western redcedar is generally considered to have non-dormant seed. This can be problematic if proper care is not given during post collection handling as germination can occur while seed are still in the cones (Figure 81). This 'pre-germination' occurs because there are no internal restrictions to germination. If adequate moisture is present within the seed, the factor controlling germination is temperature build-up. In Figure 81b the radicle of the germinating seed is stunted, which may result from impact damage, dehydration, or fungal infection.

The very light weight and irregular shaped seed of western redcedar provide problems in mechanical sowing at the nursery. Seed are not easily transferred to containers using common seeding equipment. The current solution is to pellet seed of western redcedar (Figure 82). Dry seed are pelletized with a mixture of diatomaceous earth and various binders that are slowly built up over the seed with misting to produce an elliptical pellet. Pelleting does not involve imbibition and therefore does not affect seed physiology or storability. The lack of dormancy in western redcedar make it suitable for pelletting. It is probable that the seed coating protects the resin vesicles from damage as well as providing a regularly shaped propagule.

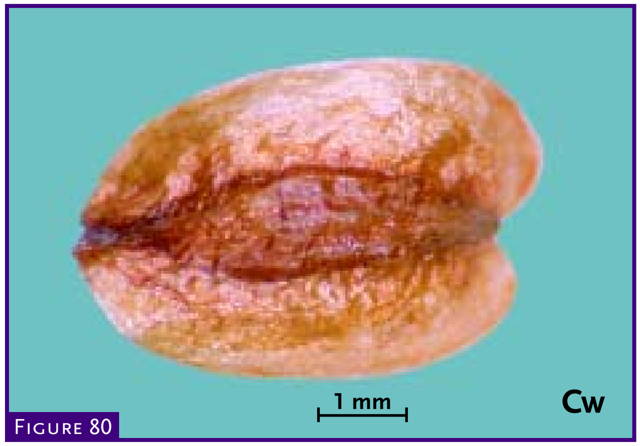


Figure 80

The morphology features of a western redcedar seed.

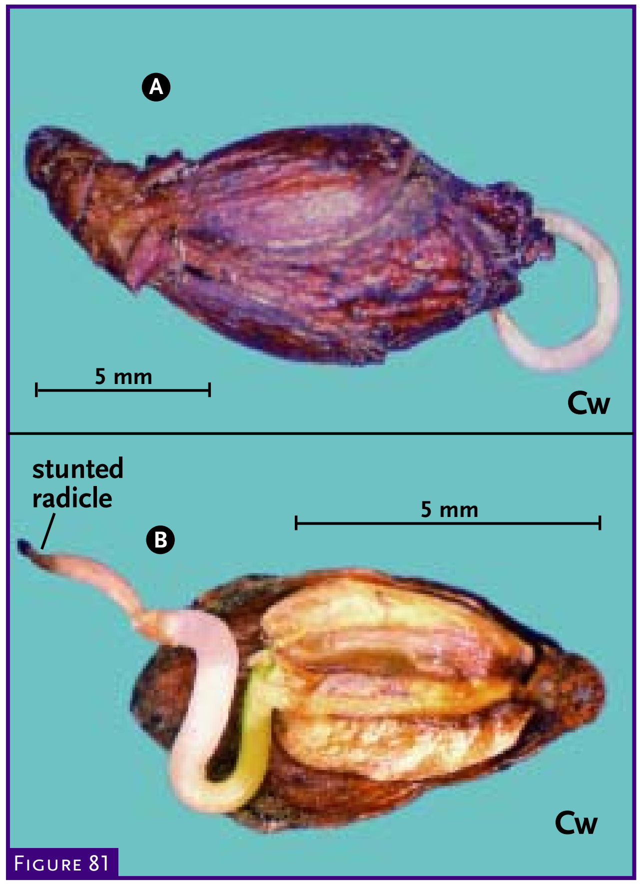


Figure 81

Premature germination in western redcedar displayed (A) in the cone and (B) with the cone scale dissected away.

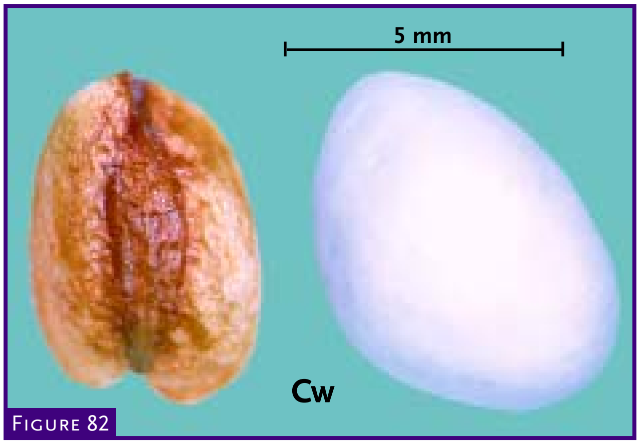


Figure 82

A comparison of a naked and pelleted seed of western redcedar.

The embryo of western redcedar occupies a larger proportion of the seed than other species (Figure 83). The megagametophyte is greatly reduced restricting the amount of storage reserves available and making its condition difficult to assess. Due to the limited megagametophyte and water holding reserves in western redcedar seed it is important that water is available to initiate and continue the germination process. In addition to thoroughly soaking blocks, misting will aid in pellet breakdown and avoid problems of pellets becoming 'cemented' to the germinant. A reduction in grit depth will also improve the chances of all viable seed germinating before their reserves are fully utilized.

The germination environment is a crucial stage to manage in western red-cedar. Initial photosynthesis will also be less than other species due to the presence of only two cotyledons.

Yellow-cedar

Chaemacyparis genus
Cupressaceae family

Only one species in this genus is found in Canada. It has a restricted range, but it is highly desirable for reforestation. Persistent seed wings, much thicker than western redcedar, are present giving the seed an oval appearance (Figure 84). No resin vesicles are present. The seed wings are covered in wax, which is also present as deposits in sclerenchyma cells and within the nucellar region. Compared to Pinaceae species, all of the seed coat layers in yellow-cedar appear compact with no cavities between them. The sclerenchyma cells of the stony layer continue to thicken until the seed matures, and this may also be implicated in physical dormancy[32]. The species is considered to have the deepest embryo dormancy of conifers in western Canada (requires longest and most complex pretreatment), and is suspected of having physical dormancy associated with the tissues surrounding the megagametophyte.

Although western redcedar cones resemble those of the Pinaceae, yellow-cedar cones are spherical without a central stalk (Figure 85). All cone scales originate from a central spot limiting the number of potential seed from three to five per cone.

Another complication with yellow-cedar is the variation found in the reproductive cycle enabling seed to mature in either one or two years following pollination depending on environmental conditions[15]. Mature and immature cones can be

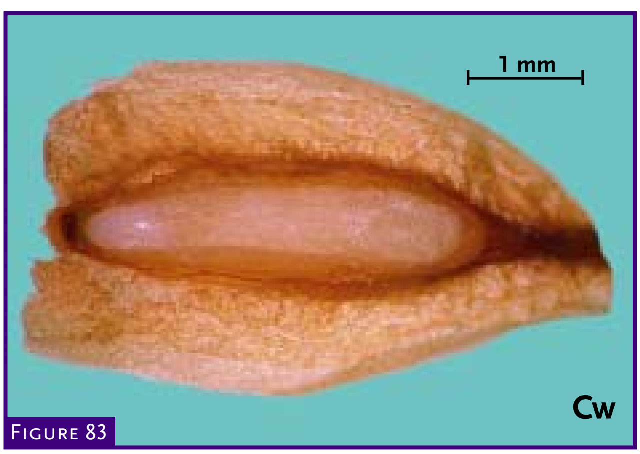


Figure 83

A longitudinal section of an imbibed western redcedar seed.

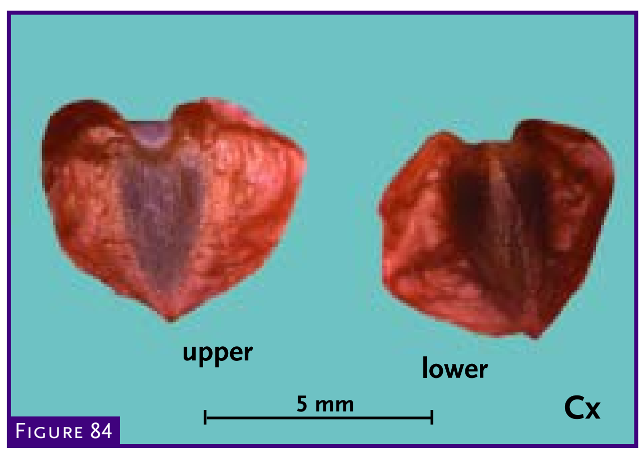
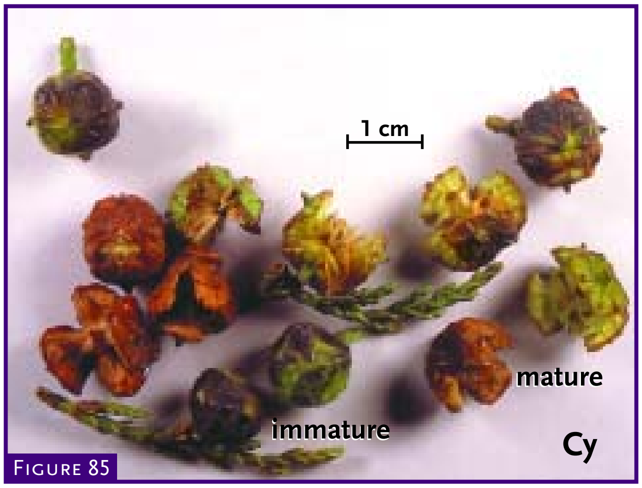


Figure 84

The upper and lower surfaces of a yellow-cedar seed.

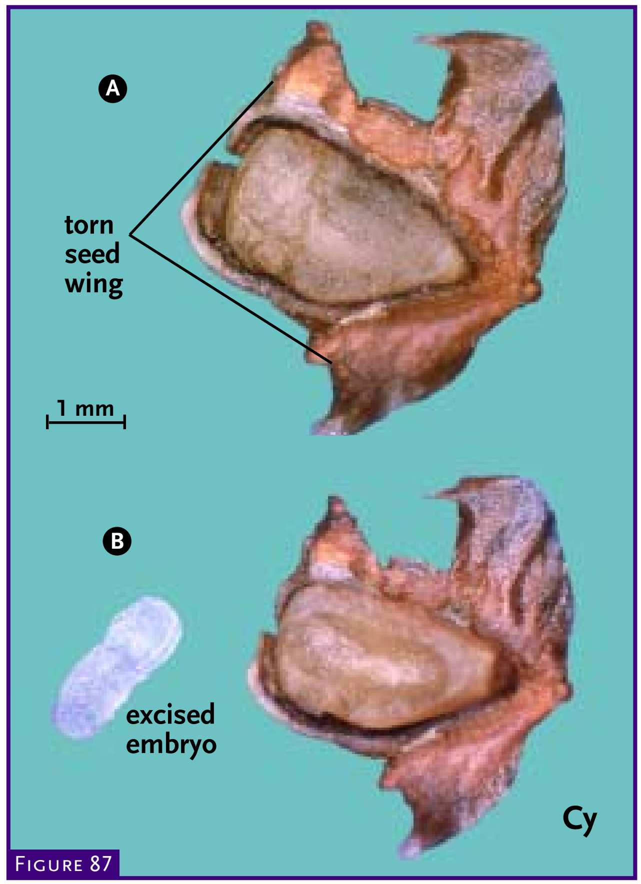


Mature and immature cones of yellow-cedar.

A longitudinal section of an imbibed yellow-cedar seed.

found on the same branches and both may be combined in a collection. The morphology of the mature and immature seed varies dramatically. Seed from immature cones are white, soft, and moist[27]. The seed can usually be easily separated during seed processing, but will decrease seed yield. Also, the extra moisture associated with these immature seed is undesirable.

A longitudinal section of a stratified yellow-cedar seed is shown in Figure 86 with the laterally elongated wings that give the seed an oval appearance. The embryo does not occupy as great a volume of the seed as western redcedar, but more than the species in the Pinaceae. In dry seed the embryo is difficult to distinguish from the megagametophyte due to its clear coloration (Figure 87), and this is more problematic with immature seed.



A dry yellow-cedar seed in (A) longitudinal sections and (B) with the embryo excised.