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Reproduction of Conifers

A Handbook for Cone Crops Assessment

S. EIS AND D. CRAIGDALLIE

Canadian Forestry Service / Pacific Forest Research Centre
Victoria, B.C., BC-X-219, March, 1981



ABSTRACT

Reproductive process of conifers is briefly described. Morphological characteristics of different stages of the process are identified and presented on photographs to provide an aid for estimating next year's cone crops. Advance knowledge of prospective cone crops should allow for better planning of reforestation programs. The handbook will be published in a loose-leaf format so that other species can be added as material becomes available.

RÉSUMÉ

L'auteur décrit brièvement le processus de reproduction des conifères. Il identifie les caractéristiques morphologiques des différentes phases du processus et en présente des photographies pour aider à l'évaluation de la récolte de cônes de la prochaine année. Il est plus facile de planifier les programmes de reboisement si les perspectives de récolte des cônes sont connues à l'avance. Le manuel sera publié sous forme de feuilles mobiles et par étapes, au fur et à mesure que les espèces seront disponibles.

INTRODUCTION

In 1979, British Columbia Ministry of Forests used 1666 kg of seed to produce in the nurseries about 63 million seedlings for reforestation. By 1995, the seedlings production is expected to reach about 185 million. Such a rapidly increasing reforestation program requires collection, processing, storage and sowing of hundreds of seed provenances.

To successfully collect the forest tree seeds, a knowledge of prospective cone crops is needed several months before cone maturation. The ability to estimate seed crops in advance will come with understanding of the reproductive cycle of individual tree species

and with the knowledge of the morphology of the reproductive structures.

This handbook was written with that in mind. Its text is simplified for the layman and only a few technical terms are used. The photographs concentrate on the main stages of development, generally only those that may be recognized by an unaided eye; a hand lens may be useful in the early stages of development.

The handbook will be published in a loose-leaf format, so that other species may be added as they become available.

ACKNOWLEDGMENTS

The earliest stages of reproductive bud development were abstracted from J. N. Owens and M. Molder papers published in the Canadian Journal of Botany.

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Environment Canada
Canadian Forestry Service
Pacific Forest Research Centre
Victoria, B.C., Canada, V8Z 1M5
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SUMMARY OF THE REPRODUCTIVE CYCLE OF CONIFERS

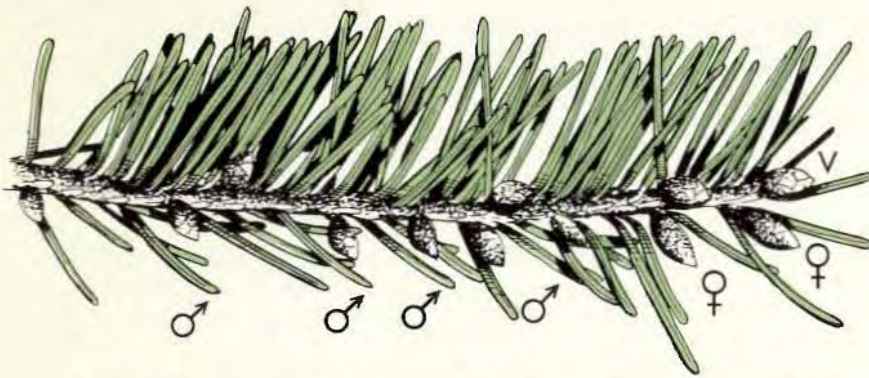


Fig. 1. Some species may have vegetative and reproductive buds of both sexes on the same shoot. Position, shape and size are usually typical, though the size may decrease with the distance from the tip.

BUDS

Buds are generally undeveloped shoots. In the earliest or **primordial** stage, they are merely masses of undifferentiated or **meristematic** cells but, in most conifers, they soon become elaborate structures. They are **dormant** during the unfavorable growing period of late autumn and winter. During this period, they are protected by a series of overlapping scales. Bud scales are often covered by wax or hair, which increases their efficiency as protective organs.

According to their position on the stem, buds may be classified as **terminal**, **subterminal** or **lateral**. Ter-

minal and subterminal buds are usually largest and best developed. Lateral buds are often small and inconspicuous. Most of them remain dormant, but damage to terminal buds often reactivates their development.

According to their function, buds may be **vegetative**, which will give rise to vegetative shoots, or **reproductive**, which will develop reproductive structures. By the time buds enter dormancy, they are usually well developed.

STROBILI

The reproductive buds develop into

strobili or **cones***. The cones are of two kinds, the **microsporangiate** or male** which produce **pollen** and the **ovulate, megasporangiate** or female** which produce the seed. When mature, the latter are the structures commonly recognized as cones.

In most genera of conifers, the microsporangiate or male bud during dormancy contains a well-developed miniature pollen cone, consisting of a simple **axis** or stem, bearing a series of spirally arranged, compressed, scale-like **microsporophylls**, each of which bears, attached to its lower surface, two sack-like **microsporangia** filled with pollen. The megasporangiate or female bud contains a cone that consists of an axis and usually spirally arranged **bracts**. At the base of the bracts, attached to the axis and the bract, is an **ovuliferous scale** which bears, freely

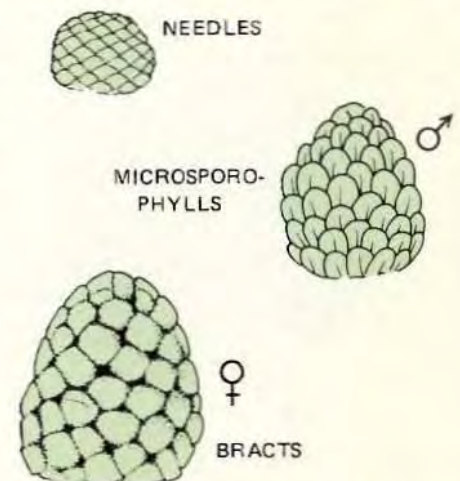


Fig. 2. When bud scales are removed, vegetative tip and reproductive strobili can be easily recognized.

* Conifers do not produce true flowers.

** Botanically, the terms male and female, in reference to conifer buds and cones, are incorrect terms. They are, however, commonly used and understood.

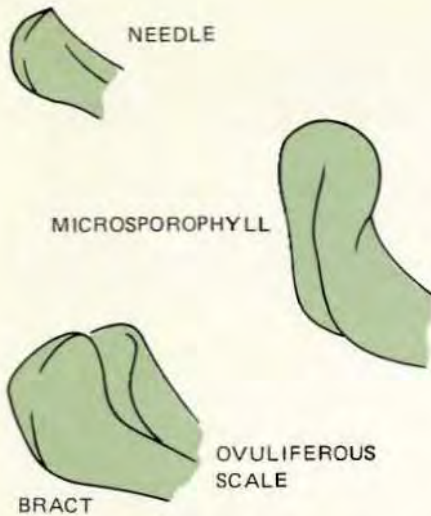


Fig. 3. Though color may be similar, the primordia of needles, microsporophylls and bracts with ovuliferous scales above are distinctly different.



Fig. 4. In spring, the axis of the male strobilus elongates and microsporangia enlarge. Pollen is ready for release.

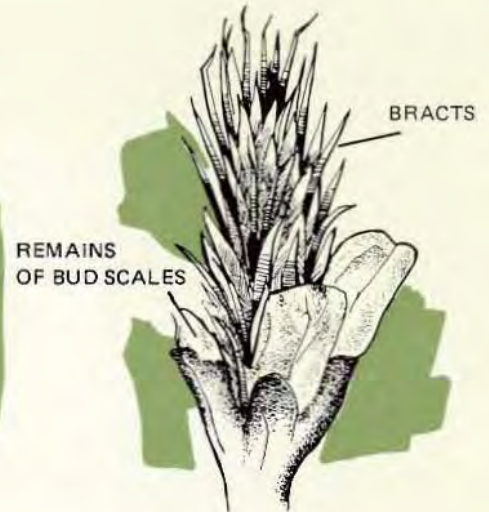


Fig. 5. In female strobilus, the internodes elongate, and bracts separate, enabling pollen to sift down to the ovuliferous scales.

attached to its upper surface, two ovules.

In spring, usually before much activity takes place in the vegetative buds, the axes of male strobili elongate, separating the rapidly enlarging microsporangia. Then, during dry weather, microsporangia dry out and separate along distinct lines and pollen is re-

leased. Female strobili resume development at the same time as male strobili. In some genera, more bracts and ovuliferous scales are initiated at the apex. Before pollination, internodes elongate, separating the bracts so that pollen can sift down through the spaces to the ovuliferous scales.

Pollen cones are small structures

lasting usually for only a few weeks. After pollination, they dry out and fall off. The **megasporangiate** cones are of longer duration. In some genera, they develop in 1 year, as in spruces; in others, as in pines, 2 years are required for full development. After maturity, the cones may fall off, disintegrate or remain on the tree for several years, even after shedding the seeds.

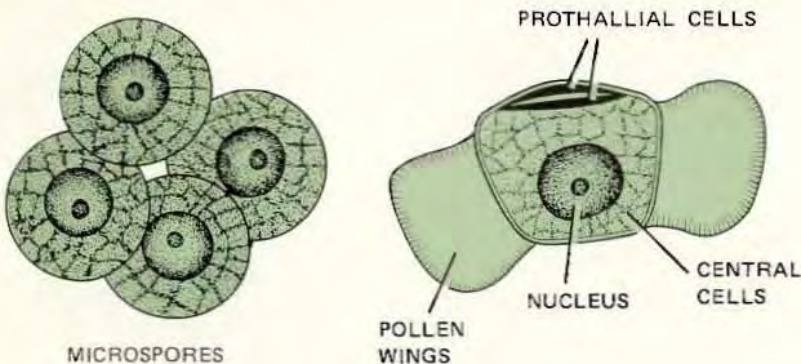


Fig. 6. Microspore mother cell, by meiotic division, gives rise to a group of four microspores having haploid number of chromosomes. The microspores soon separate and develop wings. At this stage, they are called pollen.

POLLEN

Within the microsporangia or pollen sacks, **microspore mother cells** are produced. By the process of maturation, which involves a **meiotic division**, they give rise to a sphere of four **microspores**. The spores soon separate into individual cells and at this stage are referred to as **pollen grains** or just pollen. Because meiotic division precedes their formation, they have a **haploid** or half number of **chromosomes**. In the spring, pollen is produced in tremendous amounts and appears at maturity as yellow dust.

OVULE

The ovule, located on the upper surface of the scale, consists of a **megasporangium** surrounded by a special covering, the **integument** which later becomes the **seed coat**. In most conifers, the integument covers the ovule as a cup-like overgrowth. At the tip of the ovule, the encircling parts of the integument leave a little opening called the **micropyle** which allows the pollen grain to enter and come in contact with the megasporangium.

The **megasporangium** is the inner tissue of the young ovule. In the young stages, this tissue is undifferentiated, but later, several **megaspore mother cells** are produced at the center. Maturation of a megaspore mother cell includes meiotic division, and produces a group of four **megaspores** which, similar to microspores, have a haploid chromosome number. Contrary to the condition found in microspores, the megaspores are never shed, but are permanently retained within the megasporangium of the cone scale.

POLLINATION

The **pollen grains**, or **microspores**, undergo two or more divisions. In most conifers, at this stage of development, the pollen is shed.

Pollination is the term applied to the transporting of the pollen from the male cones to the female cones. In conifers, it is accomplished by the floating of pollen through the air. This is called **wind pollination**.

When they reach the female cone, the pollen grains fall down among the scales, reaching the ovules located at their base. When receptive, an ovule secretes a drop of resinous material which eventually dries out and pulls the pollen grains through the micropyle.

After a short period, the **pollen tube** begins to grow, penetrating the tissues of the megasporangium. At this stage, the final division takes place in the pollen grain and two **sperm** are produced.

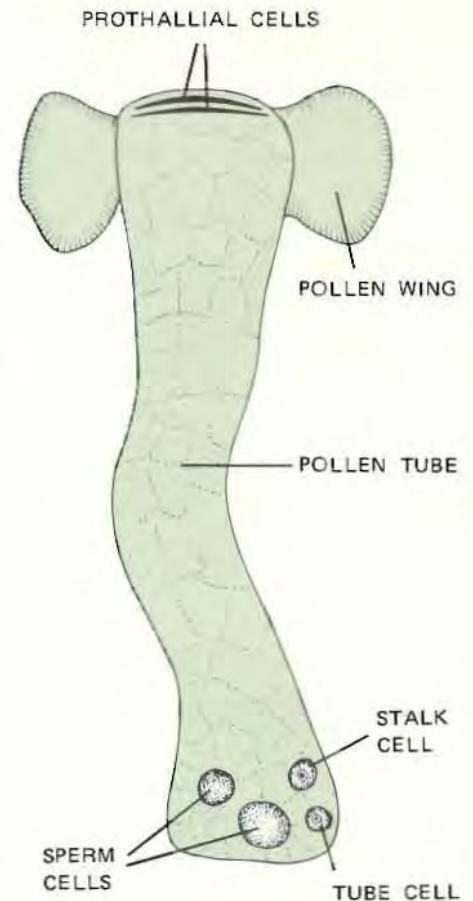


Fig. 8. Shortly before fertilization, the body cell has divided into two male cells or sperms. The stalk cell, the tube cell and the prothallial cells degenerate.

FERTILIZATION

The fertilization is accomplished by the **fusion** of the nucleus of one of the sperm with the nucleus of the megaspore or egg cell. This results in the doubling of chromosomes, which restores their number to that characteristic of the species. In general, where the development of the cone takes 1 year, fertilization occurs in early summer; in those where development of the cones takes longer, fertilization may occur in the spring of the second year.

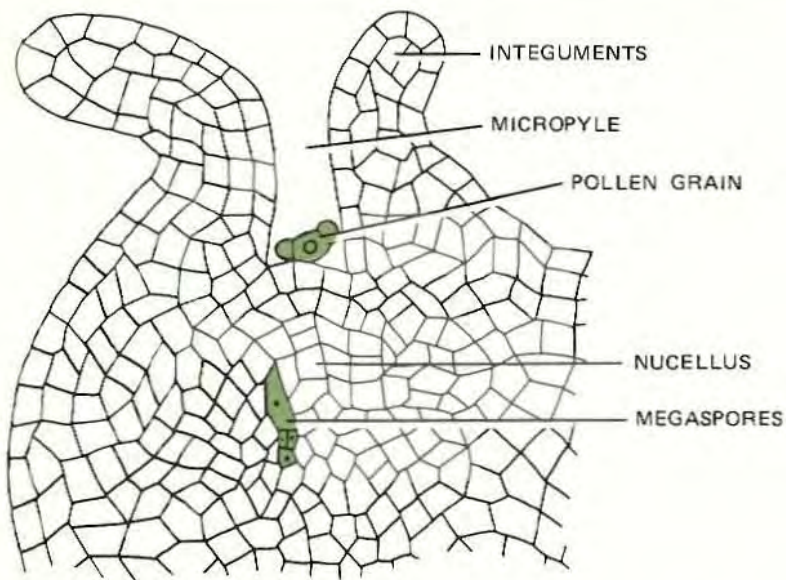


Fig. 7. At the time of pollination, four megaspores are arranged in the center of the nucellus. Only one, the largest, is functional, the other three degenerate.

Soon after fertilization, rapid division of the megaspore nucleus takes place, followed by formation of the cell walls and eventually the complete seed is formed.

SEED

The conifer seed is a complicated structure. It consists of an **embryo**, surrounded by a mass of stored food and protected by a thick and usually hard **seed coat**. The embryo is, in a sense, already a complete plant with an elementary **vascular system**, an axis with **cotyledons** or primary leaves and a well-developed **radical** or root apex. The **shoot apex** is usually only a cone of meristematic cells.

SEEDLING

The seeds of conifers germinate slowly and usually after a prolonged resting period. Upon germination, the **primary root** of the embryo emerges, usually pushing the seed coat up through the ground. Later, the cotyledons are freed from the seed coat and the young seedling begins a long period of growth to develop into a mature tree.

TREE

At first, the seedling produces only vegetative buds. **Sexual maturity** is dependent on species, size, age and environmental conditions. Between 10 to 50 years of age, trees begin also to produce reproductive buds. For a few years these may be only of one sex, but eventually both male and female buds are produced and the reproductive cycle repeats itself.

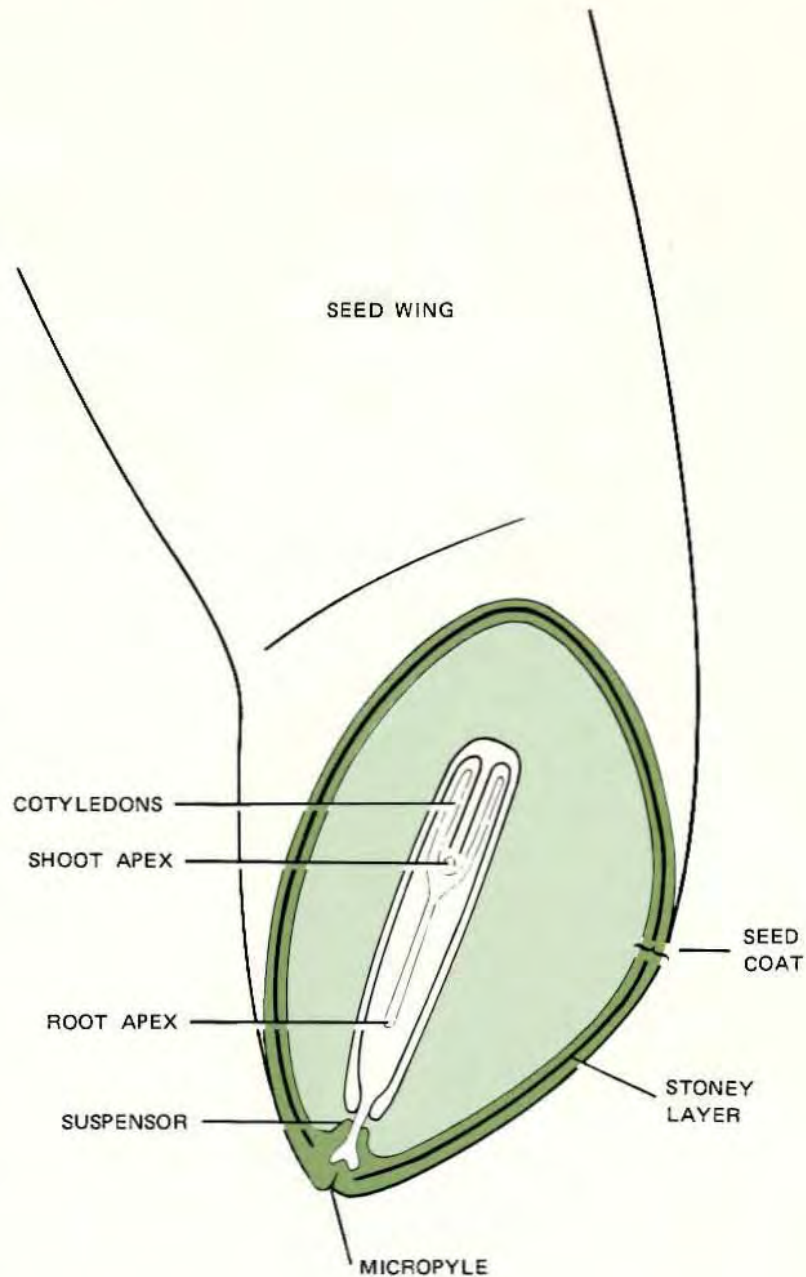


Fig. 9. Seed is a dormant embryo embedded within a female gametophyte which provides food supply for the new growth. All this is covered by a protective, multi-layered seed coat.

Douglas-fir



1. In heavy crop years, vegetative and reproductive buds of both sexes may occur on the same shoots. The shape and size is indicative of their function, though the size decreases with distance from the tip.



2. Vegetative bud is slim, the male bud ovate and widest in the middle. Microsporophylls can be distinguished from needle primordia.



3. Female bud is ovate and widest at its base. Three-pronged, sharp-pointed, purple bracts differ markedly from microsporophylls or needles.



4. Pollination takes place before vegetative bud break. Male strobili elongate, microsporangia split open and pollen is released. After pollination, male strobili wither and die.



5. At pollination, female strobilus stands erect. Elongation of the axis separates the bracts, allowing for entry of pollen.



6. After pollination, the female cones become pendant and turn green. The three-pronged bracts remain the prominent feature.



7. Seed is about 7 mm long, 3 mm wide and 2 mm thick. There are on an average 90,000 seeds per kg.

Douglas~fir

Douglas-fir begins to produce cones at about 20 to 25 years of age. Preceding light cone crop, the female buds tend to occur mainly at the top and male buds in the middle of the crown; preceding heavy crops, the reproductive buds of both sexes may occur throughout the crown and sometimes even on the same shoots (1). The function of the buds, whether they are vegetative, male or female, can be recognized from their outer appearance from about the beginning of August. If the bud scales are peeled off or the buds are cut open, identification can be made even earlier. Because bud development continues until unfavorable weather forces dormancy in November or December, later identification becomes progressively easier.

The terminal buds are usually vegetative throughout the crown (1). Preceding light crops, the reproductive buds of both sexes occur mainly in subterminal positions (2 and 3), whereas preceding heavy crops, the subterminal positions are occupied by female buds, while male buds are distributed lower along the shoot, sometimes forming a group of three to five at the base of the shoot (1).

BUD DESCRIPTION

The vegetative buds are rather slender (1); reproductive buds are more egg-shaped, somewhat shorter and usually lighter brown, have fewer bud scales and less white resin on the surface of the scales. Both sexes are similar (2 and 3), but the male buds tend to be smaller (1) and broadest near the middle (2), whereas female

buds are usually somewhat larger and broadest closer to their base (3).

When bud scales are removed or the buds are cut open, bud recognition becomes easy. The vegetative bud contains the entire following year's shoot, with flanks densely covered with spirally arranged, unelongated, green needles (2). In cross-section, the needles are oblique-angled. This whole structure is only about 2 mm long; the rest of the bud cavity is empty (2). In contrast, the bud cavity of the reproductive buds is completely filled with reproductive structures.

By the time the buds enter dormancy, the male bud contains a well-developed pollen cone, consisting of a simple axis covered with spirally arranged scale-like, blunt and reduced appendages or microsporophylls (2). Each microsporophyll bears, at its lower surface, two yellow or light green microsporangia filled with pollen. The length of the male cone during the winter dormancy is about 4 to 5 mm.

The female cone, during dormancy, is about the same size as the male cone. It consists of an axis bearing a series of spirally arranged, long, pointed trident bracts (3). In the axil of each bract is a small ovuliferous scale which bears at its upper surface two ovules. The scales are visible only upon dissection.

BUD BREAK

The first growth and differentiation occurs in the reproductive buds in late

February or early March, about a month or more before any activity takes place inside the vegetative buds.

Inside the male buds, the cone axis elongates and microsporangia enlarge and develop into two large rounded pollen sacs. Following bud burst, pollen cones show a wide range of colors, yellow being most common, but often ranging into green or red. At the time of pollination, the pollen cone is usually pendant and about 2 cm long (4). Soon after pollination, it dries out and breaks off.

Inside the female bud, the bracts and the ovuliferous scales enlarge, with a corresponding elongation of the axis. The lower bud scales become slightly separated, revealing the light-brown or purple inner bud scales. The seed cone buds usually double in length before bud burst. At pollination time, the female cone stands erect and is about 3 cm long. Its appearance is dominated by the large three pronged bracts, which are purple to red (5). After pollination, the female cones turn green and become pendant. Fertilization takes place about 4 to 6 weeks after pollination and initiates the development of the embryo and, subsequently, the seed.

The cones reach their final size during July. By then, they are about 7 to 9 cm long and less than 2 cm wide with protruding, three pronged usually appressed bracts (6). The subsequent maturation involves drying and death of the vegetative tissues and a change of color to brown. In a mature seed, the embryo is loosely packed within a nutritive tissue. Seed wings develop from the ovuliferous scale. The mature seed is about 7 mm long, 3 mm wide and 2 mm thick (7). The seed wing is about 10 to 12 mm long and 5 mm wide. There are about 65,000 to 130,000 seeds per kg. Most seeds are released by late October, the remainder during the winter.

Grand Fir



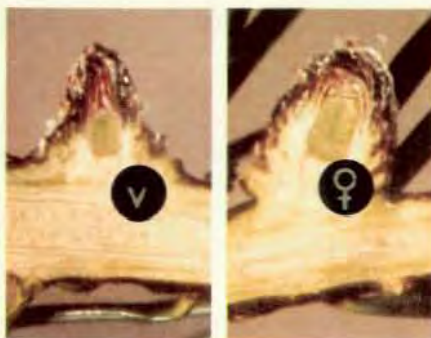
1. Terminal buds are always vegetative.



2. Lateral vegetative buds are smaller than female buds and develop into short, weak shoots.



3. Female buds are upward-facing and large.



4. Inside overwintering lateral vegetative buds, the short, next year's shoots do not fill the bud cavity entirely. The cavities in female buds are filled with female strobili.



5. Male buds occur in axillary positions on the lower side of less vigorous shoots.



6. The male strobili enlarge to their full size during April and their color gradually changes to yellow.



7. Female strobili rapidly elongate during April. Only bracts are visible.



8. Cones remain upright. They disintegrate on branches during windy weather, thus, leaving a spikelike axis.



9. The seeds are triangular to oblong and brown or tan.

Grand Fir

Grand fir starts to produce cones around 50 years of age. After that, the crops are fairly frequent (often every second or third year), though the number of cones is rarely great.

The position of the buds is the best distinguishing feature for the identification of their probable function. The terminal buds are always vegetative (1). Seed cones develop only from upward-facing axillary buds (3) in the top of the crown, whereas pollen cones develop only from axillary buds on the underside of less vigorous branches in the lower part of the crown (5).

Primordia capable of developing into female or male strobili are initiated every year in mature trees. Whether they develop into strobili, produce vegetative shoots, or become latent is probably determined by the preceding environmental factors. Because it is difficult to determine the pathway of development of a potential seed-cone bud from its outer appearance during dormancy, dissection is recommended.

BUD DEVELOPMENT

During dormancy, the vegetative buds (1) are spherical to oval, about 3 mm in diameter, and usually covered with a layer of resin. Terminal vegetative buds (1) have about 35 bud scales; lateral buds, only about 25. Dormant vegetative buds (2) contain a dome-shaped apex about 1.5 mm wide and 1 mm high, with all the next year's growth already initiated (4). Outer bud scales are dark green, brown-green to brown, and leathery, while inner bud scales are green, membranous, and translucent.

Seed cones develop singly or in groups of 2 or 3. During dormancy, the female strobili fill the bud cavity entirely (4). By that time, they are

about 2.5 mm wide, 4 mm long, and have all bracts and most of their ovuliferous scales. The spherical to ovoid resin-encased buds are about 7 mm wide and 8 to 10 mm long.

On branches bearing female buds, usually some buds develop only rudimentary zonation; these usually abort. Other buds, identical to female buds in position and outer appearance, initiate only needle primordia and, eventually, produce only short, non-vigorous, vegetative shoots.

Male buds (5) develop from apices in the axils of most of the needles on the abaxial (lower) side of less vigorous shoots. They are smaller than vegetative or potentially female buds and, in late summer, they are dome-shaped. Before dormancy, they increase in size and become spherical. Dormant pollen-cone buds range from light green to blue, blue-black, or brown, are oval or spherical, 3 to 4 mm in diameter, have about 20 bud scales, and are usually covered by a thin layer of resin. Dormant male strobili inside them are about 2 mm long, green to dark green, and have all of their microsporophylls and microsporangia for the next season.

On branches bearing pollen cones, many buds develop only a few bud scales, after which they remain inactive.

BUD BREAK

Around the middle of March, cell division begins in the male and female strobili. The male strobili enlarge first and the buds burst around the beginning of April—2 weeks or more ahead of the female buds and about 3 weeks ahead of vegetative buds. The male strobili (6) are at first purple, orange, or bluish red, but, as the microsporangia enlarge, the

color gradually turns light green and then yellow. Pollen is shed about 3 weeks after bud burst. While strobili are shed during fall and winter, the receptacles persist on the twigs for many years.

After bud burst, female strobili (7) rapidly elongate. The bracts increase in length about sixfold over the dormancy size. The elongation of the strobilus axis separates the bracts and, at this stage, around the end of April, female strobili are presumably fully receptive to pollen. Weather permitting, pollen dispersal takes place, usually as soon as this "open stage" is reached. During pollination, the female strobili are about 25 mm long, light green to blue-green or purple-green, and stand erect. After pollination, the bracts reflex upward and become tightly appressed to the side of the cone.

Soon after the receptive stage, the bracts are overgrown by the ovuliferous scales. As a result, the color of the strobili changes from yellow-green or purplish green of the bracts to the gray, dark blue or deep purple of the ovuliferous scales. The cones (8) remain upright. The maximum cone size, about 6 to 7 cm in length and about 3 cm in diameter, is achieved by early or mid-July. During August, the cones gradually turn brown.

Cones dry out and scales abscise from the axis, allowing the cones to disintegrate as branches are disturbed by the wind. Seed dispersal occurs in late September or early October, leaving the spike-like cone axis, which may persist on the tree for several years.

Mature seeds (9) are typically triangular to oblong, about 6 to 7 mm long, 4 mm wide, 2 mm thick, with large wings. The rather soft seed coat is brown, gray-brown, creamy brown, or tan. Most of the seed is filled with fleshy endosperm and a well-developed embryo may extend the full length of the endosperm. There are 700 to 1,200 cones per hectolitre, yielding about 3 to 4 kg of seeds, with 30 to 60,000 seeds per kg. Germination is extremely variable, 20 to 65 per cent, averaging about 50 per cent.

Interior Spruces



1. Vegetative buds are small and completely covered with green outer scales.



2. Vegetative buds have a large cavity and spirally-arranged needles on a short axis.



3. Male buds are broad in the midsection.



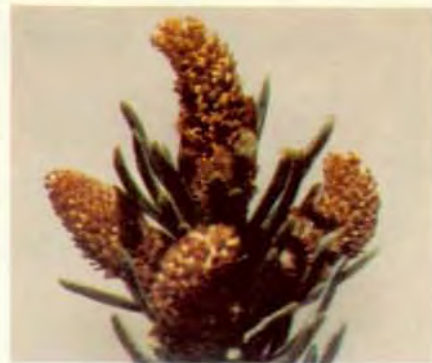
4. Microsporangia fill the bud cavity.



5. Female buds are broadest near the base.



6. Bracts and scales are easily recognized as double structures.



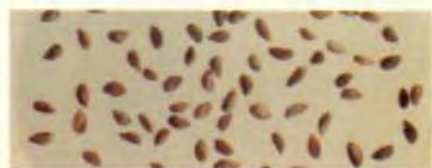
7. By pollination time, microsporangia have developed into rounded pollen sacs.



8. During pollination, the female strobilus stands erect with scales perpendicular to the axis to allow for the entry of pollen.



9. Only cone scales are visible, since the bracts finished their development by pollination.



10. Seeds are about 2.5 mm long, pale brown, and glossy.

Interior Spruces

WHITE AND ENGELMANN

White spruce and Engelmann spruce hybridize freely wherever the ranges of their distribution overlap, and they are frequently referred to collectively as "interior spruce". Except for cones, their reproductive structures differ only in minute detail and, for the purpose of this publication, they will be treated together.

Interior spruces are sporadic cone producers, good crops occurring about once in 6 years, with usually one or two light crops in between. Cone production starts around 40 years of age, but there is a considerable variation, dependent on the site. As in most conifers, the female reproductive structures occur at the top of the crown and male structures around the middle, with considerable overlap in heavy crop years, when reproductive buds may occur in any position on the shoot. Reproductive buds occur mainly in terminal and subterminal positions, thus ending the terminal shoot growth. This eventually results in seed-producing trees having an irregular and distorted crown shape.

The initiation of the reproductive process in the buds takes place early in the growing season, but buds can rarely be recognized as reproductive before about the middle of September, unless a microscope is used. The development continues until winter dormancy, and recognition becomes progressively easier, especially if the bud is cut open or the bud scales are peeled off.

BUD DESCRIPTION

Bud size generally decreases with distance from the tip of the branch.

During winter dormancy, the vegetative buds (1) are smaller, 4 to 6 mm in length, and dome shaped, while the reproductive buds (3 and 5) are larger, 5 to 8 mm, and ovate to obovate. The outer scales on all buds are thick and green and cover the vegetative buds completely. In the reproductive buds, the inner brown and glossy membranous scales protrude over the upper portion of the bud. Female buds (5) are usually more pointed than the male buds (3) and are broadest near the base; the male buds (3) are broadest in the middle. It is often difficult to recognize the sex of the reproductive buds from their outer appearance, and dissection and examination of the appendages with a hand lens may be necessary.

A vegetative bud contains a large cavity (2) and, at its base, a small mound of sharp-pointed, green needle primordia spirally-arranged around next year's shoot. The needle primordia are oblique-angled in cross-section. In contrast, the strobili in reproductive buds (4 and 6) usually completely fill the cavity. In a female strobilus (6), the spirally-arranged appendages are also green, but they are larger and easy to recognize as double structures consisting of bracts and, in their axils, ovuliferous scales, each bearing two ovules at its upper surface. The male bud contains a pollen cone (4) consisting of a short axis covered with spirally-arranged, light green, leaf-like microsporophylls, bearing two yellow-green microsporangia at their lower surface.

BUD BREAK

The time of bud break depends on geographic location and weather and

occurs from late April to late May, with vegetative buds breaking about a week or two later than the reproductive buds. Inside the male bud, the pollen axis elongates, thus separating the microsporophylls; the microsporangia enlarge and develop into rounded pollen sacs (7). During pollination, which lasts about 8 to 10 days between the end of May and the end of June, the pollen cone (7) is 12 to 15 mm long, the leaf-like microsporophylls are yellow-green to orange or light purple, and the pollen sacs are creamy yellow. Soon after pollination, the male cone dries, turns brown, and is shed.

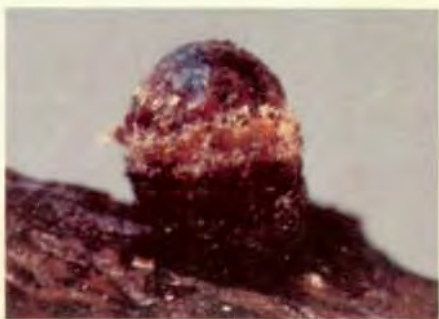
Inside the female bud, the seed cone elongates and ovuliferous scales enlarge. At pollination time, the seed cone (8) is 18 to 25 mm long and stands erect. The scales, standing perpendicular to the axis, are purple with light purple or orange fringes. Bracts finish their development around pollination time; they are visible, but shorter than the scales. After pollination, the female cones become pendant and turn green. Fertilization takes place about 4 weeks after pollination.

Cones reach their full size by the beginning of August. They are about 40 mm long and 12 to 15 mm wide, with only the scales visible (9). The seeds appear fully developed by the end of August. Subsequent ripening involves drying and death of the vegetative tissue with a change of color to lustrous light brown. Seed dispersal takes place in September and, by the middle of October, the cones are usually empty, though, in some years, seed is also dispersed on the snow during the winter. Mature seeds (10) are 2.5 to 3 mm long, less than 2 mm wide, and about 1.5 mm thick. The color is pale brown to brown and glossy. The seed wing is about 10 mm long and 4 mm wide, and light brown, with a dark brown stripe along one edge. There are 18,000 to 24,000 cones per hl and 8 to 20 seeds per cone. White spruce has 300,000 to 900,000 seeds per kg, while Engelmann spruce yields 250,000 to 700,000 per kg.

Larches



1. Vegetative buds are ovate; the remains of the last year's needles usually cover most of the bud.



2. Male buds are hemispherical or broadly ovate and larger; and the bud scales protrude out of needle remains.



3. Female buds are the largest, ovate, and protrude most out of the remains of needles.



4. Needle primordia inside a vegetative bud are green and appressed.



5. Microsporophylls are leaflike with yellow pollen sacs on the abaxial side.



6. Bracts and scales are green, leaflike double structures, though the scale may be small.



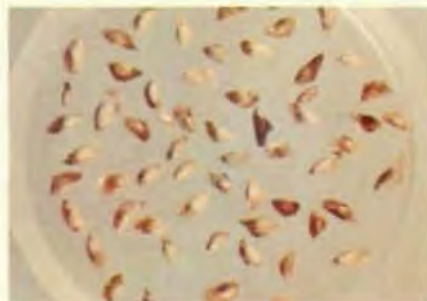
7. At pollination, the male cones elongate, thus, separating the microsporophylls.



8. In female cones, the bracts separate to allow for the entry of pollen.



9. At maturity, the color of the cones changes from green to brown.



10. The seeds are triangular and light brown to reddish brown.

Larches

WESTERN AND ALPINE LARCH TAMARACK

All three species of larch, which are indigenous to Canada, occur in British Columbia. Since there are only a few minor differences between the species, the reproductive structures described are based on the most common—the western larch.

On larches, cones are usually scattered throughout the non-shaded part of the crown. However, as in most conifers, female reproductive structures are more frequent in the upper part of the crown, whereas male reproductive structures occur usually on less vigorous branches in the central or lower regions. Reproductive structures are produced on spur shoots that have changed from the vegetative function (i.e. production of needles) to the reproductive function (i.e. production of strobili). Because spur shoots develop during the second growing season from buds in the axils of needles on new shoots, the strobili are produced on the shoots during the third or subsequent growing seasons and are never near branch tips.

BUD DESCRIPTION

During winter dormancy, vegetative buds (1) are 3 to 4 mm wide and 2 to 3 mm high and, on their short spur shoot, they look broadly ovate. The pubescent, light gray to light gray-brown bark of the spur shoot resembles outer scales. The remains of the appressed previous year's needles appear to overarch the vegetative bud and obscure brown, glabrous, feather-like, and somewhat resinous bud scales. The inner scales are membranous. The dormant pollen-cone or male buds (2) are about 4 mm wide and 3 mm high, and hemispherical or broadly ovate. The brown bud scales protrude much more through the

remains of needles than on the vegetative bud. The seed-cone or female buds (3) are 4 to 5 mm wide and 4 to 5 mm high. Since they are longer, they protrude more above the remains of the needles than the male buds. Including the spur shoot, they appear ovate to narrowly ovate.

When the bud is cut open or the scales removed, recognition is easy. A vegetative bud (4) consists of a compressed axis, covered with unelongated, pointed, boat-shaped, green needles. The whole structure is less than 2 mm long, but, because of the small size of the bud, the cavity is entirely filled.

The male bud (5) consists of a short axis densely covered with short, leaf-like microsporophylls on whose lower surface are two large, yellow-green microsporangia or pollen sacs filled with yellow pollen, in an advanced stage of development. During dormancy, the male strobilus is about 3 mm wide and 2 mm high.

The female strobilus (6) consists of a narrowly conical axis reaching almost to the top of the strobilus, covered densely with long, narrow, sharp-pointed green bracts. Each bract bears on its upper, adaxial side a rudimentary ovuliferous scale, visible only with a hand lens. However, a hand lens is not necessary to distinguish the bracts and to identify the female strobilus.

BUD BREAK AND POLLINATION

Reproductive strobili resume development during the first half of March—2 to 3 weeks before any changes take place in the vegetative buds. Vegetative buds swell around the end of March; at that time, the strobili are emerging from

the bud scales. However, needles appear to be fully flushed at pollination time, which takes place during the second half of April.

Shortly before pollination, the axis of the male strobilus elongates, separating the microsporophylls (7), which are now fully enlarged and about 5 to 7 mm long on short thin stalks. They are predominantly yellow, but may range from yellow-green to light orange. Pollen sacs split along the thin-walled line on the abaxial side. The pollen is wingless.

During the first half of March, rapid elongation of the axis takes place in the female strobilus as it emerges from the bud scales. By pollination, the internodes have elongated sufficiently to leave large spaces between the bracts, through which pollen enters to the ovuliferous scale. At pollination, the female strobili (8) are 12 to 20 mm long and 10 to 15 mm wide, with bracts perpendicular to the axis. Their color ranges from light green to purple or red.

MATURATION

After pollination, the cones turn green and increase in size. Mature western larch cones (9) measure 20 to 30 mm in length, while tamarack cones rarely exceed 15 mm. As the cones ripen in late August or early September, their color changes from green to brown or brown-purple. Seeds are usually released in early October, but empty cones, which weather to dark brown, may remain on the trees for an indefinite period. Cone collection should take place around the middle of September. There are 10,000 to 15,000 cones per hectolitre, but smaller tamarack cones yield as many as 25,000 per hectolitre.

The seeds (10) are winged, nearly triangular in shape, 3 to 4 mm long, 2 to 2½ mm wide, and about 1.2 mm thick (although the size range is considerable) and are light brown to reddish brown. There are 250,000 to 500,000 seeds per kg, but smaller tamarack seeds may yield up to 1,000,000 seeds per kg. Germination is variable.

Lodgepole Pine



1. Vegetative buds are long and slim, without swelling at their base.



2. Swelling at the base of a vegetative bud indicates presence of male strobili.



3. Next year's vegetative growth supports spur shoots with needles. At the base of the vegetative growth are clusters of male strobili.



4. The sheath of bud scales which normally covers the male strobili may be entirely missing.



5. Cluster of male strobili are easily noticeable in spring because of their bright yellow color.



6. Female strobili occur on current year's shoots; therefore, they are not visible until late in spring.



7. At pollination time, bracts stand erect or perpendicular to allow for entry of pollen.



8. At the end of the first growing season, conelets are about 15 mm long, almost round and green in color.



9. Mature cones are egg-shaped, pointed and asymmetrical. Their color is light brown. Cones from preceding cone crops are darker.



10. Seeds are about 3 - 4 mm long, ovoid, reddish brown and often mottled. They average about 250,000 per kg.

Lodgepole Pine

INCLUDING SHORE PINE

Lodgepole pine is sometimes divided into two or three subspecies. Since the reproductive organs are practically identical and since there are no reliable needle or cone differences by which they can be distinguished, it would appear that lodgepole pine is morphologically variable, with the two or three described forms constituting a single species.

Lodgepole pine is a prolific seeder and often produces fertile seed before it is 10 years old. However, seed production usually starts at the age of 15 to 20 years, with heavy seed crops at intervals of 2 to 4 years and light crops in most intervening years.

Lodgepole pine bears male and female strobili, usually over the entire crown. The female strobili occur most abundantly in the upper part of the crown, where sometimes the male strobili may be missing. The strobili are lateral in their position; the male strobili are spirally arranged at the base of the current year's growth (4), whereas the female strobili occur near the apex (6). If they occur on the same shoot, the male strobili may be separated from the female strobili by up to 15 cm of vegetative tissue at pollination.

The presence of male strobili becomes evident by late August, but the presence of female strobili cannot be detected visually until after bud break in the spring. Earlier accurate counts can be made only by careful dissections of terminal vegetative buds.

BUD DESCRIPTION

During winter dormancy, the vegetative bud consists of a sheath of semi-transparent, spirally arranged bud scales (1), which enclose an unelongated, following year's shoot, consisting of an axis covered by spur shoots (needle fascicles) with compressed short needles and, at the tip, a group of scales which overarch the apex (3).

If only a few male buds are present, they may be entirely enclosed within the terminal bud scales and appear only as a swelling at its base (2). If numerous male buds were initiated, the bud scales were forced apart, torn and largely shed, exposing the male buds (4). By the time male buds enter dormancy, the sporogenous tissue has considerably enlarged and pollen sacs appear to be in an advanced stage of development (3).

The female strobili develop entirely within the scales of the terminal vegetative bud and, because of their subterminal position on the shoot, their differentiation is delayed until the differentiation of needle fascicles, which progresses acropetally, takes place near the apex of the shoot. During dormancy, the female strobilus consists of a short shoot axis covered with spirally arranged compressed bracts which, at this stage, appear only like lateral outgrowths along its flanks. The whole structure is covered by short hood scales.

STROBILI

At the time of pollination, the male strobili form reddish yellow or brownish

yellow clusters at the base of elongated shoots; individual strobili are about 8 to 10 mm long (5). The female strobili occur singly in lateral positions (7) or in groups of 2 to 3 in subterminal positions (6), next to the already formed, next year's vegetative bud. They are about 5 to 6 mm long with a 3 to 5 mm long, thick stalk. The bracts which are the only visible parts, are red to purple with yellow spurs (6 and 7); they stand perpendicular to the axis to allow for the entry of pollen. Despite their small size the strobili are conspicuous because elongation of needles has not been completed.

Pollination is by wind. The male strobili turn brown after pollination, wither and are shed. Within 5 to 7 days following maximum receptivity, the ovulate cones close to form a compact purple conelet. In 2 or 3 weeks, they turn purplish brown or green brown and by the end of the growing season they have grown to about 15 to 18 mm (8). By this time the scales have elongated and thickened and are the only visible parts.

Fertilization occurs about 13 months after pollination, in the late spring of the second year. The development of the seed takes about 3 months and by late August or early September the seed is mature. At maturity, the cones are 2 to 4 cm long, short-cylindrical to egg-shaped and asymmetrical at the base (9). The color changes to lustrous light brown or yellow brown.

Under natural conditions, cones open on hot autumn days when there is usually little wind, so that the range of seed dispersal is not great. The seed release is only partial, as many cones remain closed and attached to the branches for many years. In this manner, large quantities of viable seed are retained.

Seeds are about 4 mm long, ovoid, reddish brown, often mottled with black (10); wings are about 12 mm long. Clean seed averages between 170 000 to 340 000 per kg.

Ponderosa Pine



1. Vegetative buds are slender and long.



2. Male buds are arranged around the base of a vegetative bud.



3. Male strobili are ovoid, yellow or purplish yellow, and about 18 mm long.



4. Female strobili are erect and occupy a subterminal position on the current year's shoots. They are red or purple.



5. Microsporangia open along a predetermined line and pollen is released in early June.



6. Female strobili develop into conelets by the end of the first year.



7. During the second year, the cones rapidly enlarge and change color to lustrous brown or russet brown.



8. The seeds are ovoid to triangular, large, brown to gray-brown, and mottled.

Ponderosa Pine

Ponderosa pine starts to produce strobili at the age of 12 to 16 years of age, but seed production is usually sporadic. Collectable seed crops are usually produced at 4- to 6-year intervals.

As in all pines, the male and female strobili occur on the same tree and, in heavy cone crops, even on the same branch. Strobili of both sexes may be produced anywhere in the crown. They are always lateral in their position. Male strobili are spirally-arranged at the base of a vegetative bud or, in the spring, at the base of the current year's shoot. They are grouped in clusters of up to about 20 and are visible by late August. The female strobili occur singly or in groups of two to four near the apex of the current year's growth, but their presence cannot be detected without dissection until the shoot has elongated in the spring.

BUD DESCRIPTION

During winter dormancy, vegetative buds (1) consist of a sheath of spirally-arranged bud scales that enclose next year's growth. This shoot consists of an axis covered with spur shoots (needle fascicles) with compressed shoot needles. The outer bud scales are reddish brown or greenish brown, usually covered with small droplets of resin that gives them a whitish lustre. The inner scales are light brown, semi-transparent, and membranous.

If many male buds are differentiated, then the sheath, which covered them originally, is forced apart and largely shed and then appear as separate buds (2). If only a few were differentiated, then the sheath remains and the appearance is that of a large, broad, vegetative bud. The male strobili undergo

considerable development before dormancy. The color of the buds is brown-green or purplish brown.

Female strobili develop entirely within the scales of the terminal vegetative bud and, because of their subterminal position on the shoot, their differentiation is delayed until acropetal differentiation of the needle fascicles takes place near the apex. During dormancy, the female strobilus is less than 1 mm long. It consists of a short shoot axis covered with spirally-arranged bracts, which, at this stage, appear only like lateral outgrowths along its flanks. The whole strobilus is covered by a few short hood-like scales.

While the vegetative buds and male strobili enter a state of dormancy during the winter and further development takes place the following spring, the female strobili continue to grow during late fall and winter.

POLLINATION

Microsporangiate strobili, emerging from the buds in spring, are usually green with a reddish tinge, but, on some trees, they may be red, pale purple, or yellow purple and this color persists until enlarging microsporangia force the microsporophylls apart. Exposed semi-transparent microsporangia, filled with yellow pollen, change the overall color to yellow or purplish yellow (3). Individual male strobili at pollination time are 14 to 20 mm long and 6 to 8 mm wide.

The megasporangiate strobili (4) appear in spring on elongating shoots in subterminal positions. They are deep purple or red with narrow orange or yellow fringes on the bracts; the scales are not visible. The female flowers,

excluding a short stalk, are about 8 mm long and 5 mm wide. They stand erect to allow for pollen entry. Despite their small size, they are conspicuous because elongation of the needles has not been completed.

Pollen is mature by the end of May. During dry weather, the microsporangia (5) open along a predetermined abaxial line and the pollen is released. Pollination occurs during the next 2 to 3 weeks.

Soon after pollination, the male strobili turn brown, wither, and are shed, while female strobili close to form a compact purple conelet. This color soon changes to brown or green-brown, and the scales elongate, thicken, and become the only visible part of the cone. Female strobili (6) develop slowly during the first year, reaching about 25 mm in length by the fall. Abortion of the conelet during this period is common and believed to be due to unsatisfactory pollination.

The pollen tube initially develops rapidly, and then rests until spring of the following year. Fertilization takes place during June, which is 13 months after pollination. Conelets enlarge rapidly (7) and reach full size by early September; their color changes from yellow-green or light brown-green to lustrous yellow-brown, green-brown, or russet brown as the vegetative tissues die and dry out. At maturity, the cones are 70 to 90 mm long and, when closed, about 35 mm wide; when opened, they are about 50 to 60 mm wide.

Cones open during hot, dry weather in early October. The seed is heavy and the dispersal range is small.

The seeds are 7 to 9 mm long, 4 to 6 mm wide, 3 to 4 mm thick, ovoid to triangular, brown to gray-brown or pale brown, and usually mottled. The wing is boat-shaped, 18 to 28 mm long, and 8 to 12 mm wide. There are 1 to 3 kg of seeds per hectolitre of cones and 15 to 50 thousand seeds per kg. Seeds have been stored for 18 years without significant loss of viability. Germination varies between 50 and 80 per cent.

Western Hemlock



1. Vegetative buds are small and slender. They are somewhat angular in cross-section because the outer bud scales have a prominent keel.



2. Female buds occur almost exclusively in terminal or subterminal position. They are spherical or oval, green and pubescent.



3. Male buds may also occasionally occur in terminal position. In such a case, they are not distinguishable from female buds by their outer appearance. Dissection and hand lens is necessary.



4. More frequently, male buds occur in lateral positions along the last year's growth.



5. In heavy crop years, male buds may occur in groups of up to 8 in subterminal position.



6. At pollination, male strobili are about 5 mm long on a thin stalk. The usual color is light purple, but may also be yellow or red. At maturity, pollen sacs are yellow.



7. Female buds are about 1 cm long on a short stalk. The tri-lobed bracts are light blue or light purple; behind them protrude dark-blue ovuliferous scales.



8. The cones are about 25 mm long and 10 mm wide. There are about 7 seeds per cone and 80,000 cones per hl.



9. Seed size is variable. Number of seeds varies from about 0.5 to 1.3 million per kg.

Western Hemlock

Western hemlock is a prolific seeder. Seed bearing usually starts between 25 and 30 years of age and some seed is produced every year, with heavy seed crops every 3 to 4 years.

As soon as the buds are formed in summer, their function, whether vegetative or reproductive, can be recognized from their outer appearance, the position on the shoot and the position in the crown.

As in most conifers, in light crop years, female buds occur mainly at the top of the crown and male buds in the middle and lower parts of the crown. In heavy crop years, and especially on open-grown trees, buds of both sexes may occur throughout the crown. The more vigorous shoots in distal positions bear female buds, while those of lower vigor in proximal positions bear male buds.

BUD DESCRIPTION

Even in heavy crop years, most terminal buds are vegetative (1). On vigorous primary branches, they are about 3 to 4 mm long and on secondary lateral branches, about 2 mm long. They are somewhat angular in cross section as a result of the slightly keeled outer bud scales. The bud scales are light brown to dark green and covered with fine hair, like the young shoots. The dormant vegetative bud consists of 20 to 26 bud scales enclosing the next year's growth. The bud is usually obscured by several short needles.

The female buds occur in terminal

positions (2). They are borne singly or, rarely, in groups of 2 or 3. They are ovate to obovate and about 3 to 5 mm long and have 20 to 26 bud scales. The outer bud scales are green to light brown, covered with fine hair and extend about three-fourths the length of the bud. Protruding inner bud scales are slightly darker brown, smooth and shiny. Soon after the buds are formed, during the first half of August, bract initiation proceeds up the flanks of the apex and, by the end of August, ovuliferous scales are initiated. During the dormant period, the lateral lobes of the scales overlap the margin on the bracts.

In poor crop years, some male buds may also occupy the terminal positions (3). However, they more typically occupy lateral positions, sometimes singly, but usually as groups of 2 to 4 at the base of last year's shoot (4) or a short distance below the terminal bud (5). They are ovate or obovate and about 2 to 3 mm in length (4). The bud scales are fewer than on female buds, rarely exceeding 20. The outer bud scales are covered with fine hair and are light brown. The pollen cone, tightly packed within the bud scales, often enlarges enough before dormancy so that the tip of the bud is covered by only light-brown inner scales through which the green male strobilus is showing.

When bud scales are removed or the buds are cut open, bud recognition becomes easy; however, because of their small size, a hand lens may be necessary. The vegetative buds contain the next year's shoot with flanks densely covered with green, spirally arranged, unelongated needles. The dormant female bud contains a strobilus with all

bracts and ovuliferous scales, although the distal ones may be poorly developed. The male bud has all microsporophylls and pollen sacs.

BUD BREAK

Initiation of activity in the reproductive buds occurs around the beginning of March, about 4 to 6 weeks before any activity takes place in the vegetative buds. In the male buds, the strobilus elongates and microsporangia develop into two rounded pollen sacs. The elongated pollen cone pushes the bud scales apart. At pollination, the pollen cone is light purple, yellowish or reddish, 4 to 5 mm long on a 3 to 4 mm long stalk (6).

Inside the female bud, the strobilus enlarges, the outer bud scales separate, and the tip which, during dormancy, was covered by brown, shiny inner bud scales, rapidly enlarges. The flanks of the female strobilus are covered with spirally arranged, light blue to purple, tri-lobed bracts, behind which protrude larger, darker blue, two-lobed ovuliferous scales (7). At pollination time, the female cones are about 1 cm long. After pollination, the scales rapidly enlarge, turn green and the cones become pendant. Fertilization takes place about 4 to 6 weeks after pollination.

The cones attain their final size in August, when they are about 2.5 cm long and 1.0 cm wide (8). The subsequent maturation involves drying and death of the vegetative tissues and gradual change of color to brown. Most seeds are released in late September and during October, but sometimes more than 50% are retained and are gradually released until the following spring. The mature seed is about 3 mm long, 1.6 mm wide and 1.1 mm thick (9), but the size range is substantial. The embryo extends about 90% of the seed length. The seed wing is about 8 to 9 mm long and 3 mm wide. The number of seed per kg ranges from about 0.5 to 1.3 million.

Yellow Cedar



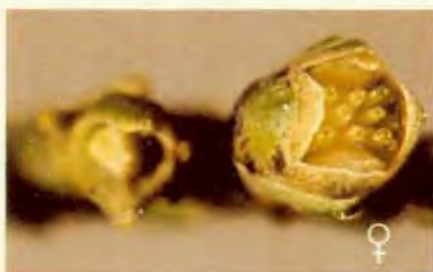
1. In heavy crop years, it is not uncommon to find female and male strobili on the same branches.



2. Female strobili occur at the tips of short shoots near the tip of vigorous vegetative branches. They are about twice the size of vegetative shoot tips and are dark greenish blue or bluish gray.



3. Male strobili enter winter dormancy in an advanced stage of development. They are egg-shaped, about 3 mm long, with green microsporophylls and yellow pollen sacs.



4. At pollination, the fused bract-scale structure separates and exposes the tips of ovules.



5. One-year-old cones are already fully grown. However, they are green and soft to pressure.



6. One-year-old cones are easy to cut. The section is light colored, the seeds small, white and soft.



7. At the end of the second growing season, the cones are hard and brown, with prominent ridges between the scales. There are about 130,000 cones per hl.



8. The seed is about 5 mm long, dark brown with light-brown wings. There are only 7 seeds per cone and about 230,000 seeds per kg. Viability of seed is very variable.

Yellow Cedar

Yellow cedar occurs at high elevations and cool northern slopes. In its natural range, it is rarely a prolific seed producer, though it usually produces some seed every year. Good crops are infrequent and at irregular intervals. In light crop years, female cones are produced on the upper, vigorous branches of the tree, while less vigorous lower branches bear male cones. In heavy crop years, male and female strobili may occur on the same branch: the tip remains vegetative, while short shoots near the end of the main branch bear female strobili and long, proximal shoots bear male strobili.

Yellow cedar does not produce buds or bud scales. Instead, the vegetative apex is enclosed by overarching scale-like leaves and leaf primordia in various stages of development (1). The reproductive structures are produced by a gradual transition of vegetative shoot tips into reproductive tips (2 and 3).

STROBILI

Male strobili (1) are usually far more abundant than female strobili (2) and, in heavy crop years, may occupy almost all the tips of shoots. A new, lateral tip develops a short distance below the male strobilus and, after pollination, when the strobili are shed, grows vegetatively for a few weeks. This new shoot may remain vegetative or produce a male strobilus in the next crop year.

As in all conifers, the initiation of the reproductive structures takes place in summer of the year preceding polli-

nation. At the onset of winter dormancy, the male strobili (3) are egg-shaped and about 3 mm long. The microsporophylls are completely exposed, green to light green, with usually 2, but occasionally 3, microsporangia (pollen sacs) attached to the basal side and extending beyond the microsporophylls. The microsporangia are yellow because pollen is in an advanced stage of development.

Female strobili (2) are produced at the tips of newly formed, short lateral shoots close to the main shoot tip of a branch. Their initial development differs little from the development of male strobili except that no branching takes place, thus these lateral shoots are eliminated for future growth or seed production. During winter dormancy, newly initiated seed cone (2) is about 2 to 3 mm long and the fused bract-ovuliferous scale structures that cover the cone are black. There are usually 3 ovules in the axil of each of the first pair of bract-scales. Occasionally, a second pair of bract-scales is present.

FLUSHING

Little development takes place during the winter. In early spring, the axis of the male strobilus elongates and the pollen sacs enlarge, giving the strobilus a bright yellow color. Pollination takes place during late April. At that time the fused bract-ovuliferous scales separate (4), exposing the tips of the ovules. Fertilization occurs in late summer, about 3 months after pollination. By October, the embryo development stops. By this time the cones attain almost their mature size, 7 to 12

mm in diameter (5). They are round, green to purplish green, soft to finger pressure, and the seeds (6) are small, soft, white and immature. They will not germinate, though they usually contain an embryo. At this stage the cones enter winter dormancy.

Embryo development continues in the following spring and by late August of the second year the cones and seeds mature. The cones turn first yellow green and later brown to reddish brown and the lines between the scales become distinct and raised (7). Seed (8) are about 5 mm long, dark brown with light-brown wings, dry and hard. Unlike most other conifers, seed wings do not develop from the ovuliferous scale, but are thin lateral extensions of the seed coat and give the seed an oval shape. Most seeds are shed in late October, but some not until mid-winter.

The seed is variable in size, 150 000 to 400 000 per kg. Germination is usually low and stratification before sowing is recommended.

GLOSSARY

Apex.	the growing point of a stem or root.
Axil	the angle formed between the axis and any organ that arises from it; e.g., ovule.
Axis	an imaginary line, round which the organs are developed.
Bract.	a vegetative scale of the cone above which lies the seed-bearing scale.
Central Cell	a cell produced inside the pollen by the first pollen cell division; from this cell in the next division, the tube cell and generative cell are produced.
Chromosomes.	fibrillar bodies formed during nuclear division, which produce the daughter nuclei.
Cotyledon	the first leaves of the embryo.
Distal	remote from the place of attachment, the converse of proximal.
Dormant	applied to parts that are not in active life, as buds in winter.
Embryo.	the rudimentary plant formed in a seed.
Flushing	initiation of growth, as in spring.
Fusion.	the union of a pair of fertile cells.
Gametophyte	the generation that bears the sexual organs.
Haploid	the organism with the half number of chromosomes, as in sexual cells.
Hybrid	a plant obtained by crossing of two related species.
Integument	the covering of an organ or body.
Internode.	the space or portion of stem between two nodes or whorls of branches.
Latent.	dormant, usually for a longer period.
Megasporangium	the inner tissue of the ovule.
Megaspore	a female reproductive cell.
Megaspore mother cell	the cell inside the megasporangium which, by meiotic division, produces 4 megaspores.
Meiotic division.	cell division that includes reduction of chromosomes to haploid number.
Meristematic cells	undifferentiated tissue capable of being transformed into special forms, as cambium, etc.
Micropyle	the lower part of the tube of the integument, where it expands to join the seed cavity.
Microsporangium.	receptacle producing microspores or pollen, such as pollen sacs or stamens.
Microspore.	the male spore in heterosporous plants, applies to the pollen grain.
Microspore mother cells	a cell that, by meiotic division, involving reduction of chromosome number, produces microspores or pollen.
Microsporophyll	leaf-like organ-bearing microsporangia.

Mitosis	nuclear division in which the diploid number of chromosomes is retained, as in growth.
Nucellus	the body of the ovule or megasporangium containing the embryo.
Nucleus	a body inside a cell formed by grouping together of the chromosomes.
Ovulate	possessing ovules.
Ovule	the organ that, after fertilization, develops into a seed; also, the young seed in the ovary.
Ovuliferous scales	inner scales in a cone that bear ovule.
Pollen, pollen grains.	the fertilizing dust-like powder produced by the male flowers.
Pollen sac.	the microsporangium.
Pollen tube.	the tube that grows from a pollen-grain and that enables passing of chromosomes of the sperm cells to the chromosomes of the egg cells.
Pollination.	transport of pollen from the microsporangia in male cones to the ovules in female cones.
Primary root.	the first main root developed from the radicle.
Primordium	a member or organ in its earliest condition.
Prothallial cells	two or more cells produced by the first divisions of the microspore; they usually degenerate.
Proximal	the part nearest the axis, as opposed to distal.
Radical	arising from the root crown, the first root apex.
Reproductive	applied to parts that share in reproduction.
Scale.	any thin scarious body, usually a degenerate leaf, sometimes of epidermal origin.
Seed	the fertilized and matured ovule.
Seed coat.	the outer coat of the seed, usually hard and brittle.
Shoot	the young growing branch or twig.
Shoot apex.	the tip of the young-growing branch or twig.
Sperm cell	usually a minute male active cell whose function is to fertilize a female cell.
Spur shoot.	a short lateral shoot, sometimes with a few foliage leaves in a tuft.
Stalk cell	the cell arising from division of the antheridial cell in conifers, which does not become the generative cell.
Strobilus	an inflorescence largely made up of scales.
Subterminal	under or below the terminal or apex.
Suspensor	a thread of cells at the extremity of a developed embryo.
Terminal	proceeding from or belonging to the end or apex.
Tube cell	the cell that gives rise to the pollen tube.