Natural Regeneration.

Objectives

- Know how dormancy is broken.
- Know the stages in germination.
- Understand that successful germination and establishment depends on the combination of viable seeds, seedbed and environmental conditions.
- Know the determinants of seed dispersal in general, and typical dispersal patterns for major BC conifers.
- Understand the properties of different seedbeds and environment modifying effects of aspect and vegetation.

Seed Dormancy and Germination

The amount of time that seed is viable after dispersal varies widely among species, from a few weeks (e.g. *Acer macrophyllum*) to a few years (e.g. some pines).

Seeds are considered dormant if they do not germinate immediately when placed under favourable environmental conditions.

Dormancy is usually the result of an interaction between the genetics of a particular species and environmental conditions.

Why is it a good strategy for temperate trees to disperse dormant seeds?

Types of seed dormancy:

1. Physiological (endogenous) dormancy

Embryo dormancy: The mature embryo cannot germinate until certain physiological changes occur that modify growth regulator concentrations. This is the most common type of dormancy for BC conifers and is broken through ‘stratification’. Seeds are allowed to absorb moisture, and then stored at 1-5°C for 1-6 months.

Growth inhibitors in seed coat: Common in desert plants or plants whose seeds are transported by animal ingestion. Stratification, washing, leaching or exposure to light can overcome.

Immature embryo dormancy: Seeds require a period of warm moist conditions for embryo maturation (e.g. *Fraxinus* spp.).

2. Physical (Imposed, or seed coat) Dormancy

Impermeable to water: Boiling or scarification breaks down (e.g. *Acacia* spp.).

Low permeability to gases: Scarification or removal of seed coat (e.g. apples).

Mechanical resistance to embryo growth: Removal of seed coat or deterioration through freeze-thaw cycles/decomposition (e.g. hazel and other nuts).

Process of germination

Imbibition (hydration): water taken up in three stages - slow, fast, slow; seed swells and seed coat breaks.

Physiological activation: hydrolytic enzymes begin converting storage materials to soluble forms (sugars, nitrogen compounds, lipids) which are mobilized and translocated to embryo to fuel growth; respiration rate increases.

Embryo growth and emergence: cell enlargement and division; emergence of seedling - usually radicle first and then cotyledons.

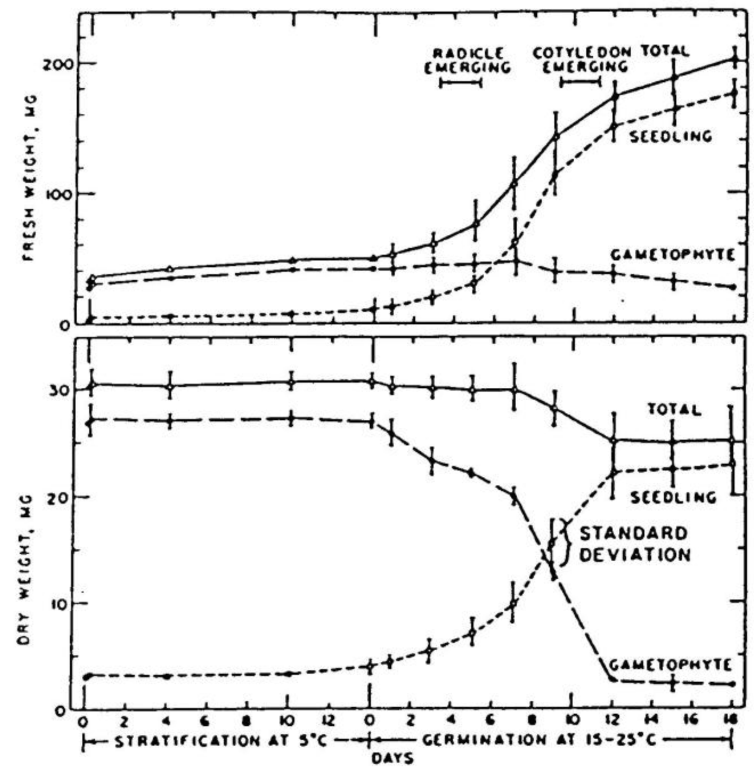
Need warm temperatures (15-30 C), moisture, gas exchange and light (red/far red ratios) for germination.

Biological Stage	Dormancy	Germination		
		Hydration	Activation	Emergence
Mature seeds				*Germinants*
Natural regeneration	Seed banks	Seeds soaked by fall rains	Overwinter in soil	Warm conditions in spring
Artificial regeneration	Storage (-18°C, <10% mc)	Soak in water	Stratification (2–5°C, >25% mc)	Sow in nursery

FIGURE 6 *Comparison of the major steps in the natural and artificial regeneration sequences of forest tree seedlings.*

The emerging seedling rapidly uses up stored food supply and must begin producing its own energy through photosynthesis.

Fig. 14.4. Epigeous germination of pine seed. (Photo courtesy of St. Regis Paper Co.).



Changes in fresh and dry weight in megagametophyte and embryo c
ings during stratification and germination. From Ching and Ching (1

- Moisture supply is critical to successful establishment.
- Shoot growth lags behind root growth and stops early in the growing season.
- Root growth continues into the early fall.

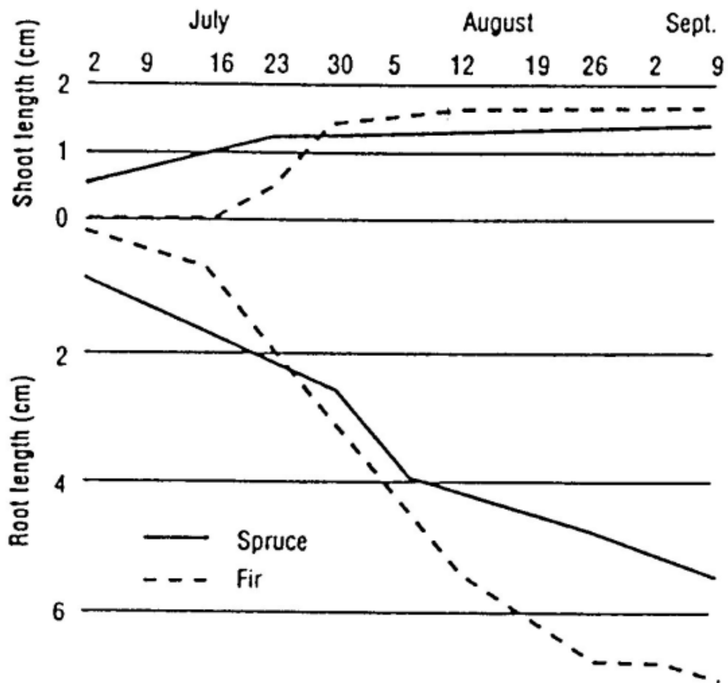


FIGURE 41. Shoot and root development of interior spruce and

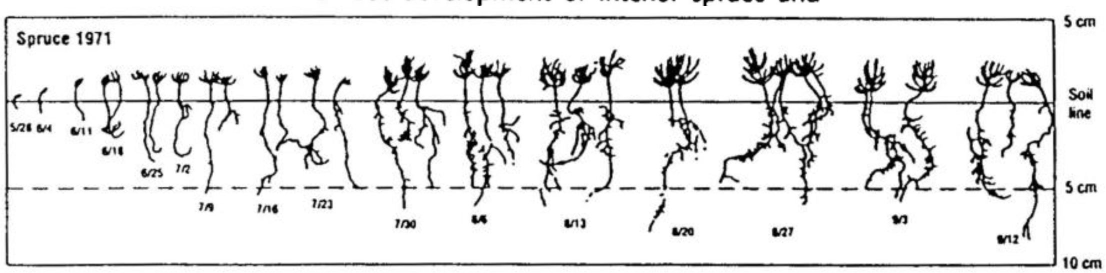
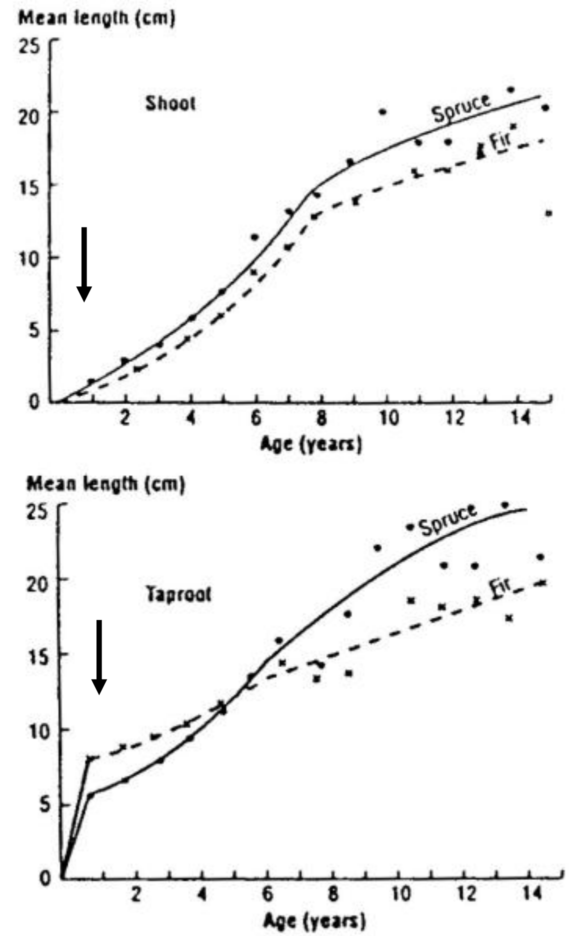


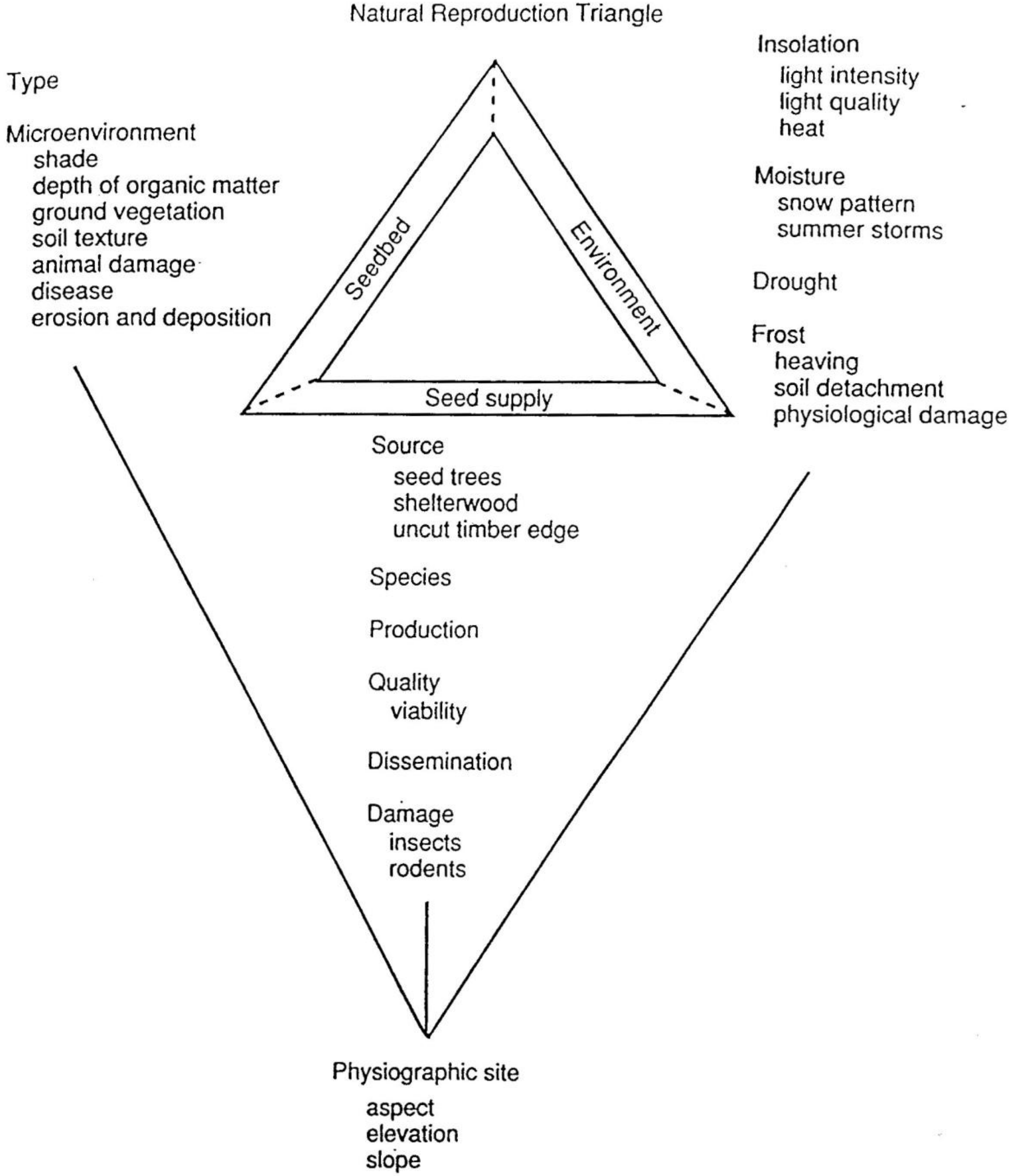
FIGURE 43. First growing season development of white spruce seedlings in Interior Alaska as indicated by weekly excavation of vigorous individuals. Numbers indicate month/day of excavation (from Zasada *et al.* 1978).



URE 44. Mean shoot and root growth of interior spruce and subalpine fir seedlings aged 0 to 15 years in the Crowsnest Forest, Alberta (from Day 1964).

Successful natural regeneration depends on:

- Adequate seed supply.
- Available seed bed during seedfall event.
- Suitable environmental conditions for germination and establishment.



So, let's look at each of the 3 sides of the regeneration triangle…

1. Seed Supply

Mechanisms of seed dispersal

- Airborne and floating on water - small seeds with cotton-like tufts *(e.g.*

- Airborne seeds with relatively large terminal wings *(e.g.*

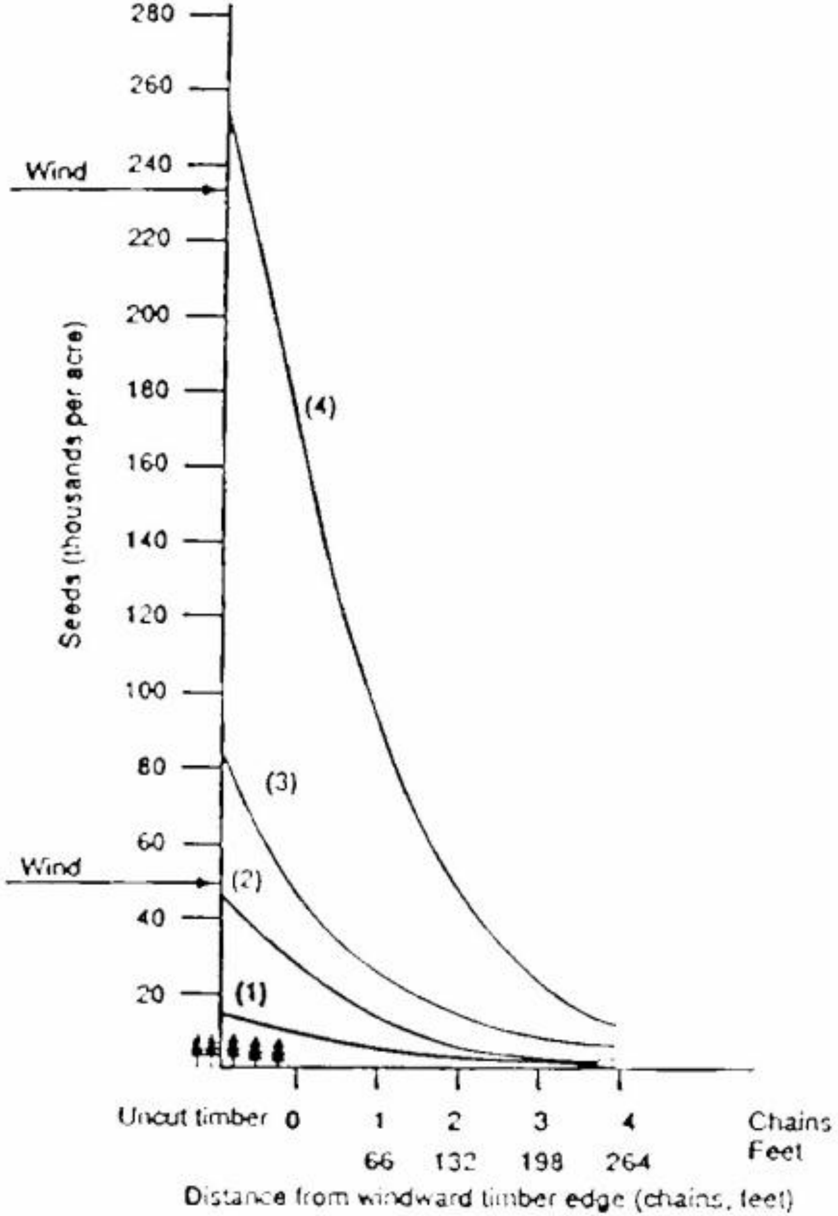
- Airborne small seeds with marginal wings *(e.g.*

- Animal/bird transport - wingless, berry like seeds ingested as food *(e.g.*

- Animal/bird transport - cached or buried *(e.g.*

The pattern of wind dispersed seed
With distance from the parent tree looks like this:

What factors does distance of wind driven seed dispersal depend on?



Engelmann spruce-subalpine fir seed dispersal from windward timber edge to 3.5 chains into the opening, averaged over all years and areas, Illustrates (1) poor, (2) fair, (3) good and, (4) heavy seed crop years

TABLE 13-1
APPROXIMATE MAXIMUM DISPERSAL DISTANCES FOR THE BULK OF SEED BLOWN DOWNWIND INTO OPENINGS FROM ADJACENT PARENT TREES OF SEVERAL COMMERCIALLY IMPORTANT NORTH AMERICAN SPECIES (AFTER INFORMATION COMPILED BY FOWELLS 1965; HARLOW ET AL. 1978; BURNS AND HONKALA 1990A, 1990B).

		Effective dispersal distance for most seed in an average year[a]						
Adjacent to parent tree[b]	Only short distances	Within 50–100 ft (15–30 m)	Up to 100–120 ft (30–36 m)	Up to 120–150 ft (36–46 m)	Up to 200 ft (61 m)	Up to 300–330 ft (91–101 m)	Up to 400 ft (122 m)	At least 500 ft[c] (152 m)
American beech	Pacific silver fir	Balsam fir	Engelmann spruce	Nobel fir	California red fir	Blue spruce	W. white pine	Fraser fir
Black cherry	White spruce	Subalpine fir	Ponderosa pine	White fir	Grand fir	Black spruce		E. white pine
Butternut	Red pine	Sitka spruce		Tamarack	Lodgepole pine	Red spruce		Atl. white cedar
Walnut	Green ash	Longleaf pine		Western larch	Redwood	Jeffrey pine		Western hemlock
Black tupelo	Honey locust	Sugar pine		Shortleaf pine	N. white cedar	Pitch pine		Paper birch
Oaks		Jack pine		Slash pine	Sweetgum	Scotch pine		Yellow birch
Hickories		Eastern hemlock			Tulip-tree	Loblolly pine		Aspens
		Blue gum				Douglas-fir		Poplars
						W. redcedar		Cottonwoods
						Sugar maple		Red alder
						American elm		

[a] Some seed will disperse farther into a clearcutting, especially in strong winds, but the bulk will fall within the average distances shown.
[b] Birds and mammals will carry some seed over much longer distances, and this serves as an important dispersal mechanism within species with heavy seeds that normally land in close proximity to the parent tree.
[c] Birches often blow long distances over crusted snow. The silky-haired seeds of aspens, cottonwoods, and poplars may float for several miles before landing.

Very few seeds are dispersed for long distances, but these long distance dispersal events are important – *why?*

Once seed arrives on seedbed it joins the seed bank.

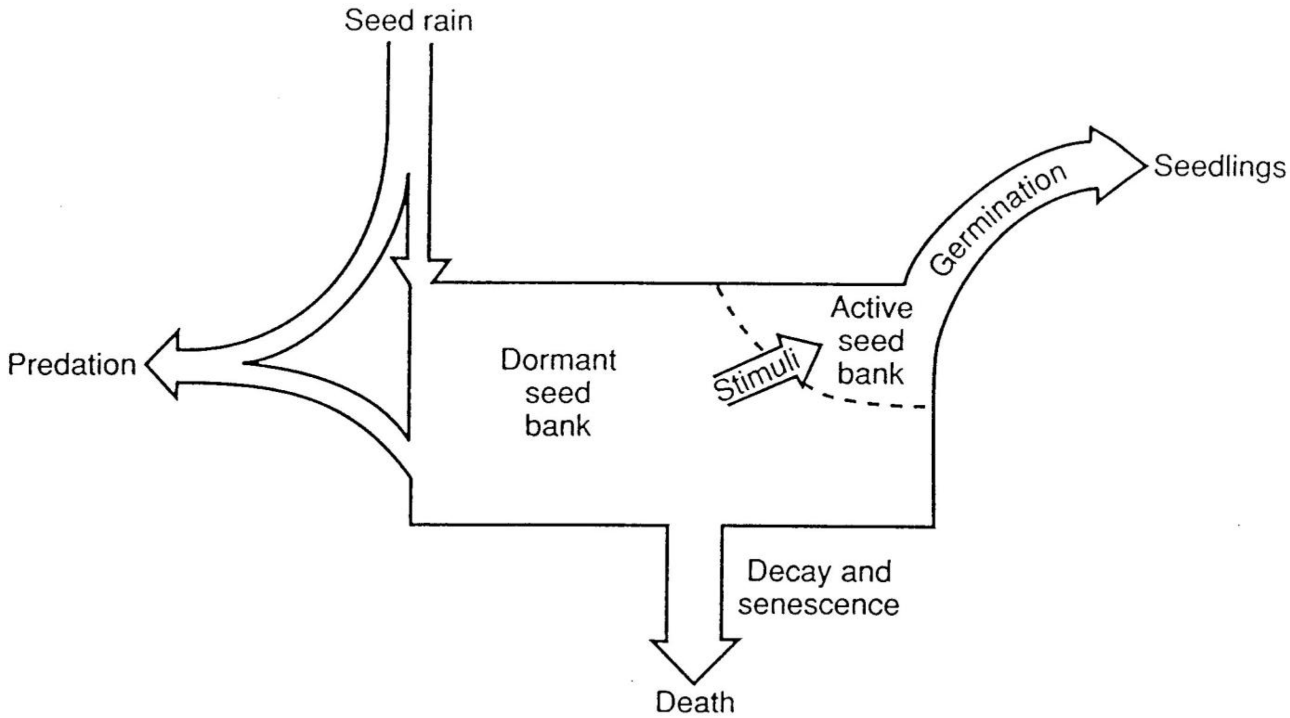


FIGURE 4-3
The character and dynamics of seed banks in the forest floor (after Harper 1977).

2. Seedbed

During initial establishment the most important seedbed property is the ability to supply moisture.

This varies with soil material (organic vs mineral) and texture.

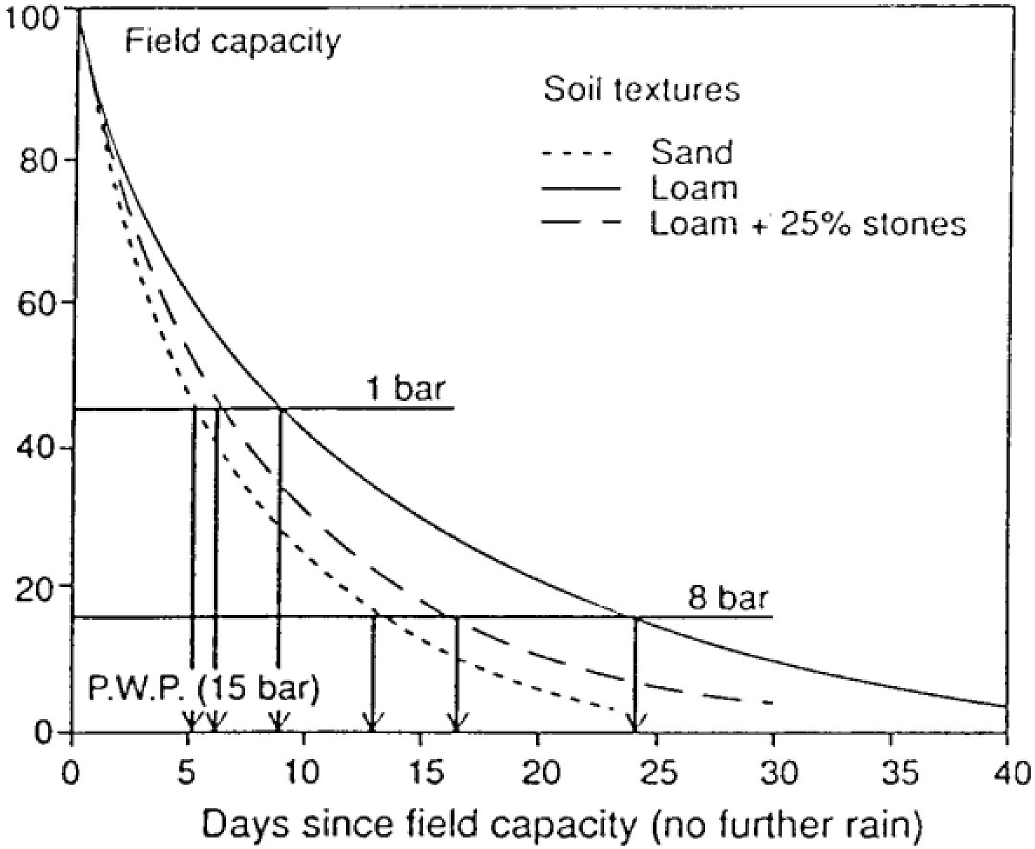


FIGURE 18.4. The influence of soil texture on soil water depletion.

Other key seedbed properties are:

- sufficient light
- non-lethal temperatures (heat and frost)
- nutrient availability
- aeration
- absence of pathogenic fungi or other seed/seedling predators

	mineral	humus	rotten wood	litter/moss
moisture	++	+	++	-
thermal	++	+	+	-
aeration	- to ++	- to +	+	++
nutrients	- to +	++	-	-
free of pathogens	+	+	+	-

3. Environment

Most species germinate and establish better with partial shade and shade is critical in warm-dry subzones.

Shade due to overstory or microsite obstacles, reduces:
• daytime temperatures
• night-time freezing in continental or high elevation climates
• moisture loss

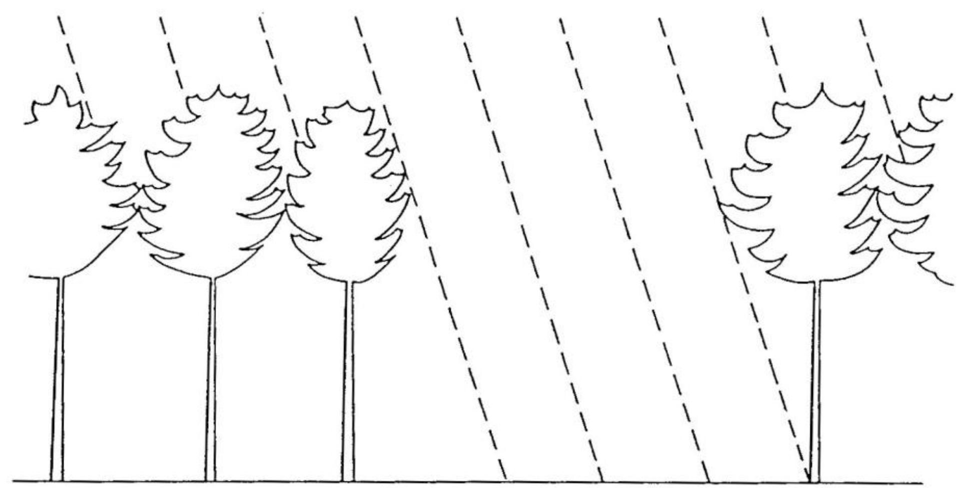


FIGURE 7-4 The zonation of solar radiation which, in combination with alteration of surface conditions, controls most of the alterable microclimatic factors significant in regulating regeneration from seed.

However, once trees are established, growth rates will be reduced as overstory density increases – *why?*

In the shelterwood system, the overstory is removed once regeneration is established.

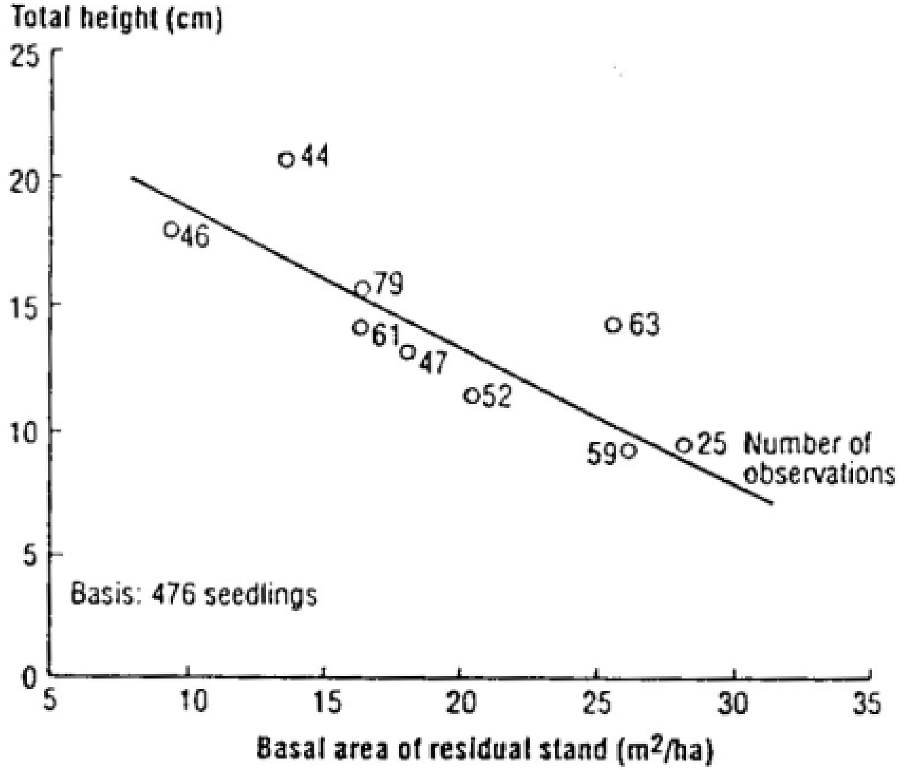


FIGURE 48. Effect of stand density on the total height of 7-year-old white spruce seedlings on scalped seedbeds (from Waldron 1966).

Ground aspect influences environmental conditions:

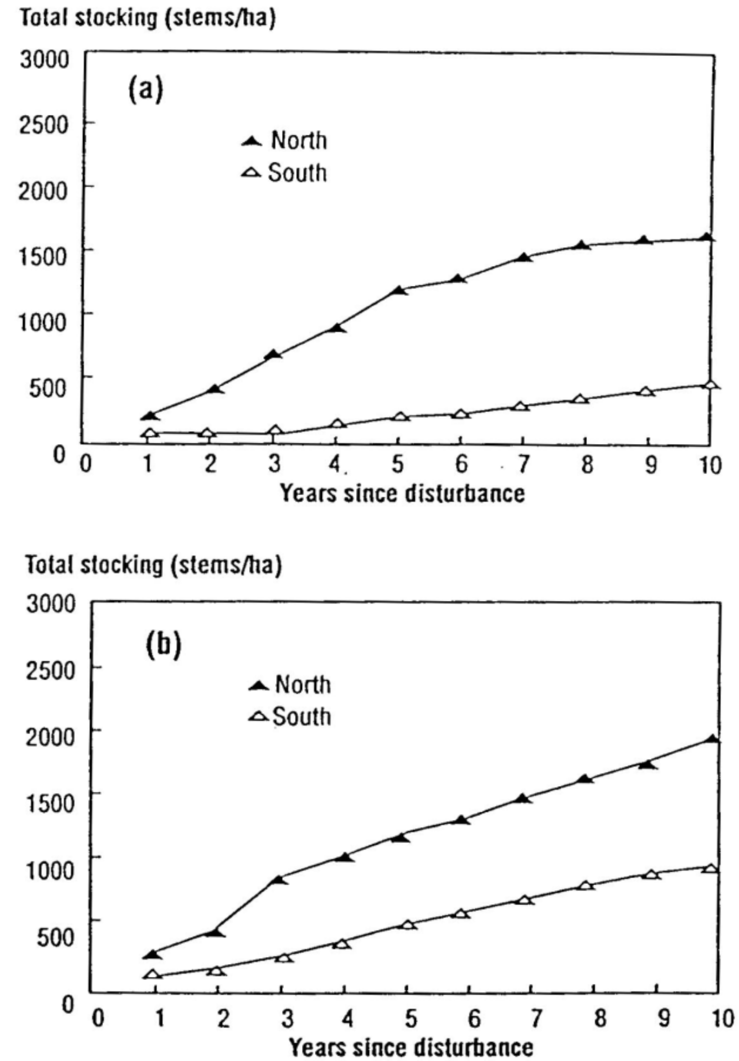


FIGURE 39. Density of Engelmann spruce natural regeneration on north- and south-facing clearcuts in (a) the Kamloops Forest Region, and (b) the Nelson Forest Region (from Butt *et al.* 1989 and Butt 1990, both unpublished).

The number of seeds required to produce a successfully established seedling is the seed:seedling ratio.

Examining this ratio provides insights into which side of regeneration triangle limits establishment.

TABLE 14. Sample natural regeneration probabilities for interior spruce. This hypothetical example compares the expected regeneration on a large clearcut with that of a shelterwood on the same site, following a heavy seed year. The probabilities are derived from this literature review.

Regeneration system	Regeneration phase	Probability	No. of seeds or seedlings /m^2	No. of seeds or seedlings /ha	Reference
large clearcut (±300 m from edge)	seed production (uncut stand)	1.0	1000	10 000 000	Dobbs 1976b; Zasada 1985
	seed dispersal	0.02	20	200 000	Dobbs 1976b; Zasada 1985; Figure 36
	seed viability (sound seeds)	0.3	6	60 000	
	seed predation	0.5	3	30 000	Radvanyi 1974
	germination	0.3	0.9	9 000	Eis 1965a
	1st-year survival	0.1	0.09	900	Figure 40; Eis 1965a
	established seedling (5 years)	0.4	0.036	360	Figure 40; Eis 1965a
shelterwood	seed production (uncut stand)	1.0	1000	10 000 000	Dobbs 1976b; Zasada 1985
	seed dispersal	0.75	750	7 500 000	Day 1970; Zasada 1985
	seed viability (sound seeds)	0.4	300	3 000 000	Dobbs 1976b
	seed predation	0.6	180	1 800 000	Radvanyi 1974
	germination	0.4	72	720 000	
	1st-year survival	0.4	28	280 000	Figure 40
	established seedling (5 years)	0.5	14	140,000	Figure 40

The distribution of natural regeneration across an opening reflects the effects of seed supply, seedbed and environment.

Different patterns would be expected for different species.

What would the patterns for Bl and Pli look like?

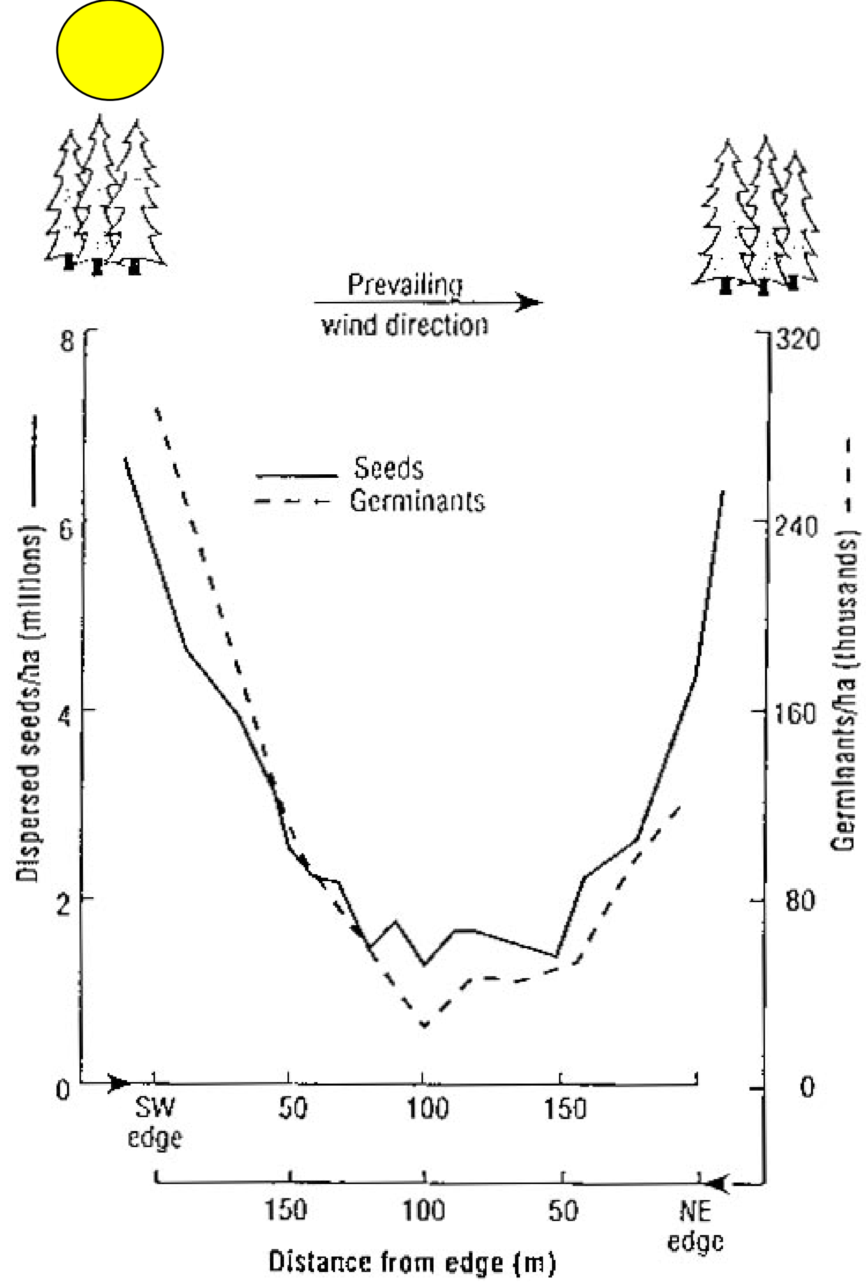


FIGURE 37. Distribution of dispersed white spruce seeds and germinants across a strip cut (from Dobbs 1976b).

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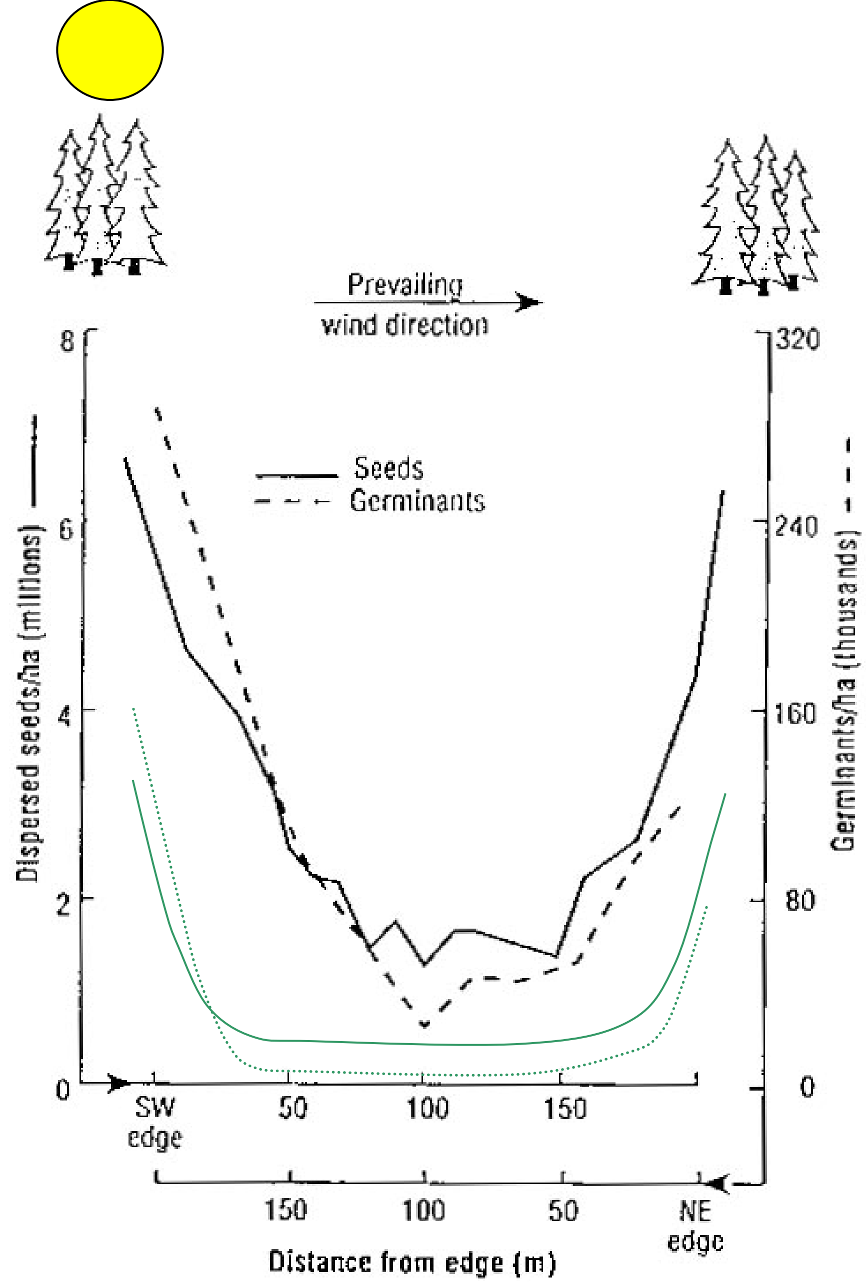

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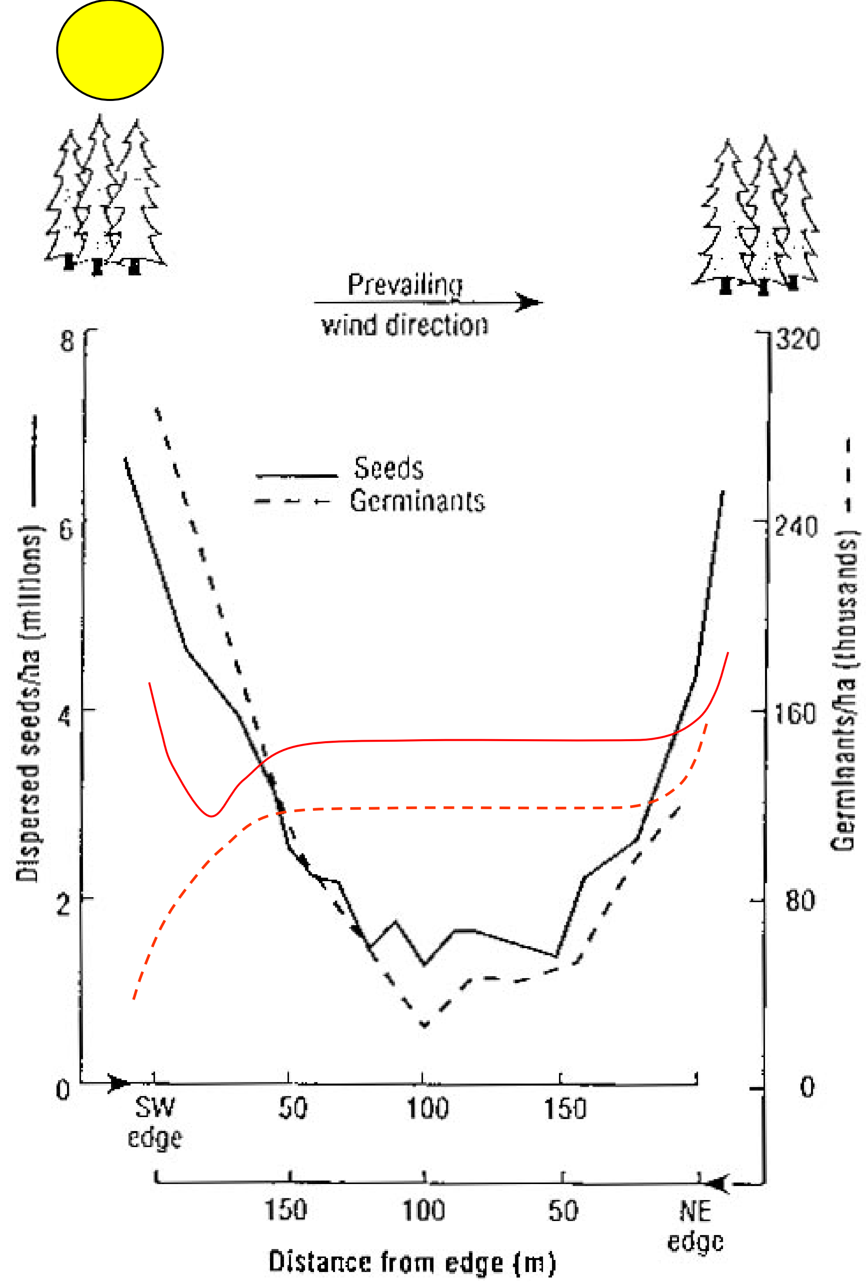


FIGURE 37. Distribution of dispersed white spruce seeds and germinants across a strip cut (from Dobbs 1976b).

Advance regeneration – seedlings and vegetative reproduction established in understory of stand prior to final harvest.

Advantages

- already established so may avoid regeneration delay and costs
- reduces rotation and fills in mid-term timber supply gaps

Disadvantages

- non-desirable species
- disease
- poor root-shoot ratio and shade foliage so must adapt to post-logging open conditions
- damaged during logging

The utility of advance regeneration for post-harvest stocking depends on:

Species

- high shade tolerance, regenerate on forest floor or rotten wood
- will vary by BEC subzone and site series *e.g.*
- must meet target stand requirements
- composition is affected by gap size

Stocking

- very high where species are seedling bankers
- low when have dense shrub/herb competition
- clumpy in response to variability in overstory density
- clumpiness increases in stands driven by gap dynamics,
- or where edaphic conditions are marginal for tree growth
- damage during logging increases clumpiness and reduces stocking.

Health

- may be infected with mistletoe from overstory, or stem or root decay from root contact or layering (e.g. *Echinodontium tinctorium, Phellinus* weirii)
- defoliating insects raining down from overstory (e.g. spruce budworm) impact regeneration.
- scarred by tree falls, slash creep, or damaged during logging

Vigour

- has often had a period of suppression, may be old individuals
- indicators of vigour are annual height increment and live crown ratio.
- prefer small trees for advance regeneration – *why?*
- vigour is greater where understory has developed in larger canopy gaps or when overstory has been losing vigour

Look for ‘natural shelterwoods’

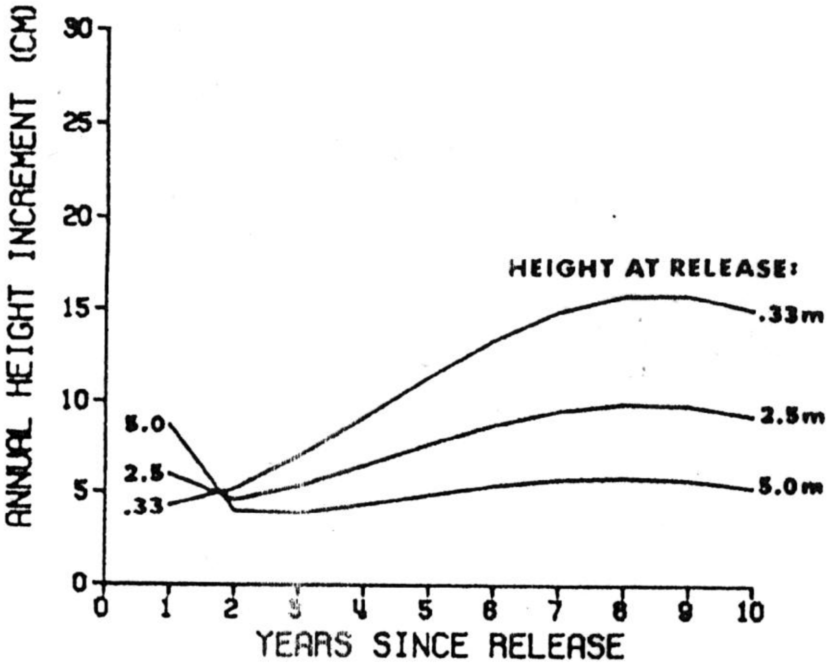


FIGURE 4. The effect of height at release on annual height increment following release.

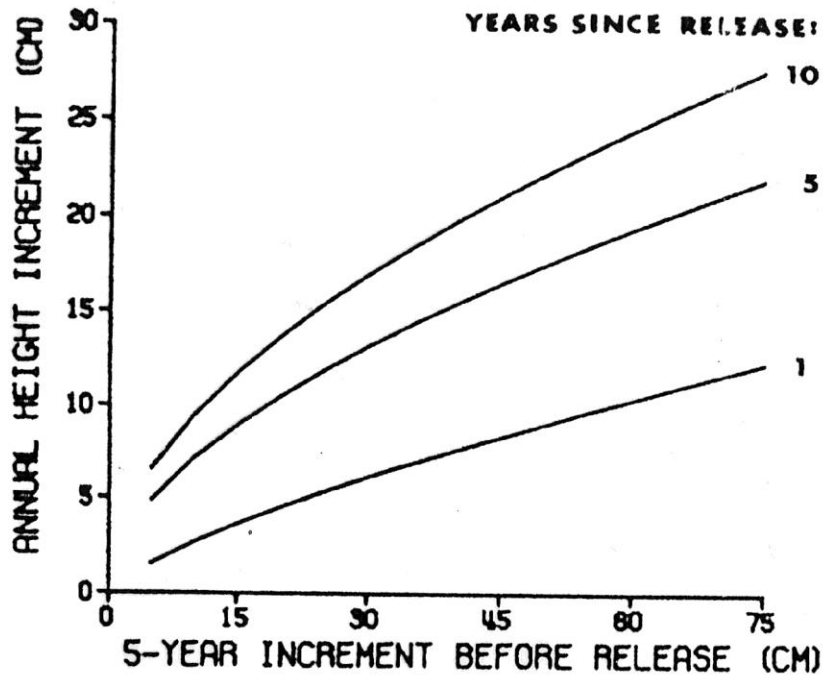
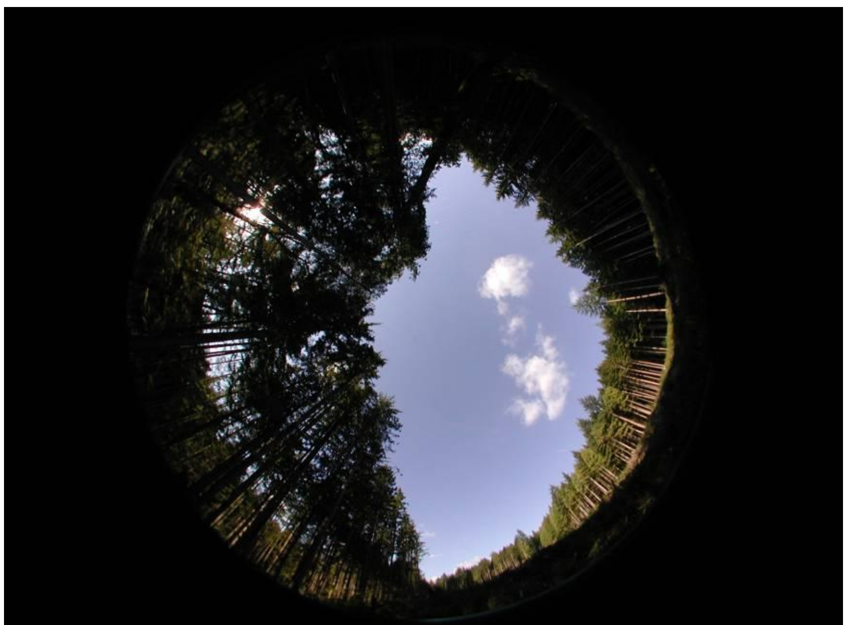


FIGURE 3. The effect of 5-year height increment before release on annual height increment following release.



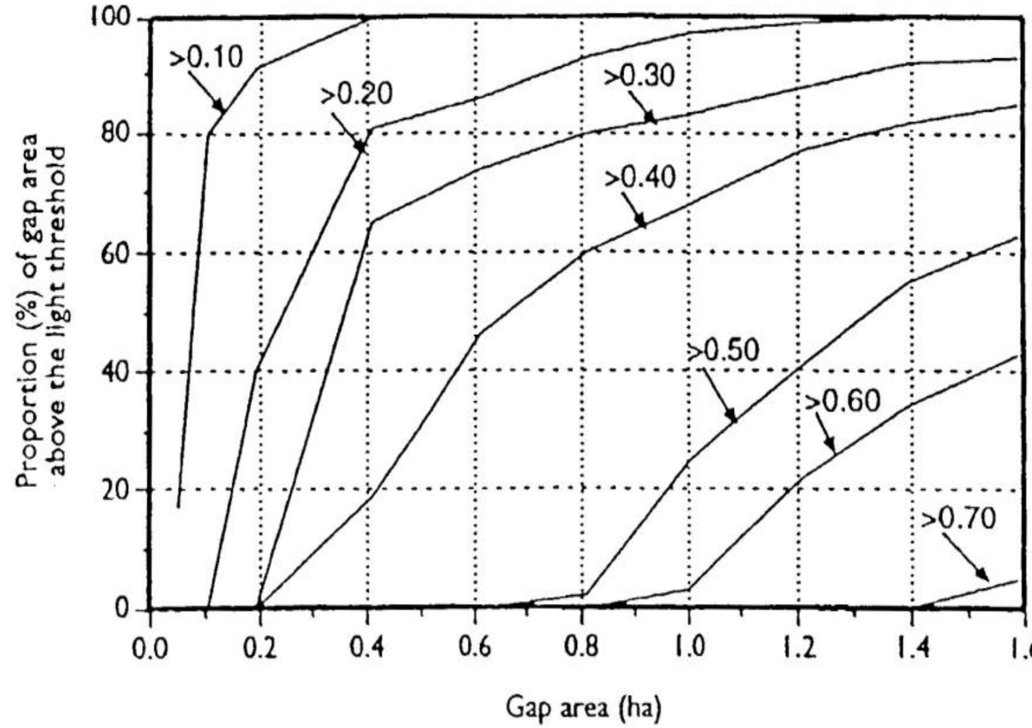


Figure 6.3
Proportion (%) of simulated canopy opening experiencing light levels above specific light thresholds as a function of gap area, using tRAYci, a spatially-explicit light model (Brunner 1997). Each line represents a specific light threshold (from 0.10 to 0.70 relative light intensity at ground level). Light simulations were done using stem map data (plot 1, Chapter 3), replicated 16 times to yield a 4 ha stand. Simulated square gaps (0.05 - 1.6 ha) were centered in the middle of the 4 ha stand.


Vegetative Reproduction

Vegetative reproduction - all forms of asexual reproduction. Except in certain cases where mutations occur, this type of reproduction produces genetically identical offspring.

Natural forms of vegetative reproduction:

Layering: branches contact moist soil, produce adventitious roots at point of contact and branch detaches from rest of tree becoming new individual. ***Cw, Cy, (S, H, B, Yew)***

Sprouting: sprouts originate from dormant or adventitious meristems often at the base of the parent tree (basal sprouts) or from shallow roots (root suckers) following a disturbance such as harvesting or fire, or as a result of canopy break-up. ***At, Ac, Ep, Mb***

These produce:

Clone - a plant or group of plants with identical genetic make-up, arising by vegetative propagation from an individual plant.

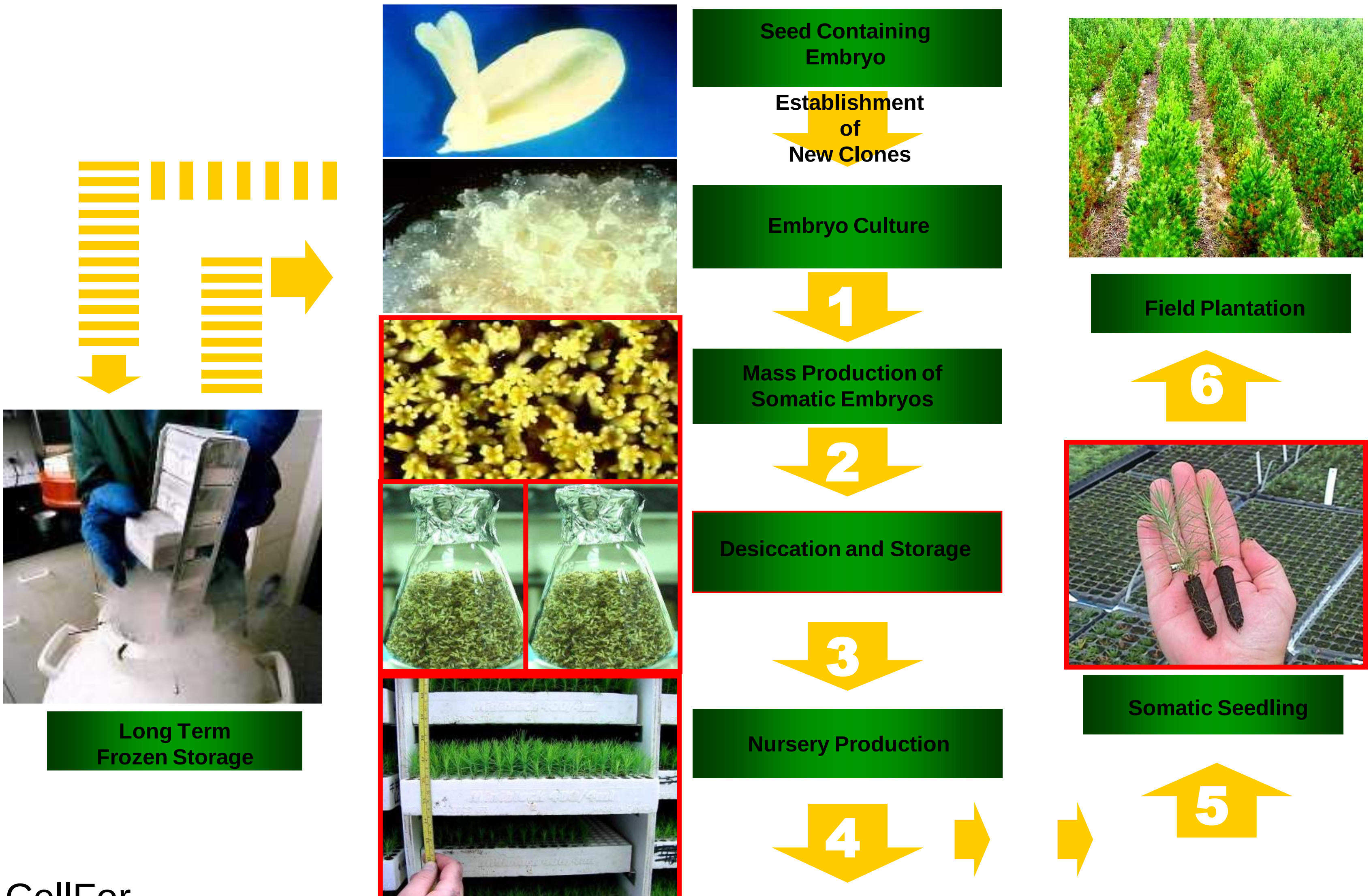
Coppicing: a silvicultural system for managing stands of stools and sprouts. Used in Europe for hazel, chestnut and oak. ***At*** is well suited to this system. ***Mb*** also, and coast redwoods, eucalypts.

Tissue and Cell Culture: also called micropropagation

organogenesis material from buds is placed in sterile growth medium containing hormones, sugars, amino acids and micronutrients where it multiplies into many buds, these are moved to new medium for formation of roots and then transplanted to soil;

somatic embryogenesis, new embryos are grown in cell suspension cultures from individual cells taken from callus tissue or embryos to produce ***emblings***. These techniques enable rapid multiplication of desired genotypes.

Somatic Embryogenesis



CellFor

Air layering: a horticultural technique where branch is girdled and is covered in moist peat with growth hormones and enclosed in waterproof covering.

Cuttings: a cultural technique in which sections are removed from stems or roots. Under well aerated, nutrient rich, warm moist conditions, adventitious roots form and shoots develop from buds. Ease of rooting varies with species, age of tree, location of cuttings, time of year. ***Yc*** produced as rooted sets. ***Ac*** is often planted as stecklings.

Grafting: horticultural technique in which a scion (shoot cutting) from one tree is grafted onto the stock (roots or rooted stem) of another tree. Used in seed orchards.

Reforestation with cuttings:

Stool - roots and stump of a tree that has had the main stem removed.

Steckling or Ramet - any segment cut from the stem or branches of a tree; a steckling has no roots.

- Cutting - a short steckling; generally 25-50cm cut from the stem or branches of a tree, basal diameter is 1-2cm.

- Whip - a long steckling; generally 100-200cm cut from the top of a small tree or stump sprout, all side branches are removed, basal diameter is between 1cm and 2cm.

Rooted cuttings – allow cuttings to form roots before planting.

TABLE 1. Yield estimates for black cottonwood under four management regimes used by Scott Paper Ltd.

	Type of Management System			
	Natural stands	Old Fraser Valley Veneer Plantations[a]	Extensively managed pulpwood stands[b]	Intensively managed pulpwood stands[b]
Rotation age (y)	30-50	25-35	25-30	15-20
Target tree size (ht/dbh)	32m/40cm	34m/38cm	35m/40cm	32m/35cm
Target tree volume (m^3/tree)	1.5	1.5	1.5	1.5
Net stand volume (m^3/ha)	250	280	300-500	300-500
Stocking at harvest (trees/ha)	200	236	250-350	400-450
MAI (m^3/ha/y)				
Fraser Block	7.9[c]	10.0	10-20	15-30+
Upcoast Block	5.4[c]	N/A	10-15	15-20

[a] Based on yield assessments of recently logged stands and stands approaching rotation age.

[b] Projections based on current growth rates and yield data from other areas.

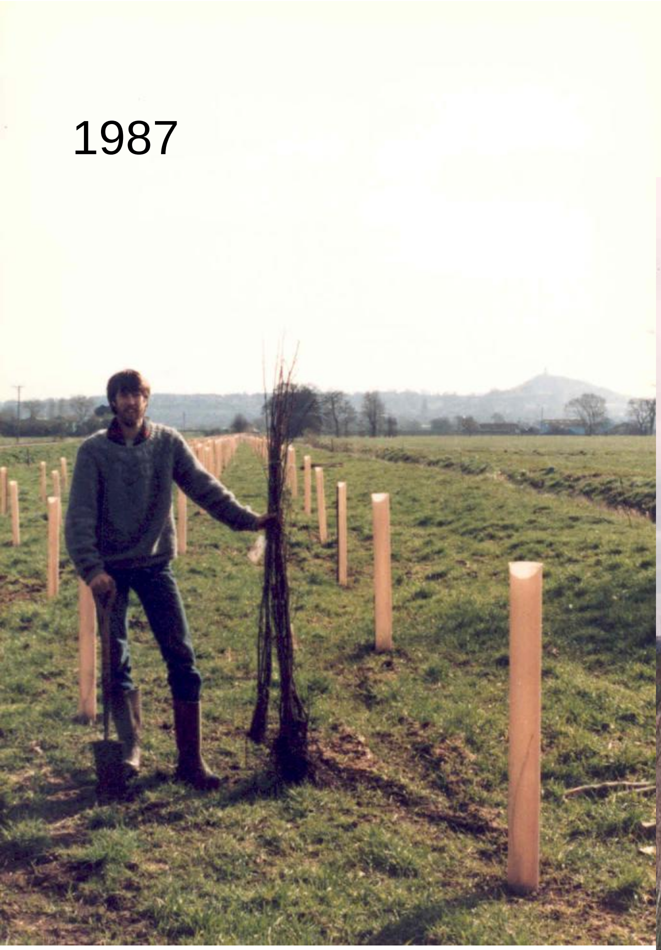
[c] Based on old B.C. Forest Service inventory data. Currently being updated with 10 new growth and yield plots.

What are the advantages of vegetative reproduction?

What are the disadvantages of vegetative reproduction?

Rooted set - a one or two year old plant started from a cutting, lifted with roots intact, roots may be pruned back:

Container rooted cutting (CRC) - a plant grown from a cutting for one year in a styroblock with root system formed, top may be cut back:


1987


1991


1993

2003

2006